공학석사학위논문

Deterrent Effects of Demerit Points and License Sanctions on Traffic Violation Using Proportional Hazard Model

비례위험모형을 이용한
벌점 및 면허처분의
교통법규 위반 억제효과 분석

2016년 2월

서울대학교 대학원
건설환경공학부
이 재 영

Deterrent Effects of Demerit Points and License Sanctions on Traffic Violation Using Proportional Hazard Model

비례위험모형을 이용한

벌점 및 면허처분의

교통법규 위반 억제효과 분석

지도 교수 이 청 원

이 논문을 공학석사 학위논문으로 제출함

2015년 10월

서울대학교 대학원

건설환경공학부

이 재 영

이재영의 공학석사 학위논문을 인준함

2015년 12월

위 원 장 _____ (인)

부위원장 _____ (인)

위 원 _____ (인)

Abstract

Deterrent Effects of Demerit Points and License Sanctions on Traffic Violation Using Proportional Hazard Model

Lee, Jaeyeong
Department of Civil and Environmental Engineering
The Graduate School
Seoul National University

The current traffic law enforcement is focused on reducing risk from human factors such as drunk driving and speeding. Among various implemented strategies, the demerit points and license sanction system are widely used as punitive and educational measure. This study has overcome the limitations of previous studies which they failed to estimate the separate effects of demerit points and license sanctions. The combined effect of both measures are assessed so it could produce more accurate and un-biased estimation and Cox proportional hazard model was used as a methodology. The used data was gained by Korea National Police Agency who mandatorily collects five years of drivers' conviction records. The data included personal characteristics, demerit point accumulation and license sanction status. The regression results showed that accumulated demerit points had specific deterrent effects. Also, license revocation showed consistent and significant deterrent effects, and the effects were greater than that of suspension. The male drivers under 30's holding motorcycle were identified as the most violation-prone driver group.

Keyword : Demerit points, License sanctions, Specific deterrence,
Proportional hazard model, Traffic law violation

Student Number : 2014-20553

<Table of Contents>

<List of Tables>

<List of Figures>

Chapter 1. Introduction

1.1. Research Background and Purpose

1.1.1 Research Motivation

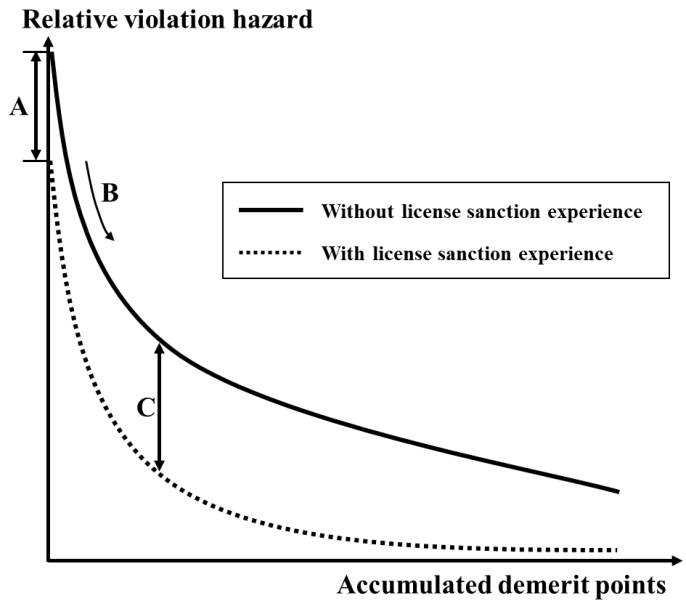
Since human factors are identified as a main cause of vehicle crashes (Farland, 1957; Haddon, 1980; Guerrero, P, 2003; AASHTO, 2010), the majority of preventive strategies and interventions are focused mostly on drivers' behavior. Among implemented strategies, the demerit points system is a widely used punitive and educational measure (ETSC, 2006). The system regulates the drivers' behavior by incur one or more license penalty points to drivers who violates specific infractions of traffic regulations. The points are put additional to fine and the drivers' license is either suspended or revoked if the cumulated points reach a specified level, or when the driver commits severe offenses.

Currently, many countries adopt administrative sanctions as their primary measures of traffic law penalty. Especially in South Korea, administrative sanctions including fine, demerit points, driving license suspension or revocation accounted for about 98% of all traffic law penalties (National Police Agency of South Korea, 2014).

The positive features of demerit point and license sanction system is as follows. The system can act as a prevention of offending traffic law because potential infringers may drive more carefully to avoid getting extra points. The system also selects risky and habitual offenders and pulls out these drivers from roads before they cause additional crashes. Therefore, the system is only effective if the demerit points can predict future crashes and recidivism can be tracked down in time. Moreover, the system consists of educational measure because the points can be deducted by taking driver improvement course. The course will have to have a sufficient level of educational elements that is effective enough to change drivers' behavior.

Despite the limitations of previous research, the effects of the administrative

sanctions have extensively been studied. The preceding studies estimated effects of demerit points and license sanctions (A or B in Figure 1). However, there is possibility of under- or over- estimation due to interactions between the points and the sanctions (C in Figure 1). Accordingly, by assessing overall effect of demerit points and license sanctions (A, B, C in Figure 1), more accurate and un-biased estimation is now possible.



A: Deterrent effect of license sanction
B: Deterrent effect of demerit points
C: Deterrent effect of interaction between license sanction and points

<Figure 1> Problem identification

1.1.2 Driving License and Demerit Point System (DPS) in Korea

In Korea, the number of people holding drivers' license is about 29.5 million, which accounts almost 60% of the population in 2014. In Korea, the Korean National Police Agency is in charge of license acquisitions and sanctions. There are six license types in Korea, including Class 1 large, Class 1 special, Class 1 regular, Class 2 regular, Class 2 small, and Class 2 moped (Table 1). The level of requirements differs by license types i.e. minimum age, prior driving experiences, type of tests.

<Table 1> License types in Korea

Type		Description	Requirements			
			Age	Written test	Course test	On-road test
Class 1	Large [a]	Truck (≥12 tons) Bus (≥15 seats)	19	√	√	–
	Special [a]	Trailer, tow truck	19	√	√	–
	Regular	Passenger car (manual) Truck (<12 tons) Bus (<15 seats)	18	√	√	√
Class 2	Regular	Passenger car (automatic)	18	√	√	√
	Small	Motorcycle (>125 cc)	18	√	√	–
	Moped	Motorcycle (≤125 cc)	16	√	√	–

[a] : Required to hold regular licenses at least 1 year

Drivers can receive demerit points in two ways. Firstly, if drivers infract traffic law, they may be given from 10 to 100 points for 1 violation. Also, drivers causing at-fault crashes receive demerit points by the number of victims and severity of the crashes. According to the license sanction types, the demerit points are accumulated for different periods. For license suspension, demerit points remain for 1 year. If the accumulated points become more than 40 points, the driver's license gets suspended for some periods. Suspension period increases 1 day for 1 point.

In terms of revocation, the demerit points can be accumulated from 1 to 3 years. Infringers lose their driving privilege if the demerit points are cumulated 121 over 1 year, 201 over 2 years and 271 over 3 years. The disqualification periods can differ by the cause of revocation. The drivers, who once received revocation and wish to drive again, will have to re-apply for the drivers' license and take the same process as the first license acquisition.

