A Business Establishment Fleet Ownership Model

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Introduction

Over the past decade, freight transportation modelling has captured considerable attention of researchers, modellers, planners and policy makers as a necessary aspect of transportation demand modelling. Behavioural agent-based models are increasingly being developed for this purpose. Business establishments, both shippers and logistics service providers, have been identified as the agents interacting to develop the complex system of goods and service truck movements. Decisions of business establishments resulting in shipment generation and goods movement within and between urban areas have been identified and subsequently modeled (Roorda et al. 2010).

A business establishment's decision of vehicle fleet composition is one of many decisions that affect its freight transportation related behavior. Business establishments may own a fleet of different types of vehicles. Alternatively, they may decide to outsource their shipping activities to a carrier and own no private fleet. If an establishment decides to own a fleet of private vehicles, a set of options is then available. For instance, owning a truck might be more beneficial than owning two vans and vice versa. Clearly, modelling business establishment fleet ownership behavior is a complicated task which has not been implemented to the best if the authors' knowledge.

Methodology

Two approaches are employed in this study to model business establishment fleet ownership behaviour. First an econometrics approach is used. Based on the general structure of this econometrics approach a Bayesian Network is developed.

Three vehicle type categories are considered in this paper: passenger car, pickup/ cube van, and truck/ tractor. The decision structure we are testing is one in which the establishment's first decision is a binary choice to purchase at least one vehicle of one category or not. If the decision is positive, then the following decision is how many vehicles of this category should be owned. The number of vehicles owned in each category results in a specific level of utility to the establishment. This utility level is compared against the utility level obtained from owning vehicles from other categories. Therefore, the decision about owning or not owning a vehicle type category is correlated with the same decision for other vehicle types, so they should be jointly modeled. This joint decision can be formulated as follows:

$U_{ip} = \beta_{ip} X_{ip} + \varepsilon_{ip}$ and $\boldsymbol{Pr}\left(Owning\ at\ least\ one\ passenger\ vehicle \middle| X_{ip}\right) =$
$\boldsymbol{Pr}\left(U_{ip} > 0 \middle| X_{ip}\right) = \Phi(\beta_{ip} X_{ip})$

$U_{iv} = \beta_{iv}X_{iv} + \varepsilon_{iv}$ and $\boldsymbol{Pr}\left(Owning\ at\ least\ one\ piclup\ or\ cube\ van\ \middle|X_{ip}\right) =$
$\boldsymbol{Pr}\left(U_{ip} > 0\middle|X_{ip}\right) = \Phi(\beta_{ip}X_{ip})$

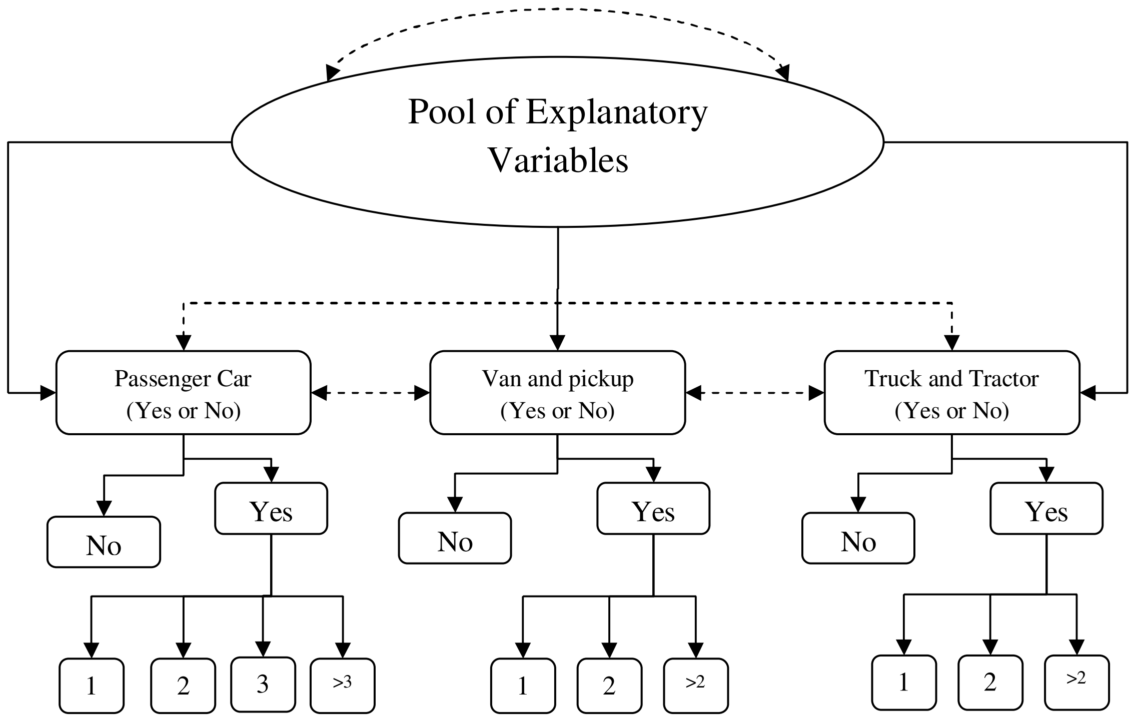
$U_{it} = \beta_{it}X_{it} + \varepsilon_{it}$ and $\boldsymbol{Pr}\left(Owning\ at\ least\ one\ truck\ or\ tractor\middle|X_{ip}\right) =$
$\boldsymbol{Pr}\left(U_{ip} > 0\middle|X_{ip}\right) = \Phi\left(\beta_{ip}X_{ip}\right)$

