

# Assessing Behavioral Patterns of Motorcyclists Based on Traffic Control Device at City Intersections by Classification Tree Algorithm

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## Abstract

According to the forensic statistics, in Iran, 26 percent of those killed in traffic accidents are motorcyclists in recent years. Thus, it is necessary to investigate the causes of motorcycle accidents because of the high number of motorcyclist casualties. Motorcyclists' dangerous behaviors are among the causes of events that are discussed in this study. Traffic signs have the important role of traffic controller, and road surface marking is a tool for traffic separation and has a significant effect on drivers' behaviors. The aim of this study is to investigate the effect of variables, including traffic conditions, motorcyclists' psychological conditions, and symptoms and function of traffic lights on the motorcyclists' dangerous behaviors. In this study, classification tree method is used to determine the effective factors in some motorcyclists' dangerous behaviors such as the amount of deviation from the center lane, lane changing, and running red lights. The classification tree is easy to understand and interpret because of the graphical display of results. The data classification tree is made based on the classification and regression tree algorithm (CRT) in this study. The data are collected from the 7 intersections in a city with the medium population by video-based observation method. Hand-held cameras randomly record the motorcyclists' motions and, then, these behaviors are investigated in the office by playing back the videos at slow motion. The obtained trees show that the variables of traffic volume have the greatest impact on the motorcyclists' diversion from the center lane and lane changing. Also, the clarity of the pavement marking is effective in reducing deviation from the middle lane by cyclists so that, in the streets with the line color contrast of more than 1.36, deviation from the center lane is reduced by 25 cm.

**Keywords:** Pavement marking, classification trees, dangerous behavior, motorcyclist, color contrast, lateral deviation from center lane.

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## 1. Introduction

Economic growth is often associated with the increased use of motor vehicles, which results in an increase in traffic accidents and deaths. The World Health Organization has announced traffic accidents as the sixth leading cause of death worldwide and the second leading cause of spending the last years of life with disabilities in developing countries by 2020 [Wong, Chung, and Hung, 2010]. According to the report, half of all road deaths occur among motorcyclists, cyclists, and pedestrians. Urban transportation is faced with one of the biggest problems, i.e. motorcyclists ride their motor in city's pavements [Zare, Admlayi, Alipur and Tarkhān, 2014]. As the lack of proper attention to the behavior pattern of motorcycles causes many traffic-related problems in urban areas and leads to the occurrence of horrible accidents, learning, and acquisition of skills and experience in the control of the vehicle, as well as human and mental factors, have a special role in preventing traffic accidents. Motorcyclists' moods and mental states are both transient and stable. Transient mental state includes alcohol and drug use by motorcycle riders [Christophersen and Gjerde, 2015]. According to researchers, sudden lane changing maneuvers, increasing delays and environment impacts [Abdi, Safarzadeh and Salehikalam, 2016].

Road conditions also have a huge impact on motorcycle traffic safety compared with the vehicles with two or more axels. Parallel longitudinal grooves in the road pavement, as well as ineffective marking, can induce variability for motorcycle riders similarly, consistent with [Elliott et al., 2003], [Marzwan, 2014]. In a study, several effective factors for the number of motorcycle accidents with obstacles on the horizontal curve road have been examined and it is found that the increasing volume of traffic causes a reduction

in motorcyclists' safety in the horizontal curve [Gabauer, and Li, 2015].

In another study that was done on motorcycle accidents during 5 years, the average death of motorcycle passengers (except riders) in accidents was announced as 3.4 people per day [Tavakoli, Rabiyan, and Besharati, 2014]. In this study, the number of passengers was selected as one of the independent variables until determining how the number of passengers could impact the behavior of motorcycle riders. Godlay et al. examined the effect of center lanes and pavement markings on drivers' speed, and concluded that pavement marking could reduce the drivers' speed. Their research results suggest that driving speeds were reduced on the narrowest lane width road, and additionally reduced on conventional road sections that contained the center marking with painted crosshatching [Godley, Triggs and Fildes, 2004].

The impact of audio-tactile profiled (ATP) road marking on traffic accidents was investigated in another work, the results of which showed that the audio-tactile signs on the side of the road had a positive impact on reducing traffic accidents [Hatfield, Murphy, Job, and Du, 2008]. In the present study, the effect of pavement marking color contrast was studied on the number of lanes changing and motorcyclist deviation from the center lane. In the study carried out by Tavakoli, for determining the effective factors in the severity of injury to the occupants of a motorcycle, a decision tree was used for data analysis [Tavakoli, Rabiyan and Besharati, 2014]. Among other studies in which a decision tree is used to analyze the data, Chang's investigation about the impact of manholes on the motorcyclist behavior in 2013 can be mentioned [Chang, 2014].

