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Investigating Motorists Perceptions towards Road Safety

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Abstract Exploring motorist attitudes and perceptions will aid in decision makers' awareness of road safety measures, allowing for the creation of policies and the introduction of effective steps to ensure that the road safety goals are met. This study aims to explore motorists' perceptions towards road safety and to come up with new ways to enhance road traffic safety in developing cities. The self-reporting questionnaires using a Likert scale were used to collect data from respondents in Denpasar, Bali Island. Using motorist perception data, the multinomial logit models were constructed to classify the factors that affect road traffic accidents. This study discovered that intersections are a high-risk area for road traffic accidents. Gaining a deeper understanding of motorist behavior at intersections will aid in the creation of a better design that meets motorist expectations when approaching an intersection. Furthermore, the ability to 'read' roads to predict hazards is a vital component of driving abilities that has been related to road traffic accidents. The key causes of traffic accidents were also discovered to be disobedient conduct and reckless driving. Based on these results, some countermeasures for improving road traffic safety in Bali were discussed with an emphasis on engineering and education perspectives.

Keywords Motorists, Multinomial Logit Model, Perceptions, Road Safety

1. Introduction

Diverse models concerning the connection between attitude and behavior emphasize the significance of awareness of traffic risk or traffic law as an initial step to alter driver behavior and move forward to road safety [1, 2]. The contention is that as long as drivers do not aware of what constitutes risky traffic behavior, they are unable to refrain from acting in a risky manner. There will continuously stay a bunch of individuals for whom risk perception is insufficient to adjust their behavior, resulting in the assertion that knowledge could be an essential but deficient situation for safe traffic behavior.

When it comes to meeting road safety targets, both real and expected risks are taken into account. According to [3], safety entails not only being safe but also feeling safe. As a result, investigating motorist behaviors and perceptions will aid in the creation of policies and the introduction of effective steps to ensure that the safety goals are met.

Situational stimuli to driver actions include road intersections [2] and traffic conditions such as turning movement and gap acceptance [4]. Besides, road safety study has focused on accident sites, main modes of transportation, accident times, and major causes of accidents [5, 6]. In past traffic accident studies, demographic factors consisting of gender and age also have been considered [7, 8]. As a result, this analysis will pay close attention to the factors found in previous studies. Using Denpasar, Bali's capital city, as a case study area, this research will provide a foundational understanding of the factors that affect road traffic safety. Based on Bali Provincial statistical data, the population of the city of Denpasar in 2017 was more than 600,000 accounted for almost 17% of the total population of Bali. Meanwhile, as many as 33% of the total motorized vehicles in Bali were registered in the city of Denpasar in which motorcycles account for almost 86% of the total types of transportation modes.

This study aims to use multinomial logit (MNL) models to analyze motorists' perceptions of road traffic safety. It also offers insight into the factors that affect motorists' characteristics and perceptions of road traffic accidents. Increased understanding of motorists' perceptions of traffic accidents would encourage educational and compliance programs aimed at improving road traffic safety to be promoted. To achieve safer driving/riding, some valuable knowledge can be exchanged with motorists. To put it another way, it is predicted that motorists will apply what they have experienced to make meaningful improvements in their travel habits. This research offers a deeper understanding of safety issues from the viewpoint of motorists, as well as critical information on factors that influence road traffic accidents.

2. Materials and Methods

2.1. Multinomial Logit Model

The outcome probabilities of a function with an unordered dependent variable are predicted using a multinomial logit model (MNL) [9]. The lowest or highest frequency, the last or first value is generally chosen as the reference group. Following that, the likelihood of each category is compared to the probability of the reference category. The probability of category $i = 2....K$ can be written as follows:

$$\Pr(Y = i) = \frac{\exp(Z_i)}{1 + \sum_{h=2}^{K} \exp(Z_{hi})} \quad (1)$$

where,

$\alpha_\iota + \sum_{h=1}^{H} \beta_{\iota\eta}\xi_{\iota\eta} = Z_{i.}$ in which for the reference category,

$$\Pr(Y = 1) = \frac{1}{1 + \sum_{h=2}^{K} \exp(Z_{hi})} \quad (2)$$

The MNL model can be expressed by rearranging (1) and (2) as follows.

$$\mathrm{Ln}\left(\frac{P(Y = i)}{P(Y = 1)}\right) = \alpha_i + \sum_{h=1}^{H} \beta_{ih}X_{ih} = Z_i \quad (3)$$

where,

$\beta_{\iota h}$, X_{ih} : vectors corresponding to the calculated parameters and predictor variables

