A Conceptual Framework for Modelling Firmography

Toka S. Mostafa and Matthew J. Roorda
University of Toronto

Introduction

Agent-based microsimulation is considered to be a promising approach for transportation behavioural modelling (Miller et al. 2004; Salvini and Miller 2005; Balmer et al. 2006). Microsimulation is being increasingly used to model commercial vehicle flows (Hunt and Stephan 2007; Kumar and Kockelman 2009; Roorda et al. 2010; Pourabdollahi et al 2012). Such models represent interacting agents whose interrelations result in transportation dynamics. Two primary interacting agents are households and firms. Households are the supply side for employment, whereas firms are the source for jobs. Households demand goods and services, while businesses supply goods and services, while also demanding goods and services from other businesses. The interaction between agents result in the generation of trips (passenger and freight), and affect the dynamics of the land use and transportation.

Agent-based models of goods movements represent the behaviour of interacting agents to determine freight flows. Firms (including carriers, shippers, and logistics service providers) are the agents interacting to develop the complex system of goods and service movements. Firms behave differently depending on their market segment. For example, manufacturing plants have strategies and behaviour that vary tremendously from logistics service providers. This heterogeneity expresses itself in such decisions as asset selection, outsourcing, and location choice.

The business strategies adopted by firms vary according to the current evolutionary stage of the firm. For instance, firms that have recently been introduced in the market may target to minimize operational costs by hiring minimum numbers of employees, and/or outsourcing their freight operations. Mature firms may adopt strategies to enhance their innovation practices, freight operations, and may consider geographic expansions to sustain adequate market shares. In brief, firm dynamics affect freight decisions, and it is important to understand the evolutionary stages of firms and the associated decisions for better freight modelling and forecasting.

This research builds upon recent attempts of Roorda et al. (2010), and Cavalcante and Roorda (2013) to simulate freight systems using agent-based microsimulation approaches. In this paper we introduce our concept for the Firmographic Engine; an agent-based microsimulation that will model the evolutionary stages of firms along with their strategic decisions such as resource acquisition, outsourcing, and asset expansion/contraction decisions. The ultimate goal of the Engine is to be used as a tool for evaluating the implications of policy on freight systems by simulating individual agents and forecasting their behaviour. Such policies include, for example: infrastructure investment, trade agreements, land use policy, government incentives, and taxation policies.

The paper is organized as follows; first a brief literature review of firmography and freight microsimulation is presented, followed by a description of the Firmographic Engine, concluding remarks and future research directions.

Firmography and freight microsimulation models

Firmography, or firm demography, is a research branch that analyzes firm dynamics such as market entry, failure, growth / decline, and changes in location. Firmography is a multidisciplinary research area that attracts researchers from fields including economics, transportation and land use modelling, sociology, finance, geography, and spatial sciences (Van Wissen 2000). Firmography assesses

individual firms, therefore, firmography is considered to be important for dynamic freight microsimulation modelling (Van Wissen, 1997; Dijk and Pellenbarg, 1999).

Several research efforts are observed in the literature to microsimulate firm dynamics and their interrelations with location and land use development (Van Wissen 2000; Khan et al. 2002; Waddell et al. 2003; Maoh 2005; Elgar et al 2009; Kumar and Kockelman 2009; Manzato et al. 2014). Few studies have been based on real-world Canadian firm data have a transportation and land use focus, and microsimulate firm dynamics (Maoh 2005; Elgar et al. 2009; Yang 2011). Maoh (2005), and Yang (2011) microsimulate firm survival, mobility, and birth for The City of Hamilton, and Elgar et al. (2009) model location choice of office firms within the Greater Toronto Area (GTA).

A few research studies have considered firm microsimulation as part of freight modelling (Kumar and Kockelman 2009; Roorda et al. 2010; Pourabdollahi et al 2012; Cavalcante and Roorda 2013). However, such studies focused primarily on specific behaviour of firms such as shipper and carrier market interactions (Cavalcante and Roorda 2013), supply chain decisions of firms (Pourabdollahi et al 2012), and estimation of firm commercial trips (Kumar and Kockelman 2009).

While Kumar and Kockelman (2009) address firm entry, exit, survival, and location choice, for Austin, Texas in the United States, to estimate commercial trip generation, their research is based on aggregate firm birth and exit data. They apply firm entry and exit rates, estimated for U.S. firms for the years of 2001-2002 and 2002-2003, randomly select exit firm candidates, and generate firm births.

We have found no comprehensive models that microsimulate freight systems and the evolution of firms in a unified framework while considering changes in the economy and innovation and technological advancements. There is a need to construct freight models that integrate the individual behaviour of the freight system

agents with the changes in the regional economy, while addressing innovation and technological advances.

