CHAPTER 2 LITERATURE REVIEW

Little emphasis has been put on motorcycle research, but the past studies focusing on car ownership, car use, and the composition of car fleet can still offer useful information connected with our problems.

Forsman and Engström (2005) classified disaggregated car ownership models into static and dynamic models. Static models, also called discrete-choice models, study the household car fleet at a specific point (Golob, Kim and Ren, 1994; Golob, Bunch and Brownstone, 1997; Ewing, Gross, and Li, 1998). The assumption that households in a static model are in equilibrium with respect to their car fleet may be violated due to the change of transaction costs (e.g. income, vehicle fixed and variable cost). Dynamic models describe car transactions either by duration models (Kitamura, 1992; Gilbert, 1992; De Jong, 1996; Yamamoto and Kitamura, 2000; Chen and Lin, 2006) or discrete-time models. Duration models estimate the time elapse between car transactions, while discrete-time models describe whether a transaction has occurred during a specific time interval. Owing to a car ownership is a dynamic process, duration models that are suitable for forecasting have been generally recommended in the recent literature (Ramjerdi et al., 2000; De Jong, et al., 2002; De Jong, et al., 2004).

2.1 Implications of Different Types of Vehicle Duration Measurements

Three duration measurements for vehicle ownership have been noted in the past studies and offer lots of policy implications. The three measurements are vehicle holding duration, the age of existing vehicles, and vehicle disposal (scrappage) age. The use of any measurements is determined by the research objective. We discuss these measurements and their implications in policy making respectively as follows.

1. Vehicle holding duration

Vehicle holding duration is defined as the time elapsed between the initial and the terminating holding of a vehicle. This measurement is usually part of the lifetime of a vehicle because a holder may own a second-hand vehicle at the initial holding or end his holding by transfer. Vehicle transaction occurs at both the initial ownership (e.g. purchased new/used) and the end of holding (e.g. vehicle w/wo replacement). Hence, holding duration has been put much attention on the households' or the holders' behavior. This measurement has been directly used as a dependent variable to formulate a duration model that dedicates to vehicle holding and transaction behavior (Kitamura, 1992; Gilbert, 1992; De Jong, 1996; Yamamoto and Kitamura, 2000).

2. Age of existing vehicles

Age of existing vehicles (or vehicle age in-use) is defined as the duration between the vehicle manufacture and the current existence in a household. The age for vehicle in-use usually exhibits vehicle characteristic being used and may be connected with energy consumption, pollution emissions, and even traffic safety. For example, as older vehicles consume more energy and also emit more than newer vehicles, the estimation of survival length of existing vehicles has revealed crucial implications for energy consumption (Kear and Niemeier, 2003) and pollution prevention (Anilovich and Hakkert, 1996; Bin, 2003). Furthermore, Blows et al. (2003) indicated that older vehicles (constructed before 1984) had around three times the odds in involvement of an accident as compared with newer vehicles (constructed after 1994).

3. Vehicle disposal (scrappage) age

Vehicle disposal or scrappage age describes the lifetime of a vehicle that is measured by the time between the vehicle manufacture and its disposal. This measurement connects also with energy consumption and pollution emissions issues. The vehicle retirement (scrappage) programs targeted at older or more polluting vehicles have been extensively studied (Deysher and Pickrell, 1997; Dill, 2001; ITRI, 2002; Chen and Lin, 2006).

According to Chen and Lin (2006), these measurements can also be divided into two different levels—vehicle and household levels, due to diverse data collection and meanings. Vehicle-level datasets are typically collected at the inspection station or vehicle registration system, while household-level datasets are typically collected during household travel survey.

