A Study on the Causes of Accidents of On-Street Parking Patrolmen: A Case Study of New Taipei City

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Abstract: In Taiwan, on-street parking fee ticket issuing is commonly conducted by patrolmen with PDAs on the street. They walk, ride bicycle or motorcycle from and to the on-street parking road sections for issuing the parking fee ticket. They are involved into accidents frequently due to their large traffic exposure. This study explored related factors to the accident occurrence on the streets where parking is charged. Using Poisson Regression Model and Binomial Logistic Regression model to investigate the influence factors cause high accident occurrences. The results depict that the age of patrolmen, using motorcycle, obstacles along the roadside, and dense of intersections of on-street parking road sections have higher accident casualty when patrolmen on duty. The results can be referred to enhance the safety of on-street parking patrolmen.

Keywords: On-street Parking, patrolmen, Accident, Poisson Regression Model, Elasticity, Binomial Logistic Regression

1. INTRODUCTION

The continuously growth of motor vehicles leads to parking problems in many urban areas in Taiwan. To solve this problem, the local governments provide more and more on-street parking spaces. Most of the parking spaces are charged parking spaces. Setting up meters would be a simple way for the local government to collect parking fee. In fact, in the past, meters were once employed in Taipei, but no more on streets now, because the parking meters were easily damaged, and it was difficult to maintain these meters. Therefore, now, the parking fee collection of on-street parking is commonly conducted by the patrolmen with PDAs, as illustrated in Fig. 1. These patrolmen patrol on the streets either on foot, by bicycle or by motorcycle. Due to long time patrolling on streets, they are exposed to high risks of traffic accidents. Therefore, this paper aimed at investigation of the accidents of patrolmen, using the data recorded by the Transportation Department of New Taipei City Government as example. First, to analyze the correlation of possible influence factor variables of traffic accidents of the patrolmen, and Poisson Regression Model was applied to set up model of traffic accidents of patrolmen. Pearson product-moment correlation and Binomial Logistic Regression were then employed to select and analyze variables that were highly related to the seriousness of injuries of the patrolmen. This study expected to set up an optimal model of traffic accidents of on-street parking patrolmen through the analysis and exploration of recorded accidents and injuries of the patrolmen. The results are expected to help the safety enhancement of on-street parking patrolmen.

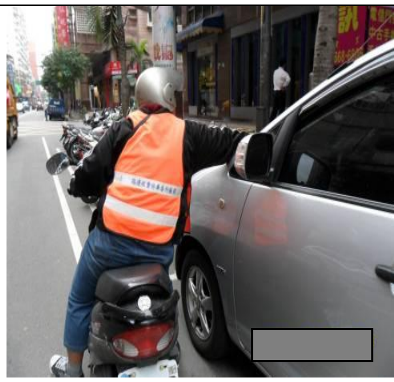
Issuing fee tickets on foot	Issuing fee tickets by bicycle	Issuing fee tickets by motorcycle
		

Figure 1. Pictures of issuing parking fee ticket by patrolmen

2. LITERATURE REVIEW

There are a lot of literature dealing with the accident cause factor and using the mathematical model to analyze the influence variables on accident occurrence international, in Taiwan, locally there are also many studies conducted in the past, such as Lain (1995) Chen (1999) Huang (2006). However, there is not any research dealt with the on-street parking fee patrolmen. About the methodology, the Poisson regression and the Multinomial Logistic Regression model are frequently adopted. Hamerslag et al., (1982) studied the impact of road and traffic characteristics on the number of vehicle accidents using Poisson regression model. The key factors on accident occurrences concluded in the study are traffic flow volume, lane width, and pavement design. Zegeer (1988) explored the relationship among the accident, traffic characteristics and highway geometry of two-lane highway. Critical variables affecting the occurrence of accidents resulted from the research are average daily traffic flow, road width, and the number of intersections. However, this paper will deal with the patrolmen especially in terms of their mode for patrolling on the street. The similar methodologies are applied.