<Table 2> License sanction policy in Korea

Sanction type	Accumulation period	Threshold points	Sanction period
Suspension [a]	1 year	40	1 days per 1 point
Revocation	1 year	121	1~5years [b]
	2 years	201	
	3 years	271	

[a] Various incentive policies exist i.e. drivers with 1 year of non-violation and crash get all accumulated points removed, drivers taking traffic safety education course get 20 points removed.

[b] Period of disqualification can differ by cause of revocation

1.1.3 Research Purpose

The background information contains two main issues, 1) whether the demerit points and the license sanctions have sufficient specific deterrent effect, 2) determining the driver group types who are less deterrent and has more tendencies to offend. Given that background information, the aims of this research are defined below.

The main purpose of this research is to estimate the deterrent effect of demerit points, license sanctions and their interactions on compliance duration of traffic law infringers. To carry out this research, the following steps are accomplished.

Firstly, specific deterrent effects of demerit points are identified. To estimate its effect, demerit points are separated into two types. One is demerit point before getting suspension and the other is demerit point before getting revocation.

Secondly, the specific deterrent effects of license sanctions are estimated. This includes drivers' license suspension and revocation.

Thirdly, the deterrent effects of suspension and revocation are compared. This analysis is required to optimize the traffic law penalty system.

Finally, the violation-prone driver group is identified.

1.2. Research Composition

In Chapter 2, the effects of demerit point system implementations are reviewed. Also, the research of the effect of demerit points and license sanctions on individual driver's traffic violation is reviewed.

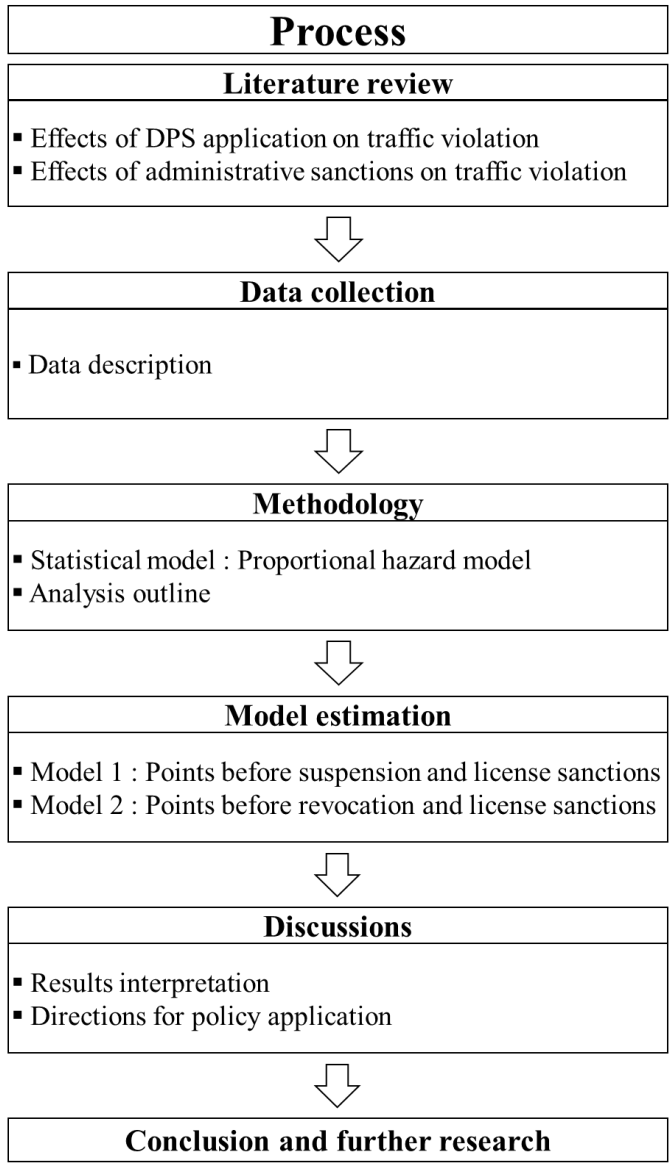
In Chapter 3, data set used in this research is described. Also the definitions of variables and basic descriptive statistics are provided. The composition of data set was explained through an example figure.

In Chapter 4, methodology of the research is introduced. The background of choosing Cox proportional hazard model for analysis is reported and the features of the model are explained. The outline of the analysis is described with the objectives of the research.

In Chapter 5, estimation results of two models are shown. The effects of demerit points before getting suspension and license sanctions on compliance duration are estimated. Then, the deterrent effects of demerit points before revocation and license sanctions on compliance duration are analyzed.

In Chapter 6, estimation results are discussed. The results are interpreted including comparison with results of previous research. Also, directions for policy application are introduced based on the estimation results.

The last chapter includes concluding remarks and suggestions for further research.



<Figure 2> Research procedure

Chapter 2. Literature Review

2.1. Effects of DPS Application on Traffic Violation

Since traffic safety has emerged as an important issue in today's society, many countries have implemented DPS in practice. The main purpose of this application is to prevent traffic law infringements by inducing pressures of losing drivers' licenses. Accordingly, scientific studies on the safety improvement effects of DPS were conducted in various countries. Especially, the deterrent effects of DPS on traffic violation behavior were examined by using before and after study of its application (Liberatti et al., 2001; Zambon et al., 2008; Benedettii et al., 2009; Mehmood., 2010; Simpson et al., 2012; Abay, 2014).

These researchers analyzed the clear deterrent effects on traffic infringements of the drivers though the research scopes of these studies were various such as seat belt use, speeding, etc. Therefore, it is hard to conclude the effects of the DPS were proved empirically.

To find out the overall effects of DPS, Castillo-Manzano et al. conducted meta-analysis using the results of previous studies. According to the analysis, the application of DPS can reduce about 30% of the number of traffic violations. However, the duration of the effects was limited to less than 18 months (Castillo-Manzano et al., 2012).

Previous studies showed deterrent effects of DPS implementation including both general and specific aspects. However, these researchers did not cover the specific effect mechanism. Therefore, this research tries to cover the specific deterrent effect as well and analysis will be carried out on the individual drivers' data.

<Table 3> Research on the effect of DPS application on traffic violation

Author(s)	Year	Country	Methodology	Deterrent effects
Liberatti et al.	2001	Brazil	Chi-squared and Fisher's tests	O
Zambon et al.	2008	Italy	Poisson model	O
Benedettini et al.	2009	Italy	3SLS regression	O
			Poisson regression	
Mehmood	2010	U.A.E.	T-test	×
Simpson et al.	2012	U.K	Questionnaire survey	O
			Chi-squared test	
Castillo-Manzano et al.	2012	-	Meta-analysis	O
Abay	2014	Denmark	Difference-in differences	O

2.2. Effects of Demerit Points and License Sanctions on Individual Drivers' Traffic Violation

Demerit point system and license sanction systems are one of the mainly adopted as administrative sanctions which are used to prevent habitual and risky traffic law violation behavior. Several numbers of studies were conducted to estimate deterrent effects of the sanctions on traffic violation. As stated before in the research motivation, the previous research evaluated the deterrent effects of only one system, either demerit points or license sanctions, not together.

The deterrent effect mechanism of demerit points was studied in both theoretical and empirical ways. Haque (1991) analyzed the effects of the number of traffic violation convictions and correction programs on compliance duration until the reconviction. The results showed that DPS influenced the compliance duration to increase from second to third offences.

Bourgeon and Picard (2007) developed incentive mechanism of demerit point system. They used a binary effort variable and they could successfully theoretically prove their model. Also, optimality of effective mechanisms was suggested.