In developed countries, the number of motorcyclists killed as percentages of the total number of road accident fatalities is 5-18%,

while in Iran, this figure is 8.23%. The recorded statistics in Iran shows that, in the last 4 years, the most important violations of motorcyclists included running the red light, unnecessary change path, and lateral movement; thus, these variables are considered the dependent variables [Hendian, Moameni and Rahim, 2015]. The aim of this study is to investigate the impact of drivers' personality characteristics and traffic factors (such as traffic volume, intensity of clear color of the pavement marking, and green time) as the independent variable on motorcyclists' three dangerous behaviors (lane changing, deviation from the center lane, and running red lights) as the dependent variable. Drivers' personality characteristics in this study refer to their behaviors such as use/non-use of turning signal and wearing/non-wearing helmets; this behavior indicates legal or illegal personality.

## **2. Research Methodology**

In this study, the factors affecting the motorcyclists' behavior are studied in an urban road network. The data were collected from passageways leading to 7 intersections in Yazd (a city with medium population), Iran, in 2015. By preparing films of the selected passages, the motorcyclists' reactions (i.e. degree of deviation from the center lane, number of lane changes, moving before the green light, use of motorcycle turn signal, and wearing helmets), traffic volume, and signal intersection timing, e.g. the duration of green light (fixed in some cases and variable in others) were selected and the color contrast of the pavement marking was determined using photos.

### **2.1 Data Collection**

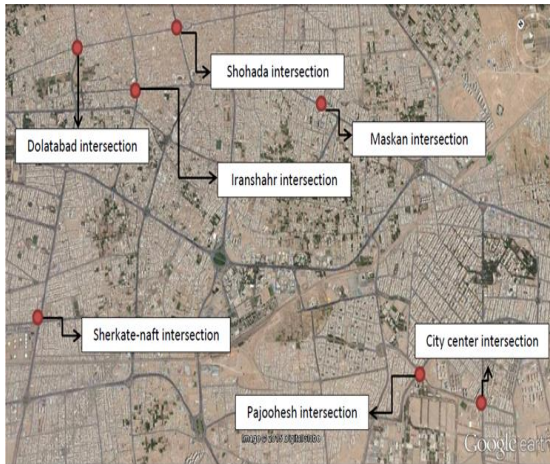
To obtain the number of lane changes, the motorcycles were followed from the moment of exposure to the intersection camera (less than 50 m) and their number of lane changes was recorded. In this study, the data of 258 motorcyclists were used for analysis. Frey and Fisher developed a model based on small

datasets, from 57 to 3,196 observations, to examine the response of modeling accuracy to changes in sample size [Frey and Fisher, 1999; Morgan, Daugherty, Hilchie, and Carey, 2003]. Increasing the amount of data used for building a model often led to no significant increase in model accuracy according to Oates and Jensen [Oates and Jensen, 1998]. Therefore, 258 data sets seemed enough. Weather conditions were constant for collecting and preparing the data. To eliminate the effect of high traffic volume (high density), the data were collected during off-peak hours. The light conditions (daylight and natural light) were normal and stable. Also, the weather was normal and sunny. In the study area, the lane width was suitable for motorcycle riders. Therefore, it was not considered as a variable. Motorcycles have much smaller dimensions and do not necessarily follow the same lane widths as cars.

The recorded videos were reviewed in the office and, in order to obtain a deviation from the center lane, each of the lanes was divided into a positive part on the right side and a negative part on the left side by grading in centimeter; the lateral distance is calculated according to the scale and space of the center of line. Placement angle and position of the camera in the video recording is not important; because of the actual size of a car in the image use to conversion dimensions in a picture to the actual size such as deviations calculation. The procedures of this study were approved by khabiri [khabiri, Elahizadeh and Diah, 2016].

The absolute value of the number which is shown in the middle of the motorcycle in the image was recorded as the lateral distance. In reviewing the videos, the motorcyclists' lane changing was followed; if it was without turning and changing the direction, it was recorded as unnecessary lane changing. Figure 1 shows the location of intersections taken from the city of Yazd and, in Figure 2, the example of the removal rate of motorcycle deviation from the center lane is represented.

## Assessing Behavioral Patterns of Motorcyclists Based on Traffic Control Device at ....



**Figure 1. Location of intersections taken from the city**



**Figure 2. Determining the amount of motorcycle deviation from the center lane**

**Table 1. Descriptive statistics of the obtained variables**

Employed variables	Percentage/Average
Drivers use of turn signal	Less than 1 percent
Drivers wear of helmet	8 percent

Drivers with no lane changing 64 percent

Motorcyclists without running before green lights 82 percent

Average of deviation from the center lane 65 centimeter

## 2.2 Calculating Color Contrast of Pavement

The goal of pavement marking is to guide vehicles and inform and help road users [MRT, 2007]. In a study, the impact of profile line-marking on the performance of drivers was investigated and it was concluded that the profile line-marking was effective for keeping the lane by drivers [Hatfield, Murphy and Job, 2008]. According to research by Khabiri evaluated the importance and influence of Pavement Condition Index (PCI) and contrast of lines color on the behavior of drivers [khabiri, Elahizadeh and Diah, 2016].