$\frac{P(Y = i)}{P(Y = 1)}$: the likelihood of a motorist being killed, seriously injured, or suffering a minor injury, using the first category as a baseline

i : the number of various injury forms

2.2. Data Collection

In Denpasar, Bali's capital city, a self-reported questionnaire form was used to conduct a cross-sectional survey. This approach was consistent with a previous study by [10], which found that considering self-reported motorists' perception is fitting because it exhibited a constant perception trend and projected a steady predictor of imminent intentions of motorists' behavior. The survey was conducted in June-July 2017. School holidays and the Bali Arts Festival take place in Denpasar in June and July. In this holiday atmosphere, it is more reliable to get an interview with the respondents. The respondents were also more comfortable in giving their perceptions. The questionnaires were distributed to 400 Denpasar-based motorists at random. Due to incomplete data, there were 77.5% (or 310 samples) of the total number of samples taken for this study.

The questionnaire has four sections containing a total of 14 main questions, as shown in Table 1. Data on motorists' socio-demographic characteristics as well as their perceptions of traffic safety were gathered. Also reported were motorist views of driving/riding through intersections and road safety initiatives. Their experience and understanding of transportation safety and traffic accident prevention initiatives were used to assess them. The respondents were given the option of choosing their answers to the questionnaire's questions.

3. Model Development

3.1. Research Hypotheses

As previously reported, this study aims to examine motorists' perceptions and knowledge of road safety. To examine the numerous associations among the measures presented in Table 1, the following hypotheses were developed:

H_1: Socio-demographic factors influence motorists' perceptions towards road safety.

H_2: Traffic safety tips and driving/riding behavior through intersection affect motorists' perceptions towards road safety.

3.2. Data Analysis

All models were constructed using Multinomial Logit (MNL) methods, with the assumption that motorists are the ones who make decisions about road traffic safety. A matrix of motorists' perceptions of road traffic safety measures is shown in Table 1. M41 (accident locations), M42 (main suspect in traffic accidents), M43 (the major cause of traffic accidents), and M44 (time of traffic accidents) were listed as dependent variables.

Meanwhile, the better the fitting of the MNL models, the higher the goodness of fit which is expressed as a pseudo-R^2 value [11]. According to [12], such measurements are often overlooked since there is no standard goodness of fit for these types of models. The classification accuracy, on the other hand, is used to assess the model's accuracy. The accuracy rate of the model classification should be at least 25%, which is higher than the proportional by chance accuracy rate of the results. The proportion of each group within a dependent variable was used to calculate the proportion by chance data accuracy rate. For example, the overall classification accuracy rating of M41 (motorist perception of accident-prone location) is 38.7%, which is higher than the proportional by chance accuracy criterion of 28.0 percent (=1.25 x 22.4 percent) (refers to Tables 2 and 3). The model classification accuracy requirements, therefore, are met (refers to Table 4).

Table 1. Items in the questionnaire

I.	**Socio-demographic factors**
M11	Sex (Male=1; Female=2)
M12	Age (<20 years=1; 20-29 years=2; 30-39 years=3; 40-49 years=4; 50+ years=5)
M13	Occupation (Public employee=1; Private employee=2; Self-employed=3; Housewife/husband=4; Retired=5; Student=6; Others=7)
M14	Riding or driving frequency (Everyday=1; 2 or 3 times in a week=2; Once a week=3; Once a month=4; Hardly ever=5)
M15	Had traffic safety education or classes at school (yes=1; no=2)
II.	**Traffic safety tips**
M21	Practices often observed for road safety (riding/driving in between minimum & maximum speed limit=1; following traffic signals or police instructions i.e. not to driving or to riding through a red light=2; riding or driving inside your lane and not overtaking=3; reducing speed before a sharp bend=4; driving/riding slow or/and stopping before approaching intersections=5; Others=6)
M22	To avoid traffic accidents (Stopping to allow pedestrians to cross at a zebra crossing=1; Taking extra caution near schools=2; Drive while fastening your seat belt=3; Not driving/riding after drinking alcohol=4; Turning on the headlights before sunset=5; Others=6).
III.	**Driving/Riding habits approaching the intersection**
M31	When the traffic signal turned into yellow from red (Drive/ride through the intersection usually as when its green=1; Speed up to cross the intersection before it changes to red=2; Slow down to stop for change to red =3; Others=4)
M32	Have ever ignored traffic signals (Never=1; Yes, but hardly ever (1 or 2 times)=2; Yes, few times (3-5 times)=3; Yes, some time (6-10 times)=4; Yes, many times=5)
M33	Reason for ignoring the traffic signals (There were no other vehicles or motorcycles in the intersection=1; Was in hurry=2; The car behind insisted=3; No traffic police was present=4; The traffic signal was difficult to see or identify=5; Others=6)
IV.	**Road traffic safety measures**
M41	Location of road traffic accident (Signalized intersection =1; Unsignalized intersection=2; Major or wide roads with dual carriage lanes=3; Minor or narrow roads=4; Sharp-curved roads=5)
M42	The main suspect of road traffic accident (Adult pedestrian crossing roads/intersections=1; Child pedestrian crossing roads/intersections=2; Car=3; Motorcycle=4; Bus/Truck=5)
M43	The major cause of road traffic accidents (Motorist or another vehicle suddenly running out into the road=1; Unnecessary overtaking by other vehicles=2; Careless or inattentive driving/riding=3; Using a cell phone while driving/riding=4; Speeding or aggressive driving/riding=5)
M44	Time of road traffic accidents most likely to happen (Early morning from 01:00 a.m. to 05:59 a.m.=1; Morning from 06:00 a.m. to 09:59 a.m.=2; Daytime from 10:00 a.m. to 3:59 p.m.=3; Late Evening from 09:00 p.m. to 00:59 a.m.=4; Evening from 4:00 p.m. to 8:59 p.m. =5

