Dynamic Research, Inc.

In-Depth investigation of motorcycle accidents

ACEM REPORT

MULTIVARIATE ANALYSIS OF MAIDS FATAL ACCIDENTS

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Technical Report

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Section I

INTRODUCTION

This report describes the results of a multivariate analysis of the in-depth motorcycle accident data collected during the MAIDS project. Data have been presented according to all powered two wheeler (PTW), as well as L1 and L3 vehicle categories where appropriate.

A. BACKGROUND

A large amount of information and numerous key findings have been provided as a result of the MAIDS research program (ACEM, 2004). In addition to this effort, ACEM has requested that a multivariate analysis be made in order to quantify the effect that various factors have upon a PTW rider fatality. It was requested that this analysis be done for all PTWs as a group as well as separately for L1 and L3 vehicle categories.

In terms of appropriate statistical methods for the multivariate analysis of vehicular accident data, recent literature suggests that multinomial logit models or multiple logistic regression models be used to examine and quantify the effect of various factors on driver and PTW rider injury severity (Shankar and Mannering, 1996, Ulfarsson and Mannering, 2004, and Savolainen and Mannering, 2007).

The multiple logistic regression model is an extension of the univariate logistic regression model. For a binary response Y, in this case a fatal outcome, and a quantitative explanatory variable *X*, it is possible to determine $\pi(x)$ which is the probability that a given case will result in a fatality when *X* takes value *x*. The univariate logistic regression model has a linear form for the logit of this probability which is:

$$\text{logit}[\pi(x)] = \log\left(\frac{\pi(x)}{1-\pi(x)}\right) = \alpha + \beta x$$

This formula implies that $\pi(x)$ increases or decreases as an S-shaped function of *x*. When there are several possible explanatory variables (*k*) for a binary response Y by X_1, X_2 ,… X_k, the equation for the logit regression model may be expressed as:

$$\text{logit}(\pi) = \alpha + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_k x_k$$

Where the parameter β refers to the effect of X_i on the logarithmic odds that Y =1, controlling for other *X*s. The parameters β are referred to as the partial regression coefficients and when expressed in the form of an equation, may be used to predict the binary outcome (i.e., in this analysis, a fatality). The regression coefficients may also be used to compute the odds ratios for a given variable by exponentiating the partial regression coefficient. For example, $\exp(\beta_i)$ is the multiplicative effect on the odds of a 1-unit increase in X_i at fixed levels of the other Xs.

Section II
METHODOLOGY

The original MAIDS accident database (version 1.3) was used as the PTW database for this analysis (i.e., all PTWs). Two additional subset databases were generated using the MAIDS database and these were separated according to L1 and L3 legal categories. The definitions of these categories are as follows:

Powered Two Wheeler (PTW): Any L1 or L3 vehicle.

L1 vehicle: A two wheeled vehicle with an engine cylinder capacity in the case of a thermic engine not exceeding 50 cm^3 and whatever the means of propulsion a maximum design speed not exceeding 45 km/h[1]. Note: The L1 vehicle category included both L1 vehicles as well as mofa vehicles.

L3 vehicle: A two wheeled vehicle with an engine cylinder capacity in the case of a thermic engine exceeding 50 cm^3 or whatever the means of propulsion a maximum design speed exceeding 45 km/h[2].

A total of 100 fatal PTW rider cases were found in the MAIDS database and a new binary variable (mcriderfatal) was generated to identify those cases in which there was a PTW rider fatality. The distribution of PTW rider fatal cases in the 3 databases is presented in Table 1.

Table 1: Distribution of PTW rider fatality data

	MAIDS Database (all PTWs)	L1 Database	L3 Database
Fatal	100	25	75
Not fatal	821	373	448
Total	921	398	523

In order to perform the multivariate analysis, a series of new variables were developed based upon existing MAIDS database variables. Table 2 describes those new variables and the MAIDS database variables that were used to form them. The new variables were generated either by the recoding of existing variables (e.g., daytime versus nighttime accidents) or by using two variables to generate a third variable (e.g., motorcycle age). In some cases, existing MAIDS variables were categorized in order to better understand the

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1 Under EU regulations, the maximum design speed of L1 vehicles is 45 km/h, rather than 50 km/h as specified in the ECE definition of an L1 vehicle.

2 Under EU regulations, the maximum design speed of an L3 vehicle shall exceed 45 km/h, rather than 50 km/h as specified in the ECE definition of an L3 vehicle.

relationship between a PTW rider fatality and a given variable (e.g., PTW engine size and PTW mass). Maximum velocity data (vmax) previously provided by ACEM were also merged with the L3 database in order to add this variable for the multivariate analysis.

Table 2: New variables generated from MAIDS Database

New variable: Time of day	
Daytime	Night
A.3.1.2 = daylight, bright OR daylight, not bright OR dusk, sundown OR dawn, sunup	A.3.1.2 = night, lighted OR night, not lighted
New variable: Type of area	
Urban	Rural
A.3.1.1 = urban, industrial OR commercial, business, shopping OR housing, apartments OR housing, residential OR urban school OR urban park	A.3.1.1 = rural developed area OR undeveloped wilderness OR rural school OR rural park
New variable: Type of roadway	
Curve roadway	Straight roadway
A.3.1.18 = curve left OR curve right	A.3.1.18 = all other responses
New variable: Intersection	
Intersection	Non-intersection
A.3.1.3 = T-intersection OR cross intersection OR angle intersection OR offset intersection OR roundabout OR over or under cross-over with feeders	A.3.1.3 = non-intersection OR alley, driveway OR other
New variable: MC rider impairment	
MC rider impaired	MC rider not impaired
A.5.1.1.32 = alcohol use OR drug use OR combined alcohol and drug use	A.5.1.1.32 = not applicable OR none
New variable: OV driver impairment	
OV driver impaired	OV driver not impaired
A.5.1.3.32 = alcohol use OR drug use OR combined alcohol and drug use	A.5.1.3.32 = not applicable OR none
New variable: Is the MC rider speeding?	
PTW rider speeding	PTW rider not speeding
If the difference between the traveling speed (A.4.2.2.a) and the posted speed limit (A.3.1.9) is greater than or equal to 10 km/h.	If the difference between the traveling speed (A.4.2.2.a) and the posted speed limit (A.3.1.9) is less than 10 km/h OR there is no posted speed limit (A.3.1.9 = 001).
New variable: PTW rider error	
PTW rider error	No PTW rider error
A.6.4.1.1 = PTW rider perception failure OR PTW rider comprehension failure OR PTW rider decision failure OR PTW rider reaction failure OR PTW rider failure, unknown type	A.6.4.1.1 = all other responses
New variable: OV driver error	
OV driver error	No OV driver error
A.6.4.1.1 = OV driver perception failure OR OV driver comprehension failure OR OV driver decision failure OR OV driver reaction failure OR OV driver failure, unknown type	A.6.4.1.1 = all other responses
New variable: PTW age	
The difference between PTW year of production (A.4.1.1.3) and the year of the accident (A.2.3)	

Once the new variables and databases were generated, a series of independent variables were selected for analysis from each database. Based on historical motorcycle research, including the MAIDS report, these variables have been found to be frequently reported factors in fatal PTW accidents. A list of the variables selected for this analysis appears in Table 3.