In this study, we examined the effect of pavement marking color on the amount of deviation from the center and number of lane changes by motorcyclists. Photos of pavement marking were taken in the same light conditions. To determine the color resolution of pavements, photos were taken vertically from the lines. Then, with the contrast checker software, the degree of contrast of color lines was determined by pavement. Numbers greater than 1 showed that the contrast was more serious [Color Contrast Checker Software, 2015]. Thus, the ratios larger than 1.0 indicated more intense contrast. Figure 3 presents an example of pavement marking photos and the calculated contrast color.

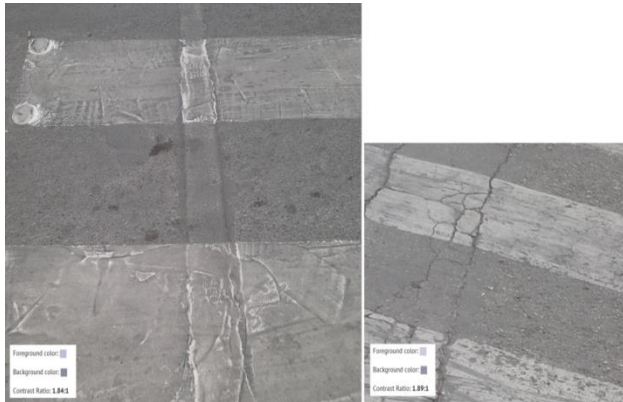


Figure 3. Example of pavement marking images and calculated contrast

Table 2. Summary of classification tree models for three dependent variables

Dependent Variable	Classification Tree (figure number)	Number of Nodes	Number of Terminals Nodes
Lane changes	Figure.4	13	7
Running the red light	Figure.5	9	5
Deviation from the center lane	Figure.6	9	5

### 2.3 Data Analysis

A classification tree is a method of non-parametric data analysis and a strong tool for prediction and classification problems [Chang and Chien, 2013]. Classification tree method for the classification of effective factors is appropriate for the independent variables [Chang, 2014]. In this method, the obtained results of the data analysis are graphically displayed, which makes it easy to understand and

interpret the tree. Using a classification tree can identify important and less important variables and virtually eliminate insignificant variables [Shariat and Tavakoli, 2010]. The scope of this method is widespread and it is used in various fields such as medicine, management, industry, and engineering [Chang and Chien, 2013].

Card model is a powerful tool for data searching and is a non-parametric model without any assumptions about the relationship between independent and dependent variables [Beshah, Ejigu, Abraham, Snasel and Kromer, 2013]. Also, it is an important method for data searching and a powerful tool for determining the most important independent variables and solving predicted and classification issues [Chang, and Chien, 2013]. Card model is also able to identify complex relationships between the variables without any need to determine the association between the independent variables [Tavakoli, Rabieyan and Besharati, 2014].

In this study, when running the statistical software to validate, the split sample method was used. The maximum tree depth and the maximum in child node were selected as 10 and 3, respectively. The three classification trees for three dangerous behaviors (lane changes, running the red light, and deviation from the center lane) were designed and its results were interpreted. According to the software output, data are correctly grouped in the classified tree created for the number of lane changes by 66.7% and in the one created for running red lights by 79.3%. All the developed classified trees up to 3 depths (three consecutive classifications) were indicated. The characteristics of the classification tree models are shown in Table 2. In this research, IBM SPSS Statistics 22 and CRT algorithm were used to construct a classification tree [SPSS Manual, 2004].

## 3. Results

Three developed classified trees were obtained from volumetric data in the previous stages, is shown in the result section.

### 3.1 Effective Factors in Lane Changing

## Assessing Behavioral Patterns of Motorcyclists Based on Traffic Control Device at ....

To determine the effective factors in lane changing using the described variables in Table 3, the obtained classification tree is shown in Figure 4. The obtained tree representation was stated as follows (Figure 4): Nodes 0 are the root node which shows a summary of the lane changing variables of motorcyclists in this study. We can see that 65% of motorcyclists without any lane changing moved on their route, while 35% of them had at least one lane changing along the way. Zero nodes were divided into two subdivisions by the variable of volume of vehicles.

