An Object Oriented Model of Business Establishments and Inter-Business Relationships

Toka S. Mostafa *

Department of Civil Engineering,

University of Toronto, Toronto, Canada

toka.muhammad@utoronto.ca

Matthew Roorda

Department of Civil Engineering,

University of Toronto, Toronto, Canada

roordam@ecf.utoronto.ca

***** Corresponding author

1 Introduction

Behavioural freight transportation modelling has recently emerged as an approach to enhance the quality of freight and logistics decision assessments. Earlier, freight transportation models were based on the conventional four-stage or commodity based approaches [1-4]. These approaches are aggregate and were generally developed using the passenger demand modelling paradigm. They fail to represent interaction among system players (agents), hence their accuracy for freight modelling is questioned [5]. Agent-based microsimulation allows for tracking of individual agent decisions, and explicit modelling of interrelated behaviour. This research builds upon recent attempts to simulate the freight system using agent-based microsimulation approaches [6-10].

Business establishments (BEs) are key agents acting in freight systems. BEs belong to different market segments, which do not necessarily share the same characteristics. For example, manufacturing plants have characteristics and behaviour that vary tremendously from logistics service providers. This heterogeneity expresses itself in such decisions as asset selection and location choice. The goal of this research is to express this heterogeneity in an agent-based microsimulation model. The model intends to express dynamic interactions among agents (e.g. formation of contracts between establishments), as well as those attributes of agents that can also change over time (e.g. number of employees, establishment location, fleet size). This paper describes the preliminary development of the microsimulation engine within which selected estimated model components are operationalized. Other model components that have not yet been estimated are left as "dummy models".

2 Method

Object-oriented modelling is a paradigm used to represent the interaction among real-world constructs (objects) to perform complex behaviour in a simple and a clearly-defined manner [11]. This research represents the object-oriented design and implementation of the conceptual framework of an agent-based model of logistics services [5].

The main entities introduced in the framework are translated into classes with structured relationships (e.g. one class may be a subclass of another, implying an “is a” relationship, or may be comprised of objects of certain classes, implying a “has a” relationship). Figure 1 shows a preliminary class representation of a business establishment, the facilities of which it is comprised and contracts that represent the outcomes of interactions with other agents. Objects (instantiations of classes) are then implemented to program the behaviour of interacting classes.

The implementation of the business establishment (BE) class, as an example, is shown in Figure 2. The attributes of the BE class include objects (or lists of objects) of other classes, including BE location, its employees, the facilities of which it is comprised, and the contracts it has with other establishments. The methods include actions that the establishment would take to update its state over time. These methods are intended to represent both fundamental strategic (firmographic) decisions, and supply chain and market interaction decisions (which other establishments to do business with). Operational decisions (e.g. vehicle routing, inventory management, etc.) are not currently represented, but the model structure will allow for expansion to incorporate these day-to-day aspects of establishment behaviour. Other classes shown in Figure 1, are detailed as well.

