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Logistics Decisions in Descriptive Freight Transportation Models: A Review

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Abstract – The objective of this paper is to provide an inventory of approaches to descriptively (as opposed to normatively) model logistics decisions within the context of freight transport modelling. Rather than taking transport modelling frameworks as a starting point, as has been the case in the literature so far, we depart from a framework of logistics decisions. The framework is developed by combining elements of over a dozen existing frameworks from the supply chain management literature. Based on this comprehensive framework, we review freight modelling approaches from the literature. We find that freight modelling can be extended by taking into account previously uncovered areas of logistics decisions, such as those related to marketing or logistics systems forecasting and planning, as well as in areas that are well known from an optimization perspective but not from a descriptive perspective, such as routing and scheduling decisions. We conclude with a systematic listing of such areas, which can be used by researchers and transport modelling practitioners to develop further those transport models that take agent decision making as a starting point.

Keywords: Freight Transport Modelling; Agent Based Model; Logistics Decision Making

1. Introduction

Freight transport modelling has developed throughout the past 50 years from transport engineering practice, as an approach to describe and predict future freight flows, with a view to making the appropriate transport policies, infrastructure designs and investment choices for transportation networks (see e.g. de Dios Ortuzar and Willumsen 2011, Tavasszy and de Jong 2013). The typical output of these models is a flow of freight transport movements, measured in tones, load units or transport movements per year. The scale is at the macro level of roads, cities or countries. The models build on knowledge of logistics decisions at the micro, or firm level, that determine freight flows. Relevant decisions of firms include, amongst others, the choice of suppliers, distribution channels, modes and routes of transport. From the perspective of the policy maker, an accurate aggregate representation of such decisions is important to anticipate responses of the logistics sector on policy measures. In the past decades, researches have come to recognize the importance of developing descriptive models of logistics decision making to build better freight transport models (Tavasszy et al. 1998, Davidsson et al. 2005, Tavasszy 2006, Wisetjindawat et al. 2007, Liedtke 2009, Roorda et al. 2010, Tavasszy and de Jong 2013, Thaller et al. 2016). The argument is that models that build on an understanding of normative principles of logistics decisions are better able to describe and predict the aggregate result of firms' behavior. Our paper constitutes a first attempt to review these models by a comprehensive consideration of logistics decisions from the supply chain management literature. In addition to recognizing that transport is part of a broader logistics process, we also define logistics here as a part of the larger system of supply chain management, taking, in the words of Larson and Halldorsson (2004) the "unionist perspective". In relation to the topic of the review, we argue that this system-of-systems embedding will allow us to create transport models

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that are eventually more consistent with principles and practices from supply chain management, thus resulting in more reliable predictions of freight flows.

Our paper is organized as follows. In Section 2, we propose a simple but comprehensive framework of logistics decisions. This will support the inventory of current freight modelling initiatives and will allow us to identify research gaps. Section 3 reviews these current models from the literature and identifies the gaps between these models and the framework of Section 2. We synthesize the gaps into a research agenda. Section 4 concludes the paper with a summary of our findings and recommendations, for researchers and model practitioners.

2. Framework for Logistics Decisions

2.1. Evolution of logistic conceptual models

The CSCMP (Council of Supply Chain Management Professionals) defines logistics as : "that part of supply chain (SC) management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements" (CSCMP 2013). We have scanned the literature to gain an understanding of frameworks that classify functional areas of logistics and their decisions. Our objective was not to provide a synthesised framework that is able to support our reasoning towards functions that are relevant for descriptive and predictive freight transportation modelling. Many basic supply chain management or logistics textbooks contain classifications of decisions. We have gone back to the main sources that introduced these frameworks. An outline of these sources is displayed in Table 1. There are many overlaps and also subtle differences. Also, one can note that, through time, little evolution is shown in these frameworks.

