A Structural Equation Model of Commercial Vehicle Ownership

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Introduction

Behavioural freight transportation modelling has recently emerged as an approach to enhance the quality of freight and logistics decision assessments. More specifically, agent-based models allows for tracking of individual agent decisions and explicit modelling of interrelated behaviour. Business establishments are noted as key agents acting within freight systems. Business establishments, including 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 modelled (Roorda et al 2010).

One of the essential decisions a company needs to make is whether to own its private vehicle fleet or outsource the shipment operations to other companies. If a firm decides to own its private fleet, the question of how many and what type of vehicles arises. It is believed that fleet composition and fleet type ownership are somehow interrelated. For instance, owning one truck might be more beneficial than owning two vans, and vice versa.

The modelling of business establishment vehicle ownership behaviour is a complicated task. As illustrated in Figure 1, the decision of whether to own a private fleet or to outsource shipment transportation operations is done at early stages of the firm establishment. This decision can be revisited later depending on the stability and growth of a firm within the market. Once the decision of owning a private fleet is done, two subsequent decisions are to follow; determining fleet size and composition.

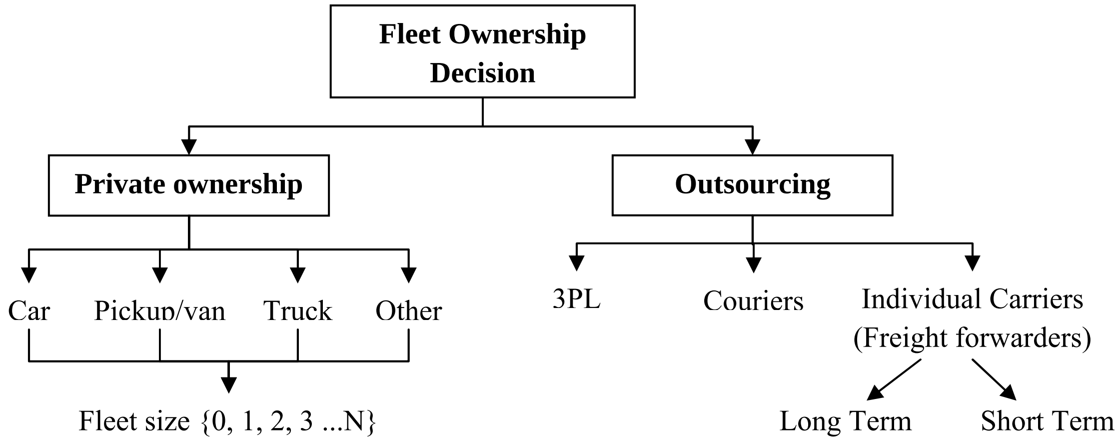

Figure 1. Vehicle Fleet Ownership Decision Hierarchy

Recent efforts have been done to model shippers and carrier selection behaviour (Cavalcante and Roorda 2012). While there had been almost no efforts to model private vehicle fleet ownership of firms, except for the efforts done by (Rashidi et al 2012). This paper presents a Structural Equation Modelling (SEM) approach for commercial vehicle ownership that considers three vehicle types: cars, pickups and vans, and trucks. The structural modelling tests different hypotheses such as the existence of substitution relationships between the ownership of cars, pickups/vans and trucks.

Method

SEM is a statistical method that is used to represent complex relationships between a set of independent variables and a set of dependent variables. SEM is also a means for multivariate regression analysis, with the special consideration of defining error terms for the derived models as well as the correlation between error terms of the unobserved variables. SEM differs from multivariate regression in that it allows the quantification of the effect of unobserved variables (latent variables) that are believed to have a direct relationship to the dependent variables and are influenced by measured variables. This is done by hypothesizing a specific model structure and statistically evaluating the resulting model.