The most important effective variable for motorcyclists' lane changing was the volume of the vehicle on track. Node 1 shows, at the volume of less than 760 Veh/hr, there was little difference between the number of motorcyclists with at least one lane changing and the number of motorcyclists without lane changing, but mostly they had at least one lane changing. This node represented the willingness of the motorcyclists to change the lane at the volumes of below 760 Veh/hr. Node 2 shows, if the vehicle volume were more than 760 Veh/hr; most of the motorcyclists did not have lane changing with a significant difference. Comparison of nodes 3 and 4 showed that increasing pavement marking color contrast had a positive impact on reducing the number of lanes changing. Comparison of nodes 5 and 6 demonstrated that increasing the volume of traffic led to increasing the number of lanes changing. At nodes 7 to 12 and various volumes, the less the deviation from the center lane, the less the number of lane changing would be.

### 3.2 Effective Factors in Motorcyclists' Running Red Lights

To determine the effective factors for running red lights using the described variables in Table 4, the obtained classification tree is presented in Figure 5.

In Figure 5, node 0 (zero), which is the root node and the first node, indicates that 81 percent of motorcyclists avoided running red lights at the intersection. Comparisons of the volume of traffic at nodes 3 and 4 show an increase in traffic volume over 961 Veh/hr had a significant increase in

running red lights. Nodes 7 and 8 show an increase in the green time up to 22.5 sec causes an increase in the number of running red lights. Nodes 5 and 6 compare the motorcyclists' behavior in terms of wearing/non-wearing helmets and show that none of the motorcyclists wearing helmets had the dangerous behavior of running red lights.

In other words, the motorcyclists who had legal behaviors and personality did not have the dangerous behavior of running red lights and 17% of the motorcyclists without helmets had the dangerous behavior of running red lights. The obtained tree representation was stated as follows (Figure 4): Nodes 0 are the root node which shows a summary of the lane changing variables of motorcyclists in this study. We can see that 65% of motorcyclists without any lane changing moved on their route, while 35% of them had at least one lane changing along the way.

**Table 3. Name of different variables in making tree decision for determining effective factors for lane changing**

Variable	Different employed manner codes/Unit of quantitative variable
<b>Lane changes (dependent variable)</b>	No(no lane change), Yes(at least one lane change)
<b>Volume of traffic</b>	Quantitative (Vehicle per hour)
<b>Amount of deviation from the center lane</b>	Quantitative (Centimeter)
<b>Color contrast of the pavement marking</b>	Quantitative
<b>Use of turn signal</b>	Yes, No