In chronological order, Novack (1984) is one of the oldest research studies on provision of a logistics framework. In this research, he developed a 12-step analytical process of diagnostic questions for transportation budgeting. A year after, Daskin (1985) associated the decision-making problems with different actors in the private and public sectors. The twelve steps of Novack (1984) were further applied on the measurement of logistics performance by Mentzer and Konrad (1991). In 1992, Novack et al. (1992) defined logistics in a different way, distinguishing between two perspectives, i.e. channel and organizational views. Here, categorization of activities appears in two dimensions (physical and transactional activities). In another research, Neng Chiu (1995) considered eight primary functions of distribution centers (DC) with an illustrative example in Taiwan. Sink et al. (1996) and Sink and Langley Jr (1997) studied third-party services and classified all activities expected from a 3PL. The fundamental activities in a logistics system are defined in Lambert et al. (1998), known as Lambert's model. Croom et al. (2000) classify supply chain management, and logistics as a part of it, according to both content- and methodology-oriented criteria. Another framework is from Hesse and Rodrigue (2004), who considered the evaluation of logistics during a long period of time, while the activities covered by logistics were gradually updated in the framework. The Lambert framework has the broadest view amongst all frameworks and also envelops some of these, e.g. Bowersox et al. (2002), Gunasekaran and Ngai (2003), Riopel et al. (2005) and Sople (2007). Lambert's framework was later used in Lambert et al. (2008) by a functional translation towards a supply chain management context. Interestingly, after this time, the literature shows very little evolution in generic frameworks. The attention has shifted from generic frameworks to specific domains of decision making within these frameworks, driven by upcoming issues such as sustainability (Wong et al. 2015), risk (Gianniakis and Louis 2011) and collaboration (Luthra et al. 2017). These specific frameworks largely build on the existing generic frameworks referenced above. We have not found any recent research that attempts to feed the developments of these partial frameworks back into new generic conceptual frameworks.

Based on the above sources, we assembled a generic framework of freight transport-relevant logistics decisions (Figure 1). We combined elements into one holistic framework, aligning terms with similar meanings from different sources. Initially, the framework included nearly 100 different terms, also showing considerable overlap. We selected the decisions that fit into the 3 main functional areas of logistics decision making that directly relate to the physical movement of goods: Transportation, Inventory/Warehousing and Planning/Administration. We combined terms choosing dominant expressions until we reached at most 7 decisions per area.

Table 1. Evolution of theoretical frameworks for logistics through time

Author	Classification of functional areas of logistics
Novack (1984)	A 12-step analytical process of diagnostic questions for transportation budgeting.
Daskin (1985)	Inventory management, marketing/pricing, own/hired/contracted carriage, production planning, facility location, vehicle routing/scheduling, price and level of service, fleet size and makeup, network configuration, pricing/ taxing of infrastructure, infrastructure provision and maintenance, degree and nature of regulation.
Mentzer and Konrad (1991)	Transportation, warehousing, logistics administration, order processing, inventory control, and utilization.
Novack et al. (1992)	Production/operations management, Physical distribution management, transportation management, marketing and purchasing (logistics is defined as linkages across these disciplines).
Neng Chiu (1995)	Receiving, warehousing, order picking, moving and handling, reprocessing and assembling, sorting and merging, checking, and vehicle route scheduling (these are primary functions of the DC).
Sink et al. (1996)	Transportation, warehousing, inventory management, order processing, information systems, packaging.
Lambert et al. (1998)	Customer service, demand forecasting, inventory management, material handling, order processing, packaging, parts and service support, plant and warehouse site selection, procurement, reverse logistics, traffic and transportation, warehousing and storage.
Hesse and Rodrigue (2004)	Physical distribution (inventory, distribution planning, order processing, transportation, and customer service), materials management (demand forecasting, purchasing, requirements planning, and manufacturing inventory), warehousing, materials handling, and packaging.
Croom et al. (2000)	Physical distribution, cross docking, logistics postponement, capacity planning, forecast information management, distribution channel management, planning and control of materials flow, integration of materials and information flows, and JIT, MRP, VMI, waste removal.
Bowersox et al. (2002)	Network design, transportation, information, inventory, warehousing, material handling and packaging.
Gunasekaran and Ngai (2003)	Strategic planning, Inventory management, Transportation, Capacity planning, Information technology.
Riopel et al. (2005)	Strategic level, Network level (physical facility, communication and information), Operations level (demand forecasting, order processing, production, procurement & supply, transportation, packaging, materials handling, Inventory, warehousing)
Vaidyanathan (2005)	Transportation, warehousing, freight consolidation and distribution, product marking, labeling, and packaging, inventory management, traffic management and fleet operations, freight payments and auditing, cross docking, product returns, order management, packaging, carrier selection, rate negotiation, logistics information system.
Sople (2007)	Material handling, logistical packaging, shipping, order processing, information flow, warehousing, inventory control
Lambert et al. (2008)	Customer Relationship Management, Supplier Relationship Management, Customer Service Management, Demand Management, Order Fulfillment, Manufacturing Flow Management, Product Development and Commercialization, Returns Management.