Table 2. Motorist perceptions of accident-prone locations

Accident-prone locations	Number of Samples	Percentage	Percentage squared
Signalized intersection (code=1)	33	10.6%	1.1%
Unsignalized intersection (code=2)	82	26.5%	7.0%
Major roads with dual carriage lanes (code=3)	85	27.4%	7.5%
Minor or narrow roads (code=4)	40	12.9%	1.7%
Sharp-curved roads (code=5)	70	22.6%	5.1%
	Total = 310		Total = 22.4%

Table 3. Overall classification rate

Observed	Predicted					
	Signalized intersection (1)	**Unsignalized intersection (2)**	**Major roads (3)**	**Minor roads (4)**	**Sharp-curved roads (5)**	**Percent Correct**
Signalized intersection (1)	10	6	12	1	4	30.3%
Unsignalized intersection (2)	3	47	19	3	10	57.3%
Major roads (3)	5	32	29	7	12	34.1%
Minor roads (4)	3	10	13	7	7	17.5%
Sharp-curved roads(5)	3	19	17	4	27	38.6%
	7.7%	36.8%	29.0%	7.1%	19.4%	38.7%

Table 4. Model validity

Model	Data Observed	1.25*Data Observed	Model Results	Model Accuracy
MNL M41	22.4%	28.0%	38.7%	Satisfied
MNL M42	25.0%	31.2%	49.7%	Satisfied
MNL M43	40.8%	51.0%	63.9%	Satisfied
MNL M44	17.0%	21.2%	37.7%	Satisfied

Notes:

M41 = Location of road traffic accident; M42 = The main suspect of traffic accident;

M43 = The major cause of traffic accidents; M44 = Time of traffic accidents

4. Results and Discussion

Tables 5 and 6 show the approximate results of the MNL models M41, M42, M43, and M44. To be more precise, both models clarify that socio-demographic influences (attached to H_1), as well as traffic safety tips and driving/riding habits approaching intersections (attached to H_2), that were developed at the start of the study, have been statistically accepted. In other words, these factors of socio-demographic, traffic safety tips, and driving/riding habits when approaching intersections play a significant role in motorists' perceptions of road safety. In many cases, the alternative basic constants in all four models are small in comparison to the other coefficients, indicating that the predictors employed in the models are adequate because they justify a greater proportion when collecting motorists' perceptions of road safety. The findings for each model are explained in the subsections below.

MNL model – M41. Location of road traffic accident (signalized intersection=1; unsignalized intersection=2; major roads with dual carriage lanes=3; minor roads=4; sharp-curved roads=5). For this MNL model, "sharp-curved roads" were chosen as the reference category. In terms of road traffic accident locations, the important and positive coefficient (=1.16) shows that male motorists believe signalized intersections are not as safe as sharp-curved roads. This means that the odds of male drivers outnumbering female drivers is 3.19 (OR = $\exp^{1.16}$). Male motorists have a 219% higher chance of being involved in an accident than female motorists. As opposed to the reference category of "sharp-curved roads," motorists do not feel safe at signalized intersections, unsignalized intersections, major roads with dual carriage lanes, or minor or narrow roads, even though they follow best practices for road safety by riding/driving in between minimum & maximum speed limit. With values of 1.91, 1.88, 1.18, and 1.42, the related coefficients were statistically significant at the 95% and 99% confidence levels.