Vehicle duration variables mentioned above are important inputs either as dependent or independent variables to establish the models regarding car ownership, car use, and car fleet composition in a household. Besides, these car fleet models usually fall into an essential part of a broader perspective of emission forecasting models. Forsman and Engström (2005) proposed a forecasting system that combined with aggregated and disaggregated models to predict total number of cars, the distribution of cars of different types and ages, and kilometers linked to specific car types and ages, in order to evaluate a wide variety of policy scenarios (e.g. the introduction of CO_2-differentiated vehicle taxes). They also compared five existing model systems such as the ALternative TRANSport systems (ALTRANS) in Denmark, the COWI Cross-Country Car Choice Model in several European countries, CARMOD in Australia, FACTS (Forecasting Air pollution through Car Traffic Simulation) in the Netherlands, and DVTM (Dynamic Vehicle Transaction Model) raised by De Jong, and pinpoint the gaps and shortcomings in these existing model systems. The main shortcoming of these model systems were static ownership models except for DVTM, and in addition, all the existing systems had no considerations about motivational factors (e.g. travel attitude, personality, and lifestyle), which has been recently noted by a couple of studies (Wu et al., 1999; Steg et al., 2001; Choo and Mokhtarian, 2004).

In sum, the choice of vehicle duration measurements may be usually associated with the research objectives and thus have different policy implications matched with the objectives.

2.2 Vehicle Ownership Duration and Determinants

Several studies specific to automobile ownership duration have been extensively studied and offered us abundant empirical results for reference (Gilbert, 1992; De Jong, 1996; Yamamoto and Kitamura, 2000). Gilbert (1992) employed consecutive monthly observations during a six and a half year period to establish a competing risk model for three different events: replacement with a new vehicle; replacement with a used vehicle; and disposal without replacement. De Jong (1996) applied retrospective automobile panel data about vehicle replacement to test several functional forms of duration models, according to different assumptions of time dependence on hazard rate, heterogeneity, and time-varying covariates. Yamamoto and Kitamura (2000) employed vehicle specific error components in their duration models to interpret unaccounted associations between actual and intended holding durations.

Many covariates including vehicle, user, household or aggregate socioeconomic attributes associated with automobile holding durations were examined in the above studies. Forsman and Engström (2005) presented the overview of variables used in disaggregated models of car ownership, car type, and use. Choo and Mokhtarian (2004) also summarized the significant explanatory variables used in several studies on static discrete-choice models regarding vehicle type choices and concluded that disaggregate choice models (multinomial logit and nested logit) were generally used for the vehicle type choice. They also raised vehicle and household characteristics that constituted the explanatory variables in the models.

In addition, several studies have focused on the households' joint decision on car ownership and car use to estimate discrete and continuous models simultaneously (Mannering and Winston, 1985; Train, 1986; Hensher et al., 1989). The joint discrete/continuous framework for vehicle ownership and use has also been extended to households' car/motorcycle ownership and use in Taiwan (Jou and Chen, 2003; Jou, Liu, and Wang, 2004; Jou, Chen, and Weng, 2004). Jou, Chen, and Weng (2004) applied an Ordered Bivariate Probit model and a Seemingly Uncorrelated REgression (SURE) model respectively to identify the existence of the substitute relationship between car and motorcycle both for their ownership and usage.

Different from a static discrete-choice model, a dynamic duration model may incorporate the variables changing with time (time-varying covariates) such as income, number of owned cars, and vehicle odometer readings, etc. by several waves of observations. However, comparatively little research (e.g. De Jong, 1996; Chen and Lin 2006) applied the time-varying covariates possibly due to the difficulty and high cost of data availability.

According to the past studies, we summarize the possible explanatory variables used in establishing vehicle duration models in Table 1.

Table 1 Examples for Explanatory Variables in Vehicle Duration Models

Variable category	Variable sub-category	Examples of variables
Vehicle	Fixed costs	Purchase price Annual vehicle tax Insurance
	Variable costs	Fuel price Operating costs
	Vehicle characteristic	Engine size Fuel-type Vehicle age in-use Odometer reading Kilometer traveled Brand Model
Household	Socio-demograghic	Size of household Life stage of household Number of children Age of primary user of holder Gender of primary user or holder Living area Housing form Number of license holders
	Socio-economic	Personal or household income Employment status Education level Occupation
Household vehicle fleet		Number of owned vehicles (passenger cars and motorcycles) Average market price of household fleet Average age of household fleet
Aggregate socio-economic factors		Consumer confidence index Price index of motor fuels Unemployment rate Inflation rate for new cars, used cars, automobile maintenance and repair, and unleaded gasoline, etc. Service station availability (relevant for alternative fuel vehicle)

Note: Adapted from Forsman and Engström (2005).

