On the Demand for Flexible and Responsive Freight Transportation Services

Masoud Khakdaman

Delft University of Technology

On the Demand for Flexible and Responsive Freight Transportation Services

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by

Masoud KHAKDAMAN
Master of Science in Supply Chain Management,
Malaysia Institute for Supply Chain Innovation (MISI), Malaysia
Massachusetts Institute of Technology (MIT), United States of America
Master of Engineering in Industrial Engineering,
Universiti Teknologi Malaysia (UTM), Malaysia
born in Qom, Iran

This dissertation has been approved by the promotors.

Composition of the doctoral committee:

Rector Magnificus	chairperson
Prof.dr.ir. L.A. Tavasszy	Delft University of Technology, promotor
Dr.J. Rezaei	Delft University of Technology, copromotor

Independent members:

Prof.dr.ir. R.R. Negenborn	Delft University of Technology
Prof.dr.ir. R.A. Zuidwijk	Erasmus University Rotterdam
Prof.dr.ir. T. Vanelslander	University of Antwerp
Prof.dr.ir. A. Kinra	University of Bremen
Prof.dr.ir. C.G. Chorus	Delft University of Technology, reserve member

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To my parents
To my wife: Bahareh
To my son: Radmehr

Preface

Learning is a never-ending pleasure in my life. The most beautiful moment in this journey is when something in my head says, 'Ahaaa, now I get it...'. This deep joy is a unique feeling that spurs me on to do deep and holistic research. A well-known example of this is perhaps doing a PhD! A long journey with many uncertainties towards an unclear destination! The only thing that is clear is the excitement of discovering something or solving a problem that at the end of the day makes you feel, "Ahaaa, now I have understood/discovered/solved it...".

Like many others, my PhD journey was uncertain and vague, with many hopes and holes along the way. However, the most important resource to successfully navigate this journey is having supervisors who understand you and have confidence in your abilities. I was very fortunate to have such nice people in my supervisory team. Lori and Jafar, thank you so much! You were always there for me and your kind support and professional mentorship helped me in every way to navigate the uncertainties of the PhD journey. Lori - thank you for giving me the great opportunity to be your student, for believing in my abilities, and for understanding my weaknesses. It has been a great pleasure working with you. Your broad scientific knowledge along with holistic and comprehensive view of the industry and its practical problems were one of the most valuable assets I always wanted in my PhD supervisory team. Apart from the scientific knowledge, I have learnt a lot from your mentorship and leadership style all these years. Jafar - being a student of such a research scholar was a fantastic opportunity for me and has shaped my attitude towards conducting high quality research. Thank you for growing and developing me as an independent researcher. One of the most fruitful things I have learned from you is how to think critically and outside the box and look at problems from different perspectives.

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1 Introduction

1.1 Background

Freight transportation as one of the major drivers of global economic development has been developed and improved via several innovations during the last decades. Globalization dynamics, freight network integration, mass-individualized logistics services, digitalization and advanced transportation technologies (see, for instance, Tavasszy, 2020, for an elaborated description) are among major recent logistics' innovations transforming both demand and supply of freight transportation services offered by logistics service providers (LSPs) to their customers, i.e., shipper firms. Changes in the LSPs[1] service deployment will ultimately transform characteristics of LSPs' logistics service packages. This results in emerging new service features that not only influence business operations of the customer firms directly or indirectly, but also change shipper firms' expectations in the long run. This ultimately transforms LSPs' business strategy from a supply-based to a demand-driven approach (Black and Halatsis, 2001).

Many scholars and practitioners are involved in developing innovations to achieve effective and efficient global integrated logistics and transportation operations. As a fundamental principle in supply chains, a long-lasting competitive advantage comes from a deep understanding of customers' needs in the first step and addressing/shaping their needs afterwards (Müller, 1991; Chopra and Meindl, 2007). While forecasting customers' demand for an existing product is often inaccurate, forecasting the demand for a new product is even more difficult as it involves high uncertainty. Forecasting the demand for a new service is rather complicated since a service generally have a wider range of variables (Latham, 2021). Lots of market failures in newly introduced product/services are due to lack of a deep and holistic understanding of customers' demand (Bayus, 2008).

[1] Throughout this thesis whenever we use a Logistics Service Provider (LSP) we mean a company that offers an array of logistics services including transportation, warehousing, forwarding, custom brokerage, cross-docking, return management, distribution of goods and logistics management services. In real-word, it could include 3rd/4th Party Logistics (3PL/4PL), and Integrate Logistics Provider (ILP) (Bagchi and Virum, 1996; Sheffi, 2013).

Similar to other innovations, transportation innovations challenge conventional standards in the business environment, influence customers' requirements and shape new demand patterns in the long run. This includes the creation of new service attributes and components. The investigation of the impacts of future technological and institutional innovations requires a deep understanding of future demand. For example, we can take into account ongoing innovations influencing freight transportation such as digitalization (e.g., smart logistics, Blockchain technology), synchromodality, and Physical Internet (PWC, 2019). From a service package design perspective, these innovations can incorporate new service features not only in the core transportation operations, but also in the ancillary services.

To illustrate how these transportation innovations can create new service features, we consider the case of synchromodal transportation, which is the youngest member of a family of transportation systems (such as multimodality, intermodality and combined transportation (see, a comprehensive review by Reis, 2015) designed to improve overall efficiency of the transportation system through combining several modes of transportation. Synchromodal transportation has two distinguishing features of flexible (adaptive) mode choice and decision-making based on real-time information, where LSPs have the flexibility to make real-time decisions about switching between transportation modes and routes, in response to the demand variations and resource/network availabilities (e.g., congestions, transit times, delays, pricing - see more details from Van Riessen et al., 2015, and Behdani et al., 2016). A successful implementation in a large-scale network requires shippers to move away from a transportation mode choice approach towards a transportation service choice approach, where almost no awareness could be provided by LSPs to shippers before transportation execution. Thus, an operational feature of synchromodal service is transferring the mode choice decision from shippers to LSPs. Another service feature is flexibility of transportation services which allows shippers to change service components based on their business circumstances. The combination of synchromodal transportation with other innovations such as digitalization could create new value-adding service features. These service features are ancillary services that go beyond the main transportation service, such as customs-oriented services, container tracking, storage and handling, and stripping and packaging (Roso et al. 2009).

The subject of freight demand has been investigated from the 1970s (Baumol and Vinod, 1970), mostly in the context of transportation mode choice studies. Most of these studies take into account a specific modal choice where rail, road, water, air or a combination of them as co-modal, multimodal and intermodal are being investigated through various forms of choice modeling (see, for instance, Tavasszy and de Jong, 2013; Ben-Akiva et al., 2013; Reis, 2014). The second strand of studies consider abstract mode choice where the mode of transportation is not specific, and only service attributes demonstrate the transportation service (see, for instance, Quandt and Baumol, 1992). In both research streams, service features such as transportation safety and security, service frequency, transportation cost, transit time, service reliability and service flexibility are considered as the common components of a logistics service (Reis 2014). Almost all studies in this area have considered transportation cost, time and reliability to be the three core attributes of a logistics service (Reis 2014), while transportation service flexibility and value-added services, among all, are largely ignored in the existing literature.

In sum, recent innovations in freight transportation services are offering shippers new choices when choosing services, in dimensions like flexibility, value-added services and delegated modal control. Flexibility allows the shipper to change the service specification after the first agreement, until the final fulfilment of the service. Value-added or ancillary services related to non-transportation aspects such as cleaning containers. Mode choice is a separate subject as it has traditionally been the shipper's decision. Much like Vendor Managed Inventory (VMI) does with the inventory replenishment decision (Marquès et al., 2010), delegated modal control involves moving mode choice into the suppliers realm and thereby from the tactical (planning) to the operational (execution) spheres. Together, these and other new service offerings claim big advantages for shippers. The research starts with the problem that no one has yet tried to measure these advantages. This lack of knowledge makes it difficult for LSPs to compose multi-dimensional service packages and to set prices in the market. Fulfilling this practical need requires a major research effort, to formulate and empirically model the demand for these services. We aim to address this research gap in this thesis.

1.2 Research objective and questions

The main objective of this research is:
To measure the influence of innovative, logistics-related service attributes on the demand for innovative freight transportation services.
To achieve this objective, four sets of research questions are formulated as follows.
First set of research questions:

- *What new service attributes drive the choice of shipper firms for innovative freight transportation services?*
- *What factors in the shipper firms' business context drive their choice for innovative freight transportation services?*

These research questions aim to explore some of the main drivers of shippers' demand for modern freight transportation services. We elaborate on the need for demand information and clarify the importance of having a service choice approach to freight transportation rather than the conventional mode choice approach. We investigate the importance of three key service attributes that are growing in importance, i.e., operational control of transport mode, service flexibility and ancillary value-added services. We express the important role of contextual factors on the choice of service, including supply chain strategy, demand volatility, and internal flexibility.
To achieve the objective of research and relevant to the first set of research questions, we introduce the 2nd, 3rd and 4th set of research questions to examine shippers' attitudes with regards to the new service attributes and contextual factors of freight demand in three consecutive studies as follow.
Second set of research questions:

- *Under which circumstances and to what extent are shippers willing to delegate mode and route selection decisions to the LSPs?*

With this research question we investigate the willingness among shippers to delegate their mode choice authority to the LSPs. We consider the global shippers' agreement/permission to fully delegate modal control authority to LSPs as an emerging paradigm in transportation and logistics. We validate this paradigm in the context of synchromodal transportation, since decisions regarding transportation mode/route selection are made by LSPs in real-time. Taking existing research on the transportation demand into account, mode choice studies are largely based on the current paradigm wherein shippers predominantly select the transportation mode. However, their preferences and heterogeneity in relation to the new emerging paradigm in synchromodal transportation, and their attitude about a service choice approach have not yet been examined.
Third set of research questions:

- *How strong is the willingness of shipper firms towards using LSP-driven flexible logistics services?*
- *How different is the choice of shippers for LSP-driven flexible logistics services when they operate within a volatile demand and a stable demand business setting?*

- *Which shippers' internal supply chain flexibilities mediate the effect of demand-volatile market setting on their choice of LSP-driven flexible logistics services?*

These research questions are designed to examine the willingness of shipper supply chains to utilize flexible logistics services. Knowing more about the relevant shippers' characteristics e.g., shipper firms' market environment such as demand volatility, would help LSPs to understand the extent their customers seek a flexible logistics service to address uncertainties in their competitive markets. Understanding the shipper firms' business settings, e.g., levels of uncertainty, risk and vulnerability they face in their (everyday) decision-making for the end-to-end supply chain, as well as internal capabilities e.g., internal supply chain flexibilities such as volume flexibility, help LSPs design tailor-made service packages that better address their customers' needs. We explore the impact of shipper firms' market environment such as demand volatility, as well as internal supply chain flexibilities such as volume, product, launch, sourcing and postponement flexibilities on the shippers' choice of flexible transportation services. Although successful cases of the application of LSP-driven flexible logistics services exist in practice, willingness of shipper firms to address their operational challenges using capabilities of the LSP-driven flexible services remained as one of the underexplored areas in the logistics and transportation service choice literature.

Fourth set of research questions:

- *How strong is the alignment between transportation strategy and supply chain strategy in global supply chains?*
- *How should firms align their transportation strategy to their supply chain strategy?*

These research questions are introduced to investigate the impact of an important contextual factor of freight demand, i.e., supply chain strategy of shipper firms, on the attributes of innovative freight transportation services that represent a shipper's transportation strategy. One of the key success factors for shipper firms is how their transportation strategy is aligned with their corporate supply chain strategy. It is not clear in the existing literature which transportation strategies should be developed by different industries to make an alignment between transportation strategy and supply chain strategy.

1.3 Research methodology

To address the research questions, we applied the following research methodologies.

To address *the first set of research questions*, we developed a comprehensive questionnaire using relevant research articles in the literature for identifying major drivers of demand. We applied this questionnaire to conduct a comprehensive study among Global Fortune 500 companies, aimed at understanding what drives the demand for modern transportation services.

The main approach to address *the second and the third sets of research questions* is discrete choice modelling (Ben-Akiva and Lerman, 1985). The choice behavior of shippers are described by estimating choice models based on the random utility maximization (RUM) theory which is introduced by McFadden (1974). The RUM theory is based on the assumption that an individual always selects the alternative with the highest utility. The utility is composed of two components: a systematic, observable utility and an error term representing unobserved factors by the analyst in the choices of the individual. For every alternative, the systematic utility contains important attributes that are likely to play a role in individual's decision making: in the case of transportation services, attributes such as transportation cost, transit time and service reliability are common examples. The systematic utility is usually formulated using a linear combination of the attribute values. Based on the assumptions about the distribution of the error term, different choice probability formulations can be obtained, representing different families of models, including multinomial logit, nested logit, mixed logit and probit (see more details in Train, 2009).

To answer *the research question in the second set*, we first estimate a multinomial logit model to identify the preferences of shippers regarding the main attributes of the synchromodal transportation services, such as cost, transit time, reliability (punctuality), modal control, flexibility (changeability, adaptability) and value-added services. Next, latent class modelling (Kamakura and Russell, 1989) is used to capture the non-observable heterogeneity of the shippers' preferences within each class. The model estimations are based on stated preference (SP) data from our survey among global shippers.

In order to tackle the *third set of research questions*, we conduct an econometric approach which includes three stages. We first estimate a multinomial logit model to identify the shippers' preferences to use transportation flexibility in logistics services. Second, we estimate an interaction effects model to identify the impact of shippers' demand volatility on their choice of flexible transportation services. Third, we estimate a mediation model (Preacher et al., 2007) to investigate if the effect of shipper's demand volatility on their perception of flexible logistics service is mediated by the shipper's internal supply chain flexibilities, e.g., volume flexibility. Finally, we estimate a latent class model to capture unobserved heterogeneity and the potential impact of mediators.

Regarding *the fourth set of research questions*, we first combine the main attributes of a transportation service, as representative of firms' transportation strategy. Second, we apply Lee's framework (Lee, 2002) to categorize firms based on different product types, demand and supply uncertainties, and supply chain strategies. Third, we assess the alignment of transportation strategy and supply chain strategy of international supply chains using a structured multi-criteria decision-making (MCDM) method called Best-Worst Method (BWM) (Rezaei, 2015). In general, MCDM methods are used to evaluate a set of alternatives with respect to a set of decision criteria. The BWM is based on a systematic pairwise comparison of the decision criteria. BWM offers a structured way to make the comparisons by choosing the best and the worst decision criterion, comparing them with the remaining criteria, and finding the weights of the criteria using a mathematical optimization model. Rezaei (2020) illustrates several salient features of BWM including data (and time)-efficiency and allowing for checking the consistency of the provided pairwise comparisons. We finally demonstrate which transportation strategies should be applied to achieve better fit with supply chain strategy in various industries.

All the model estimations are based on stated preference (SP) data from our survey among Global Fortune 500 companies (Fortune magazine, 2017) and major customer firms of the 40 largest global LSPs (Logistics Quarterly magazine, 2011), including all different industries and commodity types that account for the majority of global transportation volume and value.

1.4 Thesis relevance

The scientific contributions of this thesis are as follows:

First, this thesis addresses the paradigm shift in logistics and transportation service choice, concerning shippers' willingness to delegate the authority to decide the mode of transportation to the LSPs. A new choice modelling attribute, called *modal control*, is introduced. The approach empirically validates one of the fundamental assumptions of implementing synchromodality in practice.

Second, we identify shipper firms' needs for LSP-driven logistics service flexibility, offering a comprehensive definition of flexible services covering both transportation and inventory management. Flexibility is operationalized in this broader context and incorporated into a comprehensive discrete choice study. Our definition, which extends the definitions by Swafford et al. (2006) and Ben-Akiva et al. (2008), has not yet been applied in any mode choice study. Although successful cases of the application of LSP-driven flexible logistics services exist (for example, DB Schenker (2019) for the retail/apparel industry and DSV (2019) for automotive industry), the willingness among shipper firms to use LSP-driven flexible services remains an underexplored area.

Third, we examine shippers' willingness to use value-added services, above and beyond the primary transportation service. Although value-added services have been applied in logistics and transportation since the 1980s (Pettit and Beresford, 2009), so far, no transportation service choice study has incorporated them as a service attribute into a choice experiment.

Fourth, we assess the impact of contextual factors of demand, i.e., shippers' end-consumer demand volatility and internal flexibility capabilities on the shippers' choice of flexible logistics services. A true understanding of shipper firms' business settings, e.g., levels of uncertainty, risk and vulnerability they face in their (everyday) decision-making for the end-to-end supply chain, as well as internal capabilities e.g., internal supply chain flexibilities such as volume flexibility, would help LSPs design customized service packages that truly address their customers' needs. This thesis is among the first to explore the impact of contextual factors of demand on the shippers' choice of flexible transportation services.

Fifth, we assess the alignment between transportation strategy and supply chain strategy for global supply chains considering different contextual factors such as industry characteristics, commodity types, shipment sizes and product types. This highlights the importance of transportation strategy and supply chain strategy alignment for improving overall supply chain performance. We define transportation strategy in conjunction with different transportation service attributes and demonstrate which transportation strategies should be applied to achieve better fit with supply chain strategy in various industries.

Finally, this thesis adopts an international perspective to depict preferences, taste heterogeneity and segmentation of leading shippers. While earlier studies are limited in their geographical diversity, operational complexity and sample size, we focus on a large, global sample of international supply chain leaders. We found no studies that reflect on the demand-related characteristics of global shippers in connection to recent innovations in transportation and logistics, including synchromodal transportation.

