CHAPTER 1 INTRODUCTION

1.1 Research Background

Vehicle age and holding duration are two important duration variables in the study of transportation behaviors. They are connected not only with transportation planning and management strategies, but also with issues of environmental protection and traffic safety improvements. Much research studying vehicle ownership, use and the composition of the household fleet have been focused on automobiles (Forsman & Engström, 2005), but little has been noted on motorcycles. This might not seem to be strange because most developed countries have been automobile-dominated in their transport systems. However, it is valuable to put much emphasis on motorcycle ownership and use since the ownership rate of motorcycles has being increasing for many Asian countries such as Malaysia, Vietnam, and Taiwan, and the same goes in some European countries like the United Kingdom, German, and Italy (Taiwan's Ministry of Transportation and Communications (MOTC), 2006).

Motorcycle usage behavior and safety may be related to the age of motorcycle being used. Older motorcycles have a higher likelihood of being less reliable and poor maintained. Thus, they may influence the owners' behaviors on frequency, time, or distance of use, and even the owners' decision on the timing of replacing or disposing of them. Moreover, the substitution relationship among motorcycles, passenger cars and even public transit systems may be manipulated by specific traffic management strategies such as registration tax and usage fee imposed on motorcycles, and these strategies may result in the change of motorcycle holding duration and scrappage age. Older motorcycles have also a higher likelihood of being one of the causes attributable to an accident possibly due to their rather poorer maintenance and structure conditions. Even though this is relatively difficult to identify when compounded by riders' behavior in traffic safety research, it remains, however, one of the key issues in accident prevention and safety promotion.

In addition, the age of motorcycle in-use may be associated with energy consumption and emission pollution as well. In Taiwan, motorcycles less than three

years old had only a 7% rejection rate in a yearly mandatory idle testing[1] inspection, while the rate reached 24.3% for motorcycles aged ten years or more in 2004 (EPA, 2005). Older, more polluting motorcycles may be easy to identify, but little has been done to investigate whether regional motorcycle inspection and maintenance (I/M) policies and their implementation have any impact on the motorcycle age distribution. The regional perspective of this association is important, because local I/M programs have adopted different strategies to deal with older motorcycles. In particular, regions with poorly implemented I/M programs may allow older motorcycles to remain in service, thus aggravating the emissions problem.

The duration variables mentioned above appear to have different implications. Holding duration of a motorcycle is measured by the spell between the initial and the end of its holding. Hence, the transactions at the initial holding (buying a second-hand or brand new motorcycle) and the ownership termination (transfer or disposal) should be especially noted. For example, the distinction between buying a used motorcycle and a new one reveals a different behavior meaning, and likewise, a motorcycle being transferred instead of being disposed of also shows a difference in usage behavior. On the other hand, the disposal (scrappage) age of a motorcycle is the overall life span from the manufacture (or the initial registration) to the disposal time. It is obvious that the holding duration of a motorcycle is usually less than its disposal age because a holder may initially own a second-hand vehicle or end his holding by transfer.

Several research specific to the ownership duration for automobiles have been raised (Gilbert, 1992; De Jong, 1996; Yamamoto and Kitamura, 2000), but little has been noted on the study of holding time for motorcycles. In addition, comparatively little has been studied about motorcycle scrappage age in connection with the emissions inspection performance at a regional level. To establish the strategy implications, in addition to the determinants at an individual level, it is valuable to study the determinants associated with motorcycle age and ownership duration using a regional perspective.

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[1] An idle test measures the concentration of pollutants emitted by a gasoline-powered motorcycle using a testing pipe 60 cm long and 4 cm wide on the inner diameter, while the motorcycle is idling. From the beginning of 2005, a new regulation has exempted motorcycles aged less than three years from a yearly mandatory inspection.

1.2 Motorcycle Licensing System and I/M Program in Taiwan

Motorcycles in daily transportation for many Asian countries are no less important than automobiles. The number of motorcycles per thousand persons at the end of 1999 was 113 for Japan and 233 for Malaysia respectively, while for Taiwan, it was as high as 497 (International Road Federation, 2003). The registered number of motorcycles has amounted to over 13 millions (i.e. about 580 motorcycles per thousand persons and 1.8 motorcycles per household) and made up around two-thirds of all motor vehicles at the end of 2005 (MOTC, 2006). Taiwan has the highest motorcycle ownership rate around the world at the time of study.