Wear of helmets

Yes, No

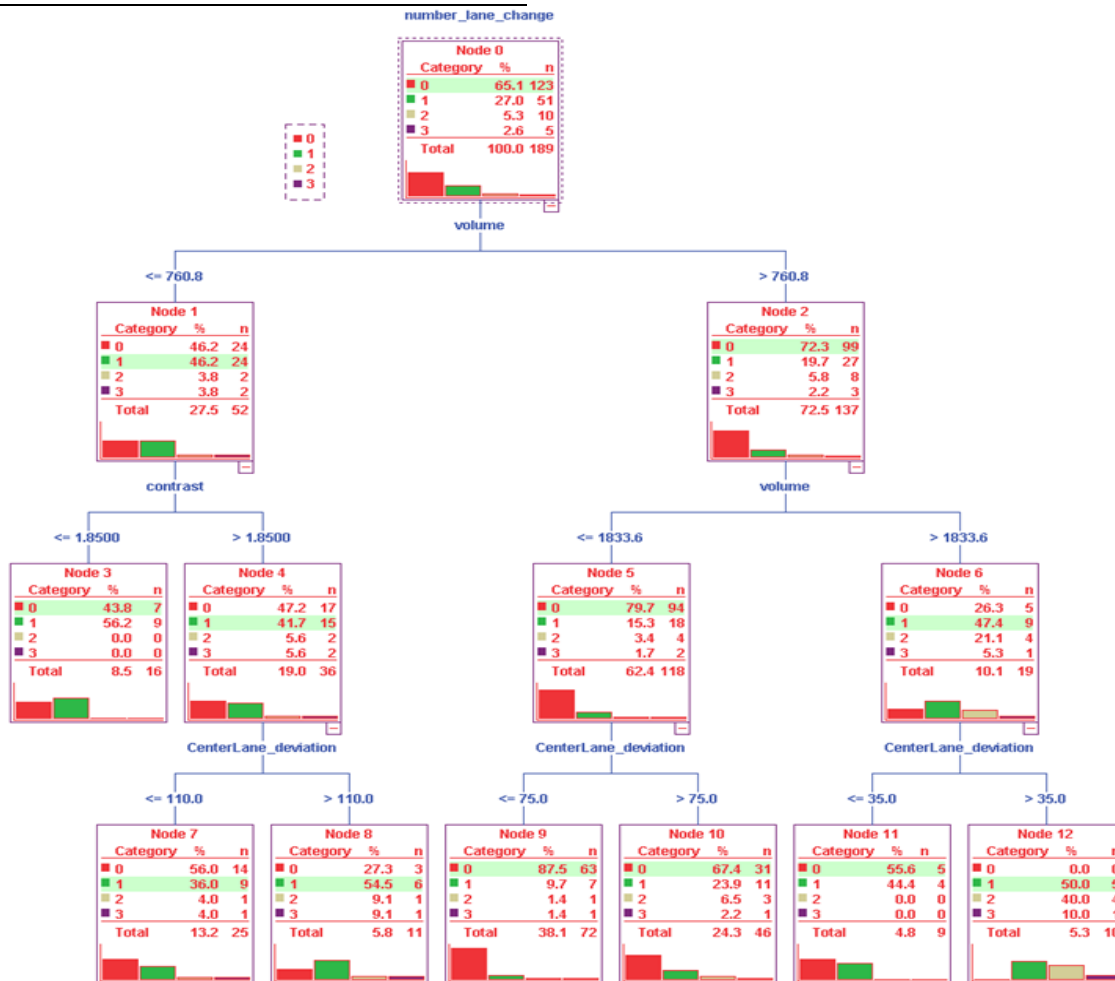


Figure 4. Developed classified tree by card method for determining effective factors for lane changing

Zero nodes were divided into two subdivisions by the variable of volume of vehicles. The most important effective variable for motorcyclists' lane changing was the volume of the vehicle on track. Node 1 shows, at the volume of less than 760 Veh/hr, there was little difference between the number of motorcyclists with at least one lane changing and the number of motorcyclists without lane changing, but mostly they had at least one lane changing.

This node represented the willingness of the motorcyclists to change the lane at the volumes of below 760 Veh/hr. Node 2 shows, if the vehicle

volume were more than 760 Veh/hr; most of the motorcyclists did not have lane changing with a significant difference. Comparison of nodes 3 and 4 showed that increasing pavement marking color contrast had a positive impact on reducing the number of lanes changing. Comparison of nodes 5 and 6 demonstrated that increasing the volume of traffic led to increasing the number of lanes changing. At nodes 7 to 12 and various volumes, the less the deviation from the center lane, the less the number of lane changing would be.

### 3.3 Factors Affecting Deviation from the Center Lane

For determining the Effective Factors on the quantity of motorcycle deviation from the center lane, using the variables described in.

**Table 4. Name of different variables used in making classification tree for determining the effective factors in running the red light**

Variable	Different employed manner codes/Unit of quantitative variable
Running motorcyclists running red lights (dependent variable)	Yes, No
Volume of traffic	Quantitative (Vehicle per hour)
Use of turn signal	Yes, No
Wear of helmets	Yes, No
Green time	Quantitative (Second)

Table 5, the obtained classified tree is shown in Figure 6.

The obtained tree representation was stated as follows (Figure 6): Node 0 (zero), which is the same as the root, and the first node are divided into two branches by the variable of volume of vehicles. The most important variable affecting the degree of displacement from the middle of the lane is the volume of vehicles on tracks. Node 1 indicates that if the volume of the vehicle is less than 1035 Veh/hr, the rate of displacement from the middle by motorcyclists will be 79 cm on average. However, node 2 demonstrates that when the volume of vehicles exceeds 1035 Veh/hr, the rate of displacement from the middle will be 50 cm on average. Figure 6 indicates that, at node 0, the average deviation from the center lane is predicted to be 63 cm. Traffic volume divides this node into

the following two nodes.

At the traffic volume of less than 1035 Veh/hr, the amount of movement from the center lane is increased. Probably, the reason for the growth in displacement from the middle of lane could be the lower number of vehicles (overlapping reduction) and increase the possibility of more lateral movement by motorcyclists. From nodes 4 and 5, it can be seen that, when the marking color contrast is less than 1.56, the deviation from the center lane is 90 cm and, when the contrast is higher than 1.85, the deviation is 83 cm.

However, the comparison of nodes 3 to 6 shows that changes in traffic volume may change the effect of marking color contrast on the amount of deviation. The traffic volume of less than 620 Veh/hr at nodes 7 and 8 shows an increase in traffic volume which causes a reduction in forecasting the average deviation by the software.

### 4. Discussion

Table 6 illustrates the normalized significance of the model variables. Accordingly, we can see that the variable of traffic volume is the only important variable in the three models, followed by the variable of the color contrast of pavement marking with the normalized significance of 79% (effective in two dangerous behaviors). Based on Table 6, the dangerous behaviors of motorcyclists depend on the traffic volume. In other words, the most important and efficient variable is traffic volume.