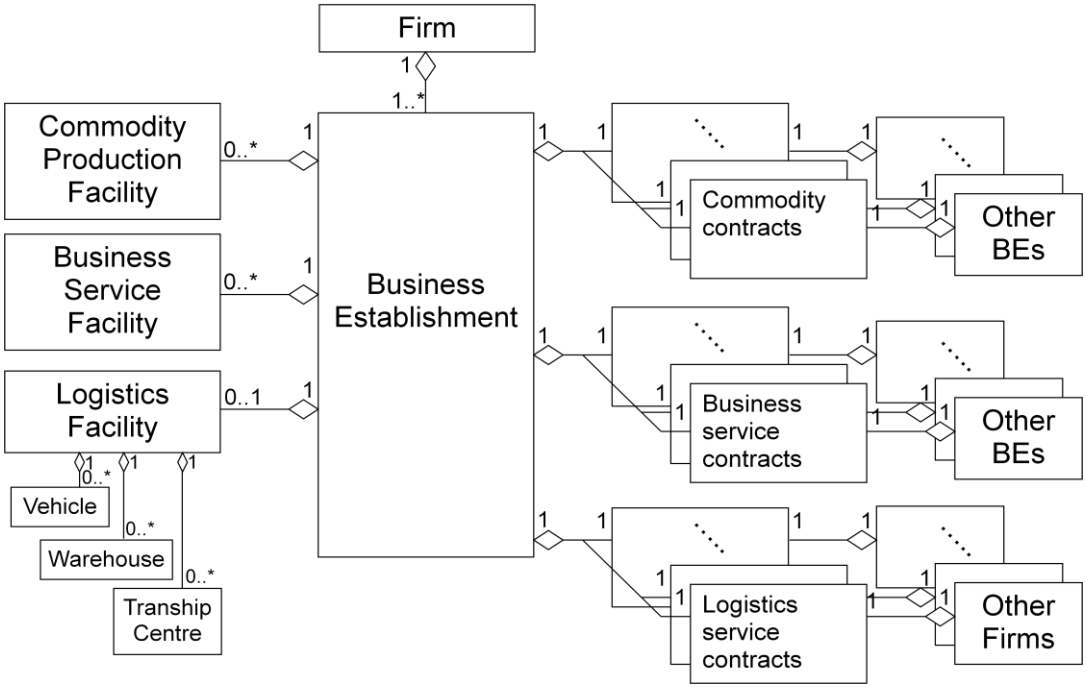

Figure 1 – Conceptual structure of a business establishment [5]

Note: Lines indicate a "has a" relationships. Numbers at each end of a line show the number of agents/objects involved in the relationship. Lines with a diamond represent an aggregation relationship, where the diamond end is a "whole" and the other end is a "part".

Class Name	**Business_establishment**
Attributes	Establishment_id
	Location
	List_of_employees
	Commodity_production_facility
	Business_service_facility
	Logistics_facility
	List_of_commodity_contracts
	List_of_business_service_contracts
	List_of_logistics_service_contracts
Methods	Update_location()
	Update_workforce()
	Update_commodity_production()
	Update_business_services()
	Update_logistics_facility()
	Update_contracts()

Figure 2 – Simplified design of the business establishment class

The model developed in this paper takes advantage of basic object-orientation concepts of *encapsulation, abstraction, polymorphism*, and *inheritance*. Appropriate application of these concepts results in an efficient and concise model design that ensures programming flexibility, design consistency, and efficient memory management.

3 Proof of concept

The prototype model is coded in the C# programming language. The model is compatible with the ILUTE (Integrated Land Use, Transportation, Environment) model [12], such that modelling frameworks could eventually be conveniently merged. The prototype is implemented and tested for proper execution, and reasonable aggregate outcomes. The prototype is based on establishment attribute data available from InfoCanada (2012) for the Toronto Area, and behavioural submodels derived from recent research conducted by the research team. Population synthesis methods are used to estimate firm-related attributes that are not included in the InfoCanada database (e.g. fleet size), and "dummy models" are applied to represent behaviour for which formal models have not yet been estimated.

References

[1] Pendyala, R., Shankar, V., McCullough, R., 2000. Freight travel demand modelling: synthesis of approaches and development of a framework. *Transportation Research Record 1725*, 9–16.

[2] Cambridge Systematics, 1996. Quick Response Freight Manual: Final Report. Prepared for the Federal Highway Administration, September.

[3] Fischer, M., Ang-Olsen, J., La, A., 2000. External urban truck trips based on commodity flows: a model. *Transportation Research Record 1707*, 73–80.

[4] Cambridge Systematics, 1998. Collection and Analysis of Commodity Flow Information in the Portland Metropolitan Area: Compendium of Technical

[5] Roorda M., R. Cavalcante, S. McCabe, and H. Kwan (2010). A conceptual framework for agent-based modelling of logistics services. *Transportation Research Part E*, 46 (1): 18–31

[6] Boerkamps, J., van Binsbergen, A., Bovy, P., 2000. Modeling behavioral aspects of urban freight movement in supply chains. *Transportation Research Record 1725*, 17–25.

[7] Hunt, J., Stefan, K., 2007. Tour-based microsimulation of urban commercial movements. *Transportation Research Part B* 41 (9), 981–1013.

[8] Liedtke, G., 2006. An Actor-Based Approach to Commodity Transport Modelling. Nomos Verlagsgesellschaft, Baden Germany.

[9] Wang, Q., Holguin-Veras, J., 2008. Investigation on the attributes determining trip chaining behavior in hybrid micro-simulation urban freight models. *Transportation Research Record 2066*, 1-8.

[10] Wisetjindawat, W., Sano, K., Matsumoto, S., Raothanachonkun, P., 2007. Micro-simulation model for modeling freight agents interactions in urban freight movement. CD Proceedings, 86th Annual Meeting of the TRB, Washington DC, January.

[11] McCormack, J., and S. Roberts. 1996. Exploiting object oriented methods for multi-modal trip planning systems. *Information and Software Technology* 38 (6): 409-17.

[12] Salvini, P., and E. J. Miller. (2005), ILUTE: An operational prototype of a comprehensive microsimulation model of urban systems, *Networks and Spatial Economics 5 (2):* 217-34