Modelling the Choice and Timing of Acquiring a Driver's License: Revelations from a Hazard Model Applied to Post-secondary Students in Toronto

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Abstract

The declining rate of acquiring drivers' licenses by young adults in developed countries has elicited concern among transportation researchers because of the potential consequences for future urban transportation systems. Using a dataset collected through a large-scale survey of the students of four major universities in Toronto the paper employs the econometric technique to quantify the effects of personal/household attributes, land use characteristics and public transit accessibility indicators on the choice and timing of acquiring drivers' licenses by post-secondary students in Toronto. Living conditions of post-secondary students in the form of living with parents/family show the highest influence in discouraging and even delaying in acquiring drivers' licenses. However, the empirical model also identifies that better transit accessibility plays the second most critical role in delaying or even discouraging the choice of acquiring a driver's license. Public transit pass ownership is proven to be an important mobility tool that discourages as well as delays the acquiring of drivers' licenses by young adults. Post-secondary students living in densely populated neighborhoods are more likely to delay or to not acquire a driver's license. Young adults who delay acquiring their driver's license may remain transit-users during their time as students and may also continue to have similar public transit use in future. The results of this investigation suggest that increasing investment in public transit will have an immediate effect in managing traffic congestion, but will also help reduce private car dependency in future.

Keywords: driver's license use, young adults, transit accessibility, hazard model, land use, transportation

1. Introduction and Background

The enthusiasm for and the urgency felt for acquiring a driver's license by young adults started to decrease in developed countries in the early 1990s (Noble 2005; Sivak and Schoettle 2012a, 2012b). Canada, like other developed countries, is also experiencing a gradual and consistent decline in the rate of driver's license acquisition by young adults between the ages of 15 to 35 (Sivak and Schoettle 2011). Various stakeholders are concerned about the prospect of the next generation of workers becoming active in economic and social sectors with a smaller percentage holding driver's licenses compared to current or previous generations. This is also a concern to automobile manufacturers as it signals possible impending negative economic consequences or at least a shift in the economic landscape in developing nations. However, for transportation planners and public health officials, there is optimism that a decline in the reliance on private automobile means an increase in public transit ridership as well as an increase in walking and bicycling for transportation (Kenworthy and Newman 2011; Metz 2013).

Various factors have been posited as being responsible for the decline in acquiring a driver's licenses by young adults in developed countries. Among the most discussed factors are the increasing: the cost of car ownership; traffic congestion that makes private car ownership a less attractive option than previously; investment in public transport and active transportation infrastructures; and technological innovations that eliminate the need for physical travel for many activities, etc. It is also widely speculated that with the continuous creation of new electronic gadgets and the multitude of online activities, car ownership may no longer be perceived as an indicator of freedom, wealth or success by the current generation of young people compared to that of previous generations (Maynard 2014). In addition, changing patterns of living arrangements of young people in many developed countries, especially in terms of delaying leaving home and/or living with parents during student life may be a factor (Cobb-Clark 2008). Empirical investigations regarding factors influencing young adults' decreasing interest in acquiring a driver's license are needed. Vine et al. (2014), for example, conducted an empirical investigation of the relationship between online activities and the probability of acquiring drivers' licenses by young adults. Their study showed that online activities increase the rate of acquiring drivers' licenses. Additional study on this issue will enrich our understandings further.

From the perspective of transportation planning the decrease in the declining rate of license acquisition by young adults is important as they are the next generation of workers and will, therefore, have a long-term influence on the needs and performance of future urban transportation systems. Among young adults, post-secondary students require particular attention for two reasons. First, this group will likely become leaders in the financial and technological sectors and will have a strong influence on many aspects of society (Zhou 2012). Second, post-secondary students are a sub-group of the general population that are often under-represented in household travel surveys used in regional transportation planning and policy investigations (Lavery et al. 2013). For example, post-secondary students represent more than 5 percent of the total population of the Greater Toronto Area (GTA) and the Hamilton area. A large-scale (5 percent sample) household travel survey of this region, conducted by the Transportation Tomorrow Survey (2011), captured 2 percent of the sample share that belongs to post-secondary students.

This paper contributes to the growing literature of empirical investigations on factors affecting the choice and timing of acquiring a driver's license by young adults. It uses a dataset collected jointly by the four universities in Toronto in 2015. The Ontario College of Art and Design (OCAD) University, Ryerson University, the University of Toronto and York University formed a team in 2015 to conduct a travel behaviour survey of 184,000 students. Its purpose was to obtain a better understanding of their travel behaviour by presenting a more accurate representation of their in regional travel in the GTA. In addition to presenting an empirical investigation, the paper also employs an advanced econometric model to investigate the factors that have a significant effect on the choice and timing of acquiring a driver's license by post-secondary students. Results of the study provide a clear understanding of this group's travel-related behaviour and thus have robust policy relevance.

The remainder of the paper is organized as follows. The second section offers a brief review of the literature on empirical investigations of driver's license acquisition by young adults. The third section presents an overview of the dataset available for the current investigation. The fourth section contains the econometric formulation of the model used for empirical investigation. The fifth section discusses the empirical investigation. The paper concludes with key findings and recommendations for further research.

2. Literature Review

The body of literature investigating the reasons for the declining rate of driver's license acquisition by young adults and factors that influence the choice and/or timing of that acquisition is limited, but growing.

In one of the earliest investigations of this issue, Ruud and Nordbakke (2005) considered the delay in acquiring licenses by young people as an opportunity for public transportation to play the role of a mobility tool and to influence their future travel behaviour. They identified that living with parents and innovations in telecommunication technologies could deter young peoples' interest in driving a car as something beyond just a means of travel or a mobility tool. Noble (2005) investigated various factor for the low acquisition rates among young people in the United Kingdom (UK) and found that a lack of affordability of both owning and maintaining cars was the main reason. The study also found that the increasing cost of training for acquiring a license might affect the choice of not acquiring a driver's license. As well, they found that there was no evidence of environmental concern that might influence the choices of not acquiring a license.

McDonald and Trowbridge (2009) investigated the effects of land use characteristics of home locations on the choice of acquiring a driver's license by youth aged 16 to 19. They used a 2001 American National Household Travel survey data to evaluate the impacts of population density on the probability of acquiring licenses by youth. They found that youths from densely populated neighborhoods are more likely to delay their acquiring of driver's licenses in the United States (US).

Williams (2011) investigated the reasons for delaying acquiring driver's licenses in the US with the objective of suggesting better-licensing policies for young people. This study used a sample

survey of young people between 15 to 18 years of age. It identified several reasons for delaying or not obtaining a license. These reasons included: the lack of a car in the household; the cost of owning/maintain cars; living with family/parents and thereby having support for transportation; availability of other modes of transportation as an alternative to driving; and time constraints in learning to get a driver's license.