Dionne et al. (2011) extended the previous model of Bourgeon and Picard (2007). They improved the model with continuous effort level function. Furthermore, Dionne et al. (2011) analyzed empirical data to estimate the effects of demerit points on compliance duration. They found that as the points accumulated, drivers' violation hazard level decreased for avoiding license sanctions. This

phenomenon was described as moral hazard.

Basili et al. (2015) explained the rationale of drivers' reaction to demerit points. They divided drivers into three types which were deterred, partially deterred and non-deterred drivers. Empirical analysis included accumulated demerit points, and cumulated number of prior convictions and other personal characteristics as independent variables. Although the deterrent effects of demerit points were identified, the probability of infraction increased as the number of past infractions accumulated. This indicates the existence of recidivism.

The evaluation studies of license suspension and revocation were mainly focused on driving under the influence (Hereinafter, DUI). Hagen, (1977) conducted a comparison study which focused on whether drivers received license action. The results showed that drivers with license action experience were significantly less convicted by DUIs.

Mann et al. (1991) estimated the effects of fine, license suspension and criminal punishment regards to the frequency of crashes and violations. They reported that license suspensions were consistently related to traffic safety benefits.

DeYoung, (1997) conducted quasi-experimental study comparing effects of sanctions on DUI infringers. He concluded that inducing license actions along with alcohol treatment had the most effective sanction for preventing DUI recidivism.

Meanwhile, there were a few research dealing with the full traffic law violation types. Salzburg et al. (1982) evidenced that license revocation could significantly reduce moving violation convictions and collisions. However, it did not show an impact on alcoholic drivers.

Kim et al. (2010) analyzed the deterrent effects of license suspension and revocation on individual driver's convictions and crashes. Both sanctions were shown to have significant deterrent effects and the suspension was observed to have larger effect than that of revocation.

These previous studies had limitations on estimating the collaborate effects of demerit points and license sanctions. Furthermore, the deterrent effects can be estimated more precisely by using compliance duration. This is because the number of violations or the reconviction rate can't truly reflect the changes in the specific compliance duration.

<Table 4> Comparison between preceding research and this research

Author(s)	Year	Demerit points	License sanction	Violation type	Survival analysis
Haque	1990	√	–	All	–
Bourgeon and Picard	2007	√	–	All	–
Dionne et al.	2011	√	–	All	√
Basili et al.	2015	√	–	All	–
Hagen	1977	–	√	DUI	–
Mann et al.	1991	–	√	DUI	–
DeYoung	1977	–	√	DUI	–
Salzburg et al.	1981	–	√	All	–
Kim et al.	2010	–	√	All	–
This research	2016	√	√	All	√

Chapter 3. Data Collection

The study used license-related data and violation data of newly licensed driver from October 2009 to September 2014, which was collected and preserved by the Korean Traffic Bureau of National Police Agency.

Data processing was required before conducting the analysis. Firstly, drivers without violation record had to be excluded because of the possibility of licensed non-drivers. Secondly, the license can be revoked without any warning if the driver commits extreme violation such as DUI with blood alcohol content (BAC) over 0.10, and rejection of alcohol test request etc. Those extreme cases were excluded in the analysis. Lastly, accumulated points before revocation in 2 or 3 years were not considered in this research because there were not enough cases. As a result, among the 6,232,282 newly licensed drivers in the observation period, 367,944 drivers were investigated in this research. The information listed in Table 5 presents variables used for the analysis.

<Table 5> Definition of variables

Variable	Description
Covariates	
Gender	Male or female
License type	Class 1 regular, class 2 regular, class 1-large, class 1-special, class 2-motorcycle
Age	Age when convicted grouped by 10 years
Accumulated points before suspension	Number of demerit points accumulated before suspension (0 to 39 points/year)
Accumulated points before revocation	Number of demerit points accumulated before revocation (0 to 120 points/year)
Suspension experience	Whether driving license was suspended or not
Revocation experience	Whether driving license was cancelled or not
Dependent variables	
Event	Conviction or reconviction of traffic violation
Duration	Compliance days from acquirement of driving license to conviction or conviction to reconviction

Basic descriptive statistics about the variables are provided in table 6. The data is comprised of significantly more male drivers than female drivers. In terms of the license type, passenger vehicle drivers account for about 51%. Also, the majority of the drivers are relatively younger drivers who are in their 20s and 30s. On average, the events occurred where accumulated demerit points are 7 before suspension and 16 before revocation. About 24% of the drivers experienced suspension and only about 1% for revocation. In total, 432,373 events are occurred by 367,944 drivers. This indicates that most drivers violate only 1 time during the observed period and the average compliance duration is 550 days.

<Table 6> Descriptive Statistics of drivers' data

Index	Frequency (case)	Proportion (%)	Mean	Std. err
Gender				
Male [b]	671,151	83.9		-
Female	129,166	16.1		
License type				
Level 1-regular [b]	408,218	51.0		
Level 2-regular	193,160	24.1		
Level 1-large	129,716	16.2		-
Level 1-special	15,305	1.9		
Level 2-motorcycle	53,918	6.7		
Age a				
Under 30's b	308,358	38.5		
30's	197,294	24.7		
40's	166,454	20.8		-
50's	102,675	12.8		
Over 50's	25,536	3.2		
Accumulated points before suspension		-	7.49	9.990
Accumulated points before revocation			15.92	26.441
Suspension experience	89,326	11.2		-
Revocation experience	3,341	0.4		
Event	432,373	54.0		
Censoring c	367,944	46.0		
Duration		-	551.46	441.495

a When demerit points imposed

b Reference variables in estimated model

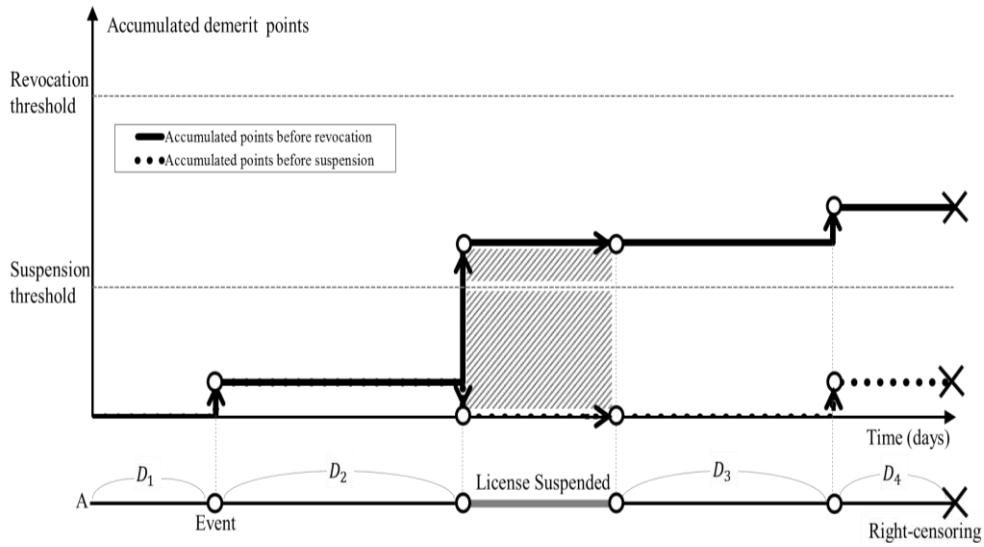
c All right-censoring due to the end of observation

To generalize the analysis of this research, descriptive statistics of collected data and that of whole drivers in 2014 are compared. The proportion of male drivers in this research data is higher than that of whole drivers which corresponds to the previous data. The license types also show similar proportions.