In sum, in this thesis we measure the demand for innovative freight transportation services by investigating how shippers demand characteristics, i.e., modal control delegation, transportation flexibility and value-adding services, and the contextual factors of demand, i.e., shippers' internal flexibility capabilities, end-consumer demand volatility and underlying supply chain strategies, impact the choice of innovative logistics services. We show the importance of moving from mode choice to *service* choice approach to pave the way for adopting various new innovations in freight transportation. We also evaluate the alignment of transportation strategy and supply chain strategy in global supply chains and recommend fitting strategies for improving overall supply chain performance.

This thesis derives valuable insights for practitioners in industry and policymakers in governmental roles. Practitioners in LSP firms can use the results of this thesis to renovate their service package design in order to offer innovative transportation services to their shipper customers. This would need updating their supply and capacity planning as well as revenue management system. For shipper firms, the insights from this thesis could help realizing the added value brought by innovative transportation services to improve their supply chain operations and overall business competitiveness. For public policymakers, the insights drawn from this thesis can be applied as input for long-term decisions about improving integration and sustainability of the global logistics network.

1.5 Outline of the thesis

Figure 1 shows an overview of the thesis, that is based on journal articles that are published or are under review at the time of writing the thesis. Thus, chapters 2 to 5 are identical to the published work. The author of this thesis has been in the lead for the research and is also lead author of the journal articles. The thesis first starts with introducing the concept of service choice approach in freight transportation and identifying some of the main drivers of shippers' demand for innovative freight transportation services (Chapter 2). We then investigate shippers' preferences for new service attributes and contextual factors of freight demand in three consecutive studies (Chapters 3, 4 and 5). We do this by conducting a comprehensive study among major global firms in the context of synchromodal transportation as a real-world freight transportation system that simultaneously enables both demand-driven business strategy for LSPs and abstract mode choice for shippers (Tavasszy et al. 2018). Chapter 3 and Chapter 4 (partially) are mainly introducing three new service attributes called modal control, flexibility and value-added services and measure their impacts on the shippers' choice. The rest of Chapter 4 and Chapter 5 investigate the impacts of three major contextual factors of demand called demand volatility, internal flexibility and supply chain strategy. The last chapter closes the thesis with conclusions and recommendations for research, practice and policymaking.

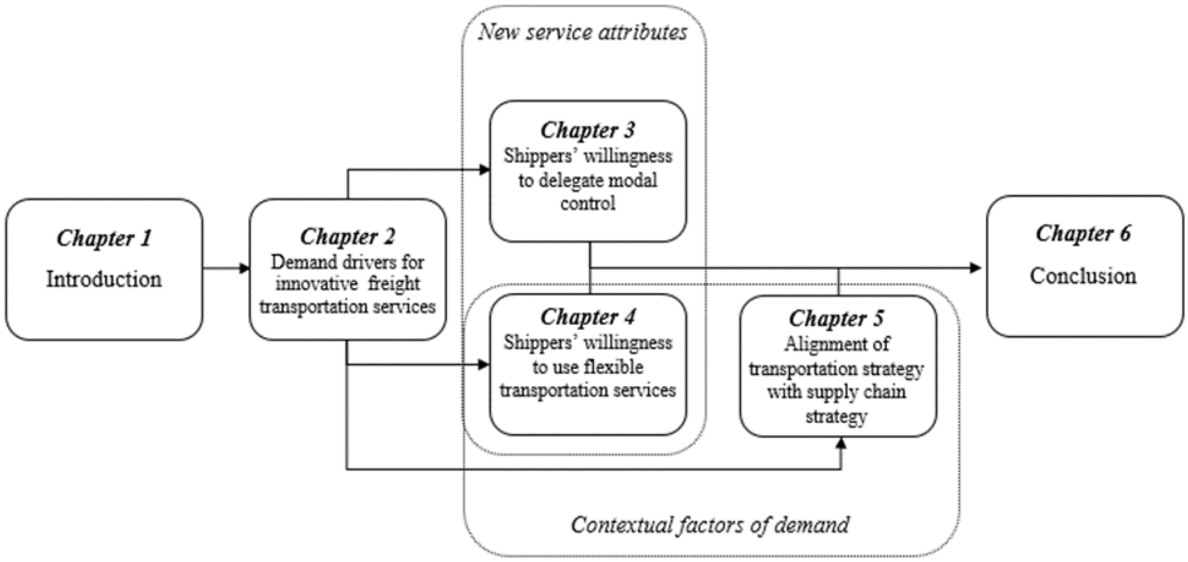

Figure 1. Organization of the dissertation.

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2 On the drivers of demand for innovative freight transportation services

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Abstract

Contemporary innovations in freight transportation and logistics are instrumental to achieve more integrated, efficient and sustainable services in the global market. While much attention is going to how these innovations change the future technology and organization of the supply of services, little work is done on depicting their changing relationship with freight transportation demand. We present findings from a comprehensive study among Global Fortune 500 companies, aimed at understanding what drives the demand for modern transportation services. We investigate the importance of three key service attributes that are growing in importance, i.e., operational control of transport mode, service flexibility and ancillary value-added services. We measure the influence of contextual factors on the choice of service, including supply chain strategy, demand volatility, internal flexibility and industry type. This leads to recommendations for shippers on how they can adjust their supply chains in the future to benefit from new freight services. Our findings also stress the need for the logistics industry to adopt modern service choice approaches.

2.1 Introduction

Many logistics innovations aim to reduce the fragmentation of the landscape of services and improve integrity of worldwide logistics. If services within the supply chain can co-operate and connect better, costs can be reduced through economies of scale, and door-to-door services can be improved. To this end, many technological and organizational developments in logistics and transportation are ongoing (i.e., smart logistics, digital transformation, synchromodality, Physical Internet, Blockchain technology and so on (Pwc, 2019), and outstanding success stories about well-performed collaborations and partnerships between global logistics service providers (LSPs)[1] and international shipper firms are reported (e.g., DSV and Volvo, 2019; UPS and Marken, 2019; DB Schenker and retail/fashion industry, 2019). In order to implement the logistics integration worldwide, LSPs are considered as the central players since more than 70% of companies in the USA, Western Europe and Asia Pacific have outsourced their transportation and logistics functions to the LSPs (Hsiao et al. 2010; Capgemini 2014). For LSPs to implement worldwide integration in logistics, they need to match (and synchronize) their supply of freight services with shippers' demand (ALICE, 2017). To this end, LSPs need a good understanding of dynamics and contextual factors of global freight demand to be able to provide better freight services that create demand-supply integration (Khakdaman et al., 2020). This requires LSPs to adapt their business strategies toward a more demand-driven rather than supply-based logistics system (Black and Halatsis 2001).

Moving to a demand-driven logistics system necessitates a deep understanding of freight demand by three main stakeholders of global logistics system, i.e., customers of freight transportation (shipper companies such as BMW and Zara), suppliers of freight transportation (LSPs such as UPS and DSV) and the system-level agents that these customers and suppliers are operating within it (government, or industry organizations). Regarding shippers, they need to understand how their transportation strategy impacts logistics services that they receive from LSPs. Transportation as the connector of nodes in the shippers' supply chain network plays a fundamental role in delivering right goods to right consumers at the right time. Thus, requesting proper logistics services from LSPs directly impacts their success in satisfying customers and business goals. When it comes to LSPs, having a deep understanding of their customers' needs and desires directly impacts their service package design, supply and capacity planning and overall revenue generation, in particular, for highly competitive markets. LSPs need to understand different market segments and future dynamics in these markets to be able to make right strategic decisions for future developments that match their supply of services with future demand (Khakdaman et al, 2020). Finally, regarding global logistics, LSPs have a central role to make a synchronized demand-supply integration worldwide, i.e., via collaboration with their shippers as well as other LSPs, to help achieving global sustainability goals for logistics.

The subject of freight demand has been investigated from the 1970s, mostly in the context of transportation mode choice studies. Much research has been conducted on relative pricing of different modes and how to improve service levels in various business contexts (De Jong, 2014) A recent review by Reis (2014) identified transportation safety and security, service frequency, transportation cost, transit time, service reliability and service flexibility as the common components of a logistics service that influence modal choice decisions of shipper supply chains. Future demand models need to be adapted in several directions to allow to assess the impacts of logistics innovations on freight transport flows (Tavasszy, 2020). In particular, we need to move from mode choice to service choice in freight transportation. Various new innovations in freight transportation require us to adopt such a service choice approach. For example, in Europe, synchromodal transportation[2] was introduced by the industry as a service concept, to move away from a modal focus in service selection to a focus on service attributes i.e., lead time, service cost, service reliability, service flexibility and so on, by using a pool of

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[1] Throughout this paper whenever we use a Logistics Service Provider (LSP) we mean a company that offers an array of logistics services including transportation, warehousing, forwarding, custom brokerage, cross-docking, return management, distribution of goods and logistics management services. In real-word, it could include 3rd/4th Party Logistics (3PL/4PL), and Integrate Logistics Provider (ILP).

[2] Synchromodal transportation can be explained as 'synchronized intermodality' which has added two distinguishing features to intermodal transportation: flexible (adaptive) mode choice and decision-making based on real-time information (see further details in Khakdaman et al (2020) and Tavasszy (2020)).

all different transportation modes, switching between them in real time, and making real-time resource allocation to different demand orders (Khakdaman et al, 2020).
As a result of the above, also the role of new service attributes such as modal control delegation, transportation flexibility and value-adding services in service choice of shippers is becoming apparent. In the literature, however, discussion of these topics has been rare. In addition, the impacts of contextual factors of demand such as shippers' internal flexibility capabilities, end-consumer demand volatility and underlying supply chain strategies needed revisiting to understand the ability of shippers to respond to these service attributes in their service choices. In this article, we investigate how shippers demand characteristics and the contextual factors of demand impact the choice of modern logistics services. We define the concept of service choice approach in section 2. Section 3 presents our findings from a comprehensive study about shipper preferences. In section 4 we discuss how a better understanding of freight demand can impact operations in LSPs and shippers' organization and conclude the paper.

2.2 The service choice approach to freight transportation demand

Shippers determine many, if not all aspects of a transportation service, when they place a transportation order to the LSPs (Tongzon, 2009). Figure 1 shows demand and supply interaction in a typical freight transportation system, where shippers place transportation service orders based on their preferences and business requirements. At the supply side, LSPs design and deliver transportation service packages based on their customers' preferences. The price of service packages is determined via the LSP's pricing and revenue management system[3] which closely connects with their supply and capacity planning system. In order to deliver the transportation service, LSPs need to supply different resources, i.e., transportation modes, from resource providers or from their own resources.

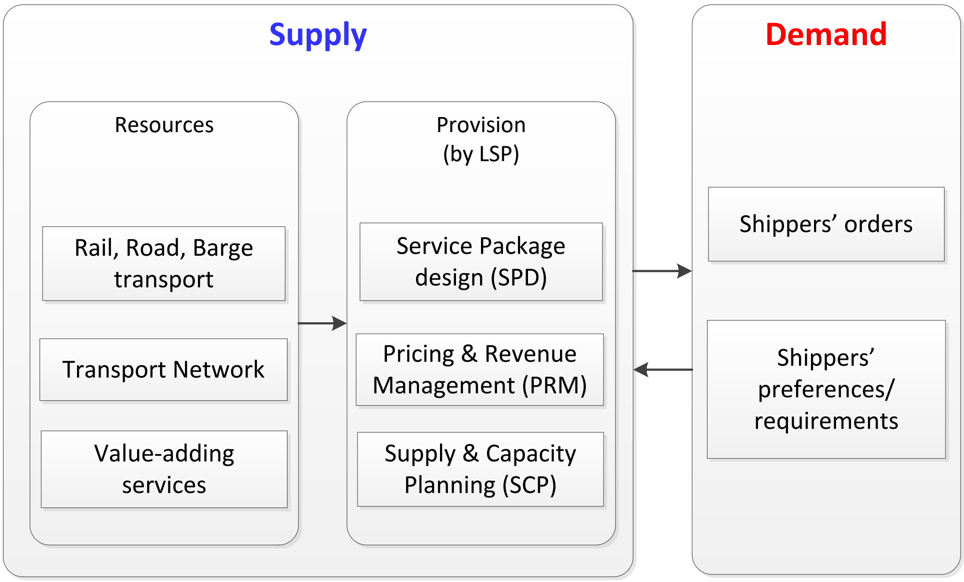

Figure 1. Typical freight transportation system.

When looking at freight demand from a service choice perspective, one explicitly recognizes the components or dimensions of a service. These components can be bundled in many different combinations to enable LSPs offer a spectrum of services from simple and conventional transportation services (i.e., a low-cost service) up to highly customized service packages to the

[3] Revenue Management (RM) is the study of disciplined tactics for making product/service availability and pricing decisions, aiming at maximizing revenue growth (Cross, 2011).

shippers to account for heterogeneity and variety in shippers' preferences and demand. From a service choice perspective, service components of a freight transportation service typically include:

- An origin and destination location such as warehouse, terminal or a city
- One or more transportation mode(s) such as rail, road, waterway and air
- Transportation routes
- Service lead times
- Total price
- Service reliability i.e., on-time delivery of the goods
- Service flexibility i.e., adaptability of service to changes in the order
- Service frequency or availability
- Commodity type(s)
- Required value-adding service(s) e.g., tracking, packaging and customs
- Order time or demand generation time such as normal or peak period
- Shipment quantity i.e., number of containers
- Shipper/client relation such as loyalty customer or need-based customer

A solid understanding of shippers' demand characteristics is needed by LSPs to make effective decisions for their supply and capacity planning (Klassen and Rohleder, 2002), service package design (Frei, 2008) and pricing and revenue management system (Cross, 2011). Table 1 illustrates different types of activities, decisions and processes in the business processes that need understanding of shippers' demand.

Table1. The need for demand information in different activities of LSPs

Purpose of using demand information	***Service package design***	***Supply & capacity planning***	***Pricing & revenue management***
Strategic decisions (A few years)	* Understanding customer's preferences in long-term * Designing special service packages for loyalty customers * Designing regular services for need-based customers * Determining level of service attribute based on the overall market share	*Estimating required capacity and associated infrastructures (Volume, TEU, Tonne)	* How much revenue generation is required in the long-term financial plans of the company * Long-term pricing strategies with regards to long-term demand forecasts * Potential revenue growth regarding long-term shifts in demand
Tactical decisions (Annually)	* Designing flexible service packages capable of fulfilling demand fluctuations	* Which services to purchase and how much capacity *Which services to hire and how much capacity * Static capacity allocation or dynamic	*Capturing revenue opportunities based on resource utilization rates * Dynamic pricing of the services based on the dynamic demand forecasts
Operational decisions (Daily, Weekly, Monthly)	* Adjusting and rearranging services based on customer's requests	* Required daily capacity of each service * Efficient operations scheduling	* Incorporating micro demand fluctuations in regular demand forecast

After demonstrating the service choice approach and the need for demand information in different activities of LSPs, in the next section we present findings of our survey about service requirements of global shipper firms.

2.3 Service requirements of shippers: survey results

In order to understand how new service attributes and different contextual factors impact the service choices of shippers, we conducted a comprehensive study among 556 firms, sampled from the lists of (1) Global Fortune 500 companies (Fortune magazine, 2017) and (2) major customer firms of the 40 largest global LSPs (Logistics Quarterly magazine, 2011). Together these represent many different industries and account for the majority of global transportation volume and value. The subject of the survey was a service choice study to identify demand preferences of shippers choosing a transportation service. We used a discrete choice experiment (based on discrete choice theory) and a multi-criteria decision-making questionnaire (based on the Best-Worst Method, see Rezaei, 2015). In total, we approached 2752 c-level and senior managers in the supply chain, transportation, logistics and distribution functions (e.g., director of logistics, vice-president of supply chain) via a web-based survey. Altogether, 296 professionals from 194 unique firms responded to our survey, which resulted in the largest survey sample on this topic to date. For a detailed account of the study, we refer the reader to Khakdaman et al (2020). We summarize the findings below.

2.3.1 New service attributes and their impact on shippers′ service choice

While transportation cost, time and reliability are conventional service attributes used in almost all mode choice studies, we introduced three new attributes that are necessary for developing tailor-made services packages based on the service choice approach: modal control, flexibility and value-added services. Modal control reflects the authority level of a shipper to decide its preferred transportation mode. While most shippers (about 80% in our study) determine the transportation mode for LSPs as part of their service request, the delegation of modal control authority to the LSPs provides significant additional freedom for LSPs to improve their performance, through real-time switching between different modes of transportation based on network circumstances. Modal control delegation is a fundamental prerequisite for future innovations in freight logistics in order to achieve an efficient and integrated logistics network (a.k.a. Physical Internet; see Montreuil, 2011). Our findings illustrate the strong connection between modal control and service choice: we find that over two-thirds of shippers may be willing to relinquish control over transportation modes and routes, if they are rewarded by better services or lower costs. Flexibility is defined as the ability of a transportation service to satisfy requests for change in service components during booking and execution of the transportation service. This may involve delivery time/location, shortening or extending lead times, and consolidating or deconsolidating volume/variety via warehouses or cross-docking terminals (mode-volume switch locations). Compared to earlier research, en-route flexibility in such an investigation is a new component. The third new attribute is value-added services, or ancillary services beyond the basic transportation service, which hasn’t received significant attention in relevant literature either.