As compared to the reference group of "sharp-curved roads," those motorists who obey police instructions and observe road safety procedures do not feel safe at unsignalized intersections. With a value of 1.75, the related coefficients were statistically significant at the 99% confidence level. This is in line with a recent study that found intersection accidents to be much more complex and result in a wider range of scenarios than other forms of road accidents, such as straight-road collisions [4]. This may due to a rise in the number of collisions at conflict points, intersections have become a vital place for motorists. As a result, understanding motorist behavior at intersections can aid in the creation of a better design to meet motorist expectations when negotiating an intersection, particularly in mixed traffic conditions [2].

Furthermore, as opposed to sharp-curved roads, motorcyclists aged 20 to 29 years do not consider minor or narrow roads as accident sites, as the related coefficient is negative and important at the 95% confidence level (β = -1.85). In comparison, private-employee motorists (β = 1.67) believe that minor or narrow roads are more likely to be the site of an accident than sharp-curved roads.

Table 5. Influencing factors on accident locations and main suspect of accidents

	MNL model – M41				MNL model – M43	
	Accident locations				The main suspect of accidents	
Variables	**Intersection with traffic signal**	**Intersection without traffic signals**	**Major or wide roads with dual carriage lanes**	**Minor or narrow roads**	**Adult pedestrian crossing roads/intersections**	**Child pedestrian crossing roads/intersections**
Constant	(-2.35)	(-2.47)	(-1.92)	(-1.28)	(0.80)	(-0.36)
Gender	Male (**1.16***)	--	--	--	--	--
Age	--	--	--	20-29 years (**-1.85***)	--	--
Occupation	--	--	--	Private employee (**1.67***)	--	--
Practice observed for traffic safety	Riding/driving in between minimum & maximum speed limit (**1.91***)	Riding/driving in between minimum & maximum speed limit (**1.88****) Following traffic signals or police instructions (not driving/riding through a red light) (**1.75****)	Riding/driving in between minimum & maximum speed limit (**1.18***)	Riding/driving in between minimum & maximum speed limit (**1.42***)	--	--
Reason for ignoring traffic signals	--	--	--	--	There were no other vehicles or motorcycles in the intersection (**2.33***) Was in hurry (**2.24***)	There were no other vehicles or motorcycles in the intersection (**2.66***) Was in hurry (**2.18***)

Notes: ** and * indicate significantly different from zero at the levels of 1% and 5% respectively

MNL model – M42. The main suspect of road traffic accident (adult pedestrian crossing roads/intersections=1; child pedestrian crossing roads/intersections=2; car=3; motorcycle=4; bus/truck=5). The reference category was considered as “bus/truck” for this MNL model. As opposed to the reference category of "bus/truck," those motorists who ignore traffic signals because there are no other cars or motorcycles at the intersection see both adult and child pedestrians crossing roads/intersections as the key suspects in traffic accidents. With values of 2.33 and 2.66, the related coefficients were statistically significant at the 95% confidence level.

In comparison to bus/truck, those motorists who ignore traffic signals because they are in a rush see both adult and child pedestrians crossing roads/intersections as the key suspects in traffic accidents. With values of 2.24 and 2.18, the related coefficients were statistically significant at the 95% confidence level. This is in line with a past study [13] that analyzes the ability of drivers’ hazard perception. The study discovered that knowledge of dangerous situations in the traffic area, or the ability to "sense" roads to predict road hazards, is a significant component of driving skills that correlate with vehicle accident involvement. Another past study also found that the concealed unmaterialized hazards, for example, a road user who is obscured behind a parked vehicle but did not cross the road or a road user standing on the curb and visible to the driver but not entering the road, are possible sources of danger that are typically obscured by other road users [14].