SEM has Simultaneous Equation Modelling capabilities, in which dependent variables are considered to have an effect on other dependent variables. For instance, in the commercial vehicle ownership model, the truck ownership dependent variable can have a relationship (either substitution or complementary) with ownership of pickups/vans and/or cars. For example, Equation 1 shows a set of structural equations that models three dependent variables; y_1, y_2 and y_3 using a set of explanatory variables represented in the vector X. SEM allows for simultaneous consideration of the effect of other dependent variables, Y, and quantification of the error terms (ε) associated with each equation.

$$y_1 = \alpha_1 + \beta_1 X + \gamma_1 Y + \varepsilon_1$$

$$y_2 = \alpha_2 + \beta_2 X + \gamma_2 Y + \varepsilon_2 \qquad \text{Equation (1)}$$

$$y_3 = \alpha_3 + \beta_3 X + \gamma_3 Y + \varepsilon_3$$

Data, Model Structure, and Results

Two different variable sets are considered: company related attributes, and geographic characteristics of census tracts where the company is located. Company attributes from approximately 2,000 establishments were collected from three surveys that used the same survey instrument: The Regional of Peel Commercial Travel Survey (2009), the Region of Durham Commercial Travel Survey (2010) and the Greater Toronto and Hamilton Area Commercial Travel Survey (2012). The dataset includes basic information about the companies such as the number of employees, the number of years in business and the industrial class. It also includes estimates of company goods and service demand such as previous years inbound and outbound shipment values. Census tract attributes were developed in a GIS analysis to reflect the geographic characteristics of company locations.

Various model structures have been tested. Some of them considered latent variables and others considered direct relations between independent and dependent variables. The final model structure is a multivariate regression structure where the three dependent variables (cars, pickups/vans and trucks) are directly affected by the set of independent variables, with simultaneous effect between the dependent variables, and no latent effects are found to be significant (Figure 2). The SEM program in STATA 12 software was used for this modelling exercise.

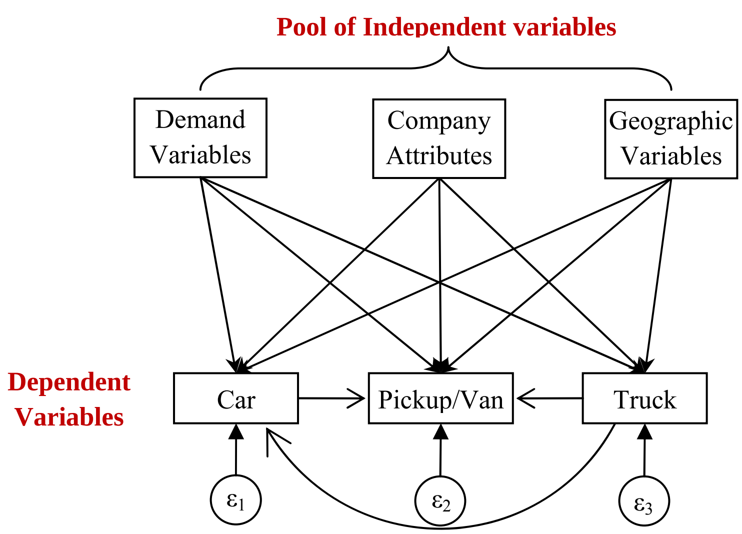

Figure 2. Final Model Structure

The model reveals simultaneous effects between the ownership of trucks and both the car and pickup/van ownership, and between car and pickup/van ownership.

The results reveal a substitution relationship between pickup/van and truck ownership, indicating that each 14 owned trucks would reduce the number of owned pickups/vans by one. Alternatively, complementary relationships between car and pickup/van ownership, and between car and truck ownership are observed. The model results indicate that, on average, for each owned car there is a 0.4 increase in the number of owned pickups/vans, and for each owned truck there is a 0.27 increase in the number of cars owned. At 80% confidence level, only the region in which companies are located is found to have a statically significant effect on vehicle ownership, while other geographical characteristics, such as proximity to different roadways, and density of land use types within census tracts were not found to have statistically significant effects.

References

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