3. METHOLOGY

3.1 Accidents of Patrolmen

This study analyzed 115 accident cases of the patrolmen occurred in New Taipei City, recorded from June 2005 to December 2010. Among these 115 cases, 105 victims are female and 10 victims are male. Patrolmen aged from 50 to 59 had the most accidents, 60 cases, followed by aged 40 to 49 having 39 cases, aged 30 to 39 with 9 cases and aged from 60 to 69 with 7 cases. 75 patrolmen were wearing reflective safety vests while 40 patrolmen were not.

Among 115 accidents, 80 accidents happened on clear days, 25 accident on rainy days, and 10 accidents on cloudy days. 80 accidents occurred in daytime. There were 7 in the early morning and 4 in the dusk. In terms of time period, 22 cases took place between 2 p.m. and 4 p.m., followed by 18 cases between 6 a.m. and 8 a.m., and still 27 cases after 6 p.m.

The number of recovery days of injured patrolmen was shown in Table 1. In most cases, the patrolmen took less than 5 days leave for recovery.

Table 1 List of recovery days injured patrolmen

Seriousness of the accidents (Days that injured patrolmen took leave for recovery)	Times of the accidents	
	Times	Percentage
less than 5 days	47	41%
from 5 days to 10 days	27	23%
from 10 days to 15 days	11	10%
from 15 days to 20 days	2	2%
more than 20 days	28	24%

3.2 Data Analysis

3.2.1 **Correlation coefficient**

Pearson's correlation coefficient γ_{xy} ranges from -1 to 1. Its formula is:

$$\gamma_{xy} = \frac{S_{XY}}{S_X S_Y} = \frac{\sum\left(X_i - \overline{X}\right)\left(Y_i - \overline{Y}\right)}{\sqrt{\sum\left(X_i - \overline{X}\right)^2 \sum\left(Y_i - \overline{Y}\right)^2}} \tag{1}$$

S_X : sample standard deviation of X

S_Y : sample standard deviation of Y

S_{xy} : covariance of variables X and Y

A value of 1 or -1 implies perfectly positive correlation or negative correlation between X and Y. A value of 0 implies that there is no linear correlation between the variables. In this study, the relationships between 13 possible influence factors of accidents and the number of the occurrence of accidents were analyzed with Pearson’s correlation. According to the analysis results, there are 5 significantly positively correlated variables and 1 negatively correlated variable are selected for further analysis was conducted.

3.2 Poisson Regression

Poisson regression is adopted to model the accidents. In the model, a set of coefficient parameters β and an input variable vector *x*, the mean of the predicted Poisson distribution is given by

$$E\left[Y_i\right] = \lambda_i = e^{\beta x_i} \quad x_i : \text{independent variables}, \ \lambda_i : \text{number of accidents} \tag{2}$$

The Poisson distribution's probability mass function is given by

$$P\left(Y_i = y_i \,|\, x_i\right) = \frac{e^{-\lambda_i}\lambda_i^{y_i}}{y_i!} \qquad y_i = 0,1,2\ldots \tag{3}$$

$$E\left[Y_i\right] = \lambda_i$$

$$Var\left[Y_i\right] = \lambda_i$$

where Y_i : the times of accident occurrence on section i where parking is charged in a time unit

$P\ Y_i$: the probability of the times of accident occurrence on section i where parking is charged in a time unit

$E\ Y_i$: the expected value of the times of accident occurrence on section i where parking is charged in a time unit

$Var\ Y_i$: the variance of the times of accident occurrence on section i where parking is charged in a time unit

By using the method of maximum likelihood the set of parameters θ that makes this probability as large as possible are found out. The equation of a likelihood function in terms of β is:

$$L(\beta) = \Pi \frac{\exp\left[-\exp(\beta x_i)\right]\left[\exp(\beta x_i)\right]^{y_i}}{y_i!} \tag{4}$$

The 6 variables selected from Pearson's correlation coefficient were input to calculate Poisson regression model.