These results are consistent with the results of Norris et al. who revealed that stress and fatigue caused by driving in high-traffic volume zones had an impact on highly dangerous driving behaviors, and as the crowd increased (increased traffic volume), their dangerous driving behaviors also increased [Norris, Matthews and Riad, 2000]. Also, Dobson et Al. validated in their study that unsuitable driving behavior, on the one hand, and the high traffic volume, on the other hand, had a significant relationship with increasing driving error, driving violations, and speed [Dobson, Brown, Ball, Powers and McFadden, 1999].

The significant of accidents at intersections has been focused by researchers including Haquea



[Haquea, Chinb and Huanga, 2010]

**Table 5. Name of different variables in making classification tree for determining the effective**

<b>Variable</b>	<b>Different employed manner codes/Unit of quantitative variable</b>
<b>Running motorcyclists running red lights (dependent variable)</b>	Yes, No
<b>Volume of traffic</b>	Quantitative (Vehicle per hour)
<b>Use of turn signal</b>	Yes, No
<b>Wear of helmets</b>	Yes, No
<b>Green time</b>	Quantitative (Second)
<b>factor for the deviation from the center lane</b>	

They conducted a study on the motorcycle crash occurring at the signalized intersections and found that the number of lanes at signalized intersections significantly increased motorcycle crashes largely because of the higher exposure resulting from higher motorcycle accumulation on the stop line. Therefore, the effect of short green time (stopping of a large number of motorcycles before the stop line) also increased the potential of the dangerous behaviors. Also, out of impatience during long red lights, motorcyclists may choose the dangerous driving behavior of running red lights [Shadabmehr, 2014; Haquea, Chinb and Huanga, 2010].

In the current study, both of the above-mentioned points were represented via determining the effect

of green time in signalized intersection on the behavior of running red lights. The study also showed that motorcycle crashes increased on high-speed roadways, because the motorcyclists were less likely to react in time during conflicts, so it is suggested that a motorcycle lane is dedicated for motorcyclists [Haquea, Chinb and Huanga, 2010]. A study by Cheng et al. was done on motorcycle accidents and confirmed these results. Motorcyclists' behavior for breaking law resulted from their venture; this study showed that these people had less risk understanding [Cheng, Liu and Tulliani, 2015].

The present study demonstrated that the quality of marking color caused lateral distance from the center lane. Wang (2004) showed that the situation and amount of reflective color of marking had an influence on the amount of lateral distance from longitudinal lines [Wang and Cao, 2004]. In this study, the effect of the lane marking quality on the dangerous behavior, especially the lane changing and deviation from the center lane, was assessed. The results by Haworth et al.'s research on the 206 accidents in 1997 also confirmed this dangerous behavior so that the poor road condition or road markings caused 12% motorcycle accidents [Haworth, 2005]. Also, the studies conducted by "National Highway Traffic Safety Administration (NHTSA)" on the effect of durable pavement marking material on crash reduction showed that the use of durable pavement marking material can substantially reduce crashes by 11% [Migletz and Graham, 2002].

In this study, two types of behaviors (wearing /non-wearing helmets and use/non-use of turning signal) were considered an outer or reaction symbol of the motorcyclist's spirits or inner personality, so each of the three classification trees showed that the effect of this behavior on their dangerous behavior as compared with other factors was not important, while other researchers have intensively studied and considered psychological traits as significantly affecting risky driving behaviors. Hence, there is a need to investigate and compare separately the psychological traits of motorcyclists and traffic conditions for their dangerous driving behavior.