Table 3: Variables selected for multivariate analysis

Factor	Variable
Environmental	Daytime or nighttime
	Urban or rural area
	Curved or straight roadway
	Intersection or non-intersection accident site
	Roadway type Motorway Major arterial Minor road Dedicated bicycle/moped path Other type of roadway
	Daytime or nighttime
Vehicle	Motorcycle legal category (all PTW analysis only)
	Motorcycle age Less than or equal to 1 year 2 years to 5 years Over 5 years
	Engine displacement (All PTW and L3 vehicle analysis only) 1 to 50 cc 51 to 125 cc 126 to 250 cc 251 to 500 cc 501 to 750 cc 751 to 1000 cc Over 1000 cc
	Vehicle gross mass Under 100 kg 101 kg to 200 kg Over 200 kg
	Motorcycle style Conventional street L1 or L3 with modifications Dual purpose, on-road, off-road motorcycle Sport, race replica Cruiser Chopper, modified chopper Touring Scooter Step-through Sport touring Motorcycle plus side car Off-road motorcycle, motocross, enduro
	Vmax (L3 vehicle analysis only)

Factor	Variable
	50 to 116 km/h 117 to 172 km/h 173 to 205 km/h 206 to 240 km/h Over 241 km/h
Human	PTW rider age Up to 15 yrs 16-17 yrs 18-21 yrs 22-25 yrs 26-40 yrs 41-55 yrs Over 56 yrs
	PTW rider impairment
	PTW rider speeding (i.e., traveling > 10 km/h above posted speed limit)
	PTW rider error
	OV driver error
	OV driver impairment
	PTW rider impairment
	PTW rider speeding (i.e., traveling > 10 km/h above posted speed limit)
	PTW rider error
Collision	Traveling speed
	Crash speed
	Collision object Light passenger vehicle Large vehicle Roadway Off-road environment, fixed object Moveable object Other impact partner

In order to better understand the relationship between these variables, the different PTW categories and a fatal outcome, a series of univariate tables were generated to illustrate the distribution of each variable. Following this, an initial chi-square analysis was performed for each variable listed in Table 3. Those variables which were found to be significant (i.e., there was a significant difference between the fatal and non-fatal outcomes for a given variable) were then used to form the initial logistic regression model. Logistic regression models were developed and analyzed for all three databases using Stata SE software (i.e., all PTW, L1 only, L3 only). The dependent variable for all analyses was the occurrence of a PTW rider fatality. The maximum likelihood estimation method was used to provide maximum likelihood estimates of all regression coefficients and their standard errors.

The goal of a logistic regression analysis is to correctly predict the outcome for individual cases using the parsimonious or least complex model. To accomplish this goal, a model is created that includes all predictor variables that are useful in predicting the response variable (i.e., a PTW rider fatality). Stepwise regression is a statistical procedure that sequentially evaluates the fit of a given model before and after a variable is added or deleted. For this analysis, a backwards stepwise regression was used. This procedure begins with a full model that contains all variables and the statistical software removes the variables using an iterative process. The fit of the model is tested after the elimination of each variable in order to ensure that the model still adequately fits the data. When no more variables can be eliminated from the model, the analysis has been completed. In order to minimize the potential for multicollinearity[3] between variables, certain variables which were known to be collinear were not included (e.g., engine displacement and Vmax) and separate stepwise regression procedures were performed with each variable.

[3] Multicollinearity is a situation in which there are strong correlations among different factors, causing variables to "overlap" and appear to have little or no effect on a fatal accident. Engine displacement and maximum velocity (vmax) would be an example of two such variables.

Section III

RESULTS

Distribution of variables

The distribution of PTW rider fatalities according to time of day is presented in Table 4. The data shows that the majority of accidents occurred during daytime; however, for all PTW legal categories the proportion of number of fatal accidents to number of accidents is higher during the nighttime.

Table 4: Cross tabulation of PTW rider fatality by legal category and time of day

MC category		Time of day		Total
		Daytime	Nighttime	
L1 vehicle	Not fatal	292	81	373
	Fatal	15	10	25
	Total	307	91	398
L3 vehicle	Not fatal	382	66	448
	Fatal	59	16	75
	Total	441	82	523
All PTW	Not fatal	674	147	821
	Fatal	74	26	100
	Total	748	173	921

The distribution of PTW rider fatalities by type of area and legal category is shown in Table 5. The data shows that for L1 vehicles, more fatalities occurred in an urban area while for L3 vehicles a larger number of fatalities occurred in a rural area.

Table 5: Cross tabulation of PTW rider fatality
by legal category and type of area

MC category		Type of area		Total
		Rural area	Urban area	
L1 vehicle	Not fatal	37	336	373
	Fatal	7	18	25
	Total	44	354	398
L3 vehicle	Not fatal	142	306	448
	Fatal	44	31	75
	Total	186	337	523
All PTW	Not fatal	179	642	821
	Fatal	51	49	100
	Total	230	691	921

Table 6 presents the cross tabulation of PTW rider fatalities by the type of roadway (i.e., straight roadway versus curved roadway). The data indicate that the majority of PTW rider fatalities occurred on straight roadways for both the L1 and L3 vehicle categories.

However, it is important to note that 16.5% of all L3 vehicle crashes that did take place on a curved roadway resulted in a PTW rider fatality.

Table 6: Cross tabulation of PTW rider fatality
by legal category and type of roadway

MC category			Type of roadway		Total
			Straight roadway	Curved roadway	
L1 vehicle		Not fatal	305	68	373
		Fatal	20	5	25
	Total		325	73	398
L3 vehicle		Not fatal	296	152	448
		Fatal	45	30	75
	Total		341	182	523
All PTW		Not fatal	601	220	821
		Fatal	65	35	100
	Total		666	255	921

The distribution of PTW rider fatalities by legal category and the presence of an intersection is presented in Table 7. The data show that the majority of MAIDS accidents took place at an intersection (i.e., 60% of all cases); however, the majority of PTW rider fatalities took place at a non-intersection location (i.e., 62% of all PTW rider fatalities). Approximately 44% of all L1 vehicle accidents involving a L1 rider fatality took place at a non-intersection location while 68% of all L3 vehicle accidents involving a L3 rider fatality took place at a non-intersection location.

Table 7: Cross tabulation of PTW rider fatality
by legal category and presence of intersection

MC category			Presence of intersection		Total
			Non-intersection	Intersection	
L1 vehicle		Not fatal	117	256	373
		Fatal	11	14	25
	Total		128	270	398
L3 vehicle		Not fatal	189	259	448
		Fatal	51	24	75
	Total		240	283	523
All PTW		Not fatal	306	515	821
		Fatal	62	38	100
	Total		368	553	921

Table 8 presents the distribution of PTW rider fatalities by legal category and by roadway type. The data show that the majority of PTW rider fatalities occur on major arterials or minor roads (40% and 48% respectively). Fewer accidents occurred on major arterials when compared to minor roads (192 accidents versus 601 accidents); however, major arterial accidents account for 44% of L1 rider fatalities, 39% of L3 rider fatalities and 40% of all PTW rider fatalities.

The distribution of PTW rider fatality data according to the age of the motorcycle is presented in Table 9. Fewer than 921 cases and fewer than 100 PTW rider fatalities were reported in this data table because vehicle year of manufacture information was known in only 787 cases. The data are approximately evenly distributed across all three categories of motorcycle age (i.e., under 1 year, 2 year to 5 years, over 5 years). The highest reported frequency of PTW rider fatality was for motorcycles that were between 2 years and 5 years of age (27 cases or 39% of all reported fatalities in which the vehicle age was known). PTW rider fatalities were also most frequently reported for L1 and L3 vehicles which were between 2 years and 5 years of age (7 cases for L1 vehicles and 20 cases for L3 vehicles respectively).

The distribution of PTW rider fatalities by legal category and engine size is presented in Table 10. As expected, almost all L1 vehicles were found to have engine size of 50 cc or less. Those vehicles that were found to have an engine size greater than 50 cc showed direct evidence that the engine had been tampered with by the owner. The majority of L3 vehicles were found to have an engine size between 501 to 750 cc (i.e., 22% of all MAIDS cases). This category of engine size was also found to have the highest frequency of fatal L3 riders, approximately 30% of all reported L3 rider fatalities.