The licensing system in Taiwan classes motorcycles according to engine capacity: mopeds (engine capacity $\leqq$ 50 cc), light motorcycles (from > 50 cc to $\leqq$ 250 cc), and heavy motorcycles (> 250 cc) (MOTC, 2002a). Motorcycles with engine capacities more than 150 cc were prohibited from registration in 1980 due to the oil crisis in the early 1980s. The licensing system was amended on July 2002 because the government promised the import of motorcycles greater than 150 cc after Taiwan joined the World Trade Organization (WTO). Prior to the amendment of the regulations, the licensing classification set 50 cc as the marker to distinguish mopeds and heavier motorcycles. Since heavy motorcycles have only recently been included into the licensing system, the number of heavy motorcycles is still small (less than 1% of the total registered numbers). However, mopeds and light motorcycles (especially those with engine capacities less than 150 cc) are popular in Taiwan because of their easy operation, high accessibility, and low cost for short trips.

Being one of the principal modes mostly for short-trips in Taiwan, motorcycle use plays an important role in urban areas. According to the latest statistics from the MOTC (2004), motorcycles usage revealed the substantial substitution with other transportation means. The statistics showed that motorcycles were heavily used (i.e. 5.2 days per week and 12.2 km per day on average); 50.5% of the motorcycle riders also reported using passenger cars, while 28.6% used public transit as their daily means of transportation; in addition, around 12% rode their motorcycles as a park-and-ride transfer mode.

To control the emissions from the large amounts of motorcycles, the motorcycle I/M programs issued by Taiwan's Environmental Protection Administration (EPA)

demand that motorcycles in use undergo a yearly mandatory idle testing inspection for carbon monoxide (CO) and hydrocarbon (HC) emissions. The standards for CO and HC values are nationally consistent, and have been tightened by the EPA five times since 1988. As a result, they are the strictest standards around the world[2] (EPA, 2002).

The percentage of motorcycles failing to meet emission standards during the annual inspection was 16.1% in 2004. Even though older motorcycles only have to comply with standards dating from their year of manufacture, they still display a disproportionately high ineligibility rate (24.3% for motorcycles aged ten years or more) (EPA, 2005).

The actual inspection is implemented by local Environmental Protection Bureaus in each of Taiwan's 23 administrative districts. Regional implementation of motorcycle I/M programs appears to be inconsistent. The average inspection rate was only 51% of all registered motorcycles in 2004, with the southern and eastern regions of Taiwan revealing rates lower than average. The lowest disqualification rate in the 2004 annual inspection was 10.4% in Taipei city, while the highest were 21.8% and 21.5% in the cities of Kaohsiung and Taichung, respectively (EPA, 2005).

The inspection rate also decreases as motorcycle age increases (MOTC, 2004). The problem of pollution from older motorcycles, which are both loosely monitored and the greatest potential source of emissions, should therefore be given careful consideration. It is important to know to what extent differences in regional I/M policy implementation inflate the disposal age of motorcycles.

In addition to the I/M program, EPA has conducted the Voluntary Accelerated Motorcycle Retirement (VAMR) program. According to Industrial Technology Research Institute (ITRI, 2002), the VAMR offered an economic incentive (2,000 NT dollars) to speed up the scrappage of motorcycles during the year 1998-2000. The VAMR program was further revised to target older in-use motorcycles aged more than 7 years provided that these motorcycles have passed the annual inspection since 2001, and the cash incentive for scrappage has been raised to 3,000 NT dollars. In total, 57,434 of motorcycles attended the VAMR program during a nearly one-year spell from March, 2001.

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[2] The latest revision of emissions standards (i.e. CO < 3.5% and HC < 2,000 parts per million) took effect at the beginning of 2004.