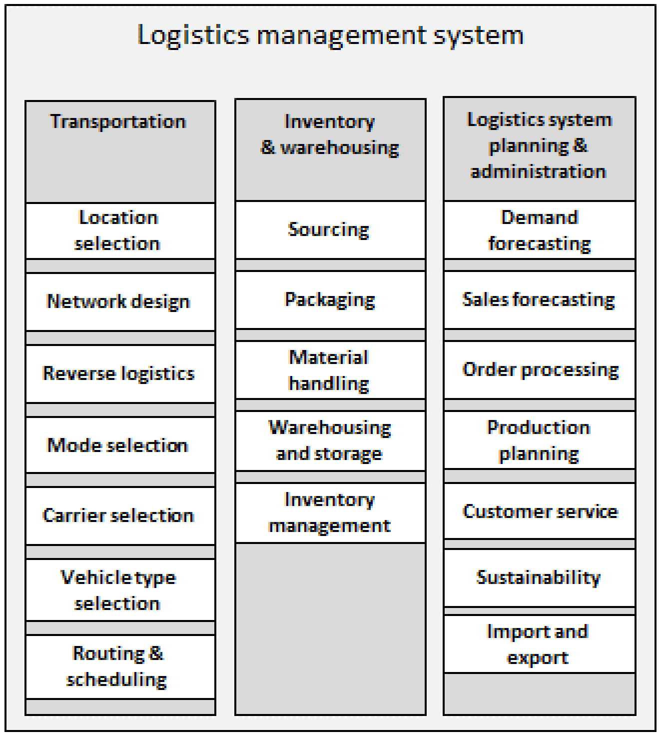

Figure 1. Framework of functional area of logistics

2.2. Logistics-Transportation relations revisited

There is scant literature that systematically addresses the conceptual relations between logistics decisions and transportation flows. McCann (2001) shows the impact on transportation patterns of upstream logistics decisions including product development, marketing and sales, and order fulfillment decisions. These decisions together significantly influence the quantity of freight, the choice of mode and vehicle type, the utilization of the vehicle and the routes and schedules followed. The quantification of these relationships has not yet been attempted but would be an interesting avenue of research. In our framework, we include the upstream decisions that fall within the realm of logistics management, as well as the directly transport related decisions. Aschauer et al. (2015) develop a quantitative model explaining logistics reorganization responses and its effects on transportation. The focus of their model in logistics terms is on sourcing behavior and transport organization decisions. A comprehensive map of relevant decisions is lacking. Figure 1 contains a map of these decisions, but is still too detailed for our review. We can also discern relations of influence between decision areas, which can help us to arrive at a more condensed conceptual framework. We use the relationship between transportation decisions and other areas of decision making (see e.g. McCann 2001 and Riopel 2005) to make a further grouping. Transportation decisions depend directly on decisions concerning physical network design, demand forecasting, production scheduling, customer service objectives, packaging design and shipment size and frequency decisions. There are also indirect connections. We arrive at 6 sets of related decisions:

1. Sales forecasting, order processing and customer service: these functions produce a list of (future) orders for production and shipping based on market knowledge and customer relations. They constitute the interface between the customer and the company and are the primary drive of all production, procurement and other logistics planning activities.
2. Demand forecasting, production planning and import/export relations: based on expected sales, these functions set the demand for materials and produce, thus acting as a second driver of the other functions.
3. Sourcing and material handling determine the detailed availability of production inputs, also deciding on order characteristics such as frequency and order size. For inbound flows these functions have a direct impact on the amount of freight transport.
4. Network and distribution channel design involve a strategic function, including planning of reverse flows and location of intermediate inventories and centers for cross-docking. It is often

at this stage that outbound shipment size decisions are made, with a direct long-term impact on freight transport volumes.