Table 11 presents the distribution of PTW rider fatalities by legal category and by motorcycle mass. Nearly all of the L1 vehicles were found to weigh under 100 kg while most of the L3 vehicles were found to weigh between 101 to 200 kg. The greatest number of fatal PTW rider cases were also reported in these two weight categories.

The distribution of PTW rider fatalities by motorcycle style and by PTW legal category is presented in Table 12. The data shows that the majority of L1 vehicles were scooter style vehicles and this PTW style category was found to have the highest frequency of L1 rider fatalities. The largest group of L3 vehicles involved in accidents was found to be sport, race replica style motorcycles and this group was also found to have the highest reported frequency of L3 rider fatalities.

Table 13 presents the distribution of PTW rider fatalities by legal category and by PTW rider age. The majority of L1 riders were between the ages of 16 and 21 (206 total cases); however, the L1 rider fatalities were generally distributed across all L1 rider age groups. The majority of L3 riders were found to be between 26 and 40 years of age and the highest frequency of L3 rider fatalities were also reported for this age group.

Table 8: Cross tabulation of PTW rider fatality by legal category and type of roadway

MC category			Roadway Type					Total
			Motorway	Major arterial	Minor road	Dedicated bicycle or moped path	Other	
L1 vehicle		Not fatal	3	46	255	52	17	373
		Fatal	0	11	11	2	1	25
	Total		3	57	266	54	18	398
L3 vehicle		Not fatal	30	106	298	0	14	448
		Fatal	6	29	37	0	3	75
	Total		36	135	335	0	17	523
All PTW		Not fatal	33	152	553	52	31	821
		Fatal	6	40	48	2	4	100
	Total		39	192	601	54	35	921

Table 9: Cross tabulation of PTW rider fatality by legal category and age of PTW

MC category			Age of PTW			Total
			less than or equal to 1 yr	2 years to 5 years	Over 5 years	
L1 vehicle		Not fatal	103	148	63	314
		Fatal	6	7	2	15
	Total		109	155	65	329
L3 vehicle		Not fatal	117	150	136	403
		Fatal	18	20	17	55
	Total		135	170	153	458
All PTW		Not fatal	220	298	199	717
		Fatal	24	27	19	70
	Total		244	325	218	787

Table 10: Cross tabulation of PTW rider fatality by legal category and engine size

MC category			MC engine size category							Total
			1 to 50 cc	51 to 125 cc	126 to 250 cc	251 to 500 cc	501 to 750 cc	751 to 1000 cc	Over 1000 cc	
L1 vehicle		Not fatal	371	2	0	0	0	0	0	373
		Fatal	23	2	0	0	0	0	0	25
	Total		394	4	0	0	0	0	0	398
L3 vehicle		Not fatal	0	77	34	49	177	63	48	448
		Fatal	0	8	3	7	29	17	10	74
	Total		0	85	37	56	206	80	58	522
All PTW		Not fatal	371	79	34	49	177	63	48	821
		Fatal	23	10	3	7	29	17	10	99
	Total		394	89	37	56	206	80	58	920

Table 11: Cross tabulation of PTW rider fatality by legal category and PTW mass

MC category			PTW mass			Total
			Under 100 kg	101 to 200 kg	Over 200 kg	
L1 vehicle		Not fatal	343	7	0	350
		Fatal	21	0	0	21
	Total		364	7	0	371
L3 vehicle		Not fatal	27	251	159	437
		Fatal	2	32	37	71
	Total		29	283	196	508
All PTW		Not fatal	370	258	159	787
		Fatal	23	32	37	92
	Total		393	290	196	879

Table 12: Cross tabulation of PTW rider fatality by legal category and PTW style

MC category		A.4.1.1.4.2-MC mechanical factors/ Specifications/ PTW style												Total
		Conventional street L1 or L3 vehicle without modification	Conventional street L1 or L3 vehicle with modification	Dual purpose, on-road off-road motorcycle	Sport, race replica	Cruiser	Chopper, modified chopper	Touring	Scooter	Step-through	Sport touring	Motorcycle plus sidecar	Off-road motorcycle, motocross, enduro, trials	
L1 vehicle	Not fatal	23	6	8	10	0	0	0	274	49	0	0	1	371
	Fatal	4	0	0	1	0	0	0	17	2	0	1	0	25
	Total	27	6	8	11	0	0	0	291	51	0	1	1	396
L3 vehicle	Not fatal	88	18	34	99	35	31	26	59	0	34	2	19	445
	Fatal	16	1	1	27	2	5	5	4	0	11	1	2	75
	Total	104	19	35	126	37	36	31	63	0	45	3	21	520
All PTW	Not fatal	111	24	42	109	35	31	26	333	49	34	2	20	816
	Fatal	20	1	1	28	2	5	5	21	2	11	2	2	100
	Total	131	25	43	137	37	36	31	354	51	45	4	22	916

Table 13: Cross tabulation of PTW rider fatality by legal category and PTW rider age

MC category		PTW rider age							Total
		up to 15	16-17	18-21	22-25	26-40	41-55	Over 56	
L1 vehicle	Not fatal	26	94	101	39	66	36	10	372
	Fatal	2	8	3	3	2	4	3	25
	Total	28	102	104	42	68	40	13	397
L3 vehicle	Not fatal	1	22	32	72	231	80	9	447
	Fatal	0	2	6	18	32	14	3	75
	Total	1	24	38	90	263	94	12	522
All PTW	Not fatal	27	116	133	111	297	116	19	819
	Fatal	2	10	9	21	34	18	6	100
	Total	29	126	142	132	331	134	25	919

Table 14 presents the distribution of PTW rider fatalities by legal category and by PTW rider impairment. The data shows that 26 of 398 L1 riders involved in a crash were impaired at the time of the crash (i.e., 6.5% of all L1 riders) while only 17 of 523 L3 riders involved in a crash were impaired at the time of the crash (i.e., 3.3% of all L3 riders). Four riders or 16% of all L1 rider fatalities were reported as impaired at the time of the crash. Six riders or 8% of all L3 rider fatalities were reported as being impaired at the time of the crash.

Table 14: Cross tabulation of PTW rider fatality
by legal category and PTW rider impairment

MC category			MC Rider Impairment: Rider not impaired	MC Rider Impairment: Rider impaired	Total
L1 vehicle		Not fatal	351	22	373
		Fatal	21	4	25
	Total		372	26	398
L3 vehicle		Not fatal	437	11	448
		Fatal	69	6	75
	Total		506	17	523
All PTW		Not fatal	788	33	821
		Fatal	90	10	100
	Total		878	43	921

The distribution of those cases in which the PTW rider was speeding, or traveling over 10 km/h above the posted speed limit is presented in Table 15. The data shows that approximately 15% of the L1 vehicle riders were speeding at the time of the crash and approximately 32% of the L3 vehicle riders were speeding at the time of the crash. Of those riders that were speeding, 12% of the L1 vehicle riders (or 7 cases) resulted in a L1 rider fatality while 24% of the L3 vehicle riders (or 40 cases) resulted in a L3 rider fatality. Overall, the data show that 24.5% of all riders were traveling over 10 km/h above the posted speed limit at the time of the accident.