Delbosc and Currie (2013a; 2013b; 2013s), in a series of studies, investigated the trends, reasons and influential factors for delays in acquiring licenses by young people in developed countries. Based on a survey of 200 young adults aged 17 to 25 in Melbourne (Australia) they found the perception of a car as an indicator of independence and prosperity had been declining. Young people were found to be more diverse in their travel mode choices than focussing solely on a private car as the only desirable transportation option. All of these factors suggest that providing better alternatives to driving for transportation would further encourage a decline in obtaining a driver's license by young people (Delbosc and Currie 2013a).

Through a synthesis of relevant studies and exploratory data analysis, Delbosc and Currie (2013b) identified several factors that influence the decrease in acquiring a driver's license by young people. These factors include: living situation (living with parents); delay in forming family; increasing costs of maintaining a private car along with a decrease in income; economic recession; increased range of public transportation services; environmental consciousness thereby perceiving a private car as not being environmentally friendly; not considering a private car as a status symbol; better electronic communication, etc. Additionally, they presented a synthesis of various studies that highlighted these reasons. Delbosc and Currie (2013c) further examined the trend toward a decline in acquiring driving licenses by young people in developed countries and noted previous studies may have established only a preliminary understanding of these reasons and causes despite having identified a series of factors/variables identified. Their research acknowledged that it would be difficult to ascertain quantitative effects of those factors/variables without further comprehensive investigation.

Recently, Delbosc and Currie (2014) presented an empirical investigation on the relationship between young adults acquiring of driving license and demographics/living arrangement related variables in Melbourne. They used four repeated cross-sectional household travel survey datasets to investigate the choice of acquiring driving licenses by the young adults (aged 18 to 30 years who may or may not be a post-secondary student) in Melbourne. The four datasets were pooled to develop one binary logit model with a year-specific dummy variable. The model does not seem to have alternative year-specific constants and scale parameters to separate any effects of unobserved year-specific factors. The empirical model only included personal and household related variables and found that the opportunity for higher education lowered the probability of acquiring a driver's license by young adults. They also found that living with parents positively influenced the probability of acquiring a license. However, they concluded that this finding was not inconclusive and would require further empirical investigation.

Teff et al. (2014) investigated the prevalence and timing of acquiring licenses by youth aged 18 to 20 years in the US through an online survey. They used a logistic regression model for investigating the factors influencing the choice and timing of acquiring a license of the surveyed individuals. They found that economic reasons (low income and not having access to a car) were

the most dominant factors in influencing the choice and timing of acquiring a license. However, the availability of alternative modal options for transportation was also found to be a highly influential factor.

Vine et al. (2014) used multivariate logistic regression to investigate the association between young adults' online activities and the declining rate of acquiring a driver's license. The study's result was inconclusive. It used two robust datasets and wide varieties of socio-economic and land use variables to highlight the relationship between online activity and the choice of having a driver's license. Contrary to population speculation, they found that the relationship between the intensity of online activities and having a driver's license may not have a linear and straightforward relationship. They found that when young adults were active in pursuing online activities they were more likely to acquire a license. They recommended further empirical investigations on socio-economic and other factors that might influence young adults' acquisition of a license.

The review of the literature indicates that there is a need for a better understanding of the reasons and factors influencing the choice and timing of acquiring driver's licenses by young people. The issue of the declining rate of the acquisition of licenses by young adults has been identified as an emerging trend that has been empirically investigated in the literature only in last 5 years. Vine et al. (2014) identified that only five studies, including their own, available in transportation literature that study this issue through empirical investigation. This paper contributes to the literature by presenting a comprehensive econometric investigation to jointly investigate the choice and timing of acquiring driver's licenses by post-secondary students.

3. Data for Empirical Investigation

The empirical model uses data from a student travel survey organized jointly by four universities located in the GTA representing over 184,000 post-secondary students in the region. The universities involved are OCAD University, Ryerson University, the University of Toronto and York University, the first of these three universities are located in downtown Toronto. Three campuses of the University of Toronto located in downtown Toronto, Mississauga (in the Region of Peel) and in Scarborough (an eastern outer suburb of the City of Toronto). The main campus of York University is located in the Region of York, and is known as the Keele campus and its second campus is Glendon campus. Students of all of these seven campuses live across the GTA and represent the majority post-secondary students in the GTA[1]. The survey was named as StudentMoveTo, which was a Web-based travel diary survey that included a series of retrospective questions regarding the acquisition of a driver's license; home location; travel modes in different seasons; and questions related to an opinion on or attitude towards different transportation issues. The survey was conducted in the autumn of 2015 simultaneously in all four universities (seven campuses) encompassing undergraduate and graduate students. It was administered by representatives from all four universities. The survey was a completely voluntary survey, which was very well accepted by the students involved. Overall completion

[1] The survey did not include colleges and post-secondary technical education centres. See http://www.studentmoveto.ca/.

rate of the survey was around 8.5 percent and that resulted in a total of 15,226 completed responses.

In this investigation, data related to personal attributes (including driver's license status and age of acquiring license); household attributes (including home location); and regular travel behaviour (regular travel modes, changes in travel modes in a different season) related information collected in the survey are used. Home location of all individuals is matched with relevant land use and transportation accessibility-related attributes to accommodate the effects of land use and transportation accessibility effects in the empirical investigations. However, after cleaning for missing variable values and/or unanswered questions a total of 13,585 records were retained for empirical investigation in the final dataset. In the final dataset, around 40 percent students do not have driver's licenses. Figure 1 presents (at the top) the age distribution of students who have and have not acquired driver's licenses along with (at the bottom) the distribution of age of acquiring driver's license. It shows a clear distinction in the distributions of the two groups. Table 1 presents the summary of variables that are available in the final dataset.