$$\varepsilon_i = \begin{pmatrix}\varepsilon_{ip}\\ \varepsilon_{iv}\\ \varepsilon_{it}\end{pmatrix} \sim iid\ N(0,\Sigma) = \mathrm{N}\left(\begin{bmatrix}0\\0\\0\end{bmatrix}\ \begin{bmatrix}\sigma_{\mathrm{p}}^2 & \sigma_{\mathrm{pv}} & \sigma_{\mathrm{pt}}\\ \sigma_{\mathrm{pv}} & \sigma_{\mathrm{v}}^2 & \sigma_{\mathrm{vt}}\\ \sigma_{\mathrm{pt}} & \sigma_{\mathrm{vt}} & \sigma_{\mathrm{t}}^2\end{bmatrix}\right)$$

where U_{ij} for *j=p, v* are the utility functions, β_{ij} for *j=p, v and t* are parameters to be estimated, X_{ij}, for *j=p, v and t* are the explanatory variables, ε_{ij} for *j=p, v and t* are the error terms, Φ is the cumulative normal distribution, and Σ is the covariance matrix.

These correlated binary probit models are linked to three multinomial logit models for each vehicle type category. The multinomial logit models select the number of vehicles owned by the establishment given the establishment has decided to own that vehicle type. The logsum value representing the expected maximum utility of owning a vehicle type category is estimated for the MNL models and used as an explanatory variable in the corresponding binary probit model in the joint system of models.

The second methodology used to model the business establishment fleet ownership behaviour is the Bayesian network approach. The complication existing in the multiple discreteness model presented above, suggests application of a more flexible modelling structure like Bayesian network model. In short, Bayesian networks are directed acyclic graphs whose nodes represent random variables in the Bayesian context. Although it is not possible to capture the complete correlation among the binary decisions discussed above, the causality relationship should be explored and the causality direction providing the better fit is selected. The next figure roughly shows the structure of the Bayesian network. The dashed arrows will be examined to find the appropriate direction that provides the best fit to the data. The topology of the causalities between the dependent and independent variables in the Bayesian network will be based on the results of the previously developed econometrics model. Then it will be modified, if required to improve the goodness-of-fit of the model. The arrow on top of the



Data and Preliminary Results

Three main data sources are used in this study. The main data source used for modeling development of this paper is the Region of Peel Commercial Travel Survey, which was conducted by the University of Toronto from October 2006 to May 2007 on a sample of 597 business establishments in the Region of Peel. The survey collected establishment information, inbound and outbound shipment and services, and a sample of truck tours for establishments owning a private fleet. A mail out mail back approach was employed for all establishments (Roorda et al., 2008). The establishment information, which includes fleet composition attributes, is borrowed from this data as the dependent variable.

A modified version of the survey instrument used for the Region of Peel is currently used to collect data from shippers located in the Greater Toronto and Hamilton Area. This data collection exercise is underway and will be completed by the coming summer. The results of this survey will be used to re-estimate the models developed based on the Region of Peel data.

Last, as it is intuitive that business establishment vehicle ownership behavior is affected by the built environment condition of the location in which the establishment is located, several land-use variables are included in the pool of explanatory variables. Variables such as road density, density of industrial sites, density of parks and recreation areas, density of educational centers, intersection density and highway density, are some of these variables.

As this research is still in progress, merely the multinomial logit models have been partially developed for which the rho-square of 0.2 was obtained. The goodness-of-fit of the models can be improved when a complete set of land-use variables are added to the models.

References

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