3.3 Elasticity

The elasticity is the measurement of how changing one economic variable affects others. The definition of elasticity is based on the mathematical notion of point elasticity. In general, the "*x*-elasticity of *y*", also called the "elasticity of *y* with respect to *x*", is:

$$\eta = \frac{\Delta y / y}{\Delta x / x} = \frac{\Delta y}{\Delta x} \cdot \frac{x}{y} \tag{5}$$

$$\beta = \frac{\Delta \mathrm{E}(y)}{\Delta x} \quad ; \ \mathrm{E}(y) \text{ is the mean of } y$$

$$\eta = \frac{\Delta \mathrm{E}(y) / \mathrm{E}(y)}{\Delta x / x} = \frac{\Delta \mathrm{E}(y)}{\Delta x} \cdot \frac{x}{\mathrm{E}(y)} = \beta \cdot \frac{x}{\mathrm{E}(y)} \tag{6}$$

The elasticity is obtained from Poisson regression model.

3.4 Binomial Logistic Regression

Binominal llogistic regression is a type of regression analysis used for predicting the outcome of a categorical dependent variable based on one or more predictor variables. A dependent variable can take on a limited number of categories. The probabilities describe the possible outcome of a single trial are model-led, as a function of explanatory variables, using a logistic function as:

$$P\langle Y=1|x\rangle = \pi(x) = \frac{e^{g(x)}}{1+e^{g(x)}} \tag{7}$$

where $g(x) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n$;

$x = (x_1, x_2, \ldots, x_n)$

Binomial logistic regression refers to the instance in which the observed outcome can have only two possible types. Generally, the outcome is coded as "0" and "1" in binary logistic regression as it leads to the most straightforward interpretation. The target group (referred to as a "case") is usually coded as "1" and the reference group (referred to as a "non-case") as "0".

$$l_k(\beta) = \frac{e^{\beta'(x_{1k}-x_{0k})}}{1+e^{\beta'(x_{1k}-x_{0k})}} = \frac{e^{\beta' x_k^*}}{1+e^{\beta' x_k^*}} \tag{8}$$

Where x_{1k} are variables vector of the target group ;

x_{0k} variables vector of the reference group ;

Logistic regression is used to predict the odds of being a case based on the predictor(s). The odds are defined as the probability of a case divided by the probability of a non case. The odds ratio is the primary measure of effect size in logistic regression and is computed to compare the odds that membership in one group will lead to a case outcome with the odds that membership in some other groups will lead to a case outcome. The odds ratio (denoted OR) is simply the odds of being a case for one group divided by the odds of being a case for another group. An odds ratio of one indicates that the odds of a case outcome are equally likely for both groups under comparison. The further the odds deviate from one, the stronger the relationship. The odds ratio has a floor of zero but no ceiling (upper limit) – theoretically, the odds ratio can increase infinitely.

$$OR_j = \frac{\dfrac{P\langle Y=1|x_j=1\rangle}{P\langle Y=0|x_j=1\rangle}}{\dfrac{P\langle Y=1|x_j=0\rangle}{P\langle Y=0|x_j=0\rangle}} = \frac{\dfrac{e^{g(x_j=1)}}{1+e^{g(x_j=1)}} \Big/ \dfrac{1}{1+e^{g(x_j=1)}}}{\dfrac{e^{g(x_j=0)}}{1+e^{g(x_j=0)}} \Big/ \dfrac{1}{1+e^{g(x_j=0)}}} = \frac{e^{g(x_j=1)}}{e^{g(x_j=0)}} = e^{g(x_j=1)-g(x_j=0)} = e^{\beta_1} \tag{9}$$

where $g(x) = \beta_0 + \beta_i x_i + \beta_j x_j + \beta_k x_k$;

$g(x_j = 1) = \beta_0 + \beta_i x_i + \beta_j + \beta_k x_k$;

$g(x_j = 0) = \beta_0 + \beta_i x_i + \beta_k x_k$

In this study, 14 possible influence factors on accidents and the seriousness of the accidents were first analyzed with Pearson's correlation. 5 significantly positively correlated variables are resulted. These 5 variables will input to set up a binominal logistic regression.