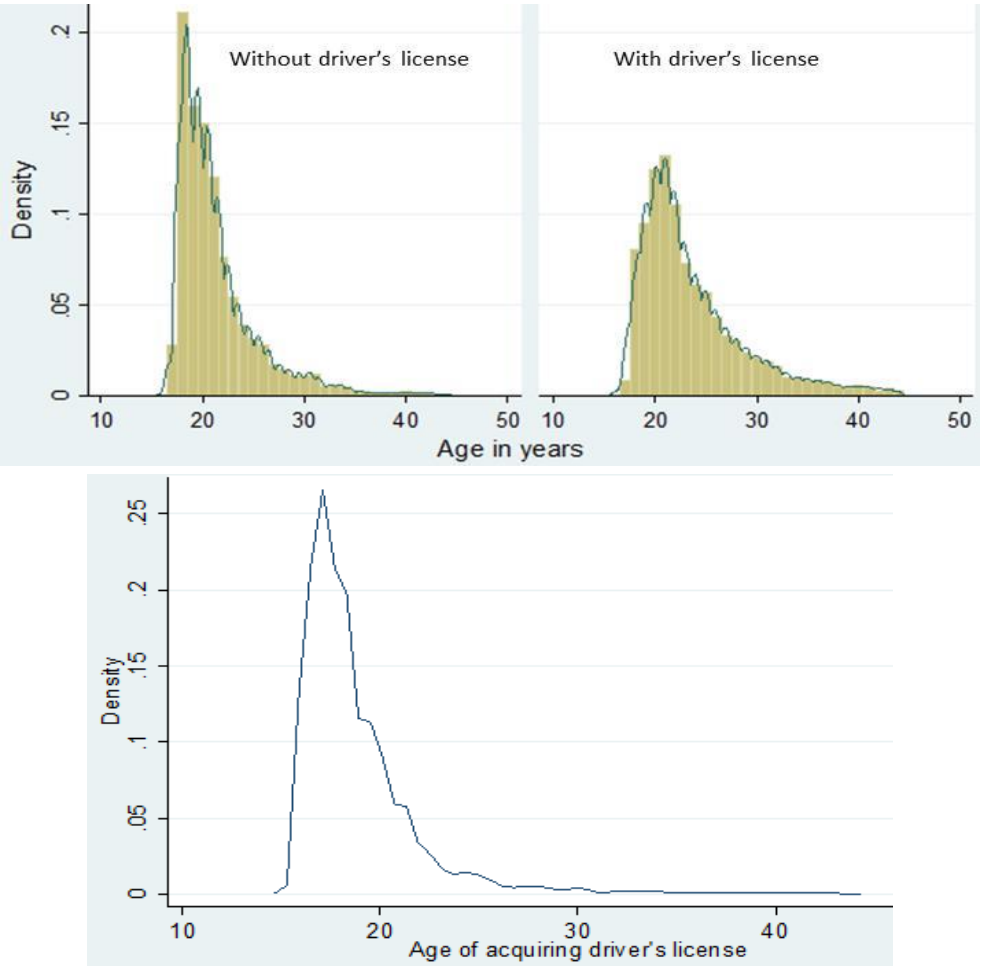


Figure 1: Differences in the age distribution of students with and without driver's licenses and distribution of age in acquiring a driver's license.

Table 1: Summary statistics

Continuous Attribute/Variable	Mean	Standard deviation
Age (years) of acquiring driver's license	18.77	03.07
Number of years living in current home	06.13	07.00
Home to campus distance in km	13.27	12.50
Household size	03.20	01.63
Number of dependent children in home	00.27	00.73
Number of cars owned by the household	01.28	01.11
Distance (km) between home and nearest bus stop	00.29	00.46
Distance (km) between home and nearest rail station	03.80	02.58
Distance (km) between home and nearest streetcar stop	11.28	11.91
Distance (km) between home and nearest subway station	08.45	10.81
Average distance (km) between intersections within a 1 km walking buffer in home location	00.18	00.11
The area (in sq. km) of the 1 km walking buffer in home location	01.4	00.45
Population density (thousand people per sq. km) in 2011	10.14	14.17
Employment density (thousand jobs per sq, km) in 2011	08.25	18.47

Categorical attribute/Variable	Sample proportion (%)
Female	66
Undergraduate student status	74
Full-time student status	90
Having driver's license	60
Owning a car by the student	18
Having a carsharing membership	6
Owning a bicycle	49
Owning a transit pass	40
Regular travel model for home to campus trips:	
Drive alone or rideshare	9
Transit	63
Bicycle	7
Walk	19
Other	2
Use of same travel mode in all seasons	91
Home type:	
Living on campus	5
Living in apartments/condominiums	37
House (detached, semi-detached, row house)	55
Others	3
Living arrangement:	
Living with family/parents	56
Living with partner	12
Living alone	11
Living with roommate(s)	21

Household category:		
	Single person household	11
	Two people of the same generation	19
	Single-parent family	10
	Two parent family	41
	Others	19
Owning residential land phone line		46
Location of home:		
	Downtown Toronto	22
	Outside downtown Toronto, but within the City of Toronto	45
	Outside of the City of Toronto	33

The sample average age of the post-secondary students is below 19 years and the females represent 66 percent of the sample share. The majority of the respondents belong to undergraduate student groups and have full-time student status. As well, the largest proportion of the surveyed individuals lives with family/parents with the majority of these belonging to a two-parent family structure. Overall, it seems that the surveyed students have good transit accessibility with less than half km of average distance between home and the nearest bus stop. As opposed to more than one average household car ownership, individual students' car ownership is less than 20 percent. Transit seems to be the main mode for a home to school trip and more than 90 percent students in the sample do not change their regular mode in winter. However, transit pass ownership level, despite discounted transit pass options in the region, is lower than that of bicycle ownership level among the surveyed post-secondary students.

4. Econometric Models

The paper intends to investigate the choice and timing of acquiring driver's licenses by post-secondary students in Toronto. Modelling the duration of the event (indicated as the license acquiring event) starting from the age of 15 years (qualifying age) and terminating at the time/age when the license was acquired is this study's means to model the timing of acquiring drivers' licenses. In this dataset, 60 percent of respondents were identified as driver's license holders, and their recorded age of acquiring the licenses is noted by year of age. Additionally, data on the timing of driver's license acquisition is time-discretized and 40 percent right-censored. Right-censored data indicates that 40 percent of respondents were not observed to terminate their license acquiring event during the survey. The hazard-based duration model was chosen for the study as it a robust modelling approach. However, as the timing of acquiring a driving license is reported in a rounded year format, a discrete-time hazard approach is necessary. As shown in Figure 1 and Table 1, the coefficient of variation (ratio of standard deviation to mean) of the license acquiring event is over 16 percent. It is clear, therefore, that considerable heterogeneity exists across the post-secondary student population in Toronto in the timing of acquiring a driver's license. Considering all of these a hazard model with non-parametric baseline and random heterogeneity is the most appropriate econometric approach. Han and Hausman (1990) and Bhat (1996) discuss the strengths of a discrete-time hazard model, but mainly for data without right-censoring. Chang and Yeh (2007) developed a hazard model for right-censored data but considered a continuous parametric hazard model formulation instead

of a discrete-time approach. In this paper, the discrete-time hazard modelling approach is extended to accommodate right-censored data.