5. Inventories, warehousing and packaging; these functions have a downstream focus and prepare products for shipping towards the customer. In conjunction with the previous function, these activities also have a direct, though shorter term impact on transport flows.
6. Transportation organization, including tactical functions such as carrier selection (own account or for hire carrier) and mode/vehicle type selection, as well as decisions of an operational nature such as routing and scheduling. This is the most direct function impacting freight transport flows.

Given the objective of our paper, our interest is in the possibility to understand the impacts that these decisions can have on the transportation system. The relevance of logistics decisions for freight transportation patterns can be summarized by looking at the volumes generated, the distances of movements and the physical impact on the network. If we map our decision-making areas onto these dimensions, we obtain the following relationships.

Table 2. Relevance of logistics decision areas for transport patterns in 3 dimensions

Functional area	**Transport dimension**		
	Freight generation (total volume moved)	Spatial distribution (distances covered)	Network usage (technology, routes)
Sales, orders, service	Sales volume Number of varieties	Distances to markets	Service requirements & scale for outbound
Demand forecasting, production planning, import/export	Transport intensity of products (water & air)	Distances within the supply chain	Service requirements for in- and outbound
Sourcing, material handling	Volumes, service levels and excess flow due to uncertainty	Distances to suppliers	Service requirements & scale for inbound
Distribution channels, network	Locations of intermediate inventories	Degree of centralization determines detours	Service requirements towards modes and vehicles
Inventory, warehousing, packaging	Network/channel inventory policy	Access to main networks from warehouses	Service requirements towards modes and vehicles
Transportation organization	Limited influence	Access to main networks	Direct influence

The tabulation should not suggest that functional areas are independent. Decisions are strongly interrelated across boundaries of management responsibility. More and more, companies are also seeking horizontal collaboration with other firms to reduce costs, risk levels, and usage of resources. As a consequence, inter-firm decision making creates even more interdependencies between these decisions, also across firms.

The next section discusses the way in which current freight transport models deal with the above 6 areas of decision making. We review the state of the art in freight modelling, with the aim to arrive at gaps in the literature concerning the coverage of logistics decisions.

3. Existing descriptive freight transport models

We use the presented framework to review and position the literature of empirical and descriptive models for freight transport. Previous reviews of freight transportation models (Tavasszy et al. 2012, de Jong et al. 2013) have touched upon elements of supply chain decision making but have not taken a framework of supply chain decision making as a starting point. In the following review we limit ourselves to descriptive, quantitative, empirical models of logistics decision making. “Descriptive” implies that we exclude normative, or optimization models for logistics decisions. “Quantitative” implies we exclude conceptual models of decision-making processes. "Empirical" implies that models are developed to be validated against observed behavior. Our primary sources are the journals from transportation engineering and economic geography literature. A systematic search was done on descriptive models for decisions mentioned in the framework above. Also, recent advances in behavioral freight modelling (Crainic 2016, Tavasszy and Friedrich 2019) have been taken into account in the review of freight models. Our primary purpose being the identification of gaps in the literature in terms of the decisions covered in our framework, we do not claim an exhaustive review within individual decision categories. Our focus lies on studies that analyze individual decision making, but in some spheres of decision making (e.g. trade) aggregate models are the standard.

3.1. Production planning

In production, logistic supply chain decisions involve site selection for the location of production; the configuration of production processes and product design. Industrial location is broadly studied in schools of economic geography, originating in the classical location choice models (Weber 1929) and more contemporary New Economic Geography approaches, introduced by Krugman (1991). This has led to a broad literature of quantitative location choice models, in which the 'upstream' location choices in supply chains are assumed dependent on the availability of inputs (commodity, labor, knowledge, and infrastructure). In general, these approaches take aggregate agents, such as industry sectors and regions, as the unit of analysis.

3.2. Sourcing and sales

At the company level, the matching of supplier and customers was recently modelled by Pourabdollahi et al. (2016) using an agent based model. Marketing and sales choices depend on the customer base and its demand characteristics. Decisions include longer and shorter-term decisions (e.g. outlet location and promotions, respectively). Mostafa et al. (2017) estimate discrete choice models for the decision to outsource products or services outside of the firm. Their findings show that outsourcing depend on firm characteristics, the economic climate and government incentives (educational programs, grants). Recently Holguin-Veras et al. (2015) developed a model of shop floor space use where the benefit of shop inventory (a lower chance for missed sales) is weighed against the cost of floor space in the city (land rents, basically). Here, shopping behavior and lost sales directly impact on the choice of location and the ordering behavior of shop owners. The equilibrium model could be estimated based on land use and transport observations, to result in an extended empirical model for cities. At the country level, considerations of sourcing and sales in freight transportation models are usually done jointly in gravity models or in spatial price equilibrium setting. Harker and Friesz (1985) developed the generalized Spatial Price Equilibrium Model (GSPEM), which has been applied in many empirical studies to follow. For a recent overview see Ivanova (2014).