In summary, firmographic models that relate freight transportation and land use with the regional economy are missing in the literature in the Canadian context. No previous models have been estimated for firm evolution on the provincial or the national levels (models introduced by Maoh et al. (2005) and Yang (2011) are for the Hamilton area). Thus, we introduce the Firmographic Engine; a microsimulation that incorporates freight transportation dynamics, land use, and the economy in a unified system.

What influences firmography?

Firm evolution is affected by groups of factors including economic conditions, market competition, individual firm characteristics and strategies, location related attributes, local policies, and government incentives (Van Vissen 2000; Maoh 2005; Moeckel 2005; Fritsch et al. 2006; Elgar and Miller 2006; Hu et al. 2008; Bodenmann and Axhausen an 2010). See Table 1 for a summary of factors identified from the literature.

Generally, within any region, the economy and firm dynamics are interrelated. For instance, in 2008 the Canadian GDP dropped by 3% decreasing the firm population by 1%, while in 2010 firm population increased by 2% corresponding to a 3% increase in the GDP (Statistics Canada 2015a, b). This indicates a possible two-way relationship between the changes in the economy and firm dynamics. Furthermore, many researchers argue that the use of innovation and advanced technologies have a positive relation with the growth and prosperity of firms (Mansfield 1962; Cassiman et al. 2010; Gundary et al. 2011; Goedhuys and Veugelers 2012).

Table 1. A Summary of Factors Affecting Firmography

Category	Factor
Firm related	- Employment size - Age - Number of business establishments - Freight operation decisions - Warehouses - Sales values - No. of offered products/services
Industry related	- Age of the industry - Market competition - Size of the industry - Technological advancements and innovations - Availability of materials
Macroeconomic related	- Economies of scale per industry - Agglomeration economies - GDP and access to capital (investment potentialities)
Location population demographics	- Average Income levels - Labour market - Population educational level - Unemployment rates - Labour cost
Location geographic characteristics	- Space availability and prices - Location of business owners - Target customers - Proximity to other businesses (e.g. suppliers, carriers, and distribution centres) - Freeway access and traffic patterns
Local policies	- Government financial incentives - Tax rates and regulations

The Firmographic Engine: A conceptual framework

The Firmographic Engine is a conceptual agent-based microsimulation platform that simulates individual firm decisions and evolution stages within freight systems, and models interrelated behaviour on a yearly basis. It is composed of four basic modules: firm generation, market introduction, performance evaluation, and strategy updates, as explained in Figure 1. The details of each module are provided in the following section.

The Engine accommodates various aspects of dynamics within the economy, market competition, industrial innovation and technological advances, and firmography. To accommodate for changes in the regional economy, the Engine is to be integrated with an economic model introduced by Bachmann et al. (2014a, and 2014b) that uses Input-Output (I-O) models to track consumption, production, and trade flows within the transportation sector on global, national, and regional levels. The concept of carrying capacity adopted in a similar study (Van Wissen 2000) is employed. Demand and supply for individual goods per location are calculated from I-O tables, and the difference between demand and supply affects the growth of firm population within the market. If the demand is larger than the supply, this means there is potential for new firms to enter the market, and for existing firms to grow their assets. If supply is greater than demand, shrinkage in firm population is expected either in the form of firms exiting the market or firms contracting their assets.