Consider *k* intervals of discrete times varying from 1, 2, 3,…..to *K* for corresponding continuous duration variable, D_i, and grouped as [0, dur_1], [dur_1, dur_2], [dur_3, dur_4]….[dur_{k-1}, ∞]
Hazard rate of any interval '*dur*' of any individual *i*:

$$\lambda_i(dur) = \lim_{\delta \to 0} \frac{\Pr[(dur + \delta) > D_i \geq dur \mid D_i \geq dur]}{\delta} \tag{1}$$

here,
λ indicates the hazard rate
δ is the time step

Considering the widely accepted proportional hazard rate assumption we can explain this hazard rate through a multiplicative function of baseline hazard rate and a covariate function (Keifer 1988):

$$\lambda_i(dur) = \lambda_0(dur) \exp\left(-\sum \beta x_i\right) \tag{2}$$

here,
$\lambda_0(dur)$ is the baseline hazard rate at the interval *dur*.

As per proportional hazard assumption, if the event terminates at duration D_i, the integrated hazard rate up to D_i can be expressed as a function of a random variable ε_i:

$$\int_0^{D_i} \lambda_i(dur) d\, dur = \exp(\varepsilon_i) = \int_0^{D_i} \left(\lambda_0(dur) \exp\left(-\sum \beta x_i\right)\right) d\,(dur)$$

$$\int_0^{D_i} \lambda_0(dur) d\, dur = \exp\left(\sum \beta x_i + \varepsilon_i\right)$$

$$\ln \Lambda_0(D_i) = \ln \int_0^{D_i} \lambda_0(dur) d\, dur = \left(\sum \beta x_i + \varepsilon_i\right) \tag{3}$$

here, $\Lambda_0(D_i)$ is the baseline integrated hazard rate.

Considering that the log of the baseline integrated hazard rate of any individual, *i*, is a constant (μ_i):

$$\ln \Lambda_0(D_i) = \ln \int_0^{D_i} \lambda_0(dur) d\, dur = \mu_i$$
$$\Lambda_0(D_i) = \exp(\mu_i) = \Delta_i \tag{4}$$

With the assumption of an extreme value distribution for the random term ε_i (which is the logarithm of integrated hazard rate) the event of not having a driver's license for an individual *i* will terminate at the duration of D_i and can be written as:

$$\begin{aligned}\Pr(t_i = k) &= \Pr\left(\ln\Lambda_0(dur_{k-1}) < \ln\Lambda_0(T_i) < \ln\Lambda_0(dur_k)\right) \\ &= G\left(\delta_k - \sum \beta x_i\right) - G\left(\delta_{k-1} - \sum \beta x_i\right) \\ \textit{where, } \delta_k &= \ln\Lambda_0(dur_k) \\ G(.) &= 1 - \exp(-\exp(.))\end{aligned} \tag{5}$$

In the case of a homogenous hazard rate (across the population under investigation) assumption, the probability that the duration of not having a driver's license terminates at an interval *k* becomes:

$$\Pr(t_i = k) = \left(1 - e^{\left(-e^{(\delta_k - \sum \beta x_i)}\right)}\right) - \left(1 - e^{\left(-e^{(\delta_{k-1} - \sum \beta x_i)}\right)}\right) \tag{6}$$

However, to accommodate a systematic heterogeneity across the population under investigation, we can consider the mixing of a positive distribution. Considering the Gamma distribution of unit mean and σ^2 variance as a positive distribution for mixing, the resulting probability equations for event termination duration at an interval *k* becomes (Han and Hausman 1990; Bhat 1996):

$$\begin{aligned}&\Pr(t_i > k) = \left(1 + \frac{1}{\sigma^2}\Delta_k e^{(-\sum \beta x_i)}\right)^{-\sigma^2} \qquad \Pr(t_i < k) = 1 - \left(1 + \frac{1}{\sigma^2}\Delta_k e^{(-\sum \beta x_i)}\right)^{-\sigma^2} \\ &\Pr(t_i = k) = \left(1 + \frac{1}{\sigma^2}\Delta_{k-1} e^{(-\sum \beta x_i)}\right)^{-\sigma^2} - \left(1 + \frac{1}{\sigma^2}\Delta_k e^{(-\sum \beta x_i)}\right)^{-\sigma^2}\end{aligned} \tag{7}$$

Now, in case of uncensored observations, the likelihood, $L_{(Uncensored)i}$, of an individual who acquired the driver's license at the age of t_i:

$$L_{Uncensored_i} = \begin{cases} \left[1 - \left(1 + \frac{1}{\sigma^2}\Delta_1 e^{(-\sum \beta x_i)}\right)^{-\sigma^2}\right] & if \;\; t_i = 1, \text{ the 1st interval} \\ \left[\left(1 + \frac{1}{\sigma^2}\Delta_{k-1} e^{(-\sum \beta x_i)}\right)^{-\sigma^2}\right] & \\ \quad - \left[\left(1 + \frac{1}{\sigma^2}\Delta_k e^{(-\sum \beta x_i)}\right)^{-\sigma^2}\right] & if \;\; t_i = k, \text{ any intermediate interval} \\ \left[\left(1 + \frac{1}{\sigma^2}\Delta_K e^{(-\sum \beta x_i)}\right)^{-\sigma^2}\right] & if \;\; t_i = K, \text{ the last interval} \end{cases} \tag{9}$$

However, for the individuals who were surveyed and did not have a driver's license until the time of the survey, the corresponding data point becomes right-censored. Right-censoring refers to the case that the observation time is not sufficiently long enough to observe the termination of

the event of acquiring a driver's license. In case of such right-censored data, we can speculate two possible cases:

1. The event will not terminate at all, which means the corresponding individual will never get a driver's license.
2. The event would have terminated if we could have extended the observation time period long enough.

Considering a binary logit probability of the case that the individual will likely to acquire a driver's license, the likelihood of any observed duration (t_i) needs to consider that (Chang and Yeh 2007):

$$L_i = \left(F\left(\sum \gamma z_i\right) L_{uncensored}\right)^C \times \left(\left(1 - F\left(\sum \gamma z_i\right)\right)\left[\left(1 + \frac{1}{\sigma^2}\Delta_K e^{(-\sum \beta x_i)}\right)^{-\sigma^2}\right]\right)^{1-C} \quad (10)$$

here,
C is an indicator that takes the value of 1 if the observation is uncensored and 0 if right-censored
$F(\sum \gamma z_i)$ is the logit probability of acquiring a license at all, where $\sum \gamma z_i$ is a linear-in-parameter function of covariate set z and corresponding coefficients γ for the individual i.