Table 15: Cross tabulation of PTW rider fatality
by legal category and PTW rider speeding

MC category			Was MC rider speeding?: MC rider not speeding	Was MC rider speeding?: MC rider speeding	Total
L1 vehicle		Not fatal	320	53	373
		Fatal	18	7	25
	Total		338	60	398
L3 vehicle		Not fatal	322	126	448
		Fatal	35	40	75
	Total		357	166	523
All PTW		Not fatal	642	179	821
		Fatal	53	47	100
	Total		695	226	921

Table 16 presents the distribution of PTW rider fatalities by legal category and by PTW rider error. A PTW rider error was coded for every case in which the primary accident contributing factor was identified as a specific PTW rider error (i.e., perception failure, comprehension failure, etc.). The data show that nearly 40% of all L1 vehicle crashes involved a L1 rider error (n=154), whereas 64% of L1 fatal crashes involved rider error. Thirty-five percent (35%) of all L3 vehicle crashes involved a L3 rider error (n=184), whereas 49% of L3 fatal crashes involved rider error. These data indicate a larger percentage of rider error occurs in fatal crashes, in comparison to all crashes.

Table 16: Cross tabulation of PTW rider fatality
by legal category and PTW rider error

MC category			MC Rider error		Total
			No MC rider error	MC rider error	
L1 vehicle		Not fatal	235	138	373
		Fatal	9	16	25
	Total		244	154	398
L3 vehicle		Not fatal	301	147	448
		Fatal	38	37	75
	Total		339	184	523
All PTW		Not fatal	536	285	821
		Fatal	47	53	100
	Total		583	338	921

The data presented in Table 17 shows a cross tabulation of PTW rider fatalities by legal category and by other vehicle driver error. The data indicates that approximately 48% of all PTW crashes involve OV driver error, whereas only 33% of fatal crashes involve OV driver error. This distribution was consistent for both the L1 vehicle category as well as the L3 vehicle category. These data indicate a smaller percentage of OV driver error occurs in fatal crashes, in comparison to all crashes.

Table 17: Cross tabulation of PTW rider fatality
by legal category and other vehicle driver error

MC category			OV driver error		Total
			No OV driver error	OV driver error	
L1 vehicle		Not fatal	186	187	373
		Fatal	17	8	25
	Total		203	195	398
L3 vehicle		Not fatal	223	225	448
		Fatal	50	25	75
	Total		273	250	523
All PTW		Not fatal	409	412	821
		Fatal	67	33	100
	Total		476	445	921

Table 18 presents the distribution of PTW rider fatalities by legal category and by other vehicle driver impairment. As the data indicate, there were very few cases in which the other vehicle driver was reported as being impaired (i.e., 22 cases or 2.4% of all cases). Of those cases, only 4 involved a PTW rider fatality (3 L1 vehicle cases and 1 L3 vehicle case).

Table 18: Cross tabulation of PTW rider fatality by legal category and other vehicle driver impairment

MC category			OV driver impairment: OV driver not impaired	OV driver impairment: OV driver impaired	Total
L1 vehicle		Not fatal	359	14	373
		Fatal	22	3	25
	Total		381	17	398
L3 vehicle		Not fatal	444	4	448
		Fatal	74	1	75
	Total		518	5	523
All PTW		Not fatal	803	18	821
		Fatal	96	4	100
	Total		899	22	921

Table 19 presents the distribution of PTW rider fatalities according to the maximum velocity of the L3 vehicle. Recall that the variable maximum velocity represents the maximum design speed of the vehicle and not the maximum velocity reported at the time of the accident. The data show that of the 61 fatal cases in which the maximum velocity was known, 74% of those cases (i.e., 45 cases) involved a L3 vehicle with a maximum velocity of 173 km/h or greater.

Table 19: Distribution of L3 rider fatalities by maximum velocity (L3 vehicles only)

MC category			Vmax Category: 50 to 116 km/h	117 to 172 km/h	173 to 205 km/h	206 to 240 km/h	Over 241 km/h	Total
L3 vehicle		Not fatal	81	76	68	62	72	359
		Fatal	8	8	14	14	17	61
	Total		89	84	82	76	89	420

The distribution of PTW fatalities by legal category and collision partner is presented in Table 20. The data show that the majority of PTW crashes involved a collision with a light passenger vehicle (i.e., 620 cases or 67% of all cases) and that 59 of these crashes resulted in a PTW rider fatality (i.e., 16 L1 vehicle crashes and 43 L3 vehicle crashes respectively). The next most frequently reported collision partner was some type of moveable object (i.e. 85 cases or 9% of all cases). These type of collisions resulted in 8 PTW rider fatalities (i.e., 1 L1 vehicle crash and 7 L3 vehicle crashes). The next most frequently reported collision partner for PTW rider fatalities was a large vehicle (i.e., 76 cases or 8.3% of all cases).

Table 20: Cross tabulation of PTW rider fatality by legal category and collision partner

MC category		Collision partner						Total
		Light passenger vehicle	Large vehicle	Roadway	Off-road environment, fixed object	Moveable object	Other	
L1 vehicle	Not fatal	266	34	16	11	43	3	373
	Fatal	16	4	0	4	1	0	25
	Total	282	38	16	15	44	3	398
L3 vehicle	Not fatal	295	31	41	46	34	1	448
	Fatal	43	7	7	11	7	0	75
	Total	338	38	48	57	41	1	523
All PTW	Not fatal	561	65	57	57	77	4	821
	Fatal	59	11	7	15	8	0	100
	Total	620	76	64	72	85	4	921

All PTW Analysis

As mentioned previously, a univariate chi-square analysis was performed using each variable listed in Table 3. This was done in order to identify those factors which may have an influence upon a fatal PTW rider outcome. Table 21 presents the chi-square results for the database that includes all PTWs. As indicated in the table, 14 environmental, vehicle and human factors were found to be statistically significant. This means that a statistically significant difference was noted between the fatal and non-fatal cases when analyzed with the given MAIDS database variable. It is important to note that each variable was considered individually and not as an aggregate group of variables.

Table 21: Univariate chi square analysis of individual factors using all PTW database

Parameter	Degrees of freedom	Chi-square	P-value
Nighttime	1	3.55	0.0594
Urban	1	35.62	<0.0001*
Curve	1	2.87	0.0900
Intersection	1	22.20	<0.0001*
Roadway type	4	26.11	<0.0001*
PTW legal category	1	16.01	0.0001*
PTW age	2	0.41	0.8153
PTW engine displacement	6	23.94	0.0005*
PTW mass	2	22.82	<0.0001*
PTW style	11	45.81	<0.0001*
MC rider age	6	12.74	0.0473*
MC rider impairment	1	5.69	0.0171*
MC rider speeding	1	27.05	<0.0001*
MC rider error	1	12.37	0.0004*
OV driver error	1	10.76	0.0010*
OV driver impairment	1	1.07	0.3014
Traveling speed	1	10.90	0.0010*
Crash speed	1	84.44	<0.0001*
Collision object	4	8.35	0.0796

* indicates significance at $\alpha < 0.05$

Table 22 represents the results of the backwards stepwise regression analysis using the statistically significant factors identified in Table 21. Where possible, variables were separated into categorical data in order to better understand any relationships between a specific category and a PTW rider fatality. The stepwise regression analysis sequentially removes those factors which do not contribute to the model's ability to predict a PTW rider fatality. A threshold significance level of 0.1 was selected for removal from the model and a threshold significance level of 0.05 was selected for addition to the model.

The results indicate that the variables of major arterial roadway, rider age, PTW rider errors, and PTWs with sidecars are all significant predictors of a PTW rider fatality. It should be noted that there were so few cases with PTWs with sidecars that this statistical finding may not be reliable (see Table 12). Engine displacement up to 50cc was added to the model; however, it was not found to be a significant predictor of a PTW rider fatality. An analysis of the odds ratios for these variables indicates that the risk of a PTW rider fatality increases with age and while the rider is on a major arterial roadway. The risk of a PTW rider fatality was actually found to decrease if the accident occurs at an intersection (i.e., the odds ratio is less than 1).