3.3. Distribution structures

There has been a limited amount of research on models for distribution structures. A recent review was given by Friedrich et al. (2014). Both aggregate and disaggregate models were built. Friedrich (2010) develops a firm-level model based partly on normative models and partly on behavioral characteristics of firms that cannot be observed directly but can be estimated. Tavasszy et al. (1998) and Jin et al. (2005) develop aggregate models for regional flows in combination with disaggregate models for logistic choices: the location of transshipment at warehouses. Kim and park (2010) present a disaggregate choice model for distribution structures, although not based on logistics costs. Davydenko and Tavasszy (2013) estimate discrete choice models for transshipment on disaggregate data and results are applied in an aggregate simulation. Shipment size choice has a strong dependency with distribution structures: transshipments at warehouse locations affect shipment size choice before and after the transshipment (Friedrich et al. 2014). Discrete choice models and hyper networks are able to describe this explicitly, but disaggregate simulation is required.

3.4. Inventory, warehousing and packaging

Inventory costs are dependent on mode, vehicle and shipment size choices (Baumol and Vinod 1970), so choices in the functional area of inventory management are closely related to decisions in the area of transportation. We discuss these transportation related choices below. In this area, we have not found any descriptive modelling in the context of freight transport modelling. This is all the more surprising given the strong relationship with transport requirements. New research is needed to explore this area further.

3.5. Transportation

Models of transportation choices are abundantly available in the literature, and may cover carrier selection, mode choice, or routing and scheduling choices.

The majority of the available work is dedicated to the choice of the mode of transport. This topic is vastly covered in empirical literature: De Jong (2014) provides a recent overview. Carrier selection is topic of research in just a few empirical studies. Holguin-Veras et al. (2009) analyzed shipper-carrier interaction in a game theoretic study in experimental economics. The study showed evidence for cooperative behavior between shipper and carrier, which implies it doesn’t matter who determines shipment size. Furthermore, the shipment size choice affects mode choice heavily. Decisions in routing and scheduling have received little attention from the descriptive perspective. Holguin-Veras et al. (2013) and Marcucci and Gatta (2017) developed choice models with explicit representation of delivery times.

Routing is addressed in some descriptive tour-based freight models such as Boerkamps et al. (2000) or Hunt and Stefan (2007); usually these models are focused on city distribution. In recent example of a national tour-based freight model was developed by Moeckel and Donnelly (2016). With the increased availability of vehicle level records of detailed trip patterns, databases are now being built that could act as a basis for the estimation of such descriptive models. Sánchez-Díaz et al. (2015) and You et al. (2016) provide recent examples of descriptive models for routing problems using detailed trip data for model development.

Both aggregate and disaggregate models were developed for port and inland terminal choice at national level (Zhang et al. 2015, Yamada and Febri 2015) and international level over longer distances (Limbourg and Jourquin 2009), based on disaggregate data (de Jong and Ben-Akiva 2007, Tongzon 2009) and using aggregate data, for maritime seaports within a limited port range (Zondag et al. 2010) up to the global scale (Shibasaki et al. 2005, Halim et al. 2016).

Vehicle type choice is often modeled simultaneously with mode- or shipment size choice (Piendl et al. 2016). Empirical studies on simultaneous shipment and vehicle type choice include Windisch et al. (2010), Pourabdollahi et al. (2013), Abate and de Jong (2014). Mommens et al. (2017) present an original approach where not shipment size, but types of loading units are simulated in freight demand model. The choice of shipment size may be a result of upstream production-, sourcing- or distribution considerations, in empirical studies it has been modelled primarily as a trade off in transport, trading off in-transit inventory against ordering or transport costs (de Jong 2007, Combes 2012, Liedtke 2009, Venkatadri et al. 2016, Combes and Tavasszy 2016).