Table 6. Influencing factors on major cause and time of accidents

Variables	MNL model – M41				MNL model – M43			
	The major cause of accidents				Time of accidents			
	Motorcycle or another vehicle suddenly running out into the road	Unnecessary overtaking by other vehicles	Careless or inattentive driving/riding	Using a cell phone while driving/riding	Early morning	Morning	Daytime	Late Evening
Constant	(0.20)	(-0.96)	(1.59)	(0.15)	(-2.53)	(-1.48)	(0.46)	(-0.91)
Gender	--	--	--	--	--	--	--	--
Age	--	--	--	--	--	<20 years (**-4.75****)	<20 years (**-3.12****)	<20 years (**-3.83****)
Occupation	Student (**2.07***)	--	--	--	--	Student (**3.50****)	--	--
Practice observed for traffic safety	--	Riding/driving in between minimum & maximum speed limit (**2.90***)	--	--	--	--	--	--
To avoid traffic accidents	Stopping to allow pedestrians to cross at a zebra crossing (**2.39****)	--	--	--	Stopping to allow pedestrians to cross at a zebra crossing (1.**69***)	Taking extra caution near schools (**1.70***)	--	--
Ignoring Traffic Signals	Never (**-3.28***)	--	Never (**-3.66***)	Never (**-6.19****)	--	--	--	--

Notes: ** and * indicate significantly different from zero at the levels of 1% and 5% respectively

MNL model – M43. The major cause of traffic accidents (Motorist or another vehicle suddenly running out into the road=1; Unnecessary overtaking by other vehicles=2; Careless or inattentive driving/riding=3; Using a cell phone while driving/riding=4; Speeding or aggressive driving/riding=5). For this MNL model, the reference category was "speeding or aggressive driving/riding". To prevent traffic collisions, motorists who stopped to allow pedestrians to cross at a zebra crossing believe that a motorcycle or other vehicle unexpectedly running out onto the road will be a major cause of the accident, as opposed to speeding or aggressive driving/riding.

Many who have never disobeyed a traffic signal, on the other hand, believe that speeding or reckless driving/riding, as opposed to a motorcycle or other vehicle unexpectedly coming out onto the road, careless or inattentive driving/riding, and using a mobile phone while driving/riding, is a major cause of the accident. In contrast to speeding or reckless driving/riding, motorists who follow road safety policies such as riding/driving in between minimum & maximum speed limit believe that excessive overtaking by other cars is a major cause of accidents.

MNL model – M44. Time of road traffic accidents. Early morning from 01:00 a.m. to 05:59 a.m.=1; Morning from 06:00 a.m. to 09:59 a.m.=2; Daytime from 10:00 a.m. to 3:59 p.m.=3; Late Evening from 09:00 p.m. to 00:59 a.m.=4; Evening from 4:00 p.m. to 8:59 p.m.=5. The reference category was considered as "late evening" for this MNL model. To prevent traffic accidents, motorists who stopped allowing pedestrians to cross at a zebra crossing believe that early morning from 1:00 a.m. to 05:59 a.m. is the most dangerous time of day, as opposed to late evening from 09:00 p.m. to 00:59 a.m. Furthermore, motorists who exercise extra caution near schools and students believe that the morning from 06:00 a.m. to 09:59 a.m. is the most dangerous time of day, as opposed to the late evening from 09:00 p.m. to 00:59 a.m. In comparison, motorists under the age of 20 assume that late evening from 09:00 p.m. to 00:59 a.m. is the most dangerous time of day, followed by morning from 06:00 a.m. to 09:59 a.m., daytime from 10:00 a.m. to 03:59 p.m., and evening from 4:00 p.m. to 8:59 p.m. Besides, early morning from 01:00 a.m. to 05:59 a.m. is deemed the most likely time for road traffic incidents (M44), with a likelihood of about 67%, followed by morning (19%), late evening (12%), and daytime (12%) (1%).