Table 22: Logistic regression model 1 using all significant factors

All PTW Model 1							
Number of observations: 869							
R^2 value: .2360							
Parameter	**Coefficient**	**Std. Error**	**z-value**	**Prob.**	**Odds ratio**	**95% CI**	
Constant	.0413	2.621	0.02	0.987			
Crash speed	.0320	0.005	6.68	0.000*	1.032	1.023	1.042
Intersection	-.5983	0.270	-2.22	0.027*	0.550	0.324	0.933
Motorway	-1.033	0.669	-1.55	0.122	0.356	0.096	1.319
Major arterial	1.331	0.271	4.92	0.000*	3.783	2.226	6.430
Conventional street MC with modifications	-2.010	1.197	-1.68	0.093	0.134	0.013	1.402
Dual purpose MC style	-1.583	1.047	-1.51	0.131	0.205	0.026	1.600
PTW legal category	-2.495	1.321	-1.89	0.059	0.083	0.006	1.098
1 to 50cc engine size	-2.514	1.318	-1.91	0.056	0.081	0.006	1.072
PTW rider error	0.623	0.259	2.40	0.016*	1.865	1.121	3.100
PTW rider age	0.028	0.011	2.55	0.011*	1.028	1.007	1.051
Cruiser MC style	-1.260	0.809	-1.56	0.120	0.284	0.058	1.386
PTW with sidecar	3.305	1.657	1.99	0.046*	27.245	1.059	700.968

* indicates significance at $\alpha < 0.05$

When the variables of nighttime accident, curved roadway and PTW age were added to the model, the regression procedure produced a model with slightly different variables (see Table 23). Accidents that occurred at night, PTW crash speed, non-intersections, major arterial roadways and rider age were all found to be significant predictors of a PTW rider fatality. PTW rider speeding was included as a variable in the overall model; however, it was not found to be statistically significant (i.e., it was not a good predictor of a PTW rider fatality). As observed in the previous model, accidents that occurred at intersections actually had a lower risk of resulting in a fatality (i.e., the odds ratio is less than 1). Accidents which take place on a major arterial roadway have nearly a 4 times higher risk of a fatality when compared to a minor roadway (i.e., the reference category). For every 10 km/h increase in crash speed, the odds of a PTW rider fatality increase by a factor of 1.31 (i.e., 1.028^10), i.e., 31%. Rider age was once again found to be a significant predictor of a PTW rider fatality.

Table 23: Logistic regression model 2 using all significant factors as well as night, curve and PTW age variables

All PTW Model 2 – Same as model 1 except night, curve and PTW age variables added							
Number of observations: 731							
R^2 value: .2323							
Parameter	**Coefficient**	**Std. Error**	**z-value**	**Prob.**	**Odds ratio**	**95% CI**	
Constant	.-5.1282	0.6209	-8.26	0.000			
Nighttime	0.9280	0.3485	2.66	0.008*	2.529	1.278	5.007
Crash speed	0.0276	0.0052	5.32	0.000*	1.028	1.018	1.039
Dual purpose MC style	-1.6828	1.1121	-1.51	0.130	0.186	0.021	1.64
Intersection	-0.7093	0.3061	-2.32	0.021*	0.492	0.270	0.897
PTW Rider age	0.0290	0.0132	2.20	0.028*	1.030	1.003	1.057
Major arterial road	1.3766	0.3062	4.50	0.000*	3.961	2.174	7.219
MC rider speeding	0.5839	0.3184	1.83	0.067	1.793	0.961	3.347

* indicates significance at $\alpha < 0.05$

In order to better understand how age relates to prediction of a PTW rider fatality, the age variable as reported in the MAIDS database was categorized into several different categories (see Table 13). Table 24 presents the results of the stepwise regression analysis using all the PTW significant variables identified above, with the exception that age was treated as a categorical variable. The categories chosen were the same as those used in the MAIDS Final Report. The data shows that the over 56 year age category was significant predictor of a PTW rider fatality in the all PTW database. The odds ratio for this group was 1.104 meaning that the risk of a PTW fatality in the over 56 year old age group was 10.4% higher when compared to the 26-40 year old age group (i.e., the reference age group). Once again, an accident on a major arterial roadway was found to have a nearly 4 times greater risk of being involved in a PTW rider fatality when compared to a minor road (i.e. the reference category).

Table 24: Logistic regression model 3 using categorized age variable

All PTW Model 3 – Same as Model 2 except rider age variable categorized							
Number of observations: 731							
R^2 value: .2503							
Parameter	**Coefficient**	**Std. Error**	**z-value**	**Prob.**	**Odds ratio**	**95% CI**	
Constant	-4.647	0.503	-9.25	0.000			
Nighttime	0.936	0.349	2.68	0.007*	2.550	1.286	5.055
Crash speed	0.033	0.005	6.55	0.000*	1.033	1.023	1.043
MC rider error	0.579	0.300	1.93	0.054	1.784	0.991	3.214
Intersection	-0.603	0.315	-1.91	0.056	0.547	0.294	1.016
PTW rider 41-55 yrs	0.705	0.383	1.84	0.066	2.024	0.954	4.291
Major arterial	1.339	0.309	4.33	0.000*	3.817	2.081	6.999
Dual purpose MC style	-1.564	1.099	-1.42	0.155	0.209	0.024	1.803
PTW rider over 56 yrs	1.494	0.711	2.10	0.036*	4.453	1.104	17.968
PTW rider 18-21 yrs	-1.419	0.750	-1.89	0.059	0.242	0.056	1.053

* indicates significance at $\alpha < 0.05$

In an effort to simplify the regression model, another model was developed by using rider age as a binary value (i.e., over or under 25 years of age). The output from this model is presented in Table 25. This model indicates that rider age becomes less of a predictor of a PTW rider fatality when presented as a binary value of over or under 25 years of age (i.e., it is removed from the model). The factors of an intersection or non-intersection, crash speed and a major arterial roadway become significant predictors of a PTW rider fatality, with the odds ratios being very similar to those values that were presented in previous models.

Table 25: Logistic regression model 4 using age as binary variable

All PTW Model 4 – Same as Model 2 except MC rider age categorized as under25 (yes/no)							
Number of observations: 731							
R^2 value: 0.2345							
Parameter	**Coefficient**	**Std. Error**	**z-value**	**Prob.**	**Odds ratio**	**95% CI**	
Constant	-4.2847	0.4229	-10.13	0.000			
Nighttime	.6783	.3490	1.94	0.052	1.971	0.994	3.906
MC rider speeding	0.6197	0.3218	1.93	0.054	1.858	0.989	3.492
MC rider impaired	0.8953	0.5089	1.76	0.079	2.448	0.903	6.637
Intersection	-0.6960	0.3063	-2.27	0.023*	0.499	0.273	0.909
Crash speed	0.0274	0.0052	5.27	0.000*	1.028	1.017	1.038
Major arterial	1.3977	0.3072	4.55	0.000*	4.046	2.216	7.388
Dual purpose MC style	-1.8467	1.2151	-1.52	0.129	0.158	0.015	1.707
PTW with sidecar	3.1693	1.7660	1.79	0.073	23.791	0.747	757.973

* indicates significance at $\alpha < 0.05$

When all variables listed in Table 3 are added to the initial full model, the stepwise regression produces a model with 8 variables, 6 of which are statistically significant predictors of a PTW rider fatality. Nighttime accidents, crash speed, rider age and a major arterial roadway all increase the risk of being in a crash involving a PTW rider fatality. Conversely, roadway collisions and OV driver errors reduce the risk of being involved in crash involving a PTW rider fatality, as noted by an odds ratio of less than 1 for each variable.