<Table 7> Data normalization

Index	Collected Data		Whole Drivers (2014)	
	Frequency (case)	Proportion (%)	Frequency (person)	Proportion (%)
Gender				
Male	671,151	83.9	24,072,246	59.4
Female	129,166	16.1	13,909,766	40.6
License type				
Level 1-regularb	408,218	51.0	17,115,160	57.5
Level 2-regular	193,160	24.1	10,178,636	34.2
Level 1-large	129,716	16.2	2,081,687	7.0
Level 1-special	15,305	1.9	3,232	0.01
Level 2-motorcycle	53,918	6.7	386,207	1.3

Data used in this research is a set of personal conviction history tracing demerit points and license status. First event occurs with the first conviction after the license acquisition with compliance duration of D_1. If the second event has occurred after D_2, the accumulated points exceeds the suspension threshold. So the driver gets suspended. However, the points are accumulated through separate tracks; suspension track and by revocation track. If points exceed the threshold, (e.g. Suspension threshold in the Figure 3) license sanction is imposed and the suspension track re-starts again from period D_3, (illustrated as a dotted line in Figure 3) since the sanction period is excluded from observation. The revocation track will, however, carry on with the previous accumulated points, illustrated as a bold line in Figure 3. At last, right-censoring occurs due to the end of observation (D_4).



<Figure 3> Data description

Chapter 4. Methodology

4.1 Statistical Model

Survival analysis is used to estimate the change of duration until the event occurs. There are three types of models in the survival analysis. Parametric models assume the distribution. Non-parametric models such as Kaplan-Meier and Life-table methods are carried out without assumption of distribution and uni-variate analysis. On the other hand, in Cox proportional hazard model (Cox, 1972), also called semi-parametric model, multi-variate analysis is available without assumption of distribution.

The proportional hazard model allows dealing with censored data unlike other regression models. The censored data is necessary to overcome the under- or over-estimation of the model coefficients. Also, the proportional hazard model requires no set duration, while other statistical models are limited to estimate the data of fixed duration. For the purpose of assessing the effects of several covariates on compliance duration, Cox proportional hazard model is applied for statistical model development.

<Table 8> Model selection

Type	Models	Distribution Assumption	Multi-variate Analysis
Parametric	Exponential, Weibull, Log-logistic	√	√
Non-parametric	Kaplan-Meier, Life-Table	–	–
Semi-parametric	Cox proportional hazard model	–	√
This research		–	√

The proportional hazard model is shown in Equation (1), where the baseline hazard is denoted as $h_0(t)$. This assumes the odds ratio of hazard, $h(t|x)/h_0$, is constant regardless of the time t. The model was also confirmed that the proportional hazard assumption is satisfied since the log-minus-log survival curve didn't cross each other.

$$h(t|x) = h_0(t) * \exp(\boldsymbol{\beta x}) \quad (1)$$

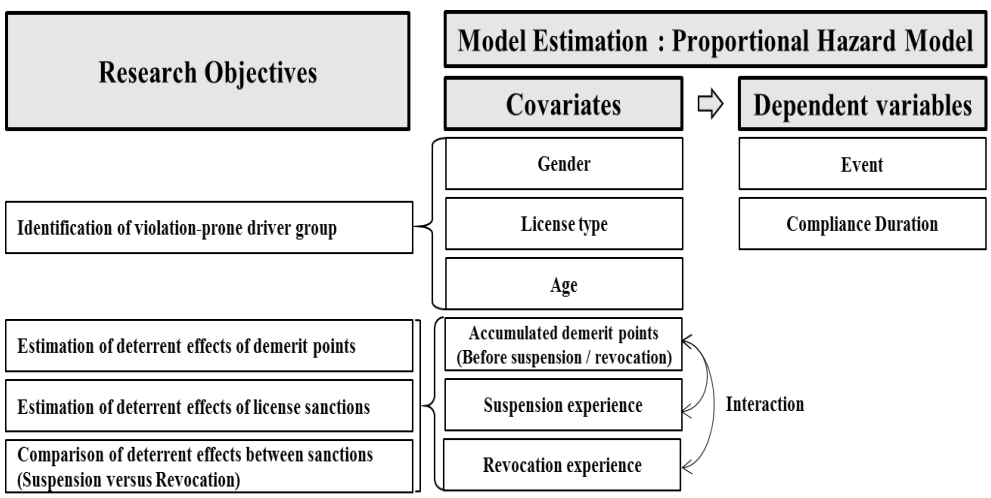
Where,

$\boldsymbol{\beta}$: Vector of regression coefficients

$\mathbf{x}$: Vector of covariates

4.2. Analysis Outline

The analysis was conducted to identify four research objectives. The first objective is to identify the deterrent effects of demerit points by using variables of accumulated demerit point. The interaction term between demerit points and license sanction experiences are also considered for the estimation. Secondly, the deterrent effects of license sanctions on the compliance duration are estimated by adopting variables of suspension and revocation experience. Also, the deterrent effects between license sanction measures are compared with each other. Lastly, using personal characteristics, i.e. gender, license type and age, violation-prone driver groups are identified.



<Figure 4> Analysis outline

Chapter 5. Estimation Results

5.1. Demerit Points before Suspension and License Sanctions

Among 432,373 cases, 46.0% cases are censored. The independent variables include gender, age, license type, accumulated points before suspension, a prior license suspension, a prior license revocation, and the interaction terms between accumulated points and license sanctions. The groups with the largest proportion are selected as the reference groups, i.e., male, Class 1 regular license type, age under 30 years. The functional form of the proportional hazard model is provided in Equation 2:

$$\begin{aligned} h(t|x) = h_0(t) * \exp(&\beta_1 x_{fem} + \beta_2 x_{2,reg} + \beta_3 x_{1,lar} + \beta_4 x_{1,spe} \\ &+\beta_5 x_{2,mot} + \beta_6 x_{30} + \beta_7 x_{40} + \beta_8 x_{50} + \beta_9 x_{\geq 60} \\ &+\beta_{10} x_{points,sus} + \beta_{11} x_{sus} + \beta_{12} x_{rev} \\ &+\beta_{13} x_{points,sus} * x_{sus} + \beta_{14} x_{points,sus} * x_{rev}) \end{aligned} \quad (2)$$

Where:

x_{fem}	: 1, if gender is female	; 0, otherwise
$x_{2,reg}$	: 1, if license type is class 2 regular	; 0, otherwise
$x_{1,lar}$	: 1, if license type is class 1 large	; 0, otherwise
$x_{1,spe}$	: 1, if license type is class 1 special	; 0, otherwise
$x_{2,mot}$	: 1, if license type is class 2 motorcycle	; 0, otherwise
x_{30}	: 1, if age is between 30 and 39	; 0, otherwise
x_{40}	: 1, if age is between 40 and 49	; 0, otherwise
x_{50}	: 1, if age is between 50 and 59	; 0, otherwise
$x_{\geq 60}$	: 1, if age is older than 59	; 0, otherwise
$x_{points,sus}$	: Accumulated points before suspension	
x_{sus}	: 1, if a driver experienced license suspension	; 0, otherwise
x_{rev}	: 1, if a driver experienced license revocation	; 0, otherwise