Based on the research we can identify four different market segments for cost and service level improvements toward the global community of LSPs, freight forwarders and carriers (Figure 2). The horizontal axis indicates whether firms are willing to yield control over the mode of transport, the vertical axis shows the inclination of the firm towards a high performing or low-cost services. The percentages indicate the share of the firms sampled that fall within a category, adding to 100%.

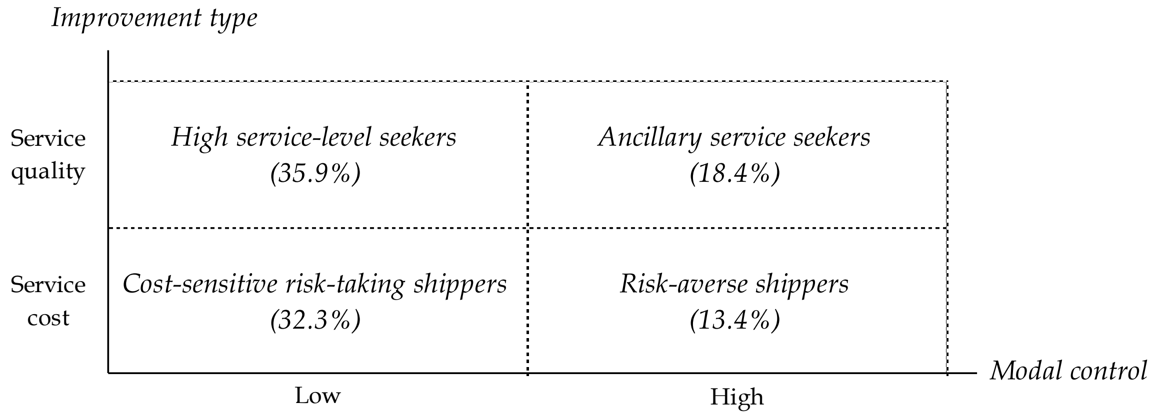

Figure 2. Market segments based on improvement type and modal control (Source: Khakdaman et al., 2020)

Our results show that there is at least one segment in the market willing to consider and pay for each of the three new attributes i.e., high service-level seekers and cost-sensitive risk-taking shippers for Modal control delegation; high service-level seekers for transportation flexibility, and ancillary service seekers for value-added services. High service-level seekers are generally dissatisfied with the current services in the market and have a high willingness to delegate modal control and use synchromodal services, on the condition that LSPs secure fast, flexible and reliable transportation services. High service-level seekers are mostly very large companies with annual revenues above US$ 10 billion. Cost-sensitive risk-taking shippers are mainly willing to relinquish modal control in exchange for cheaper transportation services. These shippers are usually large companies with annual revenue of US$ 1 to 10 billion. The third shipper segment is called ancillary service seekers and is composed of small-to-medium-sized Fortune companies who are usually willing to delegate modal control by shifting towards synchromodal services that include their desired value-added services. Risk-averse shippers group is the fourth shipper segment. Shippers in this segment prefer using their current transportation services and are not willing to take the risk of moving to synchromodal transportation or losing modal control. LSPs can explore targeted improvement opportunities in these four market segments to improve their market share and revenue margins, by designing tailor-made transportation services for their customers.

2.3.2 Contextual factors of demand and their role in shippers' service choice

From the survey it became clear that service preferences are strongly dependent on the business context that shippers operate in. We discuss the influence of 3 important contextual factors: demand volatility, internal flexibility and supply chain strategy.

Demand volatility is the most important type of supply chain uncertainty that significantly challenges supply chain competitiveness (Chung et al., 2004; Pujawan, 2004). The survey clearly showed that shippers in demand-volatile markets choose LSP-driven flexible services as a major service component. On the contrary, shippers operating in stable markets i.e., stable demand, would mainly favor a conventional cost-efficient logistics service for addressing their logistical needs. LSP-driven flexible logistics services are an external flexibility for shipper firms.

We also investigated how this is matched with flexibility that shippers can offer themselves, also known as internal flexibilities. Shippers who prefer a flexible transportation service mostly appear to exhibit high volume flexibility, and to a lesser extent other internal flexibilities i.e., product, launch, sourcing and postponement flexibility[4]. Shippers that operate in volatile markets and exhibit volume flexibility appeared to benefit most from LSP-driven flexible transportation services. This indicates that firms see flexible transportation services as a tool to supplement their own volume flexibility.

Supply chain strategies proved to be another relevant contextual factor. Lee (2002) introduced four types of supply chain strategies concerning demand and supply uncertainties of products, i.e., efficient supply chain strategy for products with low demand and low supply uncertainty, responsive supply chain strategy for products with low supply uncertainty and high demand uncertainty, risk-hedging supply chain strategy for products with high supply uncertainty and low demand uncertainty, and agile supply chain strategy for products with high supply uncertainty and high demand uncertainty. In general, shippers operating with an efficient supply chain strategy would be expected to choose a low-cost transportation service. For risk-hedging, responsive and agile supply chain strategies, a cost-efficient, reliability-oriented and fast-and-flexible transportation would be expected. In our study, we found several counter-intuitive examples, however, which seem to rule out supply chain strategy as a single determinant of transportation choices. For example, companies operating in the healthcare industry mostly seek a reliable, fast and flexible transportation strategy (which is not necessarily cost-efficient) for their efficient supply chain strategy. In another case, firms in the technology and telecommunications industries, with an innovative product, high volume uncertainties and an agile supply chain strategy, appear to apply a cost-efficient transportation strategy. These examples illustrate that the service choice of shippers is differentiated, based on the nature of industry and dynamics of demand, supply and operations. Overall, we find that there is no single type of transportation strategy for each supply chain strategy and a customized transportation strategy, and a tailor-made transportation service based on the shippers' industry nature and supply chain strategy drives their demand for freight services.

2.4 Implications for practice

We expect that a deeper understanding of transportation service requirements will lead LSPs towards designing more fitting transportation service packages. If the business context of a shipper is a very competitive market with much demand fluctuation and many supply disruptions (e.g., the apparel industry), the shipper may have an agile and/or responsive supply chain strategy for its products. LSPs will want to offer a flexible, reliable and fast transportation services to help operationalize this strategy. As a real-world example, Under Armour, a fast-growing sportswear brand worldwide, utilizes the DSV's multi-user warehouses as hubs to respond flexibly to their extraordinary rapid growth and the demand fluctuations in the market (DSV and Under Armor, 2019).

Transportation innovations and capability enhancements may improve total supply chain integration of shipper firms (Stank and Goldsby 2000; Fabbe-Costes et al. 2008). Synchromodal transportation services could support shippers' supply chain integration when LSPs share their resources toward collaborative planning forecasting and replenishment (CPFR) activities (Seifert 2003). LSPs could establish mode-volume switch locations in their synchromodal

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[4] Volume flexibility is the firm's ability to effectively increase or decrease aggregate production in response to customer demand. Product (or mix or product-mix) flexibility is the ability of a firm to handle changes in the product mix and product design relative to customer demand. Launch (or new product development) flexibility is the ability to rapidly introduce many new products and product varieties. Sourcing flexibility is the ability to find another supplier for each specific component or raw material. Postponement flexibility is the capability of keeping products in their generic form as long as possible, in order to incorporate the customer's product requirements in later stages (Martínez Sánchez and Pérez Pérez, 2005) .

transportation network, as shared warehousing hubs capable of aggregating and deconsolidating shippers' goods. Our study indicates that such supply chain solutions would need to be supported by fitting transportation services, where price and modal control matter less than appropriate performance levels in flexibility and ancillary services.

Another major area of logistics innovation is e-commerce and the associated omni-channel service propositions, putting logistics under pressure due to their strong growth and the need for vertical and horizontal integration. According to GEODIS and Accenture (2020), 5 critical capabilities are needed to build and maintain flourishing ecommerce operations: agile distribution networks; transportation flexibility; inventory visibility and order orchestration; customer experience and IT; and software optimization. From a demand perspective, the first 4 capabilities are directly associated with a basic understanding of the demand of shippers and their end consumers. Shippers generally need agile distribution networks to allow flexible delivery and return shipping. Some need transportation flexibility to allow delivery to customers around the world with short lead-times. Main logistics-related capabilities required to improve customer experience of shippers are customers' ability to modify orders, the level of customization of delivery options, tracking facilities and VASs.

In order to improve the efficiency and integration of global logistics via designing and developing innovative transportation services, below we recommend relevant guidelines to managers of shipper firms, LSPs and policymakers.

Guidelines to managers of shipper firms to identify their need for innovative transportation services and request it from LSPs:

- Define transportation strategies relevant to each product category. Consider contextual factors of your supply chains, demand fluctuations and customers' requirements.
- For each transportation strategy, identify main service attributes that should be requested from your LSP.
- Investigate what type of relationship with your LSP (short-term, mid-term or long-term collaboration/partnership) will best address your transportation strategies.
- Review changes in your demand continuously and update your required transportation strategies accordingly.

Guidelines for managers of LSPs for providing innovative transportation services for shippers:

- Design customized service solutions for diverse supply chain strategies and segments of shippers.
- Try to predict what new service attributes might be required and develop your service portfolio accordingly.
- Consider that service robustness and flexibility may be needs not expressed explicitly by shippers.

Guidelines for policymakers in governmental organizations/authorities to pave the way for LSPs for developing innovative transportation services:

- Facilitate volume switch locations to support transportation flexibility and resilience.
- Support regional transportation networks that allow switching between transportation modes.
- Support the uptake of ICT infrastructure required by LSPs and shippers for real-time support to flexible systems.
- Support community roadmaps for the creation of transportation services that align with supply chain needs.

2.5 Conclusion

We presented the concept of a service choice approach in freight transportation and discussed how a better understanding of freight demand characteristics could improve service package design, including subsequent direct benefits for the supply chain. We discussed relevant new transportation service attributes that LSPs and shipper should consider, including modal control delegation, service flexibility and value-added services. We argued the importance of contextual factors of demand such as shippers' supply chain strategy, demand volatility, internal flexibilities and industry nature on their choice of LSPs' services.

A key research direction for the future entails the continued identification and measurement of new service attributes/components, relevant to modern logistics requirements. For transportation, a shift of mind-set from a mode choice approach to a service choice approach allows to make the link to the supply chain context. As the main connector of all the nodes in the supply chain network, transportation can play a key role in success of shipper firms when its potential for addressing shippers' needs is identified by academicians and practitioners. Apart from the attributes and contextual factors discussed in this study, new ones could be identified, based on the nature and dynamics of operations in different industries, and future innovations in freight transportation that are yet to appear in our line of sight.

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3 Shippers' willingness to delegate modal control in freight transportation

Khakdaman, M., Rezaei, J., & Tavasszy, L. A. (2020). Shippers' willingness to delegate modal control in freight transportation. Transportation Research Part E: Logistics and Transportation Review, 141, 102027.
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Abstract
This paper investigates the willingness of shippers to delegate control over the transportation mode in freight transportation, using discrete choice analysis. Data originate from a large survey among global shippers. The results show that, under certain conditions, most shippers are willing to hand over mode selection authority to the service provider. Using latent class analysis, we classify shippers into four market segments, each with a different degree of willingness against different types of performance improvements. Firms can use this characterization of freight transportation demand to design service packages that will meet the demands of global supply chains.

3.1 Introduction

Understanding the preferences and requirements of customers is one of the main keys to the success of any transportation service, especially if their demands vary widely and change over time. Mass customization of goods and services in the global business environment has required logistics service providers (LSPs)[1] to adapt their business strategies toward a more demand-driven rather than supply-based logistics system (Black and Halatsis, 2001). To this end,

[1] Whenever we use the term Logistics service provider (LSP) in this paper, we refer a company that offers an array of logistics services, including transportation, warehousing, forwarding, custom brokerage, cross-docking, return management, distribution of goods and logistics management services. In real-word practice, this could include 3rd/4th Party Logistics (3PL/4PL), Integrate Logistics Providers (ILP) and so on.

Veenstra et al. (2012), and Van Riessen (2016), among others, emphasized the need for an integrated logistics network. However, the reluctance among shippers to delegate control over the transportation mode and route to the LSPs has left limited room for the global logistics system to maximize the efficiency and flexibility of the transportation network operations. Eventually, this has also made effective demand-supply integration a more difficult task for LSPs.

Delegating authority over transportation modes to LSPs is considered to be part of the outsourcing of a shippers' logistics and transportation function. The outsourcing of non-core competencies in manufacturing, logistics, IT and business processes is common practice in many industries (Rao and Young, 1994). For many shipper firms, however, logistics is still mainly remained at the out-tasking level, with transportation-related operations being outsourced to the LSPs, but not the decision-making authorities (Hsiao et al. 2010). In particular, many firms do not outsource decisions regarding the selection of transportation modes to LSPs, since, according to Tongzon (2009), shippers determine every aspect of the freight movement to maintain ultimate control over how goods are transported. As pointed out by Tsai et al. (2012), an important reason for this is the perceived risk of loss of control and visibility once shippers fully outsource the transportation function. However, Zhang and Pel (2016) emphasize that letting LSPs decide provides a mode-free booking flexibility for them, e.g., in the context of synchromodal transportation (see further details in section 2 and studies such as Tavasszy et al. 2010; Verweij, 2011), which could enable LSPs to reduce transportation costs as well as improve service levels. It could also help reduce delivery times and enhance capacity utilization of different transportation modes, resulting in a more robust, reliable and flexible transportation system (Zhang and Pel, 2016). The critical question "under which circumstances and to what extent are global shippers willing to give mode and route selection authority to the LSPs?" has yet to be addressed in the literature.

We consider the global shippers' agreement/permission to fully delegate modal control authority to LSPs as an emerging paradigm in transportation and logistics. We validate this paradigm in the context of synchromodal transportation, since decisions regarding transportation mode/route are made by LSPs in real-time. Unlike synchromodal transportation, mode choice decisions in other freight transportation systems are made predominantly by the shippers and transportation modes are booked in advance by the LSPs i.e., from their own resources or other carriers/LSPs (Coulter et al. 1989; Coyle et al. 2011; Tryfleet, 2017). As such, in a transportation system like synchromodality, with real-time modal decision-making based on the availability of different modes in the transportation network, almost no prior awareness could be provided by LSPs to shippers before transportation execution. This unique characteristic of synchromodality can provide LSPs with a network-wide freedom to fully utilize their authority on mode and route control, in order to maximize the overall efficiency, flexibility and performance of the global transportation system. Obviously, shippers could become aware of applied mode(s)/route(s) for their goods after transportation execution e.g., via the tracking and tracing capabilities offered by LSPs. Figure 1 summarizes current and emerging paradigms in transportation modal choice. In the current paradigm, the shipper is the main party selecting the transportation mode in booking transportation services.

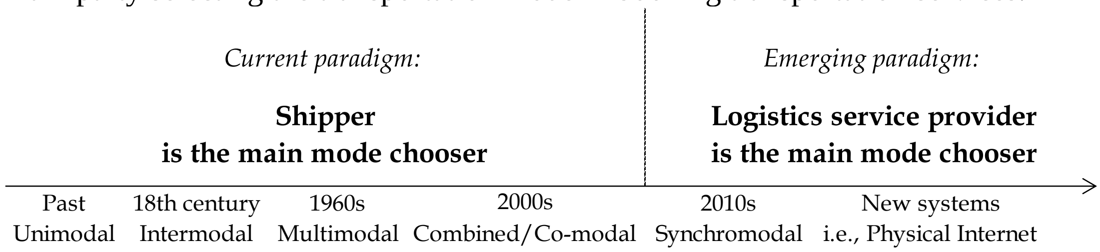

Figure 1. Paradigms in transportation modal choice

To address the question of modal control delegation, this study aims to empirically assess willingness among shippers to delegate their mode choice authority to the LSPs within the framework of evaluating their demand preferences for synchromodal service attributes, using discrete choice modelling (Ben-Akiva and Lerman, 1985). Taking existing research on the transportation demand into account, mode choice studies are largely based on the current paradigm in which shippers predominantly select the transportation mode. However, their preferences and heterogeneity in relation to the new emerging paradigm in synchromodal transportation, and their attitude with regard to a service choice approach have not yet been examined.

Delegation of modal control brings fundamental trade-offs for shippers across their end-to-end supply chains (Eng-Larsson and Kohn, 2012). Dong et al. (2018) emphasized that a broader impact of applying synchromodal transportation on the entire supply chain should be considered. To that end, the supply chain managers of the shipper companies synchronize transportation-related decisions with other decisions within their supply chain, such as inventory management, production and distribution schedules, and service level fulfilments (Dong et al. 2018). This highlights the fact that the supply chain managers of shipper companies will delegate modal control in exchange for being able to make more effective decisions within their supply chain. To consider these trade-offs, we incorporated the following two attributes in the choice experiment: flexibility and value-added services (VAS).

The freedom to choose the transportation mode and route could allow LSPs to provide flexible service components to shippers (Zhang and Pel, 2016). We define flexibility as the capability of the logistics system to provide possible changes in the service components in response to a shipper's business needs at any point in time, before and after the departure of the freight/goods towards the destination. Our definition, which extends the definitions by Swafford et al. (2006) and Ben-Akiva et al. (2008), has not yet been applied in any mode choice study. The third new attribute involves value-added services (VAS), which are ancillary services beyond the main transportation service, such as container tracking, customs-oriented services, stripping/stuffing and cleaning (Roso et al. 2009). Although value-added services have been applied in logistics and transportation since the 1980s (Pettit and Beresford, 2009), so far no transportation service choice study has incorporated them as a service attribute into a choice experiment. (see further details in section 2). The final limitation in existing mode choice literature is the fact that most studies collect a limited number of observations and/or focus a particular geographical area, such as a city, country or continent. We found no studies that reflect on the demand-related characteristics of global shippers in connection to recent innovations in transportation and logistics, including synchromodal transportation.