1.3 Research Objectives

Little has been investigated on the age or holding time for motorcycles in the international research, but in Taiwan several studies have tried to estimate the average duration of motorcycle usage (Taiwan Institute of Economic Research (IER), 1999; ITRI, 2002; Lu and Lee, 2001). These studies revealed different results, due to diversities from the definition of duration, data sources, and analysis methods. For example, Taiwan IER (1999) estimated from a recall survey that the average usage duration was about 6.35 years; however, the mean lifetime of scrapped motorcycles from the EPA's VAMR program was about 11 years (ITRI, 2002).

Some weaknesses in research design and methodology of the previous studies have been identified such as adopting a recall survey, an ambiguous definition about the duration, misusing the motorcycle age as holding duration of the owners (i.e. not taking into account the holding of the second-hand vehicles), inappropriately omitting the samples not yet experiencing a disposal or transfer event (i.e. censored data), and not yet establishing the association between the duration variable and their determinants, and so forth (Chang and Yeh, 2005). These inadequacies may increase the errors in estimation of average ownership duration for motorcycles and limit the implications of the research results.

However, these drawbacks originate mainly from the difficulties and elevated cost in establishing qualified duration data. Transportation research dependent on time is classified into the longitudinal study that usually uses several waves of panel survey with a prospective, retrospective, or mixing both methods. Each wave of panel survey records the attributes within the individual time panel and the change of the attributes between panels and the status of the duration variable concerned (if any) can be observed. Time-consuming and expensive disadvantages increase the difficulties in conducting a longitudinal study.

To overcome these difficulties, this study first attempted to apply a suitable research design to obtain both the sampled motorcycle age and the holding time span for the corresponding samples. A combination of the sampling survey of motorcycle usage conducted by MOTC in 2000 with the corresponding registration information for these sampled motorcycles in the Vehicle Registration System (VRS) was applied.

For the duration variable part, precise time according to the registration status was

collected. The registration records, however, still have some limitations. These records are determined by whether the owners have completed their registrations on the motorcycle disposal or transfer events at the time of happening. Around 11.8% of the samples that may actually have been terminated but not been registered in the VRS was identified by the owners' self-report survey (MOTC, 2000). To estimate the proportion of unfinished records with prolonged censoring (not yet undergoing any defined events that is unreasonably long) is important since they have inflated the average time of motorcycle ownership or scrappage. The specific heterogeneity produced by some incorrect registration records revealed that we should employ a special statistical method to revise our estimations.

Hence, in addition to a conventional survival analysis (or duration model) that is suitable to formulate these duration data, a split-population duration model was used to investigate the association between motorcycle age, ownership duration, and their determinants. Two main purposes were established for this study:

(1) First, we attempted to develop an appropriate design to better catch the motorcycle duration variables such as scrappage age, ownership duration, and age of second-hand motorcycle purchased at the initial holding associated with the explanatory attributes at an individual and a regional level respectively.

(2) Second, in addition to the conventional duration models, a split-population duration model was applied to compare with the conventional base model and to correct the heterogeneity of holding duration and scrappage age of a motorcycle, produced by some terminating ownership events without finishing their record status in the VRS.

1.4 Research Methods

As previously mentioned, to overcome the difficulties of collecting duration variables that usually needs to conduct a longitudinal survey, we employed the VRS records of the sampled motorcycles. Both the precise registration time for specific events such as the initial time of motorcycle manufacture, the initial holding time of the sampled owners, and the motorcycle "transfer" or "disposal" record and its date (if any) and as well the censored outcomes (not yet undergoing any defined events) at the end of the observation could be recognized. Three kinds of motorcycle duration variables were collected in this study: holding duration, scrappage age, and age of second-hand

motorcycle purchased at the initial holding. In addition, two different states both for owner's initial holding (purchased a used or new vehicle) and terminating holding (disposal or transfer) were also distinguished via the registration records.

A great many important transportation studies have been dependent on time, and their applications in duration models have been extensively reviewed (Hensher and Mannering, 1994). Motorcycle age and ownership spell are both duration variables, applying a duration model (also called a survival model) to formulate our problem appears to be appropriate. Different functional forms for survival models can be applied according to the different assumptions of hazard function dependent with time, such as parametric (exponential, Weibull, and log-normal) or semi-parametric (alternatively known as Cox proportional hazard) models. We chose the Cox proportional hazard model to estimate the different durations for it is robust to approximate a correct parametric model without needing to assume a specific functional form in advance (Kleinbaum, 1995).