Table 26: Logistic regression model 5 using all variables

All PTW Model 5 – All variables listed in Table 2							
Number of observations: 729							
R^2 value: 0.2441							
Parameter	**Coefficient**	**Std. Error**	**z-value**	**Prob.**	**Odds ratio**	**95% CI**	
Constant	-5.234	.640	-8.18	0.000			
Nighttime	1.041	0.3519	2.96	0.003*	2.831	1.420	5.641
Crash speed	0.0336	0.0049	6.84	0.000*	1.034	1.024	1.044
Dual purpose MC style	-1.6631	1.0889	-1.53	0.127	0.190	0.022	1.601
Intersection	-0.5749	0.3184	-1.81	0.071	0.563	0.302	1.051
PTW rider age	0.0364	0.0132	2.75	0.006*	1.037	1.010	1.064
Major arterial	1.4646	0.3120	4.69	0.000*	4.326	2.347	7.973
Roadway collision partner	-1.5935	0.7131	-2.23	0.025*	0.203	0.050	0.822
OV driver error	-0.6495	0.3221	-2.02	0.044*	0.522	0.278	0.982

* indicates significance at $\alpha < 0.05$

L1 Analysis

Table 27 presents the results of the univariate chi-square analysis using the L1 database. The analysis shows that urban accidents, roadway type, riders over 40 years of age, L1 rider errors, crash speed and collision object are all factors that are significant predictors of a L1 rider fatality (based on a univariate logistic regression). These factors were selected for the preliminary multiple logistic regression model presented in Table 28.

It is interesting to note that for L1 vehicles neither L1 rider age nor L1 vehicle style were found to be significant predictors of a L1 rider fatality. As expected, L1 rider speeding was not found to be significant predictor of a L1 rider fatality, confirming the maximum speed limit construction of L1 vehicles and the difficulty of traveling above the speed limit on an L1 vehicle.

Table 27: Univariate chi-square analysis of individual factors using L1 database

Parameter	Degrees of freedom	Chi-square	P-value
Nighttime	1	3.93	0.0474
Urban	1	5.91	0.0151*
Curve	1	0.05	0.827
Intersection	1	1.63	0.2012
Roadway type	3	14.01	0.0029*
L1 vehicle age	2	0.58	0.7482
L1 vehicle style	3	3.25	0.3543
L1 rider age	6	9.25	0.1600
L1 rider under 20 yrs	1	1.13	0.2880
L1 rider under 25 yrs	1	0.35	0.5546
L1 rider over 40 yrs	1	5.65	0.0175*
L1 rider impairment	1	2.93	0.0867
L1 rider speeding	1	2.95	0.0861
L1 rider error	1	6.98	0.0083*
OV driver error	1	3.16	0.0757
OV driver impairment	1	2.75	0.0973
Traveling speed	1	0.19	0.6594
Crash speed	1	14.51	0.0001*
Collision object	3	8.84	0.0315*

* indicates significance at $\alpha < 0.05$

Table 28 presents the multiple logistic regression model generated by the stepwise regression procedure using only those variables in Table 27 that were found to be significant. When all factors are taken into consideration, no variables were removed from the model and a model with all 6 variables produced the model with the highest possible R^2

value. All variables shown in the table were found to be significant at an alpha level of 0.05. In terms of relative risk, the odds ratio results for this model show a reduction in risk for L1 urban accidents (OR = 0.26) relative to non-urban accidents (i.e., rural) and an increase in risk for major arterial accidents and fixed object collisions (OR = 4.72 and 4.79 respectively). The data also show that for every 10 km/h increase in crash speed, the odds of being in a fatal crash increases by 1.71 (i.e., OR = 1.055^10).

Table 28: L1 logistic regression model using all significant variables

L1 Vehicles Only Model 1							
Number of observations: 378							
R^2 value: 0.2825							
Parameter	**Coefficient**	**Std. Error**	**z-value**	**Prob.**	**Odds ratio**	**95% CI**	
Constant	-5.316	0.950	-5.60	0.000			
Urban	-1.337	0.571	-2.34	0.019*	0.263	0.086	0.807
Major arterial	1.556	0.506	3.07	0.002*	4.726	1.753	12.741
Crash speed	0.054	0.016	3.41	0.001*	1.055	1.023	1.089
Fixed object collision partner	1.566	0.729	2.15	0.032*	4.789	1.147	19.997
L1 rider age over 40	2.317	0.590	3.93	0.000*	10.146	3.194	32.230
L1 rider error	1.374	0.523	2.63	0.009*	3.951	1.419	11.001

* indicates significance at $\alpha < 0.05$

When all variables listed in Table 27 are presented, the stepwise logistic regression procedure produces a model that includes the variables of nighttime accident, fixed object collision partner, crash speed, other vehicle driver impairment and L1 rider age (see Table 29). All variables in this model were also found to be significant predictors of a L1 rider fatality. The presence of the variable nighttime indicates that when all other factors in the model are taken into consideration, nighttime accidents become significant predictors of a motorcycle rider fatality. The odds ratio indicates that the odds of a L1 rider fatality increase 1.06 times for a nighttime accident when compared to a daytime accident. As seen in the first L1 model, a fixed object collision partner impact is a significant predictor of a L1 rider fatality in an L1 accident. The odds ratio indicates that there is an 8.1 times increase in the risk of being killed in an L1 accident when the collision partner is a fixed object when compared to a light passenger vehicle impact (i.e., the reference category). Once again crash speed was also found to be a significant predictor of a L1 rider fatality. In this model, a 10 km/h increase in crash speed increases the odds of being in a fatal accident by a factor of 1.24, i.e., 24%. Other vehicle driver impairment was also found to be a significant predictor of a L1 rider fatality, with an odds ratio of 5.74 indicating a significant risk to L1 riders when the OV driver is impaired. L1 rider age was also found to be a significant predictor of a L1 rider fatality, with a slight increase in risk (i.e., OR=1.08) for every year increase in L1 rider age.

Table 29: L1 logistic regression model using all variables

L1 Vehicles Only Model 2 – using all variables listed in Table 27 with age as a continuous variable							
Number of observations: 251							
R^2 value: 0.2874							
Parameter	**Coefficient**	**Std. Error**	**z-value**	**Prob.**	**Odds ratio**	**95% CI**	
Constant	-8.205	1.429	-5.74	0.000			
Nighttime	1.381	0.676	2.04	0.041*	3.978	1.057	14.972
Fixed object collision partner	2.094	0.834	2.51	0.012*	8.120	1.583	41.640
Crash speed	0.061	0.020	3.01	0.003*	1.063	1.022	1.106
OV driver impaired	1.748	0.898	1.95	0.052*	5.741	0.988	33.363
L1 rider age	0.079	0.022	3.54	0.000*	1.083	1.036	1.131

* indicates significance at $\alpha < 0.05$

Table 30 presents the results of the stepwise regression procedure when L1 rider age is converted to a categorical variable rather than a continuous variable. The age categories generated were identical to those used in the MAIDS Final Report. The data shows that once again nighttime accidents are significant predictors of a L1 rider fatality. The data also show that L1 riders over 41 years of age are significant predictors of an L1 motorcycle fatality. The increase in risk of dying in an L1 accident increases 8.69 times for a rider on an L1 vehicle that is between 41 and 55 years of age when compared to riders 26 to 41 years of age. The odds ratio for L1 riders over 56 years of age is also extremely high (i.e., 75.0); however, this may be due to the small sample size for this category of L1 rider (i.e., n=13) and the high number of L1 rider fatalities in this age category (i.e., n=3 fatalities); therefore, this result should be viewed with caution (see Table 13). Similar to previous L1 models, a fixed object impact was a significant predictor of a fatality and the risk of a fatality in a collision with a fixed object was found to be over 13 times greater than for an impact with a light passenger vehicle (i.e., the reference category). An interesting finding in this particular model was that traveling speed was found to be a significant predictor of an L1 motorcycle rider fatality. This is different from the previous L1 logistic regression models in that crash speed was found to be a significant predictor of an L1 motorcycle rider fatality. The odds ratio indicates that for every 10 km/h increase in traveling speed, the risk of a fatality increases by 2.12 (i.e., 1.078^10).