These likelihood functions are of closed form and can be estimated by the classical maximum likelihood estimation technique. In this investigation, the models are estimated by using a program written in GAUSS and using its MAXLIK routine (Aptech 2016). This formulation of the hazard model can be referred to as a split population non-parametric baseline hazard rate with Gamma heterogeneity. The split population accommodates the issue of right-censoring through the assumption that a portion of subjects in the population under investigation may not have a driver's license during the investigation, but will acquire it in the future. Non-parameter baseline hazard assumption allows better for capturing of the actual process under investigation rather than forcing the baseline tendency into any parametric distribution processes. Accommodation of Gamma heterogeneity ensures an over-dispersion of duration in terms of a distribution of such systematic dispersion across the population.

Once estimated, a careful assessment of the estimated parameters is needed to evaluate the corresponding impacts on the choice of not having driver's license or the age (time) of acquiring a driver's license. The final model has three components to evaluate. These are:

1. Baseline hazard rate of age when post-secondary students tend to acquire their driver's license;
2. Covariate effects on the probability of acquiring or not acquiring driver's licenses.
3. Covariate effects on the age (time in years) of acquiring a driver's license.

The baseline hazard rate at any age (duration) interval k can be estimated by using the non-parametric baseline hazard rate as:

$$\lambda_0(k)^{/} = \Pr\left(D_i \in [d_{k-1}, d_k] \mid D_i \geq d_{k-1}\right) = \left(\Delta_k - \Delta_{k-1}\right) \quad (11)$$

Estimated parameters of the covariates do not necessarily give a direct interpretation of their effects (magnitude as well as direction) on the probability of acquiring/not acquiring a driver's license as well as age (duration) of acquiring a license because of non-linear formulations of logit probability and proportional hazard formulations. However, an estimated marginal effect can reveal the relative magnitude and the direction of such influences. The marginal effect of any variable on the probability of not acquiring a driver's license (right censoring) can be estimated as:

$$ME_z = -\left(F\left(\sum \gamma z_i\right)\left(1 - F\left(\sum \gamma z_i\right)\right)\left[\left(1 + \frac{1}{\sigma^2}\Delta_K e^{(-\sum \beta x_i)}\right)^{-\sigma^2}\right]\right)\gamma \qquad (12)$$

As the hazard function is a function of age *K*, such marginal effect should be calculated separately for each age interval. Similarly, for the non-parametric baseline hazard model of the age (time/duration) of acquiring a driver's license, the marginal effects of covariates have age-category (interval) specific values. The general equation of marginal effect of any variable on age (time/duration) of acquiring a driver's license is:

$$ME_x = \begin{cases} -F(\gamma z)\left[\left(1 + \frac{1}{\sigma^2}\Delta_1 e^{(-\sum \beta x_i)}\right)^{-\sigma^2-1}\right]\beta\Delta_1 e^{(-\sum \beta x_i)} & if \quad t_i = 1, \text{ the 1st interval} \\ F(\gamma z)\left[\left(1 + \frac{1}{\sigma^2}\Delta_{k-1} e^{(-\sum \beta x_i)}\right)^{-\sigma^2-1}\right]\beta\Delta_{k-1} e^{(-\sum \beta x_i)} & \\ -F(\gamma z)\left[\left(1 + \frac{1}{\sigma^2}\Delta_k e^{(-\sum \beta x_i)}\right)^{-\sigma^2-1}\right]\beta\Delta_k e^{(-\sum \beta x_i)} & if \quad t_i = k, \text{ any intermediate interval} \\ F(\gamma z)\left[\left(1 + \frac{1}{\sigma^2}\Delta_K e^{(-\sum \beta x_i)}\right)^{-\sigma^2-1}\right]\beta\Delta_K e^{(\delta_K - \sum \beta x_i)} & if \quad t_i = K, \text{ the last interval} \end{cases}$$

(13)

As per the formulations of the proportional hazard model, the signs of the estimated marginal effects have a direct relationship to age (time/duration) of acquiring a driver's license and an opposite relationship with the corresponding hazard rates.

5. Empirical Models and Findings

Table 2 presents a summary of the estimated model parameters. The presented final specification is a split population hazard model for the age of acquiring driver's license with a non-parametric baseline and Gamma heterogeneity. The final model has a total of 59 estimated model parameters almost all of which have over 95 percent confidence on parameter estimates. There

are a few parameters with lower than 95 percent confidence, but those are retained as the corresponding variables have policy significance. As per the Chi-square test against the constant only model (a model without covariates), the final specification of a joint model with covariate function and right-censor (split population) probability is statistically justified. In terms of goodness-of-fit, the Rho-squared value is 0.35, which is reasonably high for a complicated model. The model estimated baseline and total hazard rates are presented in Figure 2. The baseline hazard rate indicates the baseline trends of acquiring driver's licenses by post-secondary students in Toronto without considering any effects of covariates. Marginal effects of covariates on total hazard rates (corresponding time/duration of acquiring a driver's license), as well as marginal effects of covariates on probability of acquiring (against not acquiring) a driver's license are estimated by using the model presented in Table 2, are presented in Figure 3.