In this research, a systematic study is conducted among Global Fortune 500 companies (Fortune magazine, 2017) and major customer firms of the 40 largest global LSPs (Logistics Quarterly magazine, 2011), including all different industries and commodity types that account for the majority of global transportation volume and value. Stated preference (SP) data from our survey among these global shippers are used to analyze their attitudes toward moving from a transportation mode choice approach to a transportation service choice approach. Firstly, multinomial logit modeling method is applied to estimate the preferences of shippers regarding the main attributes of the synchromodal transportation services, such as cost, transit time, reliability (punctuality), modal control, flexibility (changeability, adaptability) and value-added services. Next, latent class modelling is used to capture the non-observable heterogeneity of the shippers' preferences within each class. Willingness to pay for different transportation attributes is also measured.

The main contributions of this research are as follows. First and foremost, it addresses the paradigm shift in logistics and transportation service choice, concerning shippers' willingness to delegate the authority to decide the mode of transportation to the LSPs. A new choice modelling attribute, called modal control, is introduced. The approach empirically validates one of the fundamental assumptions of implementing synchromodality in practice. Secondly, flexibility is operationalized in this broader context and incorporated into the discrete choice study. In the same context, we also include value-added services, above and beyond the primary transportation service. And finally, this study adopts an international perspective to depict preferences, taste heterogeneity and segmentation of leading shippers. While earlier studies were geographically constrained, we focus on global shippers. In the following section, we present the background of the study. We discuss the research methodology, including the econometric approach, the data and the choice experiments in section 3. Section 4 is dedicated to the results and discussion. Section 5 provides managerial insights along with conclusions and future research directions.

3.2 Background of the research

Synchromodal transportation, as a technological and organizational innovation in freight transportation and logistics, is designed to enable LSPs to implement demand-driven transportation services (Tavasszy et al. 2018). A successful implementation in a large-scale network requires shippers to move away from a transportation mode choice approach towards a transportation service choice approach. Synchromodal transportation is the latest generation of a family of transportation systems designed to improve overall efficiency of the transportation system by combining several modes of transportation. As pointed out by Reis (2015), the most established concepts in this regard are multimodality, intermodality and combined transportation, which were developed in the 1980s and 1990s. Multimodal transportation, which was defined by UNCTAD (1980) as the transportation of goods using two or more modes of transportation, has been practiced since the 1960s. Intermodal transportation, which has been practiced since the 18th century, was defined and operationalized in research by Hayuth (1987), who added three main features to multimodality (one and the same unit load, door-to-door transportation and greater integration). The combined and co-modal transportation systems (UNECE, 2001; European Commission, 2006) are also types of intermodal transportation, with the latter focused more on efficiency and the former more on sustainability. Synchromodal transportation (see e.g., Tavasszy et al. 2018) has added two distinguishing features of flexible (adaptive) mode choice and decision-making based on real-time information. The word synchromodality can be explained as ‘synchronized intermodality’, where LSPs have the flexibility to make real-time decisions about switching between transportation modes and routes, in response to the demand variations and resource/network availabilities (e.g., congestions, transit times, delays, pricing - see for further elaboration and detail e.g., Van Riessen et al. (2015) and Behdani et al. (2016)). Without putting the authority of choosing modes and routes of transportation in the hands of the LSPs, the implementation of synchromodality is unfeasible within a large-scale transportation network.

Taking the research on the transportation demand into account, the existing mode choice literature is based mainly on the paradigm in which shippers predominantly select the transportation mode. Fries and Patterson (2008) reviewed different research projects involving the question whether shippers actually tend to choose between different transport modes or between different transport service offers of LSPs (i.e., letting the LSP select the appropriate transport mode). While they emphasized that there is no simple ‘yes’ or ‘no’ answer to this question, they concluded that the transportation mode is important to shippers, and highlighted that the quality and price of transport service are crucial as far as shippers are concerned, but that the transportation mode plays a non-negligible role that is an implicit part of their choice. However, it is not clear under which circumstances and to what extent shippers tend to permit LSPs to determine the appropriate transport mode. A recent literature review by Reis (2014) identified transportation safety and security, service frequency, transportation cost, transit time, service reliability and service flexibility as the common components of a logistics service that influence modal choice decisions of the shippers. Almost every research considered transportation cost, time and reliability to be the three core attributes of a logistics service (Reis 2014), while transportation service flexibility and value-added services are largely ignored in the relevant studies.

As stated in the introduction, we define flexibility as the capability of the logistics system to provide possible changes in the service components in response to the shippers' business needs at any point before and after the departure of the freight/goods towards their destination. That could include changes in the destination, increasing or reducing transit time, aggregation or disaggregation of shipment quantity, and so on. Synchromodal transportation enhances flexibility by switching between different transportation modes and routes at mode-volume switch locations (Europe Container Terminals, 2011) in the transportation network i.e., warehouses and cross-docking terminals that also allow for the consolidation and deconsolidation of freight based on the business requirements of shippers. In the existing literature on mode choice, few studies include flexibility as an attribute of the transportation service. For example, Norojono and Young (2003) referred to flexibility as the responsiveness level of the LSP to the problems, while Danielis and Marcucci (2007) saw it as the LSP's capability to change some of the service components before finalizing the service booking. Arencibia et al. (2015) defined flexibility as the LSP's capability to perform unexpected changes in the booking of transportation service, such as last-minute changes in the shipment. Our definition extends ones provided by Swafford et al. (2006) and Ben-Akiva et al. (2008) in a way that has not yet been applied so far in the transportation mode choice studies. We define flexibility as the LSP's ability to help shippers respond to their demand fluctuations, supply chain disruptions or other operational or market requirements. In our view, flexibility can drive many business values for shippers.

Value-added services (VAS) refer to ancillary services that go beyond the main transportation service, such as customs-oriented services, container tracking, storage and handling, stripping and packaging, and so on (Roso et al. 2009). LSPs now have access to a larger variety of services and can potentially align a service better to match the needs of individual or groups of shippers. As synchromodal transportation services provide the LSP new options to meet the requirements of shippers, new business opportunities also emerge to combine the basic transportation service with value-added services. Another research gap concerns the preferences of shippers about such value-added services, which have existed since the 1980s (Pettit and Beresford, 2009), even though they are not included as a service attribute in any of the existing relevant studies.

3.3 Methodology

Random utility theory (McFadden, 1974) introduced discrete choice models as one of the well-established methods in econometrics to shed light on the preferences and taste heterogeneity of customers in Business-to-Consumer and Business-to-Business markets (Ben-Akiva et al. 2008). Multinomial Logit (MNL) (Ben-Akiva and Lerman, 1985) is one of the simplest approaches that assumes fixed deterministic parameters for all individuals. Mixed logit (ML) models (Hensher et al. 2005; Train, 2009), by contrast, allow parameters to vary randomly across individuals to reflect taste heterogeneity. In ML models, a particular type of distribution e.g., normal distribution for parameters of the utility function is assumed by the analyst, parameters' mean and variance are estimated, and the significance of the variance accounts for existence of heterogeneous preferences. There is a rich body of literature involving the application of MNL and ML models in freight transportation.

To accommodate the effects of unobserved heterogeneity, we use the Latent Class (LC) modeling approach (Kamakura and Russell, 1989), which performs similar to the continuous approaches, i.e., ML, for representing heterogeneity (Andrews et al. 2002). Kamakura and Russell (1989) developed LC modeling and removed some of the drawbacks of ML models, i.e., the analyst should assume and fit distribution functions for parameters. Here, an important problem lies in specifying a well-fitted distribution function for each parameter and the need for conducting tests to validate different types of density functions. LC model (also called endogenous market segmentation or the finite (discrete) mixture model) is a special type of broader class of mixture models based on a logit kernel (Train, 2009) that uses observable variables to identify the membership function of each category of the mixture distribution. LC models assume a fixed number of latent classes among individuals and directly use data to detect behaviorally homogenous segments. To this end LC modelling does not need simulation-based estimation, which is an advantage over the ML model (Greene and Hensher, 2003). While LC modelling fits the data and captures unobserved heterogeneity as well as ML models do, it allows for a better and easier behavioral and intuitive interpretation of results to obtain managerial insights for practitioners and policymakers (Greene and Hensher, 2003; Louviere, 2006; Shen, 2009; Hess et al. 2011). Louviere (2006) highlighted that results can also be difficult to interpret when applying continuous distributions in ML models.
Although Boxall and Adamowicz (2002) reported a significant growth in the application of LC models, especially in the areas of marketing and psychology, Arunotayanun and Polak (2011) emphasized that relatively few studies involving transportation demand analysis have so far applied LC modelling. This could be due to data unavailability or the difficult, time-consuming and cost-intensive nature of data collection in general, especially from global firms, and the relatively high data-intensity of latent class approach compared to mixed logit, in particular (Marcucci, 2013). Our examination of existing literature also shows that their claim is still valid. The limited research into latent class analysis of unimodal, multimodal and intermodal transportation was conducted by Wen and Lai (2010), Arunotayanun and Polak (2011), Bergantino et al. (2013), Di Ciommo et al. (2013), Feng et al. (2013), Chu, H. C. (2014), Kim et al. (2017), Piendl et al. (2017), Duan et al. (2017), Roman et al. (2017) and Piendl et al. (2018). We used the LC modeling approach along with MNL modeling as our main research method.

3.3.1 Econometric approach

The vast majority of applications of discrete choice modeling in the area of transportation are based on the random utility maximization (RUM) paradigm. RUM considers the utility of alternative *k* for decision-maker *i* by $U_{ki} = V_{ki} + \varepsilon_{ki}$, where V_{ki} is the systematic, observable utility of alternative *k* for decision-maker *i*, and ε_{ki} is the error term representing unobserved factors by the analyst in the choices of individual *i*. Based on the assumptions about the distribution of the error term, different choice probability formulations can be obtained, representing different families of models, including multinomial logit, nested logit, mixed logit and probit. The multinomial logit (MNL) is the most basic form of the model, based on an extreme value type I (Gumbel) probability density function and the additional assumption of independent and identically distributed ε_{ki}. As discussed earlier, to reveal taste heterogeneity among shippers, we apply the LC modelling approach, in which, for shipper (decision-maker) *i* in class *s*, the utility of alternative *k* is

$$U_{ik|s} = \alpha_{k|s} + \beta_s' X_{ik} + \varepsilon_{ik|s} \quad (1)$$

where $\alpha_{k|s}$ is the segment-specific constant; β_s' is the vector of the utility parameters for segment s; X_{ik} is the vector of independent variables for alternative *k* of the decision-maker *i*; $\varepsilon_{ik|s}$, as above, is the independently and identically distributed (IID) error term of the utility function. The probability of selecting alternative *k* within each class by the shipper *i* is

$$P_{(ik|s)} = \frac{\exp\left(\alpha_{(k|s)} + \beta_s' X_{ik}\right)}{\sum_{k \epsilon K} \exp\left(\alpha_{(k|s)} + \beta_s' X_{ik}\right)} \tag{2}$$

Assuming W_{is} as the class membership probability of individual *i* belonging to class *s*, the unconditional probability of selecting alternative *k* is

$$P_{ik} = \sum_{s=1}^{S} P_{ik|s} . W_{is} \tag{3}$$

in which $P_{ik|s}$ is the choice probability within each class, and where *S* is the total number of classes. As can be seen, the probability P_{ik} depends on two kinds of probabilities: the class membership probability (W_{is}) and the choice probability within each class ($P_{ik|s}$). A standard logit formulation can be applied to display W_{is} as

$$W_{is} = \frac{\exp\,(\gamma_s' Z_i)}{\sum_{s=1}^{S} \exp\,(\gamma_s' Z_i)} \tag{4}$$

where γ_s is the vector of estimated parameters for segment s and Z_{i} is the vector of segment variables for characteristics of respondents which is also called concomitant variables of the latent class model. The γ_s parameters will demonstrate only constants if no concomitant variables are specified in the model.

The Bayesian Information Criterion (BIC) and the Akaike Information Criterion (AIC) are considered among the most usual ways to determine the optimal number of segments (Bhat, 1997; Boxall and Adamowicz, 2002). Their formulas can be expressed as

$$AIC = -2LL + 2M \tag{5}$$

$$BIC = -2LL + M \ln N \tag{6}$$

where *LL* is the convergence value of log likelihood function, expressing the fit with modelled and observed choice probabilities; *N* is the total sample size and *M* is the number of parameters in the model. Walker and Li (2007) emphasized superiority of BIC over AIC and the minimum log likelihood in LC models since BIC is stricter on imposing penalty for a larger number of parameters.

3.3.2 Experiment design and implementation

It is our aim to obtain a comprehensive understanding of the willingness among shippers to delegate modal control and their preferences with regard to the synchromodal transportation services. Our focus is on the transportation flows of the world's biggest firms, which mainly purchase and/or produce all different types of products/materials/equipment and deliver or distribute them to their customers or consumers. We were able to identify two main sources that could provide us with a list of these major firms: the list of Global Fortune 500 companies, as published every year by Fortune Magazine, containing the names of the world's 500 largest firms by revenue, and the list of major customers (firms) of the 40 largest LSPs worldwide based on Logistics Quarterly Magazine, which lists between 5 to 10 major customers (leading shippers) for each LSP. As expected, there is significant overlap between these lists. In total, 556 unique company names were identified.

In the next step, we identified the people we should contact for the stated preference survey. The decisions involving a shift towards a fundamentally new transportation service such as synchromodal transportation are strategic/tactical level decisions that affect long-term contracts of shippers with LSPs, which is why we targeted top (c-level) and senior/middle level managers of shipper firms. Because we would expect synchromodal transportation to affect various functions in the supply chain (from procurement to manufacturing to distribution), we focused on top/senior managers involved in supply chain and transportation operations. In total, 2752 c-level and senior managers in the supply chain, transportation, logistics and distribution functions (e.g., vice-president of supply chain, director of logistics) of our list of 556 global largest firms were approached.

Two web-based surveys were constructed, as a pilot and as the main study. For the pilot study, we developed an orthogonal experimental design (Street et al. 2005) to estimate the parameter priors for our main experiment, which was based on efficient design method (Huber and Zwerina, 1996; Rose and Bliemer, 2009). The response rate was 15.6% (of the 262 respondents) for the pilot study and 11.9% (of the 2490 respondents) for the main study. The details of the data collection in both cases are explained in the below section.

3.3.3 Discrete choice experiments

Constructing a D-efficient design experiment requires priors for parameters of the model that can be obtained via three different ways: existing literature, expert judgement and pilot studies (Bliemer and Collins, 2016). We chose the third option, because, in addition to this being the first study examining synchromodal transportation demand, no existing study includes control as an attribute to account for the transfer of the mode choice decision from shippers to LSPs. With regard to the second option, although we know what the right sign is for every attribute e.g., transportation cost has a negative sign in the utility function, having one or a few expert(s) assume the magnitude of the priors for synchromodal transportation increases the likelihood of obtaining biased priors, which is why we decided to conduct a pilot study, as the most reliable option to obtain priors from our population of interest.

The pilot study

An orthogonal SP experiment was created to obtain preliminary insights about shippers' preferences for two hypothetical synchromodal transportation services, against their current transportation alternative. Three sets of attributes were included in the experiment: the common attributes of modal choice, such as transportation cost, time and reliability, the special attributes of synchromodal transportation, which are control and flexibility, and value-added services (VAS). The attributes are defined as follows:

- End-to-end cost is the total amount of money paid for shipping one TEU (20-foot container) from origin to destination (adapted from Arencibia et al. 2015).
- End-to-end transportation time is the duration from the shipment's first origin to its final destination (adapted from Arencibia et al. 2015).
- Reliability is the on-time delivery of freight/goods at the destination (adapted from Arencibia et al. 2015).
- Control is the authority level of the shipper to decide its preferred transportation mode/route.
- Flexibility is defined as the ability of a transportation service to effectively fulfil a shipper's required changes in service components before finalizing the booking of the

transportation service, and while goods are on their way towards their destination. Examples include changing in delivery time/location, shortening or extending lead times, and consolidating or deconsolidating volume/variety via warehouses or cross-docking terminals (mode-volume switch locations). The shipper has full authority over the volume-related decisions (we extended the definitions of flexibility proposed by Swafford et al. (2006) and Ben-Akiva et.al (2008)).

- Value-added services (VAS) are ancillary services including tracking and tracing, storage and handling, customs and packaging offered by the LSP beyond the main transportation service (Roso et al. 2009).

The next step in designing the orthogonal SP experiment involved determining attribute levels. We considered three alternative transportation services, including two synchromodal transportation services called *budget* synchromodal service (BSS) and *premium* synchromodal service (PSS**),** and the *current* service that the shipper is using at the moment. As depicted in Table 1, each synchromodal alternative has six attributes with three levels. Cost, Time and Reliability are reflected with positive (increase) or negative (decrease) percentage compared to the current transportation service the shipper is using. The attribute levels for Control, Flexibility and VAS are based on the service-level concept for attributes like flexibility and frequency, as applied in Danielis and Marcucci (2007) and Arencibia et al. (2015). Control has two service levels (*Low* and *Not provided*) compared to the current transportation market, where shippers usually have a high level of control over selection of their desired transportation mode and route (Tongzon, 2009). *Not provided* means that decisions regarding transportation mode and route will exclusively be made by the LSP, while a *Low level* of control means that the LSP still has the authority to make decisions regarding transportation mode and route, but would consult with shipper if needed. Flexibility has four service levels (*High, Medium, Low* and *Not provided*). As an example, a *High* flexibility level means that the synchromodal transportation service is highly flexible to adapt shipper's required changes in terms of destination, delivery time window, lead time, freight volume (de)consolidation, and so on. VAS also has four service levels (*High, Medium, Low* and *Not provided*). The quantity of value-added services provided by the LSP will be reduced from a High service level to a Low one.