2.3 Vehicle Age and Pollutant Emissions

Both vehicle in-use and vehicle scrappage age have been connected with energy and pollution prevention policies. The use of older vehicles can lead to increased air pollutant emissions. Many studies have shown that the emissions of four-wheeled vehicles (Anilovich and Hakkert, 1996; Bin, 2003; Beydoun and Guldmann, 2006) and motorcycles (Lu and Lee, 2001) are positively correlated with their age. Stead (1999) applying a correction factor based on different vehicle types showed that older vehicles would produce a higher rate of both emissions and energy consumption in his model. Older vehicles may produce higher emissions because of poor maintenance (Bishop and Stedman, 1996; Anable et al., 1997), backward technology (Anable et al., 1997), or both.

The vehicle retirement (scrappage) programs also have revealed the association between the lifetime of vehicles being scrapped and emissions related issues. Dill (2001) used data from the voluntary accelerated vehicle retirement (VAVR) programs in California, and found that the VAVR programs reduced the air pollutant emissions significantly, particularly of reactive organic gases. Chen and Lin (2006) applied a duration model in exploring the vehicle scrappage decisions by the government agencies. They indicated that vehicles using regular no-lead fuel had lower survival probability than vehicles using alternative fuel and that this finding encouraged the development and the purchase of alternative fuel vehicles. In addition, Chen and Niemeier (2005) found a negative relationship between vehicles passing a smog check test and their hazards of being scrapped using a smog check vehicle database in California. They also indicated that if the vehicle is in need of repair, or is identified as a gross polluter, its disposal hazard rate increases.

According to the past studies, older, more polluting motorcycles producing more emissions and the effectiveness in reducing emissions by VAVR programs have been identified, 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. Therefore, in this study we attempt to explore the relationship between motorcycle disposal age and regional I/M performance measures such as inspection rate, ineligibility rate, and CO and HC emission levels.

2.4 Motorcycle Age and Holding Duration

Compared with age of passenger vehicles, little literature has mentioned about motorcycle age or holding duration in international studies, possibly due to a lower motorcycle ownership rate in most western countries. For example, motorcycles comprised only less than 1% of the overall vehicle fleet in state of Texas of the United States and the average age of active vehicles in the overall state fleet was 6.68 years, whereas mean age of passenger car and motorcycle in-use was 3.82 and 9.50 years, respectively (Office of Vehicle Fleet Management, 2005). The number of motorcycle registrations also simply comprised 3% of the total motor vehicle fleet in Australia, and in Victoria province, 33% and 60% of registered motorcycles were 3-5 and over 5 years old respectively. In addition, the average age of motorcycle in-use was 7.6 years, which is about half that of cars (Road Safety Committee, 1993). In addition, active age of motorcycles seems to be lower in Bangkok of Thailand. According to United Nations Development Program (UNDP) and World Bank Energy Sector Management Assistance Program (ESMAP) (2003), motorcycles made up 41.1% of the overall registered motor vehicles in Bangkok at the end of 1999, the proportion of the registered in-use motorcycles aged five years or more was only 36%, and the average age of these motorcycles was estimated at 4.5 years.

In Taiwan, several statistics and research specific to motorcycle age have been conducted (IER, 1999; MOTC, 2002b; Taipei Government Motor Vehicle Office, 2005; ITRI, 2002; Lu and Lee, 2001). A questionnaire survey on Taiwan's motorcycle market sales was conducted to investigate the behavior of motorcycle ownership (IER, 1999). The survey found that 70.7% of the sampled households had disposed of motorcycles. Of the disposed motorcycles, 12.4% of the usage duration were reported to be less than 3 years, 48.2% within 3 to less than 6 years, 27.1% within 6 to less than 10 years, and 12.3% over 10 years. The mean usage years of these scrapped motorcycles was around 6.35 years by self-report.