4. FINDINGS

As shown in Table 2, thirteen variables were conducted correlation analysis with the times of accident occurrence. Five variables in Table 2 are significantly positively correlated to the accident occurrence. They are the age of the patrolmen, the number of the lanes, patrolmen by motorcycle, the occurrence time of the accidents, and the locations of the accidents. For each variable, respectively, patrolmen aged over 50, issuing tickets on the road with less than 2 lanes, patrolling by motorcycle, issuing tickets during rush hour, and passing through intersections. These are the main factors that increase the frequency of occurrence of accidents. On the other hand, three variables, the weather condition, issuing tickets on foot and the gender of the patrolmen, are negatively correlated to the occurrence of accidents.

Table 2 Variables Correlation Analysis

Variable	γ_{xy}	$t^* = \frac{\gamma_{XY}}{\sqrt{\frac{1-\gamma_{XY}^2}{n-2}}}$	P value	Result
Gender of the patrolmen	-0.034	-0.357	0.722	not reject H_0
Age of the patrolmen	0.624	8.417	0.000	reject H_0
Patrolmen's standing next to a parking space	0.001	0.010	0.992	not reject H_0
Patrolmen issuing tickets by motorcycle	0.528	6.551	0.000	reject H_0
Patrolmen issuing tickets by bicycle	0.169	1.808	0.073	not reject H_0
Patrolmen issuing tickets on foot	-0.111	-1.178	0.241	not reject H_0
Occurrence time of the accidents	0.362	4.094	0.000	reject H_0
Sites of the accidents	0.192	2.065	0.041	reject H_0
Width of the lanes	0.021	0.222	0.825	not reject H_0
Number of the lanes	0.607	8.044	0.000	reject H_0

Lightness	0.044	0.461	0.646	not reject H_0
Weather condition	-0.212	-2.288	0.024	reject H_0
Safety equipment	0.040	0.423	0.673	not reject H_0

Table 3 illustrates the output of Poisson Regression Model. The findings indicated that the road with less than two lanes, patrolmen aged over 50, issuing tickets by motorcycle were positively correlated to the frequency of accidents, showing significant correlation. In addition, rush hour, from 7 a.m. to 9 a.m. and from 5 p.m. to 7 p.m., and the sites of the accidents, had positive correlation to the frequency of accidents, but not statistic significant correlation. Issuing tickets on rainy days was negatively correlated to the frequency of accidents.

Table 3 Poisson Regression Model Analysis

Variable	Coefficient	Standard Error	$Z = \beta / S_\beta$	P value
Age of the patrolmen X_1	1.14566	0.45526	2.516	0.0119
Number of the lanes X_2	1.39547	0.54315	2.569	0.0102
Patrolmen issuing tickets by motorcycle X_3	0.93546	0.43484	0.151	0.0315
Occurrence time of the accidents X_4	0.23564	0.20876	1.129	0.2590
Sites of the accidents X_5	0.02495	0.21549	0.116	0.9078
Weather condition X_6	-0.11226	0.22227	-0.505	0.6135

The results of Elastic Analysis, as seen in Table 4, shows that the elasticity of three variables, which were the age of the patrolmen, the number of the lanes, and patrolmen issuing tickets by motorcycle was over 1. That suggests these three variables played an important role in the occurrence of accidents. They raised the risk of the patrolmen getting injured. First, when the patrolman was older, it was more likely to have an accident on duty. As issuing tickets on the road with less than two lanes, the patrolmen were in smaller working space and were forced to work and move in the traffic flow. Because of the heavy circulation of motorcycles and cars in New Taipei City, the patrolmen riding motorcycles to issue tickets were exposed in a higher risk situation.