In addition to the conventional Cox regression model, a split-population duration model is specially developed to estimate and revise the survival time for a population in which some elements will never experience events eventually (Schmidt and Witte, 1989; Bandopadhyaya and Jaggia, 2001). Prior transportation research that employed duration models with possible applications for a split-population method is sparse. However, a portion of never experienced events, postulated in the split-population model, may elaborate on the possibility that some motorcycle owners may not alter their motorcycle registration status in the VRS, even though a specific terminating ownership event, such as a stolen vehicle or a disposal, has occurred. Therefore, to estimate the proportion of prolonged censoring data, a split-population duration model with Weibull hazard function, that assumes the terminating ownership hazard increases with time, was employed.

Several studies specific to ownership duration for automobiles can offer us abundant variables such as owner, vehicle, and socioeconomic attributes, and empirical results for reference (Gilbert, 1992; De Jong, 1996; Yamamoto and Kitamura, 2000). We established the expected assumptions with terminating ownership hazard both from prior studies on automobiles and our own speculations. Three types of covariates, including vehicle, motorcycle usage, and aggregate attributes, were introduced to the duration models to examine the regression relationships with three distinct duration variables (i.e. motorcycle scrappage age, holding duration, and age of second-hand

motorcycle purchased). “Vehicle attributes” and “motorcycle usage attributes” were retrieved from the VRS records and 2000’s MOTC sampling survey, respectively. In addition to the variables at an individual level, different administrative divisions may possess diverse characteristics regarding the standard of living, the traffic composition, and transportation management or vehicle emissions inspection policies that may affecting motorcycle ownership duration. Therefore, we use two types of “aggregate attributes” (socioeconomic and inspection performance-related variables) that came from officially published index to examine the association with duration variables at a regional perspective. Limited by the availability of the sampled owners’ individual information, another wave of attributes cannot be further gathered except for the one wave survey from the MOTC.

Additionally, two different states for the owner’s initial holding and terminating holding were separately applied a logistic regression model to examine the relative odds between the two events.

The analytical methods applied on various issues can be expressed as follows:

(1) Cox regression model

A Cox regression model was applied to three duration measurements ─ motorcycle holding duration, scrappage age, and age of second-hand motorcycles purchased. Two competing risks for ending motorcycle holding by disposal or by transfer were also estimated by the Cox model.

(2) Split-population duration model

Censored data comprised a big proportion for measuring motorcycle holding duration and scrappage age via VRS records. To estimate part of these censored data that was prolonged censoring and correct the possible estimation bias, a split-population duration model with Weibull hazard function was further employed to estimate holding duration and scrappage age respectively.

(3) Logistic regression model

Holding duration has been put much emphasis not only on the survival time but also on the transaction behavior (Gilbert, 1992; De Jong, 1996). We applied a logistic regression model to examine the likelihood of two different states for the owner’s initial holding (purchased used/new motorcycle) and terminating holding (disposal/transfer event) separately.

1.5 Overview of Dissertation

The dissertation is organized as follows. Chapter 2 presents literature review that discusses implications of different vehicle duration measurements, the overview of possible determinants associated with vehicle holding duration, relationship between vehicle age and pollutant emissions, and comparisons of different studies on motorcycle age and holding duration. We also summarize several weaknesses in research design and methodology for prior domestic studies in this chapter,. The research framework about collection of duration data via the VRS records and their speculated associations with possible determinants are proposed in chapter 3. In chapter 4, we divide the methodology into three parts: data sources, analytical methods, and model specification and hypotheses. The thorough concepts for a survival analysis and mathematical formulations for Cox regression, a split-population duration, and logistic regression model have been elaborated respectively. In addition, defined independent variables and their expected associations with duration variables are also raised. Chapter 5 demonstrates the estimated results according to the three different types of regression models and analyzes the contribution of significant variables on hazard ratio one at a time. The split-population duration model displays the estimated proportion of prolonged censoring both for motorcycle holding duration and scrappage age. Chapter 6 discusses the possible reasons for the significant determinants attributable to the different duration and event variables. Some implications and research limitations are discussed at the end of this chapter.