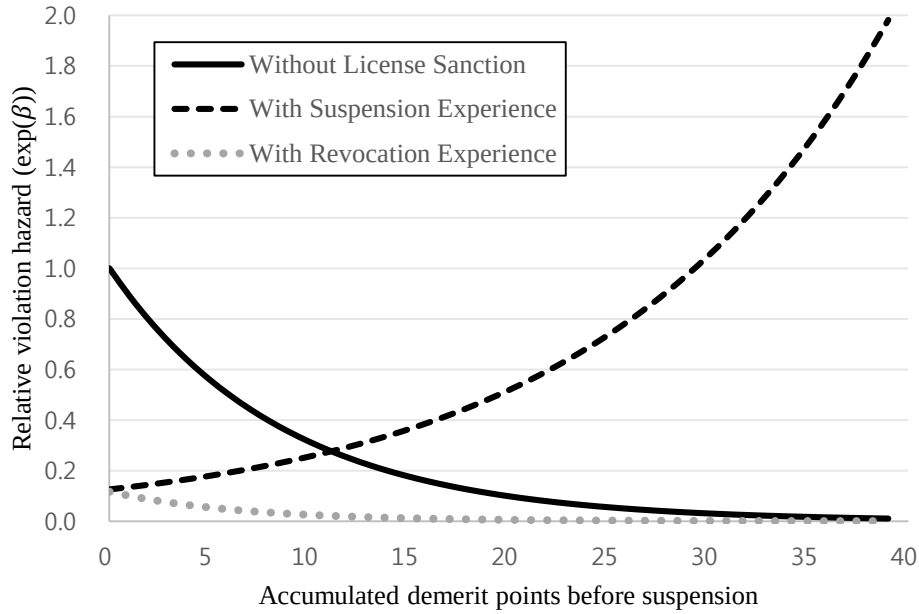
The results of developed model are statistically significant as shown in Table 9, as compared to those of the constant only model ($\chi^2(14) = 212{,}204,\ p < .01$).

The assumption of proportional hazard was examined by the log-minus-log survival plot (Figure 6). Based on the plot, the developed model has met the assumption of proportional hazard. With the confidence level of 99%, all the coefficients are shown to be significant.

<Table 9> Estimation results: Points before suspension and license sanctions

Variable	β	Std. err	exp(β)
Gender			
Male	Reference		1
Female	-.197 **	.005	.821
License Type			
Class 1 Regular	Reference		1
Class 2 Regular	.142 **	.004	1.152
Class 1 Large	.149 **	.004	1.161
Class 1 Special	.198 **	.011	1.220
Class 2 Motorcycle	.376 **	.006	1.455
Age			
Under 30	Reference		1
30~39	-.120 **	.004	.887
40~49	-.123 **	.004	.884
50~59	-.133 **	.005	.876
Over 60	-.195 **	.009	.823
Accumulated Points Before Suspension	-.116 **	.000	.891
Suspension Experience			
Without experience	Reference		1
With experience	-2.065 **	.010	.127
Accumulated Points * Suspension Experience	.186 **	.001	1.204
Revocation Experience			
Without experience	Reference		1
With experience	-2.142 **	.155	.117
Accumulated Points * Revocation Experience	-0.038 **	.011	.963

† $p < .1$, * $p < .05$, ** $p < .01$



<Figure 5> Relative violation hazard change by point accumulation before suspension

The hazard model successfully revealed statistically significant results. The accumulation of demerit points had a specific deterrent effect which increases the compliance duration of infringers ($\beta = -0.116$). This means that 1 demerit point accumulation reduces about 11% of violation hazard of prior infringers.

The experience of a prior license revocation also has the effect of reducing the hazard level. The relative violation risk has been decreased significantly after the license revocation ($\exp(\beta) = 0.117$). Moreover, after revocation, drivers tend to pay even more attention on compliance of traffic law to avoid demerit points and additional license sanctions ($\beta = -0.116 - 0.038 = -0.154$).

The experience of a prior license suspension is shown to have less deterrent effects on infringers. The compliance duration increases dramatically after the license revocation experience to reconviction ($\exp(\beta) = 0.127$). However, deterrent effect of accumulated demerit points is not sufficient to reduce suspended infringers to offend again ($\beta = -0.116 + 0.186 = 0.070$). Consequently, relative violation hazard of drivers with suspension experience exceeds that of drivers without license sanctions, where demerit points accumulated more than 11 points.

To identify features of drivers with suspension experience specifically, their

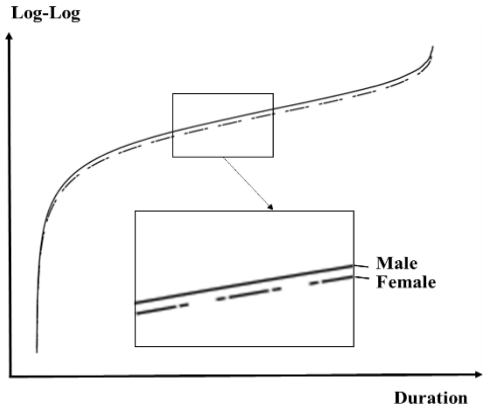
relative violation hazard changes by point accumulation before receiving suspension are estimated. In total, 87,862 events are occurred and if censoring cases perform when there is no reconviction after the license suspension, it becomes 1,604 cases. The model is statistically significant compared to the constant only model ($\chi^2(1) = 17{,}792{,}163, \mathrm{p} < .01$). The result shows that the compliance duration of suspension experienced drivers does not increase by point accumulation even before receiving suspension ($\beta = 0.067$). This tendency remained after the suspension experience ($\beta = 0.070$).

<Table 10> Estimation results: suspension experienced drivers before receiving suspension

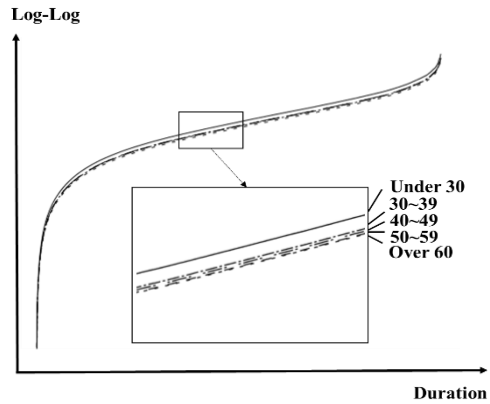
Variable	β	Std. err	exp(β)
Accumulated Points Before Suspension	0.067 **	.000	1.069

† $p < .1$, * $p < .05$, ** $p < .01$

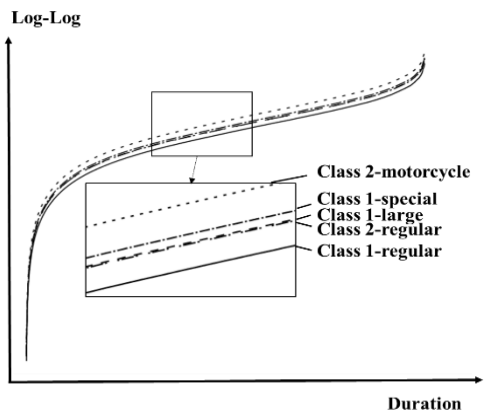
The violation-prone driver group is also identified. Male drivers under 30 years old holding motorcycle driving license has the largest hazard to be convicted with traffic law violation among whole licensed drivers group.