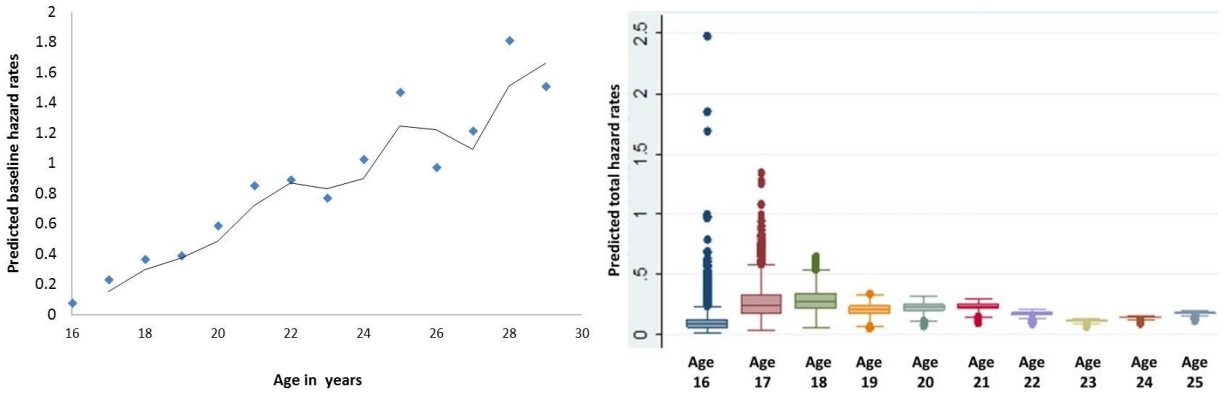
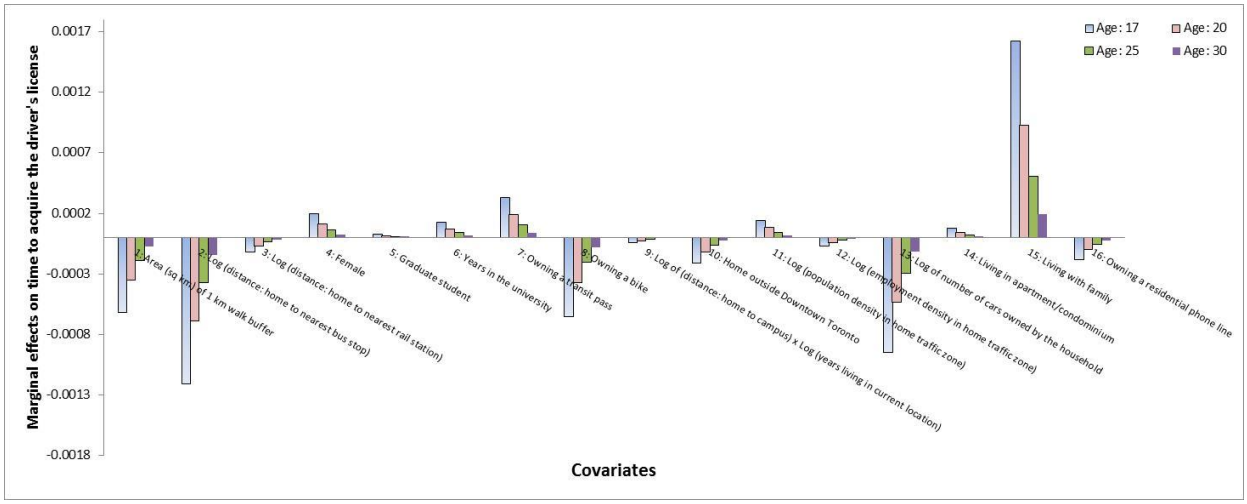


Figure 2: Estimated baseline and total hazard rates of age of acquiring drivers' licenses by post-secondary students in Toronto.



Hazard rates (baseline as well as total) show zig-zag patterns. The main reason for this pattern is the rounding of age in years while also reporting the age at which the driver's license was acquired. Overall, the baseline hazard rate increases with age. This is due to the fact that the baseline tendency of post-secondary students in Toronto is to acquire driver's licenses as early as possible. In fact, the baseline hazard rate increases tenfold from the age of 17 to the age of 30. Additionally, the baseline trend is to acquire a driver's license soon as the individual can legally

obtain it (age of 15). However, the influence of various contexts (as depicted through covariates in the model) lowers down the hazard rate drastically. Although the total hazard rate increases slightly from the age of 15 to the ages of 17 to 18, it starts dropping gradually afterward. It is also interesting to note that the dispersion of sample hazard rates gradually drops to almost zero beyond the age of 30. The empirical model clearly highlights the very strong influences of different factors that define the choice and timing of acquiring a driver's license. Such influences are discussed in the following.

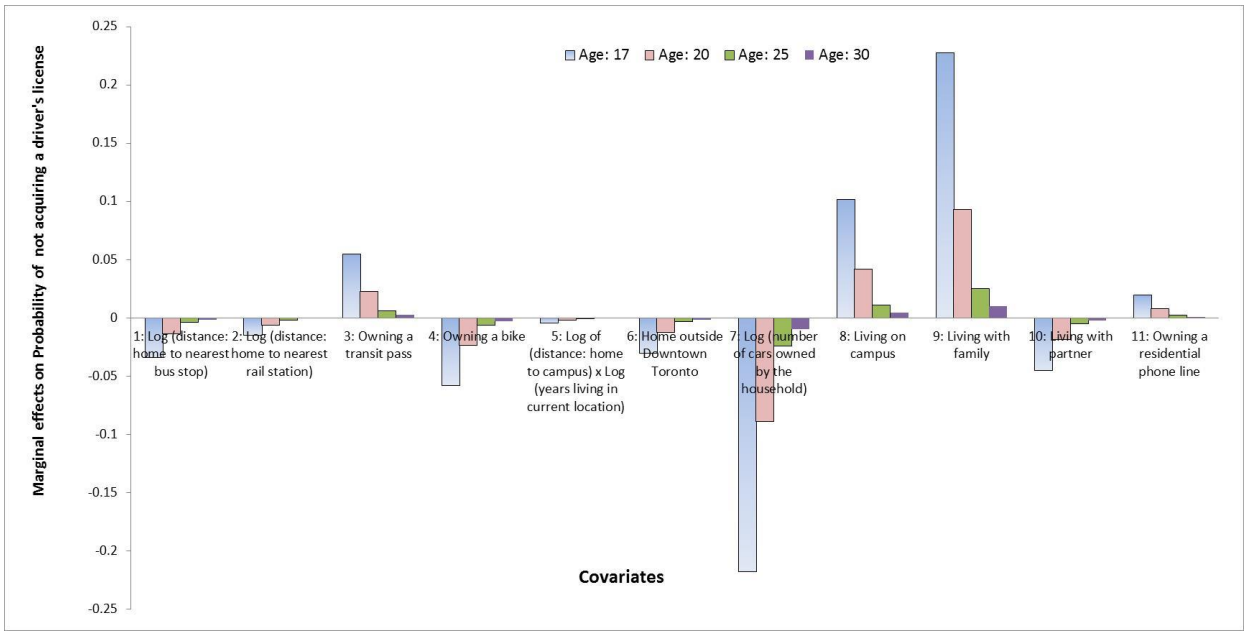


Figure 3: Marginal effects of covariates on right censoring and hazard rates.

Comparing the baseline and total hazard rate distribution, it is clear that there is a strong trend for post-secondary students to acquire their driver's licenses in Toronto by the age of 20. However, there is a portion of students who would obtain their license by the age of 30 and perhaps would not obtain it even later in their lives. While there is high variability in the exact age of obtaining a driver's license if the license is acquired before the age of 20, this variability drops drastically for those who acquire a license after the age of 20. Based on this investigation it is not possible to predict whether this population (who delay in getting a license of or don't get one at all) is changing over time or not as the dataset is a cross-sectional dataset with retrospective information regarding the age of acquiring a driver's license. However, the econometric model developed in this study can offer observations on the factors that influence the delay or haste in getting a license as well as the probability of getting (or not getting at all) driving license in the future.