Another questionnaire survey by Statistics Department of MOTC reported that the expected remaining years for the sampled in-use motorcycles was 5.2 years in the 2001 (MOTC, 2002b). Provided that the active mean age has no change over a short time period, say within 3 years, added with the mean age of motorcycles in-use (8.1 years estimated by the time on December, 15, 1999 of this study), the average disposal age expected to be 13.3 years. Applying the similar estimated method, the average usage duration in Taipei city was at least 12.7 years (4.9 of the expected remaining years from MOTC (2002b) and at least 7.8 of the mean motorcycle in-use age from Taipei Government Motor Vehicle Office (2005)). The hypothetical question about what the suitable disposal years is provided that the government takes a mandatory action was responded to be 7.1 years in both of the two waves of investigations (MOTC, 1997; MOTC, 1998).

In addition, ITRI (2002) applied the scrapped motorcycles from the VAMR program to estimate a mean disposal age of being 11 years. Around 61.8% of motorcycles attending the incentive program had scrappage age ranging from 9-12 years. Lu and Lee (2001) assumed an exponential function to calibrate the mean disposal age of motorcycles in the year 1999 from both the age distribution of motorcycle-in-use proportion in attending a yearly emissions inspection and in the VRS records. Their estimated results showed that data from emissions inspection had a mean disposal age of 7.88 years, while for the VRS records, a mean age of 10.44. Diverse data sources and estimated mean duration for motorcycle usage or disposal is exhibited in Table 2.

Table 2 Comparisons of Motorcycle Usage Duration among Different Studies

Author	Data source	Period	Usage duration/ Disposal age (years)
Institute of Economic Research	Questionnaire	1999	6.35
MOTC (expected remaining years +average in-use years (8.1))	Questionnaire & Registration records	2002 & 1999	5.2(+ 8.1)= 13.3
MOTC (expected remaining years +average in-use years (7.8))	Questionnaire & Registration records	2002 & 2005	4.9(+7.8)=12.7 (Taipei city)
MOTC (mandatory disposal years)	Questionnaire	1997	7.1
		1998	7.1
Industrial Technology Research Institute	VAMR program	2002	11.0
Lu and Lee	Emissions inspection	2001	7.88
	Registration records	2001	10.44

Several weaknesses in research design and methodology of these previous studies have been observed, they included:

1. Ambiguous definitions about the duration

The definitions on duration variables in different studies had diverse meanings. The usage duration was employed in IER (1999), while the disposed age was concerned in ITRI (1999) and Lu and Lee (2001). The usage mean years may confuse the holding duration and motorcycle age in the respondent answers. For example, a holder possessed a second-hand motorcycle or sold his/her motorcycle to a next holder cannot be well caught by the above questionnaire method. Therefore, what the real meaning of usage duration was revealed an ambiguous explanation.

2. Imprecision of a self-report survey

Self-report survey that adopted a recall method (IER, 1999) or an intention in remaining use years of motorcycles being held (MOTC, 2002b) reduced the precision of the duration measured and inflated the estimation errors in the calculation of mean duration.

3. Omitting censored data

Samples not yet experiencing an event for terminating motorcycle ownership may offer partial information from the duration of motorcycle-in-use. However, none of the past studies have incorporated these censoring data in estimating the duration variables. Inappropriate omission of censored data may lead to a biased estimation results.

4. Without considering the association with determinants

Being the most important variable concerned, duration variables for motorcycle holding duration or scrappage age has been the single focus in most studies. The association between duration variables and their determinants may have meaningful implications from the independent variables. Studies without considering this association may also limit the research applications. Chiang (2003) has tried to establish these connections, but unfortunately the duration variable measured in his thesis was recall data and thus reduced the precision of the results.

Since the above drawbacks come mainly from the difficulties in establishing qualified duration data, we attempt to apply the VRS records of the sampled motorcycles to collect the concerned durations and a survival analysis to formulate the relationships between motorcycle age, ownership duration, and their determinants.