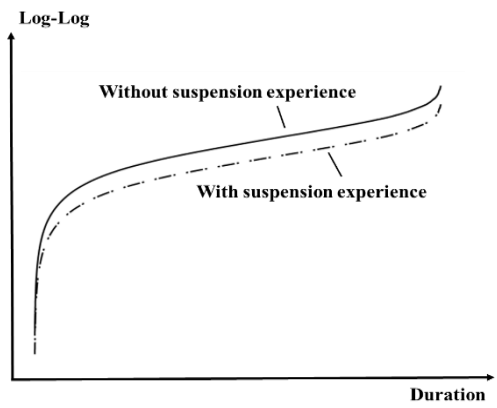
(a) Gender



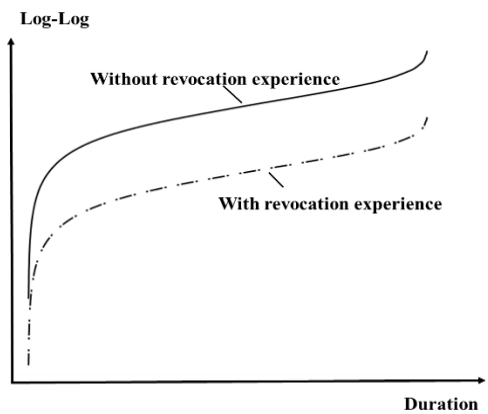
(b) Age



(c) License type



(d) Suspension experience



(e) Revocation experience

<Figure 6> Log-log survival plot of points before suspension and license sanctions model

5.2. Demerit Points before Revocation and License Sanctions

As stated in data collection chapter, the model used in this research did not consider the point accumulation before revocation in 2 years and 3 years. Therefore, among 432,373 cases, 46.0% cases are censored. The independent variables include gender, age, and license type accumulated points before revocation, a prior license suspension, a prior license revocation, and the interactions terms between points and license sanctions. The functional form of the proportional hazard model is similar to the previous model (Equation 2). The accumulated point variable is replaced by $x_{points,rev}$ from $x_{points,sus}$. The developed model is shown in Equation 3:

$$\begin{aligned} h(t|x) = h_0(t) * \exp(&\beta_1 x_{fem} + \beta_2 x_{2,reg} + \beta_3 x_{1,lar} + \beta_4 x_{1,spe} \\ &+\beta_5 x_{2,mot} + \beta_6 x_{30} + \beta_7 x_{40} + \beta_8 x_{50} + \beta_9 x_{\geq 60} \\ &+\beta_{10} x_{points,rev} + \beta_{11} x_{sus} + \beta_{12} x_{rev} \\ &+\beta_{13} x_{points,rev} * x_{sus} + \beta_{14} x_{points,rev} * x_{rev}) \end{aligned} \quad (3)$$

Where:

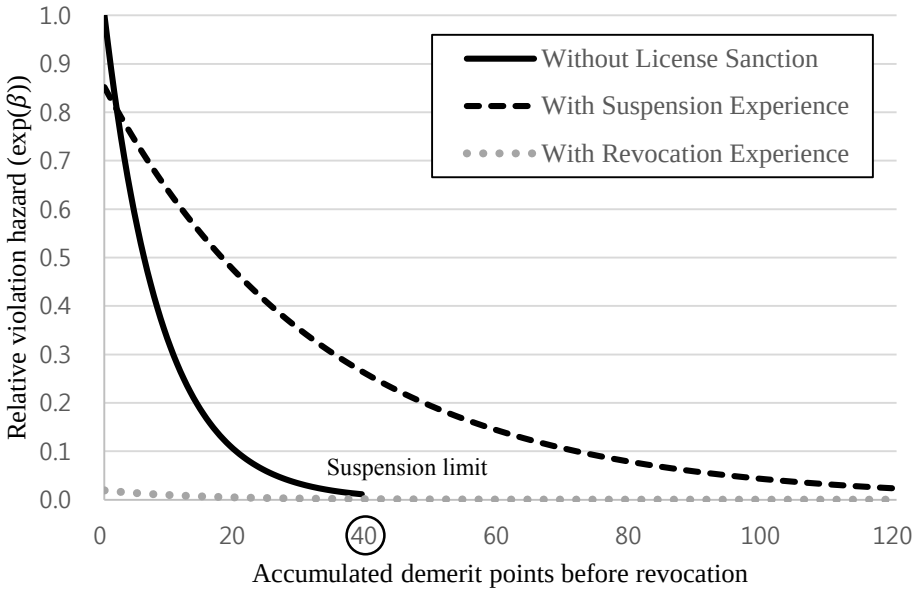
x_{fem}	: 1, if gender is female	; 0, otherwise
$x_{2,reg}$	: 1, if license type is class 2 regular	; 0, otherwise
$x_{1,lar}$	: 1, if license type is class 1 large	; 0, otherwise
$x_{1,spe}$	: 1, if license type is class 1 special	; 0, otherwise
$x_{2,mot}$	: 1, if license type is class 2 motorcycle	; 0, otherwise
x_{30}	: 1, if age is between 30 and 39	; 0, otherwise
x_{40}	: 1, if age is between 40 and 49	; 0, otherwise
x_{50}	: 1, if age is between 50 and 59	; 0, otherwise
$x_{\geq 60}$	: 1, if age is older than 59	; 0, otherwise
$x_{points,rev}$	: Accumulated points before revocation	; 0, otherwise
x_{sus}	: 1, if a driver experienced license suspension	; 0, otherwise
x_{rev}	: 1, if a driver experienced license revocation	; 0, otherwise

The results of developed model are statistically significant (Table 11), compared to those of the constant only model ($\chi^2(14) = 216{,}205, p < .01$). Based on the log-minus-log survival plot, the developed model has met the assumption of proportional hazard (Figure 8).

<Table 11> Estimation results: Points before revocation and license sanctions

Variable	β	Std. err	exp(β)
Gender			
Male	Reference		1
Female	-.198 **	.005	.821
License Type			
Class 1 Regular	Reference		1
Class 2 Regular	.143 **	.004	1.154
Class 1 Large	.145 **	.004	1.157
Class 1 Special	.191 **	.011	1.219
Class 2 Motorcycle	.370 **	.006	1.448
Age			
Under 30	Reference		1
30~39	-.121 **	.004	.886
40~49	-.123 **	.004	.884
50~59	-.137 **	.005	.872
Over 60	-.201 **	.009	.818
Accumulated Points Before Revocation	-.116 **	.000	.891
Suspension Experience			
Without experience	Reference		1
With experience	-.160 **	.013	.874
Accumulated Points * Suspension Experience	.086 **	.000	1.090
Revocation Experience			
Without experience	Reference		1
With experience	-3.956 **	.141	.025
Accumulated Points * Revocation Experience	.045 **	.05	1.055

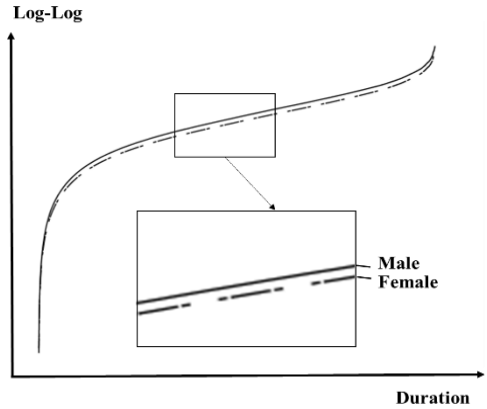
† $p < .1$, * $p < .05$, ** $p < .01$



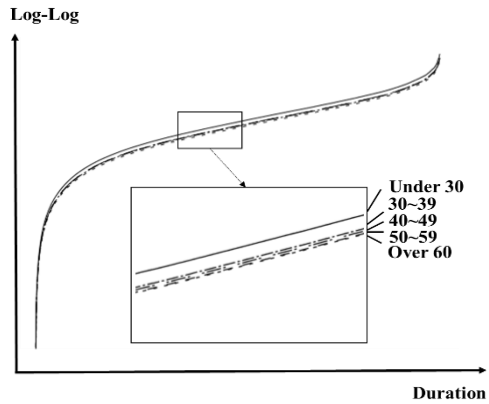
Note: Relative violation hazard of drivers without license sanctions was estimated up to 39 points because suspension threshold is 40 points.