Table 30: L1 logistic regression model using all variables
with age as a categorical variable

L1 Vehicles Only Model 3 – using all variables listed in Table 27 with age as a categorical variable							
Number of observations: 182							
R^2 value: 0.3327							
Parameter	**Coefficient**	**Std. Error**	**z-value**	**Prob.**	**Odds ratio**	**95% CI**	
Constant	-7.074	1.356	-5.22	0.000			
Nighttime	1.593	0.706	2.26	0.024*	4.918	1.233	19.616
L1 rider over 56 yrs	4.318	1.230	3.51	0.000*	75.018	6.733	835.806
L1 rider 41-55 yrs	2.162	0.819	2.64	0.008*	8.693	1.743	43.346
Fixed object collision partner	2.594	1.057	2.45	0.014*	13.377	1.687	106.100
Travelling speed	0.074	0.024	3.08	0.002*	1.078	1.027	1.130

* indicates significance at $\alpha < 0.05$

Given the findings presented in Table 30, the age variable was condensed to a binary variable of over and under 40 yrs of age. The purpose of this modification was to better understand the risks associated with 40+ year old riders while riding L1 vehicles. Table 31 presents the results of the stepwise logistic regression procedure when all variables listed in Table 27 are used as an initial model with age being categorized as a binary variable (i.e., over or under 40 yrs). The data shows that nighttime crashes were significant predictors of a L1 rider fatality, as well as OV driver impairment, crash speed, L1 rider errors, L1 riders over 40 yrs of age and fixed object collision partners. Analysis of the odds ratio shows that L1 riders who are over 40 years of age have a 20 times greater risk of being in a fatal accident when compared to those L1 riders that are under 40 years of age.

Table 31: L1 logistic regression model using all variables
with age categorized as over or under 40 yrs old

L1 Vehicles Only Model 4 – using all variables listed in Table 27 with age as over or under 40							
Number of observations: 251							
R^2 value: 0.3234							
Parameter	**Coefficient**	**Std. Error**	**z-value**	**Prob.**	**Odds ratio**	**95% CI**	
Constant	-7.372	1.305	-5.65	0.000			
Nighttime	1.458	0.695	2.10	0.036*	4.298	1.100	16.796
OV driver impaired	2.256	0.956	2.36	0.018*	9.549	1.466	62.200
Crash speed	0.057	0.020	2.86	0.004*	1.059	1.018	1.101
L1 rider error	1.364	0.729	1.87	0.061*	3.910	0.937	16.321
L1 rider age over 40	3.009	0.814	3.70	0.000*	20.265	4.110	99.928
Fixed object collision partner	1.792	0.887	2.02	0.043*	6.000	1.054	34.151

* indicates significance at $\alpha < 0.05$

Since the MAIDS report indicates that younger riders tend to operate L1 vehicles, an analysis was done to develop a model that categorized rider age as being either over or under 25 years of age. A model was developed using all the variables listed in Table 27 with the exception that age was set as a binary variable (i.e. over or under 25 years of age). Table 32 presents the results of this regression analysis. Once again, nighttime accidents, OV driver impairment, and crash speed were found to be significant predictors of a L1 rider fatality. For this particular model, an accident on a major arterial roadway was added but this variable was not found to be a significant predictor of a L1 rider fatality. Fixed object collision partners were also added to the model but not found to be a significant predictor of a L1 rider fatality.

Analysis of the rider age category indicates that L1 riders who are under the age of 25 actually have a reduced risk of being in a fatality when compared to L1 riders who are over 25 years of age. The odds ratio indicates that L1 riders under the age of 25 have a 60% reduction in risk of dying in an L1 accident when compared to L1 riders over the age of 25.

Table 32: L1 logistic regression model using all variables
with age categorized as over or under 25 yrs old

L1 Vehicles Only Model 5 – using all variables listed in Table 27 with age as over or under 25
Number of observations: 251

R^2 value: 0.3038							
Parameter	**Coefficient**	**Std. Error**	**z-value**	**Prob.**	**Odds ratio**	**95% CI**	
Constant	-4.810	0.935	-5.14	0.000			
Nighttime	1.424	0.699	2.04	0.042*	4.155	1.056	16.352
OV driver impaired	1.998	0.956	2.09	0.037*	7.378	1.129	48.192
L1 rider error	1.216	0.699	1.74	0.082*	3.373	0.858	13.269
Crash speed	0.046	0.213	2.14	0.032*	1.047	1.004	1.092
Major arterial	1.186	0.703	1.69	0.092	3.276	0.825	13.001
L1 rider age under 25	-2.297	0.756	-3.04	0.002*	0.400	0.023	0.443
Fixed object collision partner	1.692	0.887	1.91	0.156	5.433	0.956	30.883

* indicates significance at $\alpha < 0.05$

L3 Analysis

Table 33 presents the univariate chi-square analysis identifying those factors which may be good predictors of an L3 rider fatality. The table indicates that 12 factors were all found to be significant (i.e., alpha < 0.05). It is interesting to note that motorcycle engine displacement was not found to be statistically significant or a good predictor of a L3 rider fatality.

Table 33: Univariate chi-square analysis of individual factors using L3 database

Parameter	Degrees of freedom	Chi-square	P-value
Nighttime	1	1.97	0.1602
Urban	1	19.50	<0.0001*
Curve	1	1.03	0.3111
Intersection	1	17.38	<0.0001*
Roadway type	3	8.46	0.0375*
L3 vehicle age	2	0.35	0.8410
L3 engine displacement	5	6.54	0.2568
Maximum velocity (Vmax)	1	6.90	0.0086*
L3 vehicle mass	3	6.81	0.0332*
L3 vehicle style	10	23.08	0.0105*
L3 rider age	6	5.03	0.4124
L3 rider impairment	1	4.84	0.0278*
L3 rider speeding	1	17.66	<0.0001*
L3 rider error	1	7.41	0.0065*
OV driver error	1	7.49	0.0062*
OV driver impairment	1	0.12	0.7293
Traveling speed	1	21.57	<0.0001*
Crash speed	1	56.37	<0.0001*
Collision object	3	2.51	0.6427

* indicates significance at $\alpha < 0.05$

When all significant variables from Table 33 were used to form the multiple logistic regression model, the stepwise regression model sequentially removed variables until it found a best fit model that included traveling speed and four other environmental variables (see Table 34). Only traveling speed, intersection accidents and major arterial roadway accidents were found to be significant predictors of an L3 rider fatality. Analysis of the odds ratio indicates that for every 10 km/h increase in traveling speed, the odds of a L3 rider fatality increase by 1.38 (i.e., 1.033^10). The odds of an L3 rider fatality actually decrease by 55% when considering accidents that occur at intersections as compared to accidents that do not occur at intersections. As observed in the regression models for the other motorcycle categories (i.e., All PTWs and L1 vehicles), accidents that take place on major arterial roadways are more likely to result in a L3 rider fatality. For L3 accidents, the odds of a rider fatality on a major arterial roadway are 3.3 times greater than on a minor roadway (i.e., the reference category).

