A conceptual framework for agent-based modelling of logistics services

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Abstract
Freight transportation models have been traditionally developed based on passenger travel demand modeling approaches. More recently, hybrid models have been developed to attempt to incorporate behavioral elements of supply chain management and logistics chains into freight transportation models. Hybrid models have been developed for Groningen (Netherlands), Tokyo, Calgary (Canada) and Sweden. This paper builds upon these efforts by presenting an agent-based microsimulation framework that explicitly represents the diversity of roles and functions that the actors play, how they interact through markets and how interactions between actors are established in the market through contracts. The framework is developed with the intention of providing a consistent modeling philosophy with the ILUTE (Integrated Land Use Transportation Environment) modeling framework developed for the Toronto Area.

In this conceptual framework, the actors are firms and end consumers. Firms may be composed of one or more business establishments at specific locations. Business establishments may contain commodity production facilities (where commodity inputs are transformed into outputs), business service facilities (analogous to commodity production facilities, but for production of services). Firms also may contain logistics service facilities, which include vehicles, transportation network elements, and consolidation centres. End consumers initiate demand for commodities/services that flow through the production system. Each firm can simultaneously play multiple roles (shipper, receiver, carrier, etc.).

The purpose of each firm is to maximize its profit by utilizing its resources. Firms make fundamental business decisions (long range decisions) and supply chain management decisions (medium to long range decisions), while business establishments make market interaction decisions (short to medium range decisions) and operational decisions (short term decisions). Contracts result from market interactions between business establishments. Three types of contracts are considered in this framework: commodity contracts, business service contracts and logistics services contracts. Commodity contracts and business service contracts represent shipments of commodities and services, respectively, between business establishments. These contracts identify the vendor, customer, price and a list of shipments. After the establishment of a commodity contract, a logistics service contract is formed, which identifies the business establishment responsible for shipments, the logistics firm that executes shipments, the price and the list of shipments to be transported.

The process of commodity contract formation begins when a business establishment forecasts its commodity output supply and its associated commodity input demand for each commodity type over a forecast time period. The order quantity to fulfill demand is determined through an optimization of inventory levels and it is a function of the ordering cost and carrying cost. In this framework, each business establishment may act in the market as a vendor (advertising its commodities outputs) and/or as a customer (buying its commodities inputs). Customers are assumed to select the vendor using a random utility maximization model where the utility function depends on the vendor attributes, price function advertised (which depends on the length of the contract, order quantities and order frequency) and expected unit shipping cost. The length of the contract depends on the uncertainties of commodity output supply and commodity input demand. After commodity contract formation, each shipment has the following defined attributes: origin business establishment, destination business establishment or
end consumer, shipment day, commodity weight, commodity type and commodity price. The process of business service contract formation is analogous to that of commodity contract formation.

The process of logistics service contract formation begins when a contracted vendor arranges logistics for the shipments. The vendor can provide the logistics services entirely with its own private fleet, or contract logistics services out to another firm. The vendor selects one logistics firm for each shipment, or bundle of shipments. It is assumed that the vendor selects a logistics firm or uses its own logistics resources based on a random utility maximization model. The utility function depends on the logistics firm attributes, the price function for the logistics firm services for the movement of commodity from origin to destination and the vendor's own logistics resources. After the logistics service contract process, the firm responsible for transport of the shipments is known, in addition to the other shipment attributes noted above.

After the logistics service contract is formed, operational decisions about how to execute the movement of shipments are assumed to be left to the discretion of the logistics service provider. The selection of the logistics chain to be used in each shipment is considered to be an operational decision. It is assumed that the selection of the logistics chain for a specific shipment is based on a random utility maximization model where the utility function is a linear function of the negative of the observed logistics cost of each logistics chain.

This proposed conceptual framework is designed to provide sensitivity to a variety of technology trends, business trends, and policy scenarios that more conventional approaches cannot do to the same extent. Based on that, its main characteristics are: cost of logistics are explicitly represented, trends toward the outsourcing of logistics services to third party logistics firms can be represented, possibility to capture impacts related to growth or retraction of various industry sectors, impact of new supply channels can be modeled, etc.

The paper also describes the data sources available with which various components of the proposed model can be estimated for the Toronto Area, and describes additional data that will need to be collected in specially designed surveys.