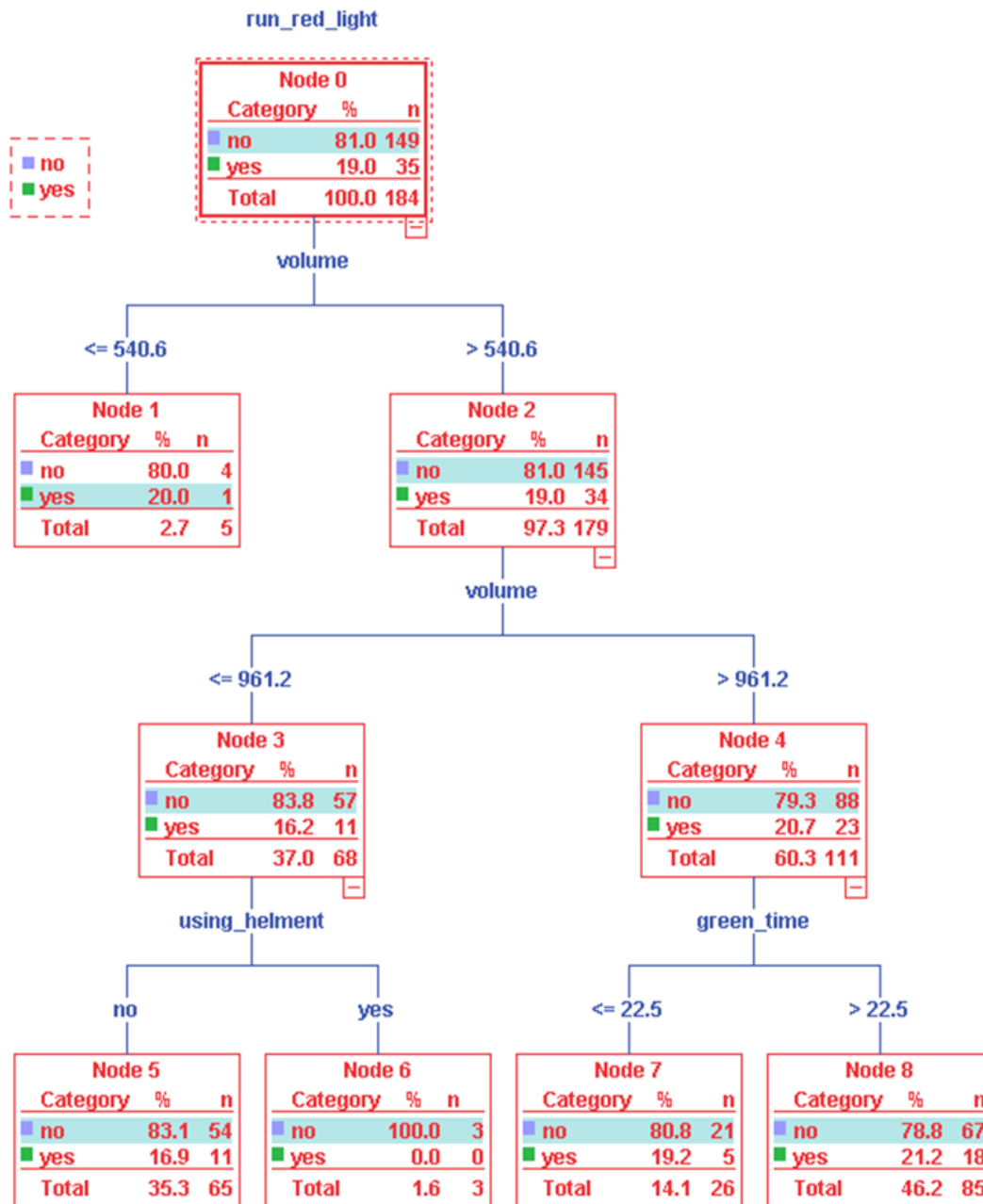


Figure 5. Developed classified tree by card method for determining effective factors for running the red light