4. Synthesis and research agenda

From this discussion of empirical literature, we create an inventory of the coverage of empirical studies on each functional area as represented in Table 3.

The review of existing literature paints the following picture of descriptive freight modelling. At the surface, the state of the art in descriptive freight modelling seems to be in line with the layered framework for logistics decision making. At the same time, we find that current freight models.

- Is limited in scope (research focused on transportation decisions)
- disregard functional interactions (including discussions of equilibrium)
- lack a distinction between strategic, tactical and operation decisions
- lack a dynamic perspective (i.e. review frequencies of decisions)

Currently, descriptive models for the public sector have a focus mainly on the functional areas of Distribution structures, Inventory and Transportation. They seek to analyze the impact of changes in transport- and distribution networks on freight transport patterns. The other functional areas are given, or represented in exogenous inputs to the analyses, e.g. in the form of economic or international or interregional trade scenarios.

Table 3. Summary of empirical literature on descriptive supply chain models

Functional area	Logistic functions	Coverage*	Level**	Authors
Sales	1. Sales forecasting 2. Customer services 3. Order processing	X	A	Harker and Friesz (1985), Ivanova (2014), Pourabdollahi et al. (2016)
Production planning	4. Demand forecasting	X	A	Weber (1929), Krugman (1991), NEG literature
	5. Production planning	X	D	
	6. Import and export	X	A	
Sourcing	7. Supplier choice 8. Material handling	X	A, D	Harker and Friesz (1985), Ivanova (2014), Pourabdollahi et al. (2016)
Distribution structures	9. Network design 10.Location selection DC's	X	A, D	Friedrich et al. (2010,2014), Tavasszy et al. (1998), Jin et al. (2005), Davydenko and Tavasszy (2013),
	11.Reverse logistics	X	A, D	Halim et al. (2016), Venkatadri at al. (2016)
Inventory, Warehousing, Packaging	12.Inventory volume 13.Warehousing and storage 14.Packaging			
Transportation	15.Carrier selection	X	A, D	de Jong (2007), Combes (2012), Liedtke (2009), Windisch et al. (2010), Pourabdollahi et al. (2013), Abate and de Jong (2014), Piendl et al. (2016), Combes and Tavasszy (2016), Venkatadri at al. (2016), Mommens et al. (2017), de Jong (2014), Holguin-Veras et al. (2009, 2013), Boerkamps et al. (2000), Hunt and Stefan (2007), Zhang et al. (2015), Yamada and Febri (2015), Limbourgh and Jourquin (2009), Tongzon (2009), Tavasszy et al.(2011), Zondag et al. (2010), Shibasaki et al. (2015), Moeckel and Donelly (2016), Marcucci and Gatta (2017), Sánchez-Díaz et al. (2015), You et al. (2016)
	16.Mode choice	X	A, D	
	17.Vehicle type choice	X	A, D	
	18.Routing & Scheduling	X	A, D	

* Topics covered by the literature are marked; ** D = Disaggregate, A = Aggregate

Actual freight decision making behavior has mostly been studied for the topic of transport choices. Interactions between mode choice and the decision on shipment size, or transshipment location were included in some studies, albeit without considering intermediate inventories through warehouses. Due to availability of trip pattern data there is also new research available on more advanced routing and scheduling choices. The choice of production location, including the effect of interfirm client-supplier relations has also been studied from a descriptive perspective. Relatively new topics in the literature include the decisions on distribution structures (direct, one echelon, two echelon structures), on ports of call in maritime transportation and on vehicle type. Here, decision makers are not clearly recognized yet, however; the choices studied are composite choices of different decision makers or even of different firms.

Other choice problems than directly transport related ones, mainly in the functional areas of (1) Inventory, warehousing and packaging as well as (2) sales and (3) sourcing, are unexplored or only show single examples of preliminary investigations in descriptive models. How firms actually choose suppliers, how they design their products or services within a context relevant for freight transportation, is still largely unknown. The objective function is, without exception, focused on the minimization of costs. Service requirements are not taken into consideration explicitly in the optimization of logistic choices but only as implicit boundary condition or as unknown parameters that are estimated.