Table 4 Elastic Analysis

Variable	Elasticity
Age of the patrolmen X_1	1.40
Number of the lanes X_2	1.80
Patrolmen issuing tickets by motorcycle X_3	1.23
Occurrence time of the accidents X_4	0.23

Sites of the accidents X_5	0.03
Weather condition X_6	-0.07

According to the result shown in Table 5, the age of the patrolmen, lightness, the sites of the accidents, the types of the accidents and patrolmen's standing next to a parking space were significantly correlated to the frequency of the accidents. These five variables were also positively correlated to seriousness of the accidents. Lightness was the mostly correlated factor of seriousness of the accidents, followed by the age of the patrolmen, the types of the accidents, the patrolmen's standing next to a parking space and the sites of the accidents.

Table 5 Correlation Analysis of Seriousness of the Accidents

Variable	γ_{xy}	$t^* = \frac{\gamma_{XY}}{\sqrt{\frac{1-\gamma_{XY}^2}{n-2}}}$	P value	Result
Gender of the patrolmen	-0.25	-0.267	0.790	not reject H_0
Age of the patrolmen	0.413	4.782	0.000	reject H_0
Patrolmen's standing next to a parking space	0.282	3.101	0.002	reject H_0
Patrolmen issuing tickets by motorcycle	0.065	0.686	0.494	not reject H_0
Patrolmen issuing tickets by bicycle	-0.153	-1.626	0.107	not reject H_0
Patrolmen issuing tickets on foot	0.066	0.696	0.488	not reject H_0
Types of the accidents	0.379	4.313	0.000	reject H_0
Occurrence time of the accidents	-0.115	-1.214	0.227	not reject H_0
Sites of the accidents	0.196	2.109	0.037	reject H_0
Width of the lanes	0.009	0.096	0.924	not reject H_0
Number of the lanes	0.078	0.826	0.411	not reject H_0
Weather condition	0.097	1.032	0.304	not reject H_0
Lightness	0.529	6.569	0.000	reject H_0
Safety equipment	-0.012	-0.127	0.899	not reject H_0

From the result shown in Table 6, the odds ratios of the five variables are more than 1. Among them, lightness is the strongest factor that would bring about the most serious injury of a patrolman in case of an accident.

Table 6 Binomial Logistic Regression Analysis

Variable	B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for EXP(B)	
							Lower bound	Upper bound
Age of the patrolmen	1.377	0.622	4.900	1	0.027	3.962	1.171	13.410
Lightness	2.101	0.590	12.700	1	0.000	8.173	2.574	25.955
Sites of the accidents	0.651	0.648	1.009	1	0.315	1.917	0.539	6.821
Patrolmen's standing next to a parking space	1.313	0.619	4.505	1	0.034	3.718	1.106	12.504
Types of the accidents	1.836	0.586	9.824	1	0.002	6.268	1.989	19.753

5. CONCLUSION AND SUGGESTION

This study found, interestingly, lightness will affect on the accident occurrence. As a requirement for all patrolmen on duty, putting on safety equipment, such as reflective safety vests, is highly suggested. Raising the public's awareness through advertisements, commercials, posters, etc. is also helpful. What's more, for some sections where traffic accidents happen more often, the authorities could shorten patrolmen's working hours on these sections, or should ask them to patrol by bicycle or on foot. Among the accidents, head-on collisions were the most common accident types. Therefore, equipping LED lamps on their motorcycles or bicycles and patrolmen's putting on reflective safety vests may increase the possibility of being seen by motorcyclists and drivers. Based on the analyses of this study, patrolmen aged over 50 had a higher possibility of being accident victims when they were on duty. The patrolmen aged over 50 may be in charge of sections with lighter traffic flows. The patrolmen got more seriously injury in accidents when there were obstacles around them. The solution is to re-arrange on-street parking spaces, especially on the roads where traffic accidents happen more frequently. This can protect the patrolmen, the pedestrians, motorcyclists and drivers from danger. Another way is to move away possible obstacles on the roads with the help of the police and the local governments. The parking fee ticket of on-street parking issued by patrolmen in Taiwan, currently and mainly, is a mainly fee collection method instead of parking meter. To ensure the working safety of patrolmen is very important. The results of this study are useful for the government to conduct countermeasures to enhance the safety.

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