The characteristics of the reference alternative i.e., the current service, is defined in a way similar to the studies that elicit responses based on differences with a base case, in line with the DC-RUM approach (see e.g., Arencibia et al., 2015, for a similar case). With regard to cost, time and reliability, the attribute levels of the reference alternative are set to zero (or no change) to be comparable to percentage changes in the synchromodal alternatives (same approach as Arencibia et al., 2015). For example, when a synchromodal alternative time is +20%, that means that the door-to-door transportation time is 20% longer than that of the current alternative. Unlike cost, time and reliability, our definitions for flexibility and VAS have not been empirically tested in existing literature. This increased our concerns about whether or not the respondents would be able to make a true comparison between the flexibility attribute of the synchromodal alternatives and that of their current option. As such, the base service level for flexibility and VAS attributes of the reference alternative was set to zero, to maintain the same picture for the respondents. Based on this assumption, the shippers are asked to compare zero flexibility (and VAS) of the reference alternative with none (zero), low, medium and high level of flexibility (or VAS) of a synchromodal alternative. With regard to the control attribute, we set it to high for the reference alternative, since 78% of shippers indicated at the start of the survey that they are the mode chooser meaning that they have high control over modal selection. Thus, when they compare the control attribute of their current service with the synchromodal alternatives, they compare their high level of control with a non-existing or low level of control in synchromodal services. Since our study is not a mode choice study, but a mode abstract study examining the extent to which shippers are willing to relinquish control within the context of mode choice, we do not examine the modal split of the current alternative.

Table 1. Attributes and their levels in the pilot study

Attributes	*Synchromodal service*		*Current service*
	1 (premium)	*2 (budget)*	
Door-to-door transportation Cost ($)	+1% +2% +4%	Current level -1% -3%	Current level
Door-to-door transportation Time (days)	-10% -20% -30%	+20% Current level -20%	Current level
Control over transportation mode and route (service level)	No control Low	No control Low	Current level
Flexibility to adapt shippers' required changes (service level)	Low Medium High	No flexibility Low Medium	Current level
Reliability in on-time delivery (% delivery times)	+10% +15% +20%	-10% Current level +10%	Current level
Value-added services (VAS): tracking, customs, … (service level)	Low Medium High	No VAS Low Medium	Current level

Using a full factorial design would need $3^{(2*5)}*2^{(1*2)}$= 236196 choice tasks. To reduce that number, an orthogonal fractional factorial design[2] (Kocur et al. 1982) was developed in which 18 choice tasks are grouped in two choice sets (two blocks), where each one contained nine choice tasks and was included in a web-based survey using an online survey platform (Surveygizmo, 2017). 262 executives from 56 firms (out of the list of 556 firms) were randomly selected for the pilot study. Each survey was sent via email to 131 respondents from the population of companies selected as responding to the pilot study. We received 19 and 22 complete responses from pilot surveys 1 and 2, respectively (representing an average response rate of 15.6%). Aggregating the results, 19 choice sets, each one containing 18 complete choice tasks (342 observations), are applied to estimate model parameters. The results of estimating the MNL model (using Biogeme software release 2.0 (Bierlaire, 2003) on the pilot study data are shown in Table 2.

Table 2. Estimation results for the pilot study (orthogonal design)

Attributes	*MNL model*	
	Coefficient	*t-value*
Current option	0.591***	3.11
Control	0.789**	1.98
Cost	-10.1***	-5.39
Flexibility	0.102*	1.69
Reliability	0.328***	3.01

[2] This design was a sequential orthogonal design, in which orthogonality holds within each alternative only.

Time	-1.06*	-1.74
VAS	0.153	1.36
Number of responses	342	
Number of respondents	38	
Log-likelihood	-338.448	
McFadden's R^2	0.138	

Note. *p<0.1, **p<0.05 and ***p<0.01 for statistical significance

All attributes have the expected signs, i.e., negative utilities for increase in cost and time and positive utilities for increase in control, flexibility, reliability and VAS. Apart from value-added services, the remaining attributes are statistically significant. The significance of the current transportation option reveals the fact that some shippers may face inertia or be unwilling to move toward synchromodal transportation.

The main study

Efficient designs are among the most popular choice experiment design methodologies due to their advantages when dealing with stated choice data. Obtaining more reliable estimates with a smaller sample size is regarded as one of the main advantages of efficient designs (Bliemer and Rose, 2005). Table 3 shows the attributes and their levels for the main study. To avoid an overly complex choice experiment, we made a number of necessary assumptions regarding other important attributes, such as safety, security, frequency and rules and regulations. We assumed that (i) international rules and regulations allow for synchromodal transportation requirements, (ii) freight will be delivered without any change in damage or loss compared to the shippers' current transportation option, and (iii) service frequency is the same as their current transportation service.

Table 3. Attributes and their levels in the main study

Attributes	*Synchromodal service*		*Current service*
	1(premium)	*2(budget)*	
Door-to-door transportation Cost ($)	+1% +2% +4%	Current level -1% -3%	Current level
Door-to-door transportation Time (days)	-10% -20% -30%	+20% Current level -20%	Current level
Control over transportation mode and route (service level)	No control Low	No control Low	Current level
Flexibility to adapt shippers' required changes (service level)	Medium High	No flexibility Low Medium	Current level
Reliability in on-time delivery (% delivery times)	+10% +15% +20%	-10% Current level +10%	Current level
Value-added services (VAS): tracking, customs… (service level)	Medium High	No VAS Low Medium	Current level

Using the parameter priors from our pilot study and revised attribute levels, the Ngene software (Choice Metrics, 2010) was applied to maximize statistical efficiency for creating a D-efficient optimal design for the main study. In order to create the choice sets for the main study we applied the Ngene software. In general, we selected a fractional factorial design as our main design type. Two major design types in fractional factorial designs are orthogonal design and efficient designs (Rose and Bliemer, 2009). Because of the advantages of efficient designs mentioned earlier, we chose efficient designs. When it comes to efficient design, several design types exists including A-efficient, S-efficient, D-efficient, C-efficient designs which are different in the way they measure the design's efficiency (Rose and Bliemer, 2009). We considered the D-error statistic[3], as the most predominantly used measure (Rose and Bliemer, 2009), to generate a D-efficient design. In particular, we applied a Dp-efficient design where none-zero priors (obtained from pilot study) are incorporated into the design procedure[4] (Rose and Bliemer, 2009).

Keeping that in mind, we obtained the choice sets from Ngene software via the following steps. In the first step, because our synchromodal alternatives were unlabeled, we considered all parameters (six attributes and one alternative-specific constant for the current option) as generic. We considered the attribute levels of the pilot study (see Table 1) and entered them into the utility function as effects codes between 0 and 1, i.e., a percentage between 0% to 100% for cost, time and reliability, and an attribute level of *None, Low, Medium and High,* coded as 0, 0.33, 0.67 and 1, for flexibility, VAS and control. We considered the main effects for the MNL model. In the next step, we added the constraint of having attribute level balance[5] in Ngene and created the initial random D-efficient design consisting of 12 choice tasks. Once the initial design was obtained from Ngene, we calculated the choice probabilities for each alternative, to ensure the utility balance between the alternatives. Next, the statistical efficiency of the design was evaluated using the D-error reported by Ngene. In the subsequent steps, we changed the initial design to identify more efficient designs i.e., lower D-error. After several trials and after investigating dominancy of the choice tasks we obtained, we realized that the high degree of overlap regarding the flexibility and VAS attribute levels between premium and budget synchromodal services may make some of the budget services dominant, in particular, from practical viewpoint. As such, we reduced the attribute levels of flexibility and VAS from three to two (removing the lowest attribute level) for the premium service to make this service more distinct from the budget service, which also helped reduce the D-error of the design. The final D-efficient design (D-error=0.08508) has 6 choice tasks. Table 4 shows an example of a choice task.

Table 4. Example of a choice task in the main study

Attributes	*Synchromodal service*		*Current service*
	1	*2*	Current level
Door-to-door transportation **Cost** ($)	+2%	-1%	Current level
Door-to-door transportation **Time** (days)	-30%	+20%	Current level

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[3] The D-error statistic is calculated by taking the determinant of the asymptotic variance–covariance (AVC) matrix assuming a single respondent, Ω1, and scaling that value by the number of parameters, K.(Rose and Bliemer, 2009)

[4] Based on the assumptions about the values for prior parameters, three type of D-efficient designs exist. If the priors are assumed to be zero, the resulting design is called Dz-efficient design. When priors are known with certainty, the design is called Dp-efficient design. If the true population parameters are not known with certainty, prior parameter estimates are drawn from Bayesian parameter distributions (with parameters θ). These designs are known as Bayesian or D_b-efficient designs (see further explanations in Rose and Bliemer, 2009)

[5] Attribute level balance means that "each attribute level appears an equal number of times for each attribute. Having attribute level balance ensures that the parameters can be estimated well on the whole range of levels, instead of just having data points at only one or a few of the attribute levels" (Rose and Bliemer, 2009).

Control over transportation mode and route (service level)	Low	No control	Current level
Flexibility to adapt shippers' required changes(service level)	High	Low	Current level
Reliability in on-time delivery (% delivery times)	+10%	Current level	Current level
Value-added services: tracking, customs etc. (service level)	Medium	Medium	Current level

One of the key advantages of the family of D-optimal designs (i.e., Efficient designs) is their robustness when it comes to minimizing the variance of the resulting parameter estimates. This helps avoid bias parameter estimates which can come from the presence of dominant alternatives in orthogonal designs (Hess et al. 2010; Bliemer et al. 2015). A dominant alternative is a choice that all of its attributes are better (or worse) than the other alternative(s). It posits no trade-off for the respondent, thus providing no information to the analyst (Hensher et al. 1988). While none of our six choice tasks are dominant, we also captioned synchromodal budget and premium services to generic services, called service1 and service2 in our web-based survey, to prevent non-trading (e.g., always choosing a dominated alternative) and lexicographic (always choosing a particular attribute) behavior of respondents. Hess et al. (2010) emphasized that non-trading behavior is far less common in the unlabeled choice experiments and the chance of lexicographic behavior is much smaller in complex choice experiments i.e., the ones with more than two attributes.

Using the Surveygizmo platform, a web-based survey was constructed consisting of three main sections. Synchromodal transportation was introduced in the first section, explaining its characteristics, the idea of the mindset shift from physical toward service connectivity, along with two examples of its operation and the resulting business value. We included containerized synchromodal transportation as a global standard norm, to avoid misunderstanding among respondents with regard to bulk, pipeline and other transportation types. The second section was designed to collect sociodemographic information of the respondents, their company and their logistics function. The third part of the survey involves the SP choice task. We conditioned the choice tasks based on different shipment sizes, since mode choice decisions are usually associated with the amount of products to be shipped.

The survey was sent via email to 2490 respondents between December 2017 and February 2018. After three follow-up rounds, 296 usable responses were collected, providing 1776 usable SP observations. Based on the number of questionnaires we distributed, the response-rate is 11.9%. We looked at if there was more than one respondent per company. In total, 194 unique companies responded to our survey, representing 38.8% of the 500 companies in our list of Global Fortune 500 companies and the main customers of largest LSPs. Table 5 shows the profiles of the respondents and companies involved.

Table 5. Demographics of the respondents

Respondent Position	*%*	*Company size (#employees)*	*%*	*Annual Revenue*	*%*	*Economic sector*	*%*
C-level/Top Mgmt	21%	<99	4%	<$100 Mn	10%	Basic Materials	12%
Senior/Middle Mgmt	79%	100- 249	7%	$100-250 Mn	8%	Consumer Cyclicals	18%
		250-999	7%	$250 Mn-1 Bn	10%	Consumer Non-Cyclicals	19%
		1000-9999	18%	$1-10 Bn	23%	Energy	6%
		10000-49999	28%	$10-50 Bn	27%	Healthcare	11%
		> 50000	36%	> $50 Bn	22%	Industrials	7%
						Technology	16%
						Telecom Services	8%
						Utilities	2%
						Others	0%
Total	100% (296)						

The estimation of the latent class model is done by applying the Latent Gold software (Vermunt and Magidson, 2005). In the first step, we determine the proper number of latent classes by estimating the models based purely on the available information on shippers' choices, without explicitly considering covariates like commodity type. Using latent Gold, we started estimating models with one to six classes. Table 6 shows the model fit of the various models. As highlighted in section 2.1, models with the lowest possible BIC and AIC measures reveal the proper number of latent classes. As shown in Table 6, when the number of classes increases, the AIC decreases, whereas BIC increases after the fourth class. As a result, the latent class model with four classes, which has the least BIC and a good model fit (McFadden's R2 of 0.409), is chosen.

Table 6. Model fit for the latent class choice models

Criteria	*Number of classes*					
	1 (MNL)	*2*	*3*	*4*	*5*	*6*
Log-likelihood at convergence	-1914.26	-1639.12	-1562.38	-1487.51	-1447.87	-1410.87
McFadden's R^2	0.1270	0.2657	0.3754	0.409	0.395	0.4379
Number of parameters	7	33	59	85	111	137
Number of observations	1776	1776	1776	1776	1776	1776
Akaike information criteria (AIC)	3842.53	3344.25	3242.77	3145.03	3117.74	3095.75
Bayesian information criteria (BIC)	3868.36	3466.03	3460.50	3458.71	3527.37	3601.33

After establishing the main LC model with four classes (see estimation results in Table 7), we need to see the impact of contextual variables (or covariates) of the shipment. Considering covariates helps explain the variability in class memberships by assessing how the probability of belonging to each class depends on different covariates. We included several contextual factors as model covariates. Covariates like product type (i.e., finished, semi-finished and raw), respondent position (i.e., C-level, senior/middle manager) and respondent's job function (i.e., supply chain, transportation/logistics, distribution) proved to be insignificant, while covariates like shipment size, commodity type and company size turned out to be significant (See Table 8). In the web-based survey, the commodity types are categorized based on the Thomson Reuters business classification (2012). The dummy variables of commodity types and shipment sizes are used as segment membership variables. The reference category for commodity type is telecommunication and, for shipment size, it lies above 100 TEUs. The annual revenue is included as a continuous variable in our modeling with Latent Gold.

3.4 Estimation results and discussion

3.4.1 Results of the Multinomial logit and Latent class models

The results of estimating the MNL and LC models are shown in Table 7. In the MNL model, all parameters have the expected sign (i.e., positive utilities for increases in control, flexibility, reliability and VAS, and negative utilities for increases in cost and time). The estimated value of cost, time, control and flexibility is significant. The estimated value of the alternative-specific constant (ASC) for the current transportation service is positive and significant, indicating that some shippers may be biased towards their current choice. As shown in Table A1 (see appendix 1), cost, time and flexibility make up a larger proportion of relative importance among all attributes.

The latent class model is developed here to clarify the apparent ambiguity of shippers' preferences for different attributes and unfold a substantial degree of taste heterogeneity. It should be pointed out that, during the estimation of the MNL and LC models, we considered high level of modal control for the current alternative, since 78% of the respondents indicated that they themselves (and not the LSP) decide the transportation mode, when asked about it in the first part of the survey. This assumption is consistent with existing literature (see e.g., Tongzon 2009). In addition, we do not consider any ASC for both synchromodal alternatives, since we included them as unlabeled generic alternatives in our modeling. This is due to the fact that we named premium and budget synchromodal alternatives as synchromodal service 1 and synchromodal service 2 in the web-based choice experiment, respectively. As such, there is no difference between them in terms of brand effect. According to Train (2009), there is no need to consider ASC for unlabeled alternatives, since there is no brand effect in generic alternatives.

Table 7. Estimation results for the MNL and latent class models

	MNL		*LCM*							
			Class1		*Class2*		*Class3*		*Class4*	
	Estimate	*z-value*	*Estimate*	*z-value*	*Estimate*	*z-value*	*Estimate*	*z-value*	*Estimate*	*z-value*
Class size (%), n=1776			35.9		32.3		18.4		13.4	
Choice share within each class (%)										
PSS	39.8		71.6		19.1		31.9		0.4	
BSS	28.8		22.7		32.6		65.9		1.1	
Current option	31.3		5.7		48.3		2.2		98.5	
Taste parameter estimates										
$ASC_{\text{Current option}}$	0.435***	4.21	-0.671*	-1.82	1.148***	4.74	-3.187***	-5.86	9.303*	1.66
Cost	-10.28***	-5.26	-9.089***	-2.62	-25.22***	-5.31	-3.452	-0.72	52.98	1.03
Time	-1.047***	-4.58	-3.341***	-4.67	-0.480	-0.93	0.760	1.31	0.280	0.02
Control	0.863***	2.87	1.603**	2.15	2.373***	3.35	-0.399	-0.52	-24.67*	-1.79
Flexibility	0.382***	3.23	1.222***	3.90	0.078	0.30	0.242	0.72	8.303	0.90
Reliability	0.692	1.50	4.583***	4.15	0.508	0.56	-6.009	-3.98	-49.47	-1.21
VAS	0.153	1.10	-0.546	-1.36	0.282	0.99	0.517*	1.73	1.988	0.24
R^2 (%)	12.7		43.6		10.6		31.5		96.5	

Note. *p<0.1, **p<0.05 and ***p<0.01 for statistical significance

One of the remarkable advantages of latent class modelling is that it allows to identify behaviorally homogeneous segments within a potentially heterogeneous population (Greene and Hensher 2003; Hess et al. 2011). In Table 7, two distinct segments of shippers are recognizable, based on their willingness to delegate control of mode and route to LSPs. The first category includes the first and second latent classes, which together make up 68.2% of the sample and are potentially willing to delegate authority involving the selection of transportation mode and route to the LSPs. The second group involves third and fourth classes (31.8%), which may not be willing to risk losing their control over the transportation mode and route.