Two types of marginal effects are estimated: the marginal effects of the covariates on the probability of getting a license and the marginal effects of the covariates on the age (opposite to corresponding hazard rates) at which someone may get a license. It is clear that covariate effects decrease with increasing age, which means covariate effects on hazard rates increase with

increasing age and this is consistent with the fact that total hazard rate drops with increasing age even though the baseline hazard rate follows the opposite pattern.

5.1 Factors Influencing the Age of Acquiring Driver's Licenses by Post-secondary Students

Two of the most influential variables (i.e., having highest marginal effects) that define the age at which a post-secondary student would acquire a driver's license are 'living with family' (as opposed to living alone or with partner or roommates) and the 'distance between home and the nearest bus stop' and these variables also have opposite effects. An individual's living arrangement has the highest impact on the timing of acquiring a driver's license by post-secondary students in Toronto. Living with family/parents reduces the need or urgency (lowering the hazard rate) of getting a license. However, the relative accessibility to a transit network, in terms of the distance between home and the nearest bus stop, counter-balances (i.e., increases the hazard rate) the delay in getting a license. The distance between home and the nearest rail station also has a positive effect on delaying the acquisition of a driver's license, but this factor is smaller than living close to the nearest bus stop. Thus the effect of the distance between an individual's home and the nearest subway station to where she/he lives was not found have any statistically significant effects.

Toronto has a comprehensive bus network; a relatively small and simple subway network within the main core of the city and rail network (GO rail) designed to serve people travelling from outside the city into the city's downtown. This investigation implies that accessibility to transit services is more important than accessibility to any particular mode of transit (e.g., subway or rail). It is clear that students living in places with limited public transit service accessibility would be influenced to acquire their driving licenses at a young age. However, having transit passes further reduces the urgency (reducing hazard rate) of acquiring a driver's license. Toronto has a discounted transit pass system for post-secondary students. This policy not only allows unrestricted use of transit service but also has a long-term impact on delaying the time of obtaining a driver's license and thus reduces potential dependency on a private automobile.

Next to these two variables; household car ownership, bicycle ownership and walkability of the home neighbourhood (depicted as the sq km areas in home zone of a 1 km walking buffer) have a strong impact on the age of acquiring a driver's license. The car ownership level of a household has a very strong influence on the timing of post-secondary students' acquiring a driver's license. Intuitively, a higher number of cars would influence the students to obtain their licenses earlier. However, it is found that the effect of the number of cars follows a logarithmic pattern; a decreasing rate of effect with increasing number of cars. Interestingly, owning bicycles and having lower walkability (depicted through a wider area for 1 km walking buffer) around the home location influenced individuals to acquire a driver's license early. Population density has a positive influence on delaying the acquiring of a driver's license. It is understandable that more densely populated neighbourhoods are more walkable neighbourhoods.

The empirical model reveals that students living in apartments/condominiums are more likely to delay in acquiring their driver's license. Apartments/condominiums in Toronto are mostly located in the core of the city where the population density is high and transit service accessibility is also high. Similarly, it is also clear that students living outside downtown Toronto

are more likely to acquire their driver's license earlier than those living in downtown Toronto. Population density drops beyond the immediate area of downtown Toronto. When comparing all of these effects of transit service accessibility, walkability, bicycle ownership and population density, it is clear that similarly to transit investment, investing in pedestrian infrastructure will have a positive influence on delaying (lowering hazard rate) the acquisition of a driver's license by post-secondary students in Toronto.

The effect of home type (apartment/condominium as opposed to houses) may also reflect the influence of stability or permanency of residences of post-secondary students. To further investigate this effect of stability/permanence of homes, the ownership of residential land telephone lines was used as a dummy variable in the model. This variable had an opposite effect of the effect of the home type in terms of living in an apartment or condominium. With increasing reliance of post-secondary students on cell phones, this dummy variable may capture the surrogate effect of a traditional stable home type as opposed to a temporary home. The empirical model reveals that post-secondary students living in homes with residential home telephone lines are more likely to acquire their driver's licenses earlier than others. This effect is also complemented by the effect of interaction between home to campus distances and the number of years living in a current home location. It is observed that living in places that are farther from the university campuses and for a long time along with having a residential land telephone line, are the factors that influence post-secondary students in acquiring their driver's licenses earlier than others. Complementary to these factors, if the location of the home is outside of downtown Toronto this will further influence the urgency (higher hazard rate) of acquiring a driver's license.

In terms of personal attributes, it seems that female post-secondary students in Toronto are more likely to acquire their driving licenses later than their male counterparts. Post-secondary students who have been in university normally delay their acquisition of a driver's license than students who have not been in the university for a long time. Interestingly, graduate students tend to delay acquiring their driving license longer than the undergraduate students.

5.2 Factors Influencing the Choice of not Acquiring a Driver's License by Post-secondary Students in Toronto

The presence of right censoring is accommodated through a joint estimation of the choice of not acquiring driving license along with hazard rate of getting a driver's license by post-secondary students in Toronto. The dataset used in this study used retrospective information about the age at which a driver's license was acquired as well as the current age of those who do not have a driver's license yet. There is no way to know whether the students who do not have driver's license would not get a license in future, but the right censoring probability provides insight regarding the factors that can increase or decrease the probability of not acquiring a driver's license in the future. The binary logit model of right censoring has an insignificant and very low constant indicating that the variables/factors used in the investigation explain most of the probability of not acquiring driving licenses. Similar to the hazard model, the effects of all variables decrease with increasing age. This refers to the fact that the choices of acquiring or not acquiring driver's licenses by the post-secondary students are more influenced by various factors

when they are younger. Similar to the hazard model, effects of all the variables decrease when the individual ages.

Effects of all variables in the binary choice of getting/not getting a driving license are consistent with those in the hazard model of age for acquiring a driver's license except for the factor of owning a residential land telephone line. This model component bolsters the effects of same variables in terms of the fact that if a variable influences the choice of not acquiring the driving license, it also influences the increase the age of acquiring the license and vice versa. Living with family and owning transit passes positively influences the choice of not getting a driver's license and these also decrease the hazard rate (thereby increasing the age) of acquiring a driver's license by post-secondary students. The accessibility of public transit services (distances between home and nearest bus and rail stations); bicycle ownership; number of cars owned by the household; distance between home and campus interacted with years of living in same home location and living outside Downtown Toronto positively influence the choice of acquiring a driver's license and these factors also increase the hazard rate (thereby decreasing the age) of acquiring a driver's license by post-secondary students. One additional variable seems to not only to influence the choice of getting a driver's license, but not the timing (age) of acquiring it. Living with a partner (as opposed to living alone or with family or roommates) seems to influence acquiring a driver's license, but it does not have a significant effect on the timing of the acquisition of one. However, it seems that students with land telephone lines tend to have a higher probability of acquiring a driver's license, but they tend to acquire it later than their younger counterparts.