Most empirical studies with a more practical scope are characterized by a combination of choice models, often even with different levels of aggregation. Integration of choices within one framework is a challenge and more often than not neglected. Some recent efforts in descriptive models show a trend towards disaggregated agent-based models that allow more advanced simulation of logistic choice behavior and include multiple choices made by individual agents. Recent efforts in agent based microsimulation specifically addressed market interactions: see e.g. Liedtke (2009) and Marcucci et al. (2017). However, even this recent research into complex logistic choices amongst different stakeholders is not transparent about the assumptions made about decision making processes. We can find very few references to the actual decision maker and the decision-making context. Without much argumentation, most researchers assume that people interviewed have a fair understanding of this process within the firm or the decisions that would be made in different scenarios.

A descriptive model for freight transport decision making should be as comprehensive as possible, but the formulation of a complete framework is a challenging task. The presented framework of logistic choices in SCM literature can be used to define the scope of a model: which decisions are included, and which decisions are conditional to the simulation model?

Based on these two general conclusions, we arrive at the following challenges for descriptive models for freight transport decision making:

- Improve models of logistic choice behavior by presenting agent detail, and by addressing the variation in decision makers. This calls for agent based models where individual attributes of relevant agents are part of the descriptive choice models. New model structures such as latent class models can be useful to better describe heterogeneity in agent behavior.
- Given the interdependencies up- or downstream of the supply chain, an important challenge lies in designing a framework that represents all relevant choices and effectively simulates the dynamics between them. We argue that the solution lies in defining a multi-layered or multi-market simulation framework representing logistic choices by different types of agents. This design will most likely comprise of a linked series of iterative (discrete) choice models, and probably with different levels of aggregation in the different functional areas.
- To build descriptive models for all logistical choices, data availability is an important prerequisite. New methodologies of data collection or new experimental setups, such as serious gaming or experimental economics, may provide data to build behavioral models.
- In data collection, of crucial importance are data at individual shipment size, and meeting sample size requirements to address the heterogeneous logistic decision making that is to be incorporated in descriptive models. Most available data is often limited in spheres of decision making and only includes information on one or two logistic decisions, such as mode and vehicle type choice. Data to analyze vehicle type, shipment size, distribution structures simultaneously are a crucial element.
- Eventually, descriptive models for freight transport are meant to support decision making in the public domain. Equally important as understanding where freight flows originate, is the understanding of policy questions. Further research could aim at developing roadmaps that prioritize areas of research depending on the needs to answer specific policy questions.

Research questions that follow from the above include:

- Which choice models are needed to empirically describe a large variety of individual decisions in supply chains, allowing to arrive at prediction of freight flows at the scale of a larger freight system (a network, a region or a country)?
- What categorization of decisions and agents is needed so that all relevant choices are represented in a freight system model? What categorization is feasible given the available resources (time, data)?
- How do we create the data necessary to feed the specification, estimation and validation of descriptive, behavioral logistics models at the individual level and at the aggregate level?
- From all the possible logistics choices that can be modelled, which ones are the most relevant for question typically occurring at the scale of a larger freight system?

These questions could form the cornerstones of a research program that bridges micro-level normative and macro-level descriptive and predictive freight modelling.

5. Conclusion

This paper describes a framework for logistic choice behavior from the supply chain management literature in a framework, across different functional areas and including the interdependencies between decisions. The empirical literature of descriptive freight transport models is compared to this framework, revealing and structuring research challenges in the field of descriptive freight transport models.

The presented framework for logistic supply chain decisions shows the individual decisions that can be identified from supply chain literature. The framework illustrates two important aspects that are relevant for building descriptive models of logistic decisions in freight transport demand: decisions take place in different functional areas with different agents and choice behavior, and secondly strong interdependencies exist between choices that are up- or downstream of the supply chain. Integration of these choices in a simulation framework is crucial in describing logistic choices in SCM.

Our review of the current descriptive freight modelling literature shows that, compared to our framework of logistics decisions, freight models have important caveats when considering their representation of firm level decisions. These relate to the scope of the decisions considered (mostly transport), the scale at which they are considered (decision maker not specified) and the lack of recognition of decision-making process complexity. This leads us to identify a series of empirical questions about the descriptive modelling of logistics decisions - in a way that this can be considered representative for a population of firms within a city, region or country. Answering these questions through research will result in comprehensive freight transport models that recognize the role of logistics decisions in shaping freight flows.

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