More than one third of the population (35.9%) belongs to the first class of shippers, which could be called *high service-level seekers*. Most of them selected premium synchromodal service (PSS) i.e., in 71.6% of choice situations. This class of shippers is seriously seeking improvements in service levels of the transportation, since the coefficients of time, flexibility and reliability are significant and have the expected signs. In addition, they selected a synchromodal service (i.e., PSS or BSS) in more than 94% of choice situations, emphasizing their willingness to delegate their authority over transportation mode and route selection to the

LSPs in return for a reliable, fast and flexible transportation service at a competitive price. The significance of control in the first latent class shows the shippers' natural instinct to maintain modal control. However, the maximum level of control is *low* for the synchromodal services selected by most respondents in this class. This highlights the fact that, although shippers like control, they prefer to maintain control at the lowest possible level (e.g., little to no control), in return for a quality service with desirable levels with regard to time, reliability and flexibility. Table A1 (see appendix 1) indicates that time, reliability and flexibility are the core attributes (highest relative importance) for these shippers. It seems that they are not looking for value-added services, as their requirements for basic service performance are more important or have not yet been met (viz. the insignificant coefficient of VAS). The negatively significant alternative-specific constant of the current transportation option ($ASC_{\text{Current option}}$) indicates that these shippers are not very satisfied with the existing transportation services in the market.

The second class of shippers (class size of 32.3%) could be called *cost-sensitive risk-taking shippers.* These firms selected a synchromodal service more than half of the time (51.7%) and their control attribute is positively significant, which tells us that they are willing to take risk and transfer their modal selection authority to the LSPs, provided they get a very cheap transportation service in return (i.e., a significantly large cost coefficient). Otherwise, they will probably return to their current transportation services, with which they are satisfied as it is (i.e., positive and significant value for ASC of the current transportation option). In 48.3% of choice situations, they selected their current transportation service and in 32.6% of they chose a BSS, which has the same or a lower price compared to their current service. The relative importance of cost and $ASC_{\text{Current option}}$ together represents more than 70% (see Table 8). These results demonstrate that the shippers in the second class are more interested in procuring the most cost-efficient transportation services, irrespective of whether that is their current service or a new service for which they would have to delegate modal control.

The third group of shippers represents 18.4% of the population and could be called *Ancillary service seekers*. They are not satisfied with their current transportation services (i.e., negatively significant $ASC_{\text{Current option}}$ coefficient). Most shippers in this group (97.8%) opt in favor of the two synchromodal services (i.e., PSS and BSS), which they believe are likely to provide a reasonable level of value-added services. These shippers are mainly looking for value-added services beyond the main transportation service.

13.4% of shippers fall into the last segment and could be called *risk-averse shippers.* They are satisfied with their current transportation service and selected that service in 98.5% of choice situations, to avoid changes in their current transportation operations. In particular, it appears that they do not even evaluate any new service package if it violates their modal control authority (see the negatively significant coefficient for the control attribute).

One of the important bias signs in a discrete choice experiment is the presence of significant ASC coefficients, usually originating in non-trading behavior of respondents, i.e., selecting a particular alternative in all choice situations. Such behavior could indicate a reluctance to consider (a) particular alternative(s), misunderstanding or fatigue during the stated choice exercise or political/strategic behavior towards particular alternative(s) (Hess et al. 2010). To examine how this bias affects our results, we investigated our dataset, which shows that only 3% of respondents selected the first alternative in all choice tasks, against 1.3% and 12.5% for the second and third alternatives, respectively. These figures still fall well within DCE's acceptable standards (Johnson et al. 2007), so it is unlikely that respondents were confused by the choice modelling exercise. Although these data could be removed from the analysis, some scholars suggest keeping them (e.g., Lancsar and Louviere, 2006) if they fall within acceptable DCE standards and within utility maximization assumption. We prefer to keep this data in our analysis, since, based on our investigation, they mainly demonstrate utility maximizing behavior of our respondents (Hess et al. 2010).

Table 8. Class membership functions of the Latent class model

	Class1		*Class2*		*Class3*		*Class4*	
	Estimate	*z-value*	*Estimate*	*z-value*	*Estimate*	*z-value*	*Estimate*	*z-value*
Commodity types								
Energy	0.969	0.80	1.690*	1.73	0.332	0.31	Base segment	
Chemicals	2.294*	1.87	2.337**	2.09	0.614	0.49		
Basic materials	2.571*	1.82	1.899	1.41	3.144***	2.47		
Industrials	2.353**	2.13	0.494	0.42	0.069	0.05		
Automobiles & auto parts	7.144	0.86	6.498	0.79	5.025	0.61		
Diversified cyclical retail	7.402	1.01	6.491	0.89	5.832	0.80		
Textiles & apparel	1.156	0.97	0.849	0.80	0.282	0.26		
Other non-cyclical retail	2.177*	1.82	0.352	0.26	-4.731	-0.48		
Food & drug	2.836*	1.89	3.169***	2.35	1.884	1.39		
Food & tobacco	1.796*	1.70	1.666*	1.79	0.175	0.16		
Health equipment	3.562*	1.85	2.185	1.05	0.915	0.41		
Pharmaceuticals	1.082	1.04	-0.010	-0.01	-0.620	-0.58		
Computer & semiconductor	3.303***	2.35	2.373*	1.73	2.137	1.55		
Electronic equipment & parts	0.912	0.86	1.233	1.38	0.734	0.78		
Others	3.930***	2.66	2.627*	1.78	0.694	0.40		
Shipment size (TEU)								
Up to 25	0.388	0.62	-0.037	-0.06	-0.646	-0.92		
25-100	-0.998	-1.36	-1.316*	-1.85	0.051	0.07		
Annual revenue	1.370**	2.17	1.164**	1.81	0.145	0.20		
Intercept	-1.708	-1.58	-0.825	-0.87	-0.240	-0.26		

Note. *p<0.1, **p<0.05 and ***p<0.01 for statistical significance

We now turn to the membership question: to what extent does the probability of belonging to a certain class depend on the type of firm, shipment size and commodity type? The class membership functions of the latent class model are shown in Table 8, while Table 9 categorizes the companies based on the number of employees and annual revenue.

Table 9. Annual revenue based on company size

Annual Revenue	*Company size (# employees)*				*Total*
	SME (Up to 999)	*LE (1000-9999)*	*XLE (10,000-49,999)*	*XXLE (50,000+)*	
Below 1 Bn	17.3% (51)	8.7% (26)	2.4% (7)	0	28.4% (84)
$1-10 Bn	0.3% (1)	6.1% (18)	13.9% (41)	3% (9)	23.3% (69)
$10-50 Bn	0	1.7% (5)	9.1% (27)	15.9% (47)	26.7% (79)
> $50 Bn	0.3% (1)	1.7% (5)	2.4% (7)	17.2% (51)	21.6% (64)
Total	17.9% (53)	18.2% (54)	27.8% (82)	36.1% (107)	100% (296)

Note. SME: small and medium-sized enterprises, LE: large enterprises, XLE: extra-large enterprises, XXLE: extra extra-large enterprises

The probability of belonging to the *high service-level seekers* group is higher for companies with annual revenues in excess of more than US$ 10 billion (i.e., positively significant coefficient in Table 8). According to Table 9, these companies are often extra-large and extra extra-large global shippers with more than 10,000 employees. The shipment quantity of this class of shippers is most likely up to 25 TEUs (i.e., positive coefficient reveals higher probability (see Table 8)). Companies operating in Industrial goods and equipment (i.e., aerospace and defense, construction and engineering, diversified industrial goods, industrial conglomerates; and machinery, tools, heavy vehicles, trains and ships), pharmaceutical industry, and other non-cyclical retail products (i.e., beverages, and personal and household products and services) most probably fall into the first class of shippers.

Extra-large and large firms (10,000-50,000 employees) with annual revenues of US$ 1 to 10 billion are more likely to belong to the second class of *cost-sensitive risk-taking shippers*, where they are also willing to send shipment sizes up to 25 TEUs. The energy industry (i.e., coal, electric utilities and IPPs, natural gas utilities, oil and gas, and oil and gas related equipment and services) falls mainly in this second class, and it is most probably the major segment for industries in the electronic equipment and parts business as well.

The third class of shippers most probably includes small to medium-sized fortune companies with fewer than 1000 employees and up to US$ 1 billion USD in annual revenues. The *Ancillary service seekers* appear to be willing to have shipment sizes in excess of 25 TEUs. Shippers of basic materials (i.e., construction materials, containers and packaging, metals and mining, and paper and forest products) are fall into this third class, while some of them are also interested in the transportation services included in the first latent class.

With regard to other industries, it seems that shippers operating in the healthcare equipment industry are mainly *high service-level seekers*, although some of them also belong to the *cost-sensitive risk-taking shippers* category. Companies operating in the chemical industry, in textile and apparel, or food and tobacco (i.e., fishing and farming, food processing and tobacco) most probably belong to the first or second class and are less likely to fall into the third class. Four industries, including automobiles and auto parts, food and drug retailing, computer and semiconductors (i.e., communications and networking, semiconductors and its equipment, office equipment; and computers, phones and household electronics), and diversified cyclical retail goods (i.e., diversified retail, homebuilding and construction supplies, household goods, and leisure products) do not have a distinguishable association to one of the four transportation service demand classes identified here.

3.4.2 Willingness to pay measures

To understand the impact of different attributes of the transportation service on the choice of shippers, we estimate their willingness to pay (WTP) for improving attributes of the services provided by LSPs (our approach is similar to the one adopted by Arencibia et al., 2015). WTP measures provide very useful guidelines to LSPs in terms of improving their transportation services, and to policymakers when it comes to evaluating different improvement policies. Using the Latent Gold software, the WTP for each attribute in the MNL and LC models is obtained as the ratio of marginal utility of the attribute and the marginal utility of the transportation cost (McFadden, 1981) (see Table 10).

Table 10. Willingness to pay for the MNL and Latent class models

Attribute	*MNL*	*LCM*		
		Class1	*Class2*	*Class3*
Time (€/day)	10.17***	36.76**	1.90	-
Control (€/service level)	8.39**	17.63	9.40***	-
Flexibility (€/service level)	3.71***	13.43**	0.31	7
Reliability (€/delivery times)	6.72	50.43***	2.01	-
VAS (€/service level)	1.49	-	1.12	14.96

Note. *p<0.1, **p<0.05 and ***p<0.01 for statistical significance

WTP figures are only calculated for parameters that have the expected sign. The average shipment cost of one TEU container is considered to be € 100. In the MNL model, the average WTP for a day's reduction in the end-to-end transportation time is estimated at € 10.17. Regarding control, flexibility and value-added services, shippers are willing to pay € 8.39, € 3.71 and € 1.49, respectively, for one level enhancement of control, flexibility and VAS. The *high service-level seekers* group of the latent class model are willing to pay € 36.76, € 50.43 and € 13.43, respectively, for every unitary improvement in time, reliability and flexibility of the transportation service demonstrating the highest intention for WTP compared to the other latent classes. As expected, the *cost-sensitive risk-taking shippers* (second latent class) are reluctant to pay much to improve service attributes, because they are looking above all for low-cost transportation services. Although not statistically significant, willingness to pay for new ancillary value-added services is highest in the *Ancillary service seekers* category (the third latent class of shippers) i.e., almost € 15 for one level of service improvement.

3.4.3 Shippers segmentation

The approach used in this study clarified the shippers' attitude toward modal control delegation and synchromodal transportation demand, and identified four different market segments for service quality and cost improvements toward the global community of LSPs, freight forwarders and carriers. Incorporating the demographic and shipment characteristics of shippers into the latent class model not only increased the model fit, but also uncovered crucial information about the type and magnitude of the shippers' companies and their commodities. The demand for synchromodal transportation is different for different shipper segments. As shown in Figure 2, there are two categories of shippers based on the type of improvement sought: cost reduction or service quality improvement (i.e., improving the quality of the transportation service in one of the attributes of time, flexibility, reliability and VAS or a combination of them).

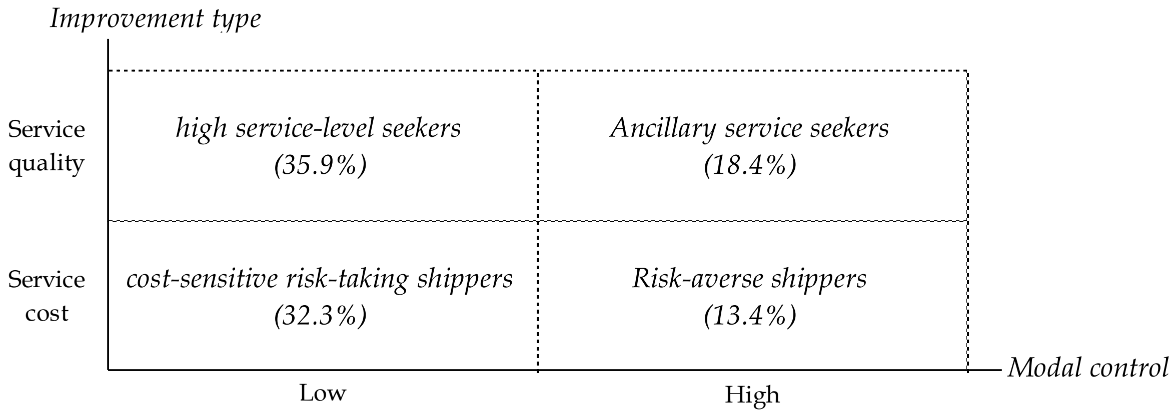

Figure 2. Service improvements sought by shippers based on their modal control

More than 54% of shippers (i.e., class 1 and class 3) are interested in service improvements, with almost 36% of shippers (i.e., *high service-level seekers*) looking for improvements in the main service attributes, such as time, flexibility and reliability, while approximately 18% are looking for ancillary services that go beyond the transportation service, such as value-added services. The remaining shippers, representing approximately 46% of the overall population (i.e., class 2 and class 4) are mainly interested in cost reductions. With regard to the delegation of modal control, the first and second classes (approximately 68% of the overall population) are willing to hand over control to the LSPs, whereby the first class of shippers need to be rewarded with service improvements, while the shippers in the second class are looking for cost reductions in return. Shippers of the fourth segment are not willing to hand over control, while shippers in the third segment appear to be less strict about deciding which mode of transportation is selected, although some of them are willing to maintain modal control.

3.5 Conclusions and practical implications

3.5.1 Main findings

In this study, we focused on the attitudes of leading shippers regarding the delegation of control over the selection of transportation mode and route to LSPs. We identified the heterogeneity in shippers' behavior and demand for synchromodal transportation. Compared to most mode choice studies, this study introduced three interesting attributes to reveal hidden decision-making attitudes among shippers that are important for developing innovative service propositions: modal control, flexibility and value-added services.

The first attribute is called *modal control*. Almost all studies involving the planning, application and implementation of synchromodality, for instance Dong et al. (2018), assume that shippers can and will hand over modal control to the LSPs. However, in practice, shippers find it difficult to relinquish control. What we assumed and empirically validated about the possibility of delegating control is very important, because it has a direct impact on the feasibility of implementing synchromodal transportation and future transportation innovations like the Physical Internet. In this study, we validate our assumption by introducing modal control as a new service attribute into a service choice experiment among major leading firms. The results emphasize the important impact of modal control on service choice of shippers. Also, it shows that there is a considerable likelihood that shippers will delegate modal control to LSPs, if they are rewarded by improved service quality or cost. Another newly defined attribute applied in this research is *flexibility*. Our definition of flexibility covers various changes required by shippers before finalizing the booking, as well as after departure of freight toward its destination. Compared to existing literature, the *en-route* part of our definition of flexibility is new. It could be provided by mode-volume switch options in the synchromodal transportation network, to allow shippers to (de)consolidate commodities based on demand fluctuations at their destination market locations. The third novel attribute is *value-added services*, or ancillary services beyond the basic transportation service, which has also received very little attention in relevant literature, in which VAS does not included in choice modeling studies. Our results show that there is at least one segment in the market willing to consider and pay for each of the three new attributes.