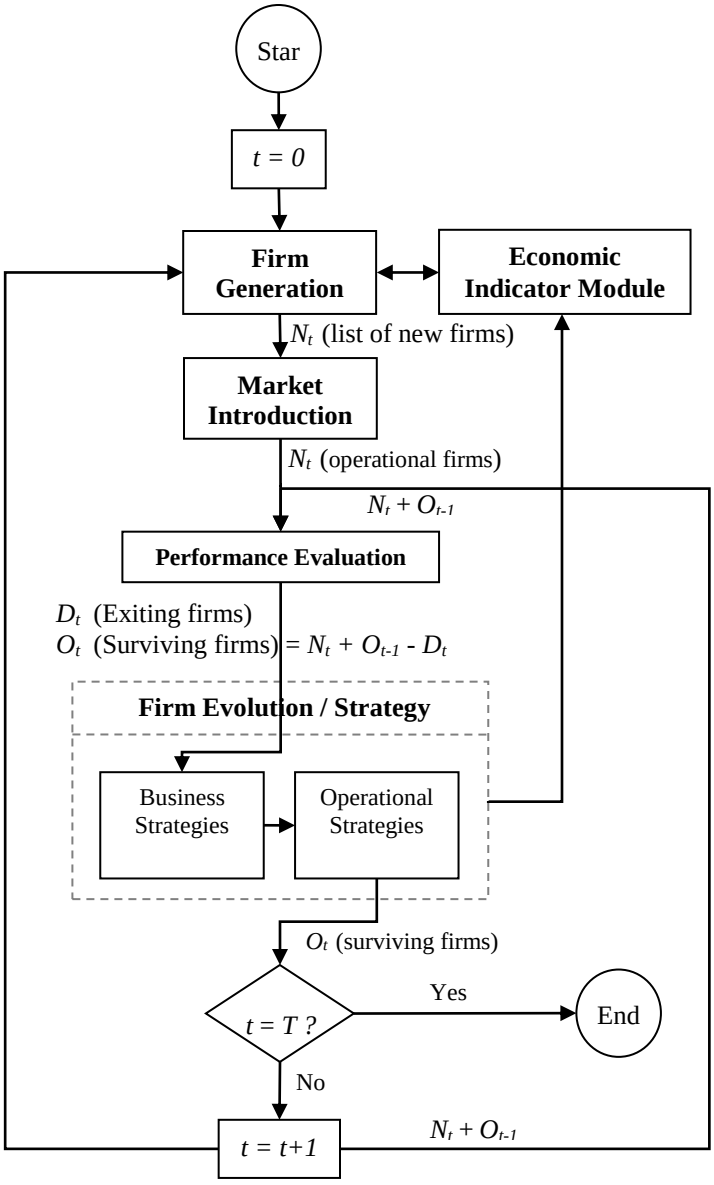

Figure 1. A Conceptual Framework of the Firmographic Engine

The Firmographic Engine: description of underlying modules

1) Firm generation is the phase in which entrepreneurs seek investment and market opportunities, and define their business strategies accordingly. The simulated strategies of concern are as follows:

1) Production strategy: defines the number of offered products/services, product prices, production quantity.
2) Financial strategy: specifies capital investments, and financial service allocations.
3) Resources strategy: decisions of outsourcing, tangible and intangible assets, facility locations, and other supporting services (e.g. human resources, research and development, and sales services).
4) Supply chain and logistics strategy: identifies the role of local and international suppliers, supply chain inputs/outputs, and selection of distribution and logistics centres.
5) Marketing strategy: decisions related to media and advertisements, promotions and discount systems, and design of product packaging.

The output of this module is a list of potential firms (N_t) with defined business strategies for the current time interval.

2) Market introduction is the phase in which firms generated from previous module are physically established within the market. This stage involves the specification and completion of operational strategies such as contract formation (e.g. logistics operations) and resource acquisition (e.g. purchasing or leasing real estate, hiring employees, and buying vehicle fleet). The result of the execution of this stage is a list of operational firms (N_t) that exist in the market.

3) Performance evaluation is the next module that assesses the behaviour of firms throughout the simulated time interval according to performance measures. Performance measures include market share growth, sales and revenues, customer satisfaction, shareholder

dividends growth, improved delivery times, gross/operating margin costs, and increases in sales of new products. Performance measures vary across individual firms depending on their long-term strategies. For example, firms with long-term strategies of market positioning and product leadership may assess their performance based on customer satisfaction and minimized delivery times, while firms adopting mass market and low-price long-term strategies may use market share and sales growth rates as performance indicators.

Based on performance assessment, firms may choose to exit the market (by either merging with another firm or completely exiting the market), or decide to continue existing in the market. The output of this module is a list of surviving (O_t,), and failed/exiting (D_t) firms.

4) Firm evolution/strategy updates is the final stage for simulating the behaviour of surviving firms. Some surviving firms may choose to revisit their strategies (both the tactical and operational ones) to sustain adequate growth and maintain their market position.

Challenges of firm micro modelling

Modelling firms at the micro level is complex because firm behaviour is highly heterogeneous and involves a large number of decisions. Firm activities have a two-way relationship with changes in the economy. Current economic models of firmography perform at the macroeconomic scale (such as Ghironi and Melitz 2004; Atkeson and Burstein 2007; Bernard et al. 2007), while firm micro-level analysis is required for freight models to explain freight related decisions.

Interrelations also exist between changes in the economy and innovation and technological advances. Technological innovations create opportunities for new investments and hence influence the economy. Such interrelation affects the operational performance of the new and current firm populations.

To model these relationships, comprehensive longitudinal firm disaggregate datasets are required that include observations of firm

decisions such as the use of technology and innovation, outsourcing decisions, local and international suppliers, and resource acquisitions.

Concluding remarks and future research directions

Freight microsimulation can better reflect our understanding of the behaviour of the agents within freight systems, and hence has potential to provide stronger support for decisions related to freight policy. Firm dynamics greatly influence the freight and logistics decisions of shippers and carriers, in addition to broadly influencing the economy. There is a need for micro-level freight models that incorporate firm dynamics, changes in the economy, and innovation and technological advancements.

The Firmographic Engine is an agent-based freight microsimulation that simulates the evolution of firms while considering existing market conditions, and the regional economy. The Engine is currently at the conceptual design stage. Various underlying behavioural models are to be estimated such as outsourcing decisions, and vehicle fleet ownership, upon micro data acquisition. The microsimulation platform is then to be implemented to simulate the various behaviour of firm population and be used eventually for policy assessment.

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