<Figure 7> Relative violation hazard change by point accumulation before revocation

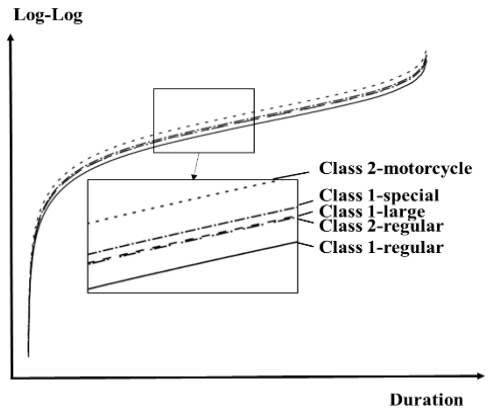
The results indicate similar results with those of the previous model in general. The specific deterrent effect of demerit point accumulation is identified. Also, license sanctions are proved to increase the compliance duration of offenders. Especially, suspension experienced drivers have longer compliance duration after points accumulation not to gain license revocation ($\beta = -0.116 + 0.086 = -0.030$). This means that violation hazard of infringers with suspension experience is mostly deterred by point accumulation even if their tendency to offend still remained. The license revocation showed consistent deterrent effects to drivers.



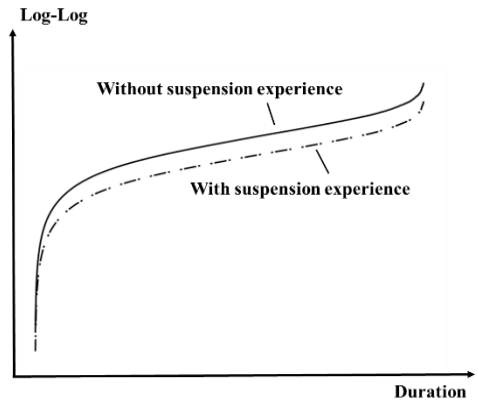
(a) Gender



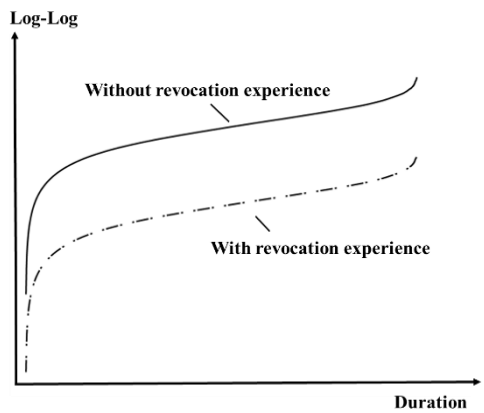
(b) Age



(c) License type



(d) Suspension experience



(e) Revocation experience

<Figure 8> Log-log survival plot of points before revocation and license sanctions model

Chapter 6. Discussion

Based on the proportional hazard model estimation results, specific deterrent effects of accumulated demerit points were identified. For the limit of both suspension and revocation, point accumulation increased the compliance duration of traffic law infringers. This result is consistent with previous research results of Haque (1987), Dionne et al. (2011) and Basili et al. (2015).

The license revocation constantly showed consistent and significant deterrent effects. The effect of revocation was larger than that of suspension. The license revocation excludes risky and habitual infringers from traffic participation for maximum 5 years. This is much more severe penalty than suspension, which act as a few month pause from driving. Thus, the estimation results imply that the stronger penalty is more effective for the prevention of recidivism. This is consistent with the principle of deterrence theory that insisted the importance of severity of penalties (Montesquieu, 1748; Beccaria, 1764; Bentham, 1789; Becker, 1968).

The deterrent effect of experience of a prior license sanction was also identified. In both suspension limit and revocation limit, the compliance duration until the first conviction after the suspension has increased. Nevertheless, the deficiency of deterrent effect of suspension action was also observed. The suspension experienced drivers might not be cautious enough about the point accumulation before suspension. The tendency to offend was shown before receiving suspension ($\beta = 0.067$), which remained after the suspension experience ($\beta = 0.070$). These infringers can be sorted as non-deterred drivers of the model of Basili et al. (2015), which classified traffic law infringers into deterred, partially deterred and non-deterred drivers. Non-deterred drivers hardly obey traffic rules and less influenced by point accumulation because their satisfaction from violating traffic law is greater than getting penalty. However, drivers with suspension experience were deterred by demerit points before revocation in this research. This means that they try to avoid license revocation which is more severe sanction than suspension.

These results indicate the direction of license sanction policies. The gap between thresholds of suspension and revocation is needed to be decreased. This is for preventing recidivism of suspension experienced drivers. Also, license revocation is seemed to be necessary for preventing recidivism of infringers. Only a few months of license pause is not enough for deterrent effect.

The violation-prone driver groups were identified which is a male drivers group under 30's holding motorcycle driving license. The lower requirement of acquirement than that of other types may have caused the relatively higher violation hazard for class 2 motorcycle drivers. To obtain motorcycle license, only written and course test are needed. This may indicate that higher cost of losing license is required for motorcycle drivers. Stricter test including on-street test for acquisition of motorcycle license is suggested.

Chapter 7. Conclusions

This research aimed to identify the deterrent effects of demerit points and license sanctions. Demerit points and license sanctions were analyzed together to overcome the limitations of estimating their overall effects. Accordingly, Cox proportional hazard model was used to estimate the effects of various covariates on the compliance duration. Five years of drivers' conviction records were collected which included personal characteristics, demerit point accumulation and license sanction status.

The regression results showed that accumulated demerit points had specific deterrent effects. In both suspension limit and revocation limit, point accumulation increased the compliance duration of traffic law infringers.

Also, license revocation showed consistent and significant deterrent effects. The effect of revocation was larger than that of suspension. This results reconfirmed the principle of deterrence theory that stronger penalty was more effective for the prevention of recidivism.

Meanwhile, the suspension action had some limitations of increasing compliance duration of infringers. Although the compliance duration until the first conviction after the suspension increased, the suspension experienced drivers were not cautious enough about the point accumulation before suspension. These infringers can be sorted as non-deterred drivers of the model of Basili et al. (2015). However, they were deterred by demerit points before revocation. This means that they try to avoid license revocation which is more severe sanction than suspension.

The license sanction policy proposal was suggested that the gap between thresholds of suspension and revocation is needed to be decreased. This is for preventing recidivism of suspension experienced drivers. Also, license revocation is necessary for preventing recidivism of infringers. Only a few months of license pause may not be enough to deter.

The violation-prone driver groups were identified. Male drivers under 30's holding motorcycle were identified as the most violation-prone driver group. To prohibit motorcycle drivers from the traffic law violation, stricter test including on-street test for acquisition of motorcycle license was suggested.

This research could be improved through further research. This research included data of five years tracing newly licensed drivers. With drivers' data including experienced drivers and longer observation period, more generalized interpretation is expected to be possible. The frequency of driving was not considered in this research. Accordingly, the exposure to traffic participants could not be controlled. Furthermore, more specific and powerful improvement policy can be derived with more personal information, e.g. occupation, income.