We find that over two-thirds of the shippers may be willing to relinquish control over transportation modes and routes, if they are rewarded by better services or lower costs. This result is particularly interesting since 78% of the shippers in our sample highlighted that they (rather than their LSPs) are currently in charge of selecting the transportation mode when we asked them about their current role regarding modal control at the start of the survey. Four distinct market segments were identified in this study, with a different nature of demand for services. The first and largest segment is called *high service-level seekers,* who have high willingness to use synchromodal services and delegate modal control, provided LSPs are able to secure high-quality transportation in terms of service time, flexibility and reliability. The *cost-sensitive risk-taking shippers* make up the second largest segment. They are mainly willing to relinquish modal control in exchange for cheaper transportation services. The third shipper segment is called *ancillary service seekers* who are to a large extent willing to delegate modal control by shifting towards synchromodal services that provide the value-added services they are looking for in a transportation service. The fourth segment contains the *risk-averse shippers* who are not willing to relinquish modal control and prefer using the transportation services they are currently using. The segments indicate that there are opportunities for a variety of transportation service improvements. While low-cost synchromodal services could be in demand in three of the four segments, the first and largest segment (making up more than one-third of the market) favors a premium synchromodal transportation service. The remarkably high WTP of this group indicates a great potential for LSPs when it comes to designing and implementing synchromodal services for the large leading shippers in this segment.

3.5.2 Implications for practice

This research indicates that there is a certain degree of eagerness among leading shippers to derive more value from transportation services, with the aim of supporting supply chain competitiveness. With regard to the first three classes of shippers which are more inclined to favor changes in transportation services, there appears to be sufficiently fertile ground to innovate logistics and transportation services, which is reinforced by the fact that the shippers in these three classes are all Global fortune 500 companies and often industry leaders. The strategic decisions that they make have significant impacts on their competitors and customers, as well as on the global market as a whole (Bloom and Kotler, 1975; Yeung, 2007; Defee et al. 2009). As a result, it is to be expected that the preferences of these global leader shippers will at some point become widespread within the industry.

Several managerial recommendations can be derived from this study as far as LSPs and public policymakers are concerned:

- LSPs can use the results in Table 8 to identify industries that may be interested in working together to develop pilot projects involving the use of synchromodal transportation services. Right value proposition for different shipper segments is key factor in attracting them. For shippers looking for cost reductions (i.e., the *cost-sensitive risk-taking shippers*), LSPs can efficiently utilize the obsolete capacity of transportation modes to obtain cost-saving benefits. Regarding customer segments that seek high service quality (i.e., the *high service-level seekers*), LSPs can provide service benefits by exploring the impact of flexibility. In addition, LSPs can adopt a gain sharing approach (Hartmann and de Grahl, 2011) and work together with other LSPs to share their mode-volume switch locations (e.g., warehouses, crossdocking terminals) in order to provide flexible services to shippers. This could enable shippers to ask for changes in the transportation lead time, delivery window, destination and shipment volume (i.e., via consolidation and deconsolidation of volumes) in response to their market circumstances. Providing long-term quality services to shippers that delegate modal control to the LSPs is crucial to gain the trust required for the long-term growth of synchromodal transportation services.
- LSPs can explore the different characteristics of the four customer segments to design tailor-made service packages with different service levels, varying in transportation frequency (e.g., daily availability), speed, reliability, value-added services and flexibility, at different prices. A sophisticated revenue management system and capacity planning and allocation process is needed to determine the long-term and short-term transportation (e.g., different modes) and ancillary (e.g., value-added services) resources required to meet shipper's demand for various service packages.
- Public policymakers could use the insights provided by this study as input for long-term decisions about transportation network improvements, with the aim of providing greater flexibility, reliability, efficiency and sustainability. As modal control delegation becomes more common, predictive freight flow models that help guide infrastructure and service investments have to be aligned to these new practices. Policy measures could be introduced to support the development of the transshipment hubs and

information systems needed for synchromodality (Veenstra and Zuidwijk, 2012). This could help the policymakers of international organizations like the European Commission to achieve their objective of re-balancing the modal share between road and rail/maritime towards a more sustainable transportation system (European Commission, 2016). Special attention should also be paid to the adoption of international rules and regulations to enable the true utilization of synchromodal services.

- The emerging paradigm in modal control delegation could pave the way for transitioning towards major transportation and logistics innovation visions, such as the Physical Internet (Montreuil, 2011). Improving the efficiency and utilization of international transportation networks could ultimately help global production and transportation community move more quickly towards global sustainable supply chains. Having full freedom to select different modes and routes could enable LSPs to work together with manufacturing/production environment toward an integrated manufacturing and logistics network. Ultimately, collaboration and coordination of suppliers, manufacturers and distributors with transportation service providers could make the vision of an open global supply network a reality.

3.5.3 Future research directions

Several new studies could be conducted to shed more light on the way the modal control delegation paradigm is emerging. Scholars can focus on specific industries, geographical areas or commodity types. Important attributes that could be added include safety and security, trust and collaboration between LSPs and supply chain actors, as well as cost and profit sharing among LSPs and shippers. Some shipment characteristics, like distance or commodity value, can be used to model the shippers' choice. Requirements and conditions of shippers when it comes to applying synchromodality could be identified. The identification of customer segments presents opportunities for differentiated planning, scheduling, network design, revenue management and real-time decision-making. Business cases could drive forward more detailed studies involving supply chain resilience and flexibility, demonstrating the value of delegated modal control in the face of network disruptions or sudden demand changes.

Appendix 1

Table A1. Relative importance (RI) and marginal effects (ME)

Attributes	*MNL*		*LCM*							
			Class1		*Class2*		*Class3*		*Class4*	
	RI (%)	*ME*	*RI (%)*	*ME*	*RI (%)*	*ME*	*RI (%)*	*ME*	*RI (%)*	*ME*
ASC $_{\text{Current option}}$	16.8	0.097 (0.02)	10.4	-0.149 (0.08)	27.7	0.255 (0.05)	49.4	-0.708 (0.12)	18.5	2.067 (1.26)
Cost	27.7	-2.286 (0.43)	9.9	-2.02 (0.77)	42.6	-5.604 (1.06)	3.8	-0.767 (1.07)	21.3	33.996 (32.9)
Time	20.2	-0.233 (0.05)	25.9	-0.743 (0.16)	5.8	-0.107 (0.11)	5.9	0.169 (0.13)	0.3	0.062 (3.94)
Control	6.7	0.192 (0.07)	5	0.356 (0.17)	11.5	0.527 (0.16)	1.2	-0.089 (0.17)	9.8	-5.484 (4.59)
Flexibility	14.7	0.085 (0.03)	19	0.271 (0.07)	1.9	0.017 (0.06)	3.7	0.054 (0.08)	16.5	1.845 (2.06)
Reliability	8.0	0.154 (0.10)	21.3	1.019 (0.25)	3.7	0.113 (0.2)	28	-1.335 (0.34)	29.6	-10.995 (9.08)
VAS	5.9	0.034 (0.03)	8.5	-0.121 (0.09)	6.8	0.063 (0.06)	8	0.115 (0.08)	4	0.442 (1.87)

Note. Standard deviation in parenthesis

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4 Shippers' willingness to use flexible transportation services

Khakdaman, M., Rezaei, J., & Tavasszy, L. A. (2020). Shippers' willingness to delegate modal control in freight transportation. Transportation Research Part A: Policy and Practice, (Under revision)

Abstract
Factors driving the choice of shipper firms for services of logistics service providers have long been recognized in the freight transportation literature. However, shippers' willingness to choose flexible transportation services, where the service package can be adapted during planning and execution, has received less attention. In particular, little is known about the contextual circumstances under which shippers would be inclined to select such a transportation service. Experimental scenarios and discrete choice modeling are applied to investigate the willingness of shippers to use flexible transportation services. We estimate multinomial logit, mixed logit and latent class models for a sample of nearly 200 global shipper firms and calculate willingness-to-pay measures for flexibility. The findings indicate particular importance of flexible services in demand-volatile markets. As logistics services may provide external flexibility for shipper firms, we also study which related internal flexibilities in supply chains drive these choices. In particular, our findings show that it is mainly volume flexibility of shippers that mediates the choice for flexible transportation services.

4.1 Introduction

Traditionally, shipper firms regarded transportation services - provided by logistics service providers (LSP)[1]- as "commodity" or non-differentiated service that is sold primarily based on

[1] Throughout this paper whenever we use a Logistics service provider (LSP) we mean a company that offers an array of logistics services including transportation, warehousing, forwarding, custom brokerage, cross-docking,

its price (Coase, 1937). In recent decades also, factors such as price, time and reliability were the core attributes driving the choice of the shipper firms (Da Silveira, 2005; Voss et al., 2006). However, globalization and intensive competition among supply chains have made advances in supply chain management practices which resulted in emerging paradigms such as outcome-driven supply chains, which aim to balance and tune cost and service parameters to end customer needs (Melnyk et al., 2010). These changes have forced LSPs also to adapt their services to the needs of shipper firms and LSPs have begun to offer more customized and differentiated services to shippers.

Recently, international LSPs have started to recognize the need of their customers for *flexibility* of logistics services (see for example, DB Schenker, 2009; DHL, 2017) (Reis, 2014). For instance, DSV, the Danish provider of worldwide transportation and logistics services, has spread their European logistics network to more than 135 multi-user warehouses in order to provide tailor-made solutions enabling their customers quickly respond to their market changes via reduction or expansion of their inventory levels at different locations in their supply chain network (DSV, 2019a). Mason and Nair (2013) report that LSPs' clients e.g., shipper firms, seek flexibility in the logistics services as a valuable competency for addressing uncertainties in their competitive markets. For example, Marken pharmaceutical company manages their highly-fluctuated demand of drugs via an adaptive distribution strategy, supported by UPS (UPS, 2019). In this study, flexibility is defined as "the capability of a logistics system to provide possible changes in the service components adaptive to shippers' business needs at any point in time, before and after the departure of the freight/goods towards the destination" (Khakdaman et al., 2020). Although successful cases of the application of *LSP-driven flexible logistics services* exist (see case examples from DB Schenker (2019) for the retail/apparel industry and DSV (2019b) for automotive industry), the willingness of shipper firms to use LSP-driven flexible services still remain an underexplored area.

While the major factors influencing shipper companies' choice of transportation services have long been identified in the rich literature of freight transportation, only a handful of studies incorporate flexibility of transportation services as a service component. None of these studies has investigated *when and under which circumstances shipper firms are willing to choose the LSP-driven flexible logistics services.* Knowing more about the relevant shippers' characteristics e.g., shipper firms' market environment such as demand volatility, would help LSPs to understand to what extent their customers seek a flexible logistics service to address their challenges. Apart from common internal attributes of a service, designing a quality service package would also need a true understanding of its external attributes (Herrmann et al., 2000). A true understanding of shipper firms' business settings, e.g., levels of uncertainty, risk and vulnerability they face in their (everyday) decision-making for the end-to-end supply chain, as well as internal capabilities e.g., internal supply chain flexibilities such as volume flexibility, would help LSPs to design tailor-made service packages that truly address their customers' needs. We consider LSP-driven flexible services as an external flexibility for the shipper firms' supply chain (usually the focal company of a supply chain), complementary to shippers' internal flexibilities, i.e., volume, product, launch, sourcing and postponement flexibility. This research is among the first studies to explore the impact of these internal supply chain flexibilities on the shippers' choice of flexible transportation services.

In this study, we investigate the willingness of shipper supply chains to utilize flexible logistics services using discrete choice modeling (Ben-Akiva and Lerman, 1985). We executed a comprehensive discrete choice experiment among Global Fortune 500 companies (Fortune magazine, 2017) and major customer firms of the 40 largest global LSPs (Logistics Quarterly

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return management, distribution of goods and logistics management services. In real-word practice it includes 3rd/4th Party Logistics (3PL/4PL) and Integrate Logistics Provider (ILP), among all .

magazine, 2011). The main contributions of this study to the literature are as follows: (i) we identify shipper firms' needs for LSP-driven logistics service flexibility, offering a comprehensive definition of flexible services covering both transportation and inventory management (ii) we show the importance of contextual factors of demand including external and internal factors, such as shippers' own flexibility in the supply chain (iii) we provide empirical evidence from a large, global sample of international supply chain leaders, while previous studies have been limited in their geographical reach.

In the remainder of the paper, research questions along with associated literature review are discussed in section 2. Section 3 presents the research design and method. Empirical results are discussed in sections 4. The last section presents the research's practical implications, conclusions and future avenues.

4.2 Research Background

In freight transportation, shippers usually choose the mode of transportation and LSPs provide the service by booking transportation modes in advance i.e., from their own resources or other carriers (Coyle et al., 2011; Tryfleet, 2017). A recent review of the transportation service and mode choice literature concludes that almost all studies consider transportation cost, time and reliability as the three core attributes of a transportation service, while flexibility is given little or no attention (Reis, 2014). We briefly review the relevant literature that has led to our research questions below.

Jeffs and Hills (1990) were the first who empirically identified transportation flexibility as an important factor in the context of UK firms. Later, Matear and Gray (1993) considered flexibility as quick response to problems and confirmed its importance for shippers in the UK and Ireland. Norojono and Young (2003) defined flexibility as a function of trip frequency and rapid response to the problems. The authors conducted their study among particular shippers in Indonesia that use rail freight services and show the importance of service frequency and rapid response to problems as representatives of service flexibility. INRETS (2000) and Gruppo CLAS (2000) interviewed decision makers in the freight transportation industry and recognized flexibility as an important factor to improve quality of intermodal transportation. Bolis and Maggi (2003) showed that flexibility is important for firms operating in Just-in-Time (JIT) context and within the consumer goods industry in Switzerland and Italy. They highlighted that in modern logistics goods can be stored while moving but the importance of price and time are higher than flexibility. Grue and Ludvigsen (2006) conducted an extensive interview with 246 shipper companies using road and rail transport services. They found transportation flexibility as an important factor in mode choice tasks of the intra-European freight transportation flows. The study by Danielis and Marcucci (2007) considered flexibility as the LSP's ability to change transportation service components before finalizing the booking of the service. Their study highlighted the significance of transportation cost and flexibility in all transportation modes, while this was not the case for transportation time and reliability. Rotaris et al. (2012) incorporate flexibility in their choice experiment for unimodal and intermodal transportation and conducted the study among UK firms. Their results confirm significance of flexibility only at 10% confidence level. Though not included in their choice tasks, Arencibia et al. (2015) defined flexibility as the capability of the LSP to perform last-minute changes in the shipment. In our study, after Khakdman et al. (2020), flexibility is defined as "the capability of the logistics system to provide possible changes in the service components adaptive to the shippers' business needs at any point in time before and after the departure of the freight/goods towards the destination". This flexibility could include changes in the destination, increasing or decreasing the transit time, aggregation or disaggregation of shipment quantity and so on" (see the systematic review by Jafari (2015) for further details). This definition expands those used by Swafford et al. (2006) and Ben-Akiva et al. (2008) and has not been applied in any transportation service choice study yet, although its importance from a wider logistics perspective has already been emphasized by Danielis and Marcucci (2007). In addition, the scale of the current studies is limited to a geographical location and do not reflect a global perspective about the value of flexibility for shipper firms. Furthermore, current mode and service choice literature ignored investigating the choice of shippers in different business and market circumstances to demonstrate when and in what circumstances shippers are willing to utilize competencies of LSP-driven flexible services.

Our first research question (RQ) investigates how shipper firms value the flexibility of transportation services. Thus,

RQ1: *“How strong is the willingness of shipper firms towards LSP-driven flexible logistics services?”*

While we expect the willingness of shipper firms for using flexible services to be significant, we do not anticipate that its importance will be the same for all shippers. Considering a large body of literature about preference heterogeneity of shippers for transportation services, shippers make trade-offs among different attributes of the logistics service based on their supply chain context. The contextual factors could come from shippers’ business and market environment as well as their supply chain capabilities .

With regards to the first contextual category, scholars usually consider two common business settings as volatile business setting (i.e., customized setting) and (relatively) stable business setting (i.e., commoditized setting) (Coltman et al., 2013). Two major types of uncertainties exist for a supply chain operating in the volatile business setting: demand volatility and supply uncertainty (Angkiriwang et al., 2014). In particular, demand volatility is considered as the most important type of supply chain uncertainty (Chung et al., 2004; Pujawan, 2004) and the key challenge of global supply chain managers in order to improve their supply chain competitiveness and sustaining a robust and reliable supply chain (MHL news, 2011). Demand volatility indicates the probabilistic nature of demand realization time, quantity, types and locations. Pujawan (2004) emphasized that demand volatility could be in the form of forecast errors (Schmitt, 1984), changes in current orders of customers (Van Kampen et al., 2010; Wong et al., 2011), uncertainties and changes in the customers’ future demand of product/service mix (Van Donk and van der Vaart, 2005; Khakdaman et al., 2015), and demand fluctuations due to the competitors’ marketing promotions (Wong et al., 2011). Demand volatility is considered as the underlying factor that sometimes creates supply and process uncertainties via its bullwhip effect.

With regards to the first research question, we investigate if shippers are willing to apply LSP-driven flexible services, in which market settings they are willing to do that. Thus,

RQ2. “*How different is the choice of shippers for LSP-driven flexible logistics services when they operate within volatile demand and stable demand business setting?”*

Apart from external business and market setting, internal supply chain capabilities can also influence shippers’ choice of flexible services. For example, Malhotra and Mackelprang (2012) investigated the complementarity of internal and external flexibilities in the supply chain. They emphasize that any investment of the shipper firm in internal modification, mix, or new product flexibility capabilities for improving overall delivery and service level will only pay off when it is accompanied by external supplier and logistic flexibility capabilities and, importantly in our case, vice versa. Our study, therefore, also explores the role of internal supply chain capabilities of shippers on their choice of LSP-driven flexible services.