6. Conclusion

The paper investigated the factors affecting the choice and timing of acquiring driver's licenses by post-secondary students in Toronto. The study used the dataset collected through a travel survey of post-secondary students in Toronto jointly organized by four university campuses located in Toronto: OCAD University, Ryerson University, York University and the University of Toronto. The dataset represents the majority of post-secondary students in the GTA region. They represent the main workforces of the region in near future and are under-represented in regional household travel surveys. The paper employed the econometric modelling technique for a clear understanding of factors that influence the choice of acquiring or not acquiring driver's licenses along with the hazard rate defining the timing (age) of acquiring licenses.

The econometric model clearly revealed that living arrangements in terms of living with family/parents have the strongest influence on the choice of not acquiring and/or delaying the time of acquiring a driver's license by the post-secondary students in Toronto. Transit network coverage and accessibility to transit services also proved to have strong influences on the choice of not acquiring and delaying the time of acquiring a driver's licenses by post-secondary students. This finding complements our understanding that transit investment is not only beneficial to provide competitive service to private automobiles in reducing traffic congestion, emission/pollution and health impacts of transportation, but also transit investment can directly influence the next generation in reducing their reliance on the private automobile. Better transit service and transit accessibility can delay or even deter the need of for acquiring a diver's license by the post-secondary students. The empirical model also revealed that a transit pass can play the

role of a deterrent in regard to the effects of household car ownership in discouraging post-secondary students in acquiring their driver's license early. Transit passes seemed to play the role of a competitive (to the private car) mobility tool for post-secondary students and had a strong influence in not acquiring or delaying the acquisition of a driver's license.

Contrary to the role of a transit pass, bicycle ownership had a complementary effect on acquiring a driver's license soon after the age of 15. Spatial context, in terms of home location outside of downtown Toronto also contributes to early acquiring of driving license by post-secondary students. Population and employment density in the home zone showed opposite effects in influencing the choice and timing of acquiring a driver's license by post-secondary students in Toronto. It seems that a higher population density influences the choice of not acquiring or delaying the acquisition of a driver's license, but the opposite is true for higher employment density. Comparing both, it seems that a balanced land use mix (right proportions of population and employment density) may perhaps nullify land-use effects on driver's license acquisition rates by young adults.

The paper presented insights into factors causing a decline in obtaining a driver's license by young adults with a case study on post-secondary students in Toronto. The paper used a closed form econometric technique and so only systematic covariate effects are captured. The effects of attitudes towards the environment, urban form, and the current transportation system in the form of a latent variable would be very interesting to decouple the actual systematic effects of covariates and apparently compounded effects of attitudes of young adults. However, this poses a considerable methodological challenge and so is recommended for future research. Similarly, even though the paper employed a dynamic econometric technique the investigation is still cross-sectional in nature as it uses a dataset collected in one particular survey. In order to better understand the nature and trend of declining rate of obtaining a driver's license by young adults and the associated factors either panel data or repeated cross-sectional data would be necessary. Perhaps repeating the same survey in future would provide that opportunity and so is recommended as the conclusion of this paper.

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Table 2: Empirical Model

Loglikelihood of Full Model	-24196
Loglikelihood of Constant-Only Model	-25577
Loglikelihood of Equi-probable Model	-37234
Chi-Squared against Constant-Only Model	2762
Rho-Squared against Equi-probable Model	0.35

Split Population Logit: Acquiring a License in Future

Variable	Parameters	*t*-Stat
Constant	0.074	0.97
Log (distance: home to nearest bus stop)	0.219	1.74
Log (distance: home to nearest rail station)	0.097	2.08
Owning a transit pass	-0.356	-8.79
Owning a bicycle	0.376	9.47
Log of (distance: home to campus) x Log (years living in current location)	0.027	2.99
Home outside of downtown Toronto	0.196	3.92
Log (number of cars at household)	1.413	23.93
Living on-campus	-0.660	-7.57
Living with family	-1.474	-21.45
Living with partner	0.294	4.08
Owning a residential phone line	-0.126	-2.37

Covariate Function of Hazard Model

	Parameters	*t*-Stat
Area (sq km) of 1 km walk buffer	-0.321	-5.00
Log (distance: home to nearest bus stop)	-0.632	-5.55
Log (distance: home to nearest rail station)	-0.062	-1.38
Female	0.105	2.67
Graduate student	0.013	0.32
Years in the university	0.067	8.09

Owning a transit pass	0.174	4.10
Owning a bicycle	-0.341	-8.21
Log of (distance: home to campus)		
x Log (years living in current location)	-0.023	-2.56
Home outside of downtown Toronto	-0.111	-2.02
Log (population density in home traffic zone)	0.075	2.83
Log (employment density in home traffic zone)	-0.037	-1.63
Log of number of cars owned by the household	-0.493	-8.34
Living in apartment/condominium	0.041	0.85
Living with family	0.850	11.69
Owning a residential phone line	-0.094	-1.73
Variance of Gamma Heterogeneity	**1.272**	**6.41**

Non-parametric Baseline Hazard Rates

Years	Parameter	*t*-stat	Years	Parameter	*t*-stat	Years	Parameter	*t*-stat
15–16	0.0754	7.049	*25–26*	0.9751	2.498	*35–36*	4.0022	1.484
16–17	0.2303	7.062	*26–27*	1.2124	2.404	*36–37*	3.6792	1.264
17–18	0.3659	6.483	*27–28*	1.8133	2.321	*37–38*	4.3451	1.185
18–19	0.388	5.687	*28–29*	1.509	2.16	*38–39*	4.6953	1.292
19–20	0.5877	4.956	*29–30*	2.4457	2.113	*39–40*	6.2466	1.345
20–21	0.8549	4.247	*30–31*	1.6468	1.757	*40–41*	5.2897	0.986
21–22	0.8932	3.679	*31–32*	2.4386	1.86	*41–42*	7.9036	1.064
22–23	0.7728	3.302	*32–33*	2.849	1.834	*42–43*	7.221	1.015
23–24	1.0256	3.015	*33–34*	3.4223	1.722	*43–44*	9.7871	0.89
24–25	1.468	2.822	*34–35*	3.2664	1.564	*44–45*	8.6106	0.726