Table 34: L3 logistic regression model using all significant variables

L3 Vehicles Only Model 1							
Number of observations: 404							
R^2 value: 0.2134							
Parameter	**Coefficient**	**Std. Error**	**z-value**	**Prob.**	**Odds ratio**	**95% CI**	
Constant	-4.284	0.556	-7.70	0.000			
Travelling speed	0.033	0.006	5.81	0.000*	1.033	1.022	1.045
Intersection	-0.809	0.348	-2.33	0.020*	0.445	0.225	0.880
Motorway	-1.233	0.756	-1.63	0.102	0.291	0.066	1.280
Major arterial	1.187	0.351	3.38	0.001*	3.280	1.648	6.528
Other roadway type	1.579	0.745	2.12	0.034	4.85	1.126	20.871

* indicates significance at $\alpha < 0.05$

When all variables are added to the initial model, 4 of the variables noted above are included in the model (see Table 35). The only variable that was removed from this model was a motorway accident, which was not found to be significant in the first L3 model developed. In the model presented in Table 35, all variables were found to be significant predictors of an L3 rider fatality. The same trends noted above were also observed for this model (i.e., increase in traveling speed increases the odds of a fatality, etc.).

Table 35: L3 logistic regression model using all variables

L3 Vehicles Only Model 2 : All factors listed in Table 33							
Number of observations: 346							
R^2 value: 0.2224							
Parameter	**Coefficient**	**Std. Error**	**z-value**	**Prob.**	**Odds ratio**	**95% CI**	
Constant	-4.421	0.637	-6.94	0.000			
Travelling speed	0.031	0.006	4.96	0.000*	1.031	1.019	1.044
Major arterial	1.444	0.391	3.69	0.000*	4.238	1.969	9.121
Other roadway type	1.853	0.759	2.44	0.015*	6.376	1.441	28.205
Intersection	-0.843	0.407	-2.07	0.039*	0.430	0.194	0.956

* indicates significance at $\alpha < 0.05$

Given the effect that the variable rider age had upon the PTW and L1 models, similar analyses were performed using age as a continuous variable as well as using the age categories used in the MAIDS Final Report. In all cases, the stepwise regression removed the L3 rider age variable from the model, indicating that age was not a significant predictor of an L3 rider fatality. However, when age was combined with the speeding variable, a significant interaction was noted. Table 36 presents the logistic regression model that was developed comparing different L3 rider age groups and speeding. The results indicate that a significant interaction was found for those L3 riders that are 22 to 25 years of age and were found to be speeding. The odds ratio indicates that the risk of an L3 rider fatality for this particular group is over 6 times greater than for L3 riders that are aged 26 to 41 years of age (i.e., the reference group).

Table 36: L3 logistic regression model using motorcycle rider speeding and L3 rider age category variables

L3 Vehicles Only Model 3: motorcycle rider speeding and age categories and interactions							
Number of observations: 517							
R^2 value: 0.0735							
Parameter	**Coefficient**	**Std. Error**	**z-value**	**Prob.**	**Odds ratio**	**95% CI**	
Constant	-2.147	0.249	-8.62	0.000			
L3 rider speeding	0.441	0.383	1.15	0.248	1.556	0.735	3.293
L3 rider age 16-17 yrs	-0.050	0.786	-0.06	0.949	0.951	0.204	4.435
L3 rider age 18–21 yrs	-0.050	0.658	-0.08	0.939	0.951	0.262	3.450
L3 rider age 22-25 yrs	-0.437	0.575	-0.76	0.447	0.646	0.209	4.994
L3 rider age 41-55 yrs	-0.189	0.495	-0.38	0.703	0.828	0.314	2.184
L3 rider over 56 yrs	1.048	0.584	1.23	0.220	2.851	0.535	15.197
Speeding X 18-21 yrs	1.245	0.025	1.21	0.225	3.471	0.466	25.870
Speeding X 22-25 yrs	1.837	0.734	2.50	0.012*	6.276	1.488	26.476
Speeding X 41-55 yrs	1.082	0.714	1.52	0.129	2.952	0.728	11.966
Speeding X over 56 yrs	-0.441	1.465	-0.30	0.763	0.643	0.036	11.355

* indicates significance at $\alpha < 0.05$

Section IV

SUMMARY

An analysis of the MAIDS database was performed in order to identify factors that may be good predictors of a PTW rider fatality. Analyses were performed using the full MAIDS database (i.e., all PTW accidents) as well as using subsets of the MAIDS database that contained only L1 and L3 accidents. It should be noted that the database used to develop all the multinomial logistic regression models was the MAIDS database. As a result, this database includes only those riders that were involved in a motorcycle crash and includes those factors which are known to be over and under-represented as previously reported in the MAIDS Final Report. How well the regression models would actually predict a motorcycle rider fatality for a different data set is not known at this time. Nonetheless, the results of this analysis provide an important insight into those factors which, when considered together, significantly increase the risk of a PTW rider fatality.

As a result of this analysis, the following major findings were observed:

- **All PTW accident characteristics**

  - The risk of a PTW rider fatality increases with age. PTW riders over 41 years of age appear to be at greater risk. PTW riders between 18 to 21 years appear to have lesser risk of being involved in a fatality when compared to 26 to 41 year old PTW riders.

  - There is a significant increase in the risk of a PTW rider fatality when the accident takes place on a major arterial roadway.

  - Accidents that take place at a site other than an intersection appear to have a greater risk of PTW rider fatality.

  - PTWs with sidecars were found to have a higher risk of PTW rider fatality; however, there are insufficient cases in the MAIDS database to confirm this conclusively.

  - When other factors are taken into consideration, no vehicle factors were found to be statistically significant predictors of a PTW rider fatality (other than the motorcycles with sidecar result noted above).

  - PTW rider speeding was not found to be a good predictor of a PTW rider fatality.

  - For every 10 km/h increase in crash speed, the odds of a PTW rider fatality increase by 1.31.

- **L1 vehicle accident characteristics**
  - Urban accidents have a reduced risk of fatality when compared to rural accidents
  - Nighttime accidents have a greater risk of fatality when compared to daytime accidents (odds ratio = 1.06).
  - Accidents involving a collision with a fixed object have an 8.1 times greater risk of involving a L1 rider fatality when compared to a collision with a light passenger vehicle
  - For every 10 km/h increase in crash speed, the odds of a L1 rider fatality increase by 1.24
  - Other vehicle driver impairment significantly increased the odds of a L1 rider fatality (odds ratio = 5.74).
  - L1 rider errors significantly increased the odds of a L1 rider fatality (odds ratio = 3.37).
  - The risk of a L1 rider fatality increases with age. L1 riders over 41 years of age have an 8.5 times greater risk of being involved in a fatality when compared to L1 riders that are 26-40 years of age.

- **L3 vehicle accident characteristics**
  - Travelling speed was found to be a significant factor in predicting an L3 rider fatality. For every 10 km/h increase in traveling speed, the odds of a L3 rider fatality increase by 1.38.
  - Environmental factors (i.e., intersections and major arterial roadways) were also found to be significant in predicting an L3 rider fatality.
  - L3 vehicle engine displacement and L3 vehicle maximum velocity are not significant predictors of an L3 rider fatality.
  - L3 rider age was not a good predictor of an L3 rider fatality. However, when considering L3 rider speeding, L3 riders aged 22-25 were found to have a significant increase in risk of L3 rider fatality when compared to L3 riders aged 26 to 40 years.
  - OV driver errors were not found to be a significant predictor of an L3 rider fatality

Section V
REFERENCES

Association des Constructeurs Européens de Motocycles, "MAIDS accident database, Final Report 1.2," 2005, www.maids-study.eu.

Shankar, V., Mannering, F. “An Exploratory Multinomial Logit Analysis of Single-Vehicle Motorcycle Accident Severity,” Journal of Safety Research 27(3):183-194, 1996.

Savolainen, P., Mannering, F. “Probabilistic models of motorcyclists’ injury severities in single- and multi-vehicle crashes. Accident Analysis and Prevention 39(5):955-963, 2007.

Ulfarsson, G., Mannering, F. “Differences in male and female injury severities in sport-utility vehicle, minivan, pickup and passenger car accidents.” Accident. Analysis and Prevention 36 (2):135–147, 2004.