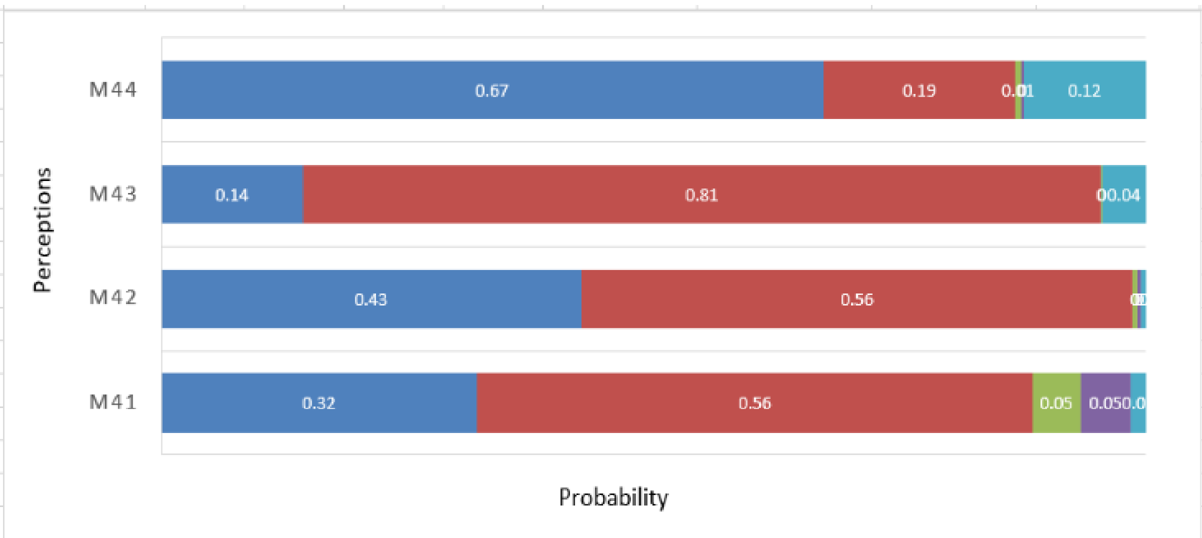
According to Fig. 1, the likelihood of a signalized intersection, an unsignalized intersection, a major or large road with dual carriage lanes, a minor or narrow road, and a sharp-curved road being considered as the site of a road traffic accident (M41) is 32%, 56%, 5%, 5%, and 1%, respectively. Unsignalized and signalized intersections are substantially regarded as the vulnerable location of road traffic collisions, according to a previous study [15].

Unnecessary overtaking by other vehicles is cited as a major cause of traffic accidents (M43) by 81% of respondents, accompanied by a motorist or other vehicle unexpectedly running out onto the lane (14%), and speeding or aggressive driving/riding (4%). Disobedient conduct and reckless driving were also found to be major causes of traffic accidents in a previous study in Indonesia [16]. This result is also in line with a previous study that found that nearly half of all motorcycle accidents were caused by careless or reckless driving [17].

Considering the factors above which contributed to road traffic accidents, the enhancement of safety systems to improve driving/riding among the population is required. The drivers/riders may be assisted with technology that can assist to avoid collisions and to alert drivers/riders to potential hazards or take over control of the vehicle while on the road.

This research, therefore, suggests some steps to minimize road traffic injuries based on the model findings. The use of video footage and other data from the black box mounted on cars known as Advanced Driver Assistance Systems (ADAS) may be developed for the safe driving of vehicles in Bali to predict and avoid accidents on public roads under mixed traffic conditions. ADAS may identify some potentially dangerous circumstances that can occur when driving or parking a vehicle, and then warn the driver or trigger auto-driving mode. The ultimate aim of ADAS is to achieve self-driving technology [18].

Meanwhile, many people assume that "not seeing" a pedestrian or cyclist indicates that the pedestrian or cyclist was difficult to see. To minimize the difficulty in identifying vulnerable road users, it is important to enhance traffic hazard identification and situation recognition when walking, cycling, or driving/riding a car, as well as prevent distraction. If this change is made, all road users will be more mindful of vulnerable road users such as pedestrians and cyclists, and their hazard awareness skills will improve as well [19].



Notes:

M41 : Location of road traffic accident

M42 : The main suspect of road traffic accident

M43 : The major cause of traffic accidents

M44 : Time of traffic accidents most likely to happen

Figure 1. Shares for each category included in the models

5. Conclusions

In Denpasar, Bali, motorists' perceptions of road traffic accidents and safety were examined, and potential steps to improve road traffic safety were established. Motorists' perception of location, the main suspect, the major cause, and the time of road traffic accidents were investigated. In terms of the accident location, intersections and pedestrian crossing roads/intersections were found to be more responsible for influencing road traffic incidents than sharp-curved roads and bus/truck respectively. Road traffic injuries were often caused by risky driving/riding behavior such as reckless and irresponsible conduct while driving and riding, as well as pedestrians crossing the road/intersection. Furthermore, motorists believe that early morning hours between 01:00 a.m. and 05:59 a.m. are a particularly dangerous time for road traffic accidents.

To increase the awareness of the surrounding environment while on the road, motorists require engineering assistance. Installing advanced driver assistance systems in a car and improving identification and situation of traffic hazards while walking, cycling, or driving/riding are examples of engineering and education initiatives to improve road traffic safety in Denpasar, Bali, in response to the study findings. Pedestrians and cyclists are among the most vulnerable road users, and all road users are urged to be more respectful of them.

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