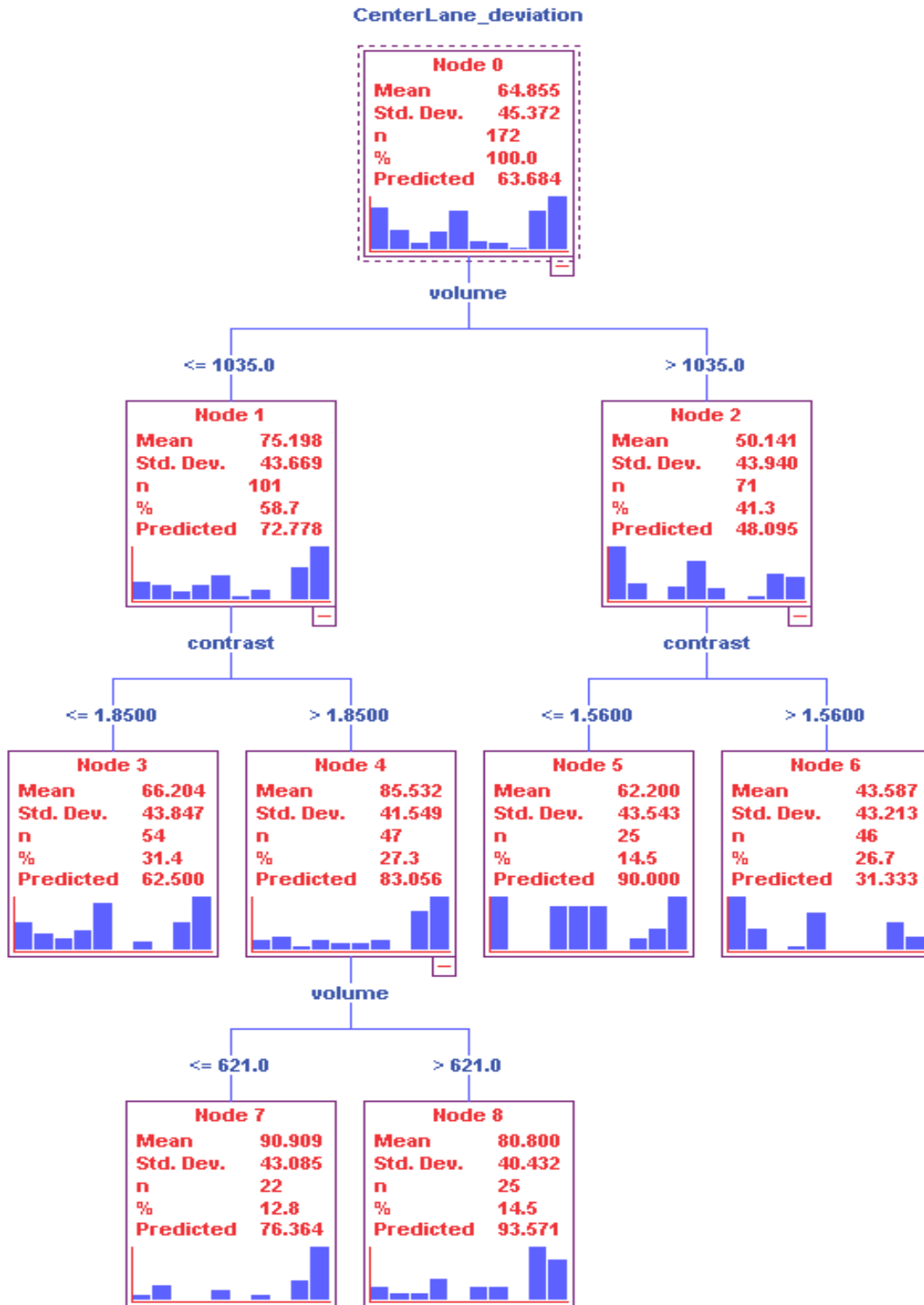


Figure 6. Classified tree is developed by card method for determining the effective factors in the deviation from the center lane

Table 6. Importance of independent variable (effective factors) for the dangerous behavior patterns of motorcyclists

Independent Variable	Independent Variable	Significant	Normalized significant (%)
Number Lane Change	Volume of traffic	0.188	100
	Deviation from the center lane	0.089	47.6
	Color contrast of pavement marking	0.045	23.8
	Use of turn signal	0.007	3.8
	Wear of helmets	0.000	0.0
Running the Red Light	Green time	0.052	100.0
	Volume of traffic	0.046	89.3
	Wear of helmets	0.006	12.6
	Use of turn signal	0.000	0.0
Deviation From the Center Lane	Volume of traffic	0.752	100
	Color contrast of	0.338	45.8

	pavement marking		
	Use of turn signal	0.000	0.0
	Wear of helmets	0.000	0.0

In this study conducted on the behavior of high-risk motorcyclists, data were obtained from a limited geographical area; therefore, further studies are needed to be carried out in larger areas. The results of this study could not be considered definitive because of environmental factors (temperature condition, light condition, and rainy weather conditions) and the anthropologist factors, society, and popular culture may change the results. Therefore, for more precise results, more studies and larger statistical communities are required.

### 5. Conclusion

In this study, to examine the dangerous driving behaviors of motorcyclists, 7 intersections were selected in a city with medium population. Moreover, behaviors including lane changing, running the red light, and deviation from the center lane were measured by the video-based observation method. Conditions such as traffic volume, timing of traffic lights, and motorcyclists' personality were investigated as the independent variables. The results of this study showed that the volume of traffic is the most important and effective parameter for the extent of deviation and motorcyclists' lane changing. The degree of deviation is 25 cm less in traffic volumes of more than 1030 Veh/h than traffic volumes of less than 1030 Veh/hr. Also, at the traffic volume of more than 760 Veh/hr and less than 760 Veh/hr, 35% and 65% of motorcyclists had lane changing, respectively. This issue shows the need for management and

law enforcement at the intersections with low volume. The achieved results of motorcyclist deviation from the center lane of modeling indicated the effect of pavement marking color on motorcyclists' deviation from the center lane. The most important results of this research were:

-Due to the diversion of traffic lanes, it is necessary to use a specific motorcycle lane for moving motorcyclists, especially when traffic volume is high.

-Motorcyclists should be banned from urban highways (with high traffic volume) in order to reduce the severity and number of accidents considering their risky behaviors (unnecessary lane changes and deviation from the center lane) and the high speed of cars.

-Considering the effect of clarity of pavement color on the reduction of deviation from the middle lane by motorcyclists, urban officials need to pay more attention to the color of pavement marking.

-Considering the effect of green time at intersections on the high-risk behavior of running red lights, it is necessary to modify traffic light timing at the intersections with the high volume of motorcyclists, as an example, the timing of red light should be shortened in the approach with the high traffic volume of motorcycles. The amount of yellow interval affects the dilemma zone and probability of red light running; it was not studied in this paper and could be considered as Future work.

## 6. Acknowledgments

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## Mohammad Mehdi Khabiri

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