References

- Abay, K. A. (2014). Monetary or Non-Monetary Instruments for Safe Driving: Panel Data Evidence on the Effect of Demerit-Point–System in Denmark. *Econ.ku.dk*
- American Association of State Highway and Transportation Officials (AASHTO). 2010. *Highway Safety Manual (HSM)*. 2010
- Basili M., Belloc, F., and Nicita, A. 2015. Group attitude and hybrid sanctions: Micro-econometric evidence from traffic law, *Transportation Research Part A: Policy and Practice*, Vol. 78, pp. 325-336.
- Beccaria, C., Thomas, A., and Parzen, J. 2009. *On crimes and punishments and other writings*. University of Toronto Press. Originally published in 1764.
- Becker, G. S. 1968. Crime and punishment: An economic approach. *Journal of political economy*, Vol. 76, No. 2, pp. 169-217.
- Benedettini, S., and Nicita, A. 2009. Deterrence, incapacitation and enforcement design. Evidence from traffic enforcement in Italy. *Quaderni del Dipartamento di Economia Politica*, 564, August. Universita´ Degli Studi Di Siena. Italy.
- Bentham, J. 2007. *An introduction to the principles of morals and legislation*. Courier Corporation. Originally published in 1789.
- Bourgeon, J. M., and Picard, P. 2007. Point-record driving licence and road safety: an economic approach. *Journal of Public Economics*, Vol. 91, No 1, pp. 235-258.
- Castillo-Manzano, J. I., and Castro-Nuño, M. 2012. Driving licenses based on points systems: Efficient road safety strategy or latest fashion in global transport policy? A worldwide meta-analysis. *Transport Policy*, Vol. 21, pp. 191-201
- Cox, D.R., (1972). Regression models and life tables. *Journal of the Royal Statistical Society. Series B (Methodological)*, pp. 187-220.
- DeYoung, D. J. 1997. An evaluation of the effectiveness of alcohol treatment, driver license actions and jail terms in reducing drunk driving recidivism in California. *Addiction*, Vol. 92, No. 8, pp. 989-998.
- Dionne, G., Pinquet, J., Maurice, M., and Vanasse, Ch. 2011. Incentive mechanisms for safe driving: a comparative analysis with dynamic data. *The review of Economics and Statistics*, Vol. 93, pp. 218–227.
- European Transport Safety Council (ETSC). 2006. *Traffic law enforcement across the EU – an overview*. www.etsc.be/documents/EU%20Overview.pdf
- Guerrero, P. 2003. *Highway Safety: Factors Contributing to Traffic Crashes and*

NHTSA's Efforts to Address Them. GAO-03-730T, US General Accounting Office.

- Haddon. 1980. Advances in the epidemiology of injuries as a basis for public policy. *Public health reports*, Vol. 95, No. 5, pp. 411-421
- Hagen, R. E. 1977. *Effectiveness of license suspension or revocation for drivers convicted of multiple driving-under-the-influence offenses* (No. Report No. 59 Intrm Rpt.).
- Haque, M. O. 1990. Evaluation of the demerit points system in deterring traffic offences. *Evaluation review*, Vol. 14, No. 1, pp. 22-41
- Kim, K. S., Myeong M. H., & Kweon, Y. J. 2011. Differences in traffic violations and at-fault crashes between license suspension and revocation. *Accident Analysis & Prevention*, Vol. 43, No. 3, pp. 755-761.
- Korean National Police Agency, 2014. *Police statistical yearbook 2014*. pp. 240-243
- Liberatti, C.L.B., Maffei de Andrade, S., and Soares, D.A. 2001. The new Brazilian traffic code and some characteristics of victims in southern Brazil. *Injury Prevention*, No. 7, pp.190-193.
- Mann, R. E., Vingilis, E. R., Gavin, D., Adlaf, E., and Anglin, L. 1991. Sentence severity and the drinking driver: Relationships with traffic safety outcome. *Accident Analysis & Prevention*, Vol.23, No.6, p. 483-491.
- McFarland, R. A., and Moore, R. C. 1957. Human factors in highway safety: a review and evaluation. *New England journal of medicine*, Vol. 256, No. 19, pp. 890-897.
- Mehmood, A. 2010. Evaluating impact of demerit points system on speeding behavior of drivers. *European Transport Research Review*, Vol. 2, No. 1, pp. 25–30.
- Montesquieu, C. 2004. *The spirit of the laws*. Digireads.com Publishing. Originally published in 1748.
- Salzberg, P. M., Hauser, R., and Klingberg, C. L. 1982. License revocation and alcoholism treatment programs for habitual traffic offenders. *American Association for Automotive Medicine quarterly jurnal*, Vol. 4, No. 2, pp. 30-37.
- Simpson, H., Chinn, L., Stone, J., Elliott, and M., Knowles, J. 2002. Monitoring and evaluation of safety measures for new drivers. *Transport Research Laboratory (TRL) report*. Crowthorne, Berkshire, UK.
- SWOV. 2012. Demerit Point System. *Fact and Sheet.*
- Zambon, F., Fedeli, U., Milan, G., Brocco, S., Marchesan, M., Cinquetti, S., and Spolaore, P. 2008. Sustainability of the effects of the demerit points system on seat belt use: a region-wide before-and-after observational study in Italy. *Accident Analysis and Prevention,* Vol. 40, No. 1, pp. 231–237.

국문 초록

교통법규 위반 단속은 주로 인적 요인에 집중한다. 다양한 처벌 수단 중, 벌점 및 면허처분은 처벌 및 교정 수단으로 널리 사용되고 있다. 따라서 벌점과 면허처분의 효과에 대한 연구가 다수 수행되어왔다. 그러나 벌점과 면허처분의 효과를 각각 분석하여 벌점과 면허처분의 상호작용으로 인한 분석의 한계점이 존재하였다. 이를 극복하기 위해 본 연구에서는 벌점과 면허처분을 동시에 고려한 효과 분석을 통해 더 정확한 분석을 수행하고자 하였다.

본 연구는 벌점과 면허처분의 억제효과 규명을 목적으로 한다. 이를 위해, Cox 비례위험모형이 다양한 독립변수가 준수기간에 미치는 영향을 분석하기 위해 사용되었다. 5년간의 운전자 위반 기록이 수집되었으며 자료는 개인속성과 벌점 누적, 면허처분 상태를 포함하였다. 분석결과, 누적벌점이 특수억제 효과를 가지고 있는 것으로 확인되었다. 또한, 면허취소처분이 일관되고 확실한 억제효과를 보였으며 면허 정지처분보다 더 큰 효과를 보였다. 반면, 면허 정지처분은 위반자의 준수기간 증가 효과 효과가 제한적이었다. 따라서, 면허 정지처분 경험자의 재범을 방지하기 위해 면허 정지 기준벌점과 취소 기준벌점 사이의 간격을 줄이는 것이 바람직하다. 또한 본 연구를 통해 면허 취소처분의 필요성이 대두되었다.

마지막으로, 30대 미만의 이륜차 면허소지 남성 운전자가 위반 경향이 가장 큰 운전자 집단인 것으로 나타났다. 이륜차 운전자의 교통법규 위반을 억제하기 위해 면허취득 비용을 높일 필요성이 있다. 이를 위해 도로주행 검정을 포함한 더 엄격한 이륜차 운전면허 취득과정이 요구된다.

주요어 : 교통법규 위반 벌점, 운전면허 처분, 특수 억제,
비례위험모형, 교통법규 위반

학번 : 2014-20553