Martínez Sánchez and Pérez Pérez (2005) identified different type of supply chain capabilities in terms of various flexibility types within a supply chain. Taking their research into account, we considered five operational flexibility types of shipper supply chains i.e., product, volume, postponement, sourcing and new product development (launch) as internal flexibilities of the focal company's supply chain. *Volume* flexibility is the firm's ability to effectively increase or decrease aggregate production in response to customer demand. *Product* (or mix or product-mix) flexibility is the ability of a firm to handle changes in the product mix and product design relative to customer demand. *Launch* (or new product development) flexibility is the ability to rapidly introduce many new products and product varieties. *Sourcing* flexibility is the ability to find another supplier for each specific component or raw material. *Postponement* flexibility is the capability of keeping products in their generic form as long as possible, in order to incorporate the customer's product requirements in later stages (Martínez Sánchez and Pérez Pérez, 2005).

We investigate the role of shipper firms' internal flexibility capabilities (e.g., volume flexibility) in leading them choosing the LSP-driven flexible services in different business environments. Therefore, our third research question is,

RQ3. *"Which shippers' internal supply chain flexibilities mediate the effect of demand-volatile market setting on their choice of LSP-driven flexible logistics services?"*

4.3 Research design and method

To answer our research questions, we implemented a comprehensive choice experiment procedure among major global firms. We built on the Thomson Reuters business classification (2012) to cover different industry types and sampled from global fortune 500 companies (Fortune magazine, 2017) and major customers (firms) of the 40 largest LSPs worldwide (Logistics Quarterly magazine, 2011).

In the next section, we present the design of our choice experiment in the context of synchromodal logistics services and its implementation among global supply chain leader firms.

4.3.1 Experiment design and implementation

We conducted discrete choice experiments (Ben-Akiva and Lerman, 1985) to elicit shippers' preferences and test the impact of firm-difference factors. We designed a comprehensive experiment to test the main effects i.e., willingness to choose flexible services (RQ1), the shipper firm's market setting effect i.e., willingness to choose flexible services in different market setting (RQ2) and the mediator role of shipper firm's internal flexibilities i.e., volume flexibility, on their willingness to use flexible services in different market settings (RQ3). In the choice experiment we considered common attributes of a logistics service such as cost, time, reliability and flexibility. Necessary for the flexible logistics context, we added the *control* attribute, since shipper firms will have to give up their authority for the selection of the transportation mode and route. We also considered Value-added services (VAS) as ancillary services beyond the main logistics service. The definitions of attributes and their levels are depicted in Table 1.

In the next step we needed to consider alternatives with different flexibility grades to investigate trade-offs. Consistent with our definition of flexibility above, we took a mode-abstract approach to our choice problem. In real-world terms this implies flexible operations by LSPs as developed recently under the idea of synchromodal systems (see for further details e.g., Van Riessen et al., 2015; Behdani et al., 2016; Tavasszy et al., 2018). Transportation options are presented as service packages and not as modes of transport. We considered two service alternatives, budget and premium, representing low and high flexibility grades, respectively. We also added the *current option* alternative as the service that the firm is presently using, for shippers that are not willing to use the first two alternatives.

As depicted in Table 1, each synchromodal alternative has 6 attributes with two or three levels. Cost, Time and Reliability are reflected with positive (increase) or negative (decrease) percentage compared to the current logistics service the shipper is using. The attribute levels for Control, Flexibility and VAS are constructed based on the service-level concept for attributes such as flexibility and frequency applied in Danielis and Marcucci (2007) and Arencibia et al. (2015). Consistent with Tongzon (2009), we considered *high level* of control for the current option alternative since 78% of shippers in our sample regarded themselves as the main mode chooser rather than their LSPs. On the other hand, control for synchromodal options has the two service-levels of *Low* and *No control*, the latter meaning that decisions regarding transportation mode and route will be made by the LSP only. *Low level* of control means that the LSP will still have the authority to make decisions regarding transportation mode and route exclusively, but they would consult with shipper, if needed. Flexibility has four service-levels of *High*, *Medium*, *Low* and *None*. *High* flexibility grade means that the logistics service is highly flexible to adapt shipper's required changes in terms of delivery time window, lead time, freight volume (de)consolidation, destination and so on. When the service level goes from high to low, the number of LSP-approved changes to the service components are decreased proportionately, i.e., three, two and one approved changes to the service components for high, medium and low level of flexibility. VAS also has four service-levels of *High, Medium, Low* and *None* which are different in terms of the quantity of value-added services offered to the shipper firm.

The characteristics of the reference alternative i.e., the current service, is defined in a way similar to the studies that elicit responses based on differences with a base case, in line with the DC-RUM approach (see e.g., Arencibia et al., 2015, for a similar case). With regard to cost, time and reliability, the attribute levels of the reference alternative are set to zero (or no change) to be comparable to percentage changes in the synchromodal alternatives (same approach as Arencibia et al., 2015). For example, when a synchromodal alternative time is -20%, that means that the door-to-door transportation time is 20% shorter than that of the current alternative. To follow the same logic for the new variables, the base service level for flexibility and VAS attributes of the reference alternative was set to zero. Shippers were asked to compare current flexibility (and VAS) of the reference alternative with *low, medium and high* level of flexibility (or VAS) of a synchromodal alternative. As stated in previous paragraph about the control attribute, we set it to *high* for the reference alternative, since 78% of shippers indicated at the start of the survey that they are the mode chooser, meaning that they have high control over the modal selection. Thus, when they compare the control attribute of their current service with the synchromodal alternatives, they compare their high level of control with a zero or low level of control in synchromodal services.

Table 1. Logistics service attributes, their definition and levels for alternative choices

Attributes	*New service*		*Current service*
	1(premium)	*2(budget)*	
Door-To-door *Cost* ($): Total amount of money that the shipper pays to the LSP for shipping one TEU (20-foot container) from origin to destination (adapted from Arencibia et al., 2015).	+1% +2% +4%	Current level -1% -3%	Current level
Door-To-door *Time* (days): Duration from the shipment's first origin to the final destination (adapted from Arencibia et al., 2015).	-10% -20% -30%	+20% Current level -20%	Current level
Control (service level): The authority level of the shipper to decide about its preferred transportation mode and route	No control Low	No control Low	Current level

Flexibility (service level): The capability to fulfil shipper's required changes in service components before finalizing the booking of logistics service and even while goods are on their move toward the destination. Examples of these changes include change in delivery time/location, shorten or extend lead times, consolidate or deconsolidate volume/variety via warehouses or cross-docking terminals (mode-volume switch locations).	Medium High	No flexibility Low Medium	Current level
Reliability (% delivery times): The on-time delivery of freight/goods at the destination (adapted from Arencibia et al., 2015).	+10% +15% +20%	-10% Current level +10%	Current level
Value-added services (VAS) (service level): Ancillary services including tracking and tracing, customs, handling and packaging offered by the LSP beyond the main logistics service (Roso et al., 2009).	Medium High	No VAS Low Medium	Current level

In the next step we design the choice set. We applied the *efficient* experiment design method (Kuhfeld, 1994; Rose and Bliemer, 2009) which needs a smaller and therefore more feasible choice sets, instead of a full fractional factorial design that considers all possible choices (Rose and Bliemer, 2009). To construct a D-efficient design experiment, priors for parameters of the model were obtained via a pilot study (Appendix A). Using these priors, we applied the Ngene software (ChoiceMetrics, 2009) to construct an optimal design with 6 choice tasks, conditioned on the two business environments of volatile demand markets and stable demand markets. In the survey, we described the volatile demand market as a business setting in which products have relatively unstable and/or unpredictable demand with shorter life cycle such as a mobile phone. The stable demand market is explained as a business setting where products have predictable and stable demand with long life cycle, e.g., toothbrushes. Table 2 shows an example of a choice task. To avoid a complex choice experiment, we made some assumptions regarding other important attributes of a logistics service such as rules and regulations, frequency, security and safety. We assumed that (i) international rules and regulations permit for flexible logistics arrangements, (ii) the service frequency is the same as the current transportation service of shippers , and (iii) goods will be delivered without any change in damage or loss compared to the shippers' current transportation option. We have communicated the above assumptions to the respondents in the choice experiment survey.

Table 2. Example of a choice task

Attributes	*New service*		*Current service*
	1	*2*	
Door-To-door transportation Cost ($)	+2%	-1%	Current level
Door-To-door transportation Time (days)	-30%	+20%	Current level
Control over transportation mode and route (service level)	Low	No control	Current level
Flexibility to adapt shippers' required changes(service level)	High	Low	Current level
Reliability in on-time delivery (% delivery times)	+10%	Current level	Current level
Value-added services: tracking, customs etc. (service level)	Medium	Medium	Current level

The logistics service choice sets were included in a web-based survey questionnaire using the Surveygizmo platform (Surveygizmo, 2017), in which we firstly introduced transportation options with two clarifying examples about the flexibility offering. Next we asked about the sociodemographic information of the respondents (e.g., position, job function) and their company's operations (e.g., company's industry type, size (number of employees), annual revenue and product types; and supply chain's internal flexibilities such as product flexibility, volume flexibility and so on). Using a Likert scale of 1 to 5 (1:Very low, 2:Low, 3:Medium,

4:High and 5:Very high), we asked respondents to indicate the level of internal flexibilities of their supply chains. Then, we asked them to choose one of their goods/materials that is shipped via containerized transportation and to choose their preferred logistics service in the 6 choice tasks based on the demand volatility/stability characteristics of the chosen product.
To build up our sample we focused on firms whose operations influence the global production and trade of goods, including firms with high overall revenues and firms that manage large freight flows. The former type of companies was found via the Global Fortune 500 list (Fortune magazine, 2017). The latter category was identified via the list of major customer firms of the 40 largest LSPs worldwide (Logistics Quarterly magazine, 2011). This magazine presents between 5 to 10 leading customer shippers for each LSP. Combining these lists and correcting for overlaps, 556 unique companies were identified.
In the next step, we identified whom to contact for the stated preference (SP) experiment. Since moving towards exploiting benefits of LSP-driven flexible services could be a strategic decision that affects long-term contracts of shippers with LSPs, we targeted both top (c-level) and senior/middle level managers responsible for leading various supply-chain-related functions (from procurement to manufacturing to distribution). In total, 2752 managers (e.g., vice-president, director of logistics, supply chain manager) were approached. The final survey was sent via email to 2490 respondents between December 2017 and February 2018 (the remaining 262 executives participated in the pilot study). After three follow-up rounds, 296 usable responses were collected that provided 1776 usable SP observations from 194 unique firms. This implies a response rate of 12% and 39% among individuals and companies, respectively. Table 3 shows the profile of the respondent companies.

Table 3. Demographics of the respondents and their firms

Respondent Position	*%*	*Company size (#employees)*	*%*	*Annual Revenue*	*%*	*Economic sector*	*%*
C-level/Top Management	21%	<99	4%	<$100 Mn	10%	Basic Materials	12%
Senior/Middle Management	79%	100- 249	7%	$100-250 Mn	8%	Consumer Cyclicals	18%
		250-999	7%	$250 Mn-1 Bn	10%	Consumer Non-Cyclicals	19%
		1000-9999	18%	$1-10 Bn	23%	Energy	6%
		10000-49999	28%	$10-50 Bn	27%	Healthcare	11%
		> 50000	36%	> $50 Bn	22%	Industrials	7%
						Technology	16%
						Telecom Services	8%
						Utilities	2%
						Others	0%

4.3.2 Econometric models

In order to analyze the managers' stated preferences, we assumed that they make the choice of LSP-driven flexible services based on their perceived utility for each choice. This assumption is based on the random utility maximization paradigm (McFadden, 1974) and similar to the main portion of applications of discrete choice modeling. We first apply the classic multinomial logit (MNL) model (Ben-Akiva and Lerman, 1985) in which the utility of logistics service choice i perceived by the decision-maker k can be expressed as:

$$U_{ki} = V_{ki} + \varepsilon_{ki}, \quad (1)$$

where

$$V_{ki} = \beta_1 CONTROL_{ki} + \beta_2 COST_{ki} + \beta_3 FLEXIBILITY_{ki} + \beta_4 RELIABILITY_{ki} + \beta_5 TIME_{ki} + \beta_6 VAS_{ki}. \quad (2)$$

In (1), V_{ki} is the systematic part of the U_{ki} and represents a function of different observed attribute levels of the logistics service shown in (2), and ε_{ki} is the error term representing unobserved factors by the analyst as well as randomness in the choices of individual *k*. The MNL model assumes independent ε_{ki}'s across different choices and follows a Gumbel distribution with location parameter 0 and scale parameter 1 (McFadden, 1974). In (2), β_i's are coefficients for the alternative specific variables, and they are the same across all individuals. The boldface variables are vectors of independent variables for alternative *i* of the decision-maker *k*. Given a choice set S, the probability of selecting logistics service choice *i* is

$$P_i = \frac{exp(V_i)}{\sum_{s \epsilon S} exp(V_s)} \quad (3)$$

While MNL assumes fixed parameters across individuals, Mixed logit (ML) model assumes individual-specific parameters to capture within-subject correlation resulting in recognizing taste heterogeneity *among* individuals. The individual-specific parameters have the same choice probabilities like Equation (3) (with individual-specific β_i's) and are assumed to draw from a probability distribution with a joint density function $f(\beta, \theta)$ where θ specifies the distribution of $\beta = (\beta_1, \dots, \beta_6)$ as parameters to be estimated. In the case of a normal distribution, the β_is are the means, and the significance of their variance accounts for existence of heterogeneous preferences. In our modeling, we do not need to include an intercept term, e.g., γ_i in (2); because of the abstract mode approach, no alternative-specific effect or "brand effect" is expected (Train, 2009). However, this is not the case for the *current option* alternative which needs an intercept variable to model its utility function.

Interaction Model

Apart from direct effects, interaction effects can be applied to identify the impact of shippers' specific characteristics on their choice. For instance, the volatility of the market demand will impact shippers' decisions on the choice of flexible services. Taking products with volatile demand characteristic as an example, the expected utility including demand-volatile market interaction terms can be represented as:

$$V_{ki} = \beta_1 CONTROL_{ki} + \beta_2 COST_{ki} + \beta_3 FLEXIBILITY_{ki} + \beta_4 RELIABILITY_{ki} + \beta_5 TIME_{ki} + \beta_6 VAS_{ki} + \alpha_1 CONTROL_{ki} DV_k + \alpha_2 COST_{ki} DV_k + \alpha_3 FLEXIBILITY_{ki} DV_k + \alpha_4 RELIABILITY_{ki} DV_k + \alpha_5 TIME_{ki} DV_k + \alpha_6 VAS_{ki} DV_k. \quad (4)$$

where DV_k stands for demand volatility of the shipper *k*, and the interaction coefficients, α_i, capture the potential effect of shipper's demand volatility on their perceived utility of a flexible service alternative. It is clear that the impact of shippers' other supply-chain-specific variables could be investigated in the same way.

Mediation Model

To examine how an independent variable (e.g., demand volatility) exerts its impact on a dependent variable (e.g., choice of flexible services), a commonly employed test for mediation process is from Preacher et al. (2007). We investigate if the effect of shipper's demand volatility (our independent variable) on their perception of flexible logistics service (our dependent variable) is mediated by the shipper's internal supply chain flexibility (our proposed mediator) e.g., volume flexibility. In order to test for mediation, we need to perform three steps: (i) assessing the impact of independent variable on the mediator variable , (ii) regressing the dependent variable on both independent variable and the mediator variable, and (iii) testing the indirect effect of the independent variable on the dependent variable via the mediator variable by applying the previous two steps (Preacher et al., 2007). The first and second steps are shown in models (5) and (6), respectively.

$$Volume\_flexibility_k = \gamma_0 + \gamma_1 DV_k + \varepsilon_k \tag{5}$$

$$V_{ki} = \beta.Main_{effects_k} + \alpha_1 FLEXIBILITY_{ki} DV_k + \alpha_2 FLEXIBILITY_{ki} Volume\_flexibility_k. \tag{6}$$

In (5), $\gamma_1$measures the impact of shipper's demand volatility on their decision to build volume flexibility in their supply chain. This effect could be easily measured via a simple linear regression. Model (6) is an MNL interaction model similar to (4), in which β is the coefficients' vector capturing the main effects, and α's are interaction coefficients. Together, γ_1 and α_2 examine the existence, strength and significance of indirect effect of DV_k (shipper's demand volatility) on V_{ki} (perceived utility of having a LSP-driven flexible services) via $Volume\_flexibility_k$ (volume flexibility of shipper's supply chain). According to Preacher et al. (2007), $\hat{\gamma}_1\hat{\alpha}_2$ indicates the point estimate of this indirect effect which can be tested for statistical significance in two ways. The first way is applying a z-test in which the standard error of the indirect effect can be approximated by

$$SE_{\hat{\gamma}_1\hat{\alpha}_2} = \sqrt{\hat{\gamma}_1{}^2 s_{\alpha 2}^2 + \hat{\alpha}_2{}^2 s_{\gamma 1}^2} \tag{7}$$

In (7), s_γ^2 and s_α^2 represents the standard error of the model coefficients γ and α, respectively. Secondly, bootstrapping can be applied to derive a confidence interval of the indirect effect. This confidence interval, if it does not include zero, indicates the significance of the mediation model. We applied both methods in our data analysis.

Latent Class analysis

While the ML models already address the three research questions, it is valuable to additionally consider a Latent Class (LC) modeling approach (Kamakura and Russell, 1989) to capture unobserved heterogeneity and the potential impact of mediators. The basic assumption in LC is that the underlying heterogeneity in the parameters is discrete rather that continuous. Furthermore, LC modeling allows allocating individuals to classes, which allows a better behavioral interpretation of results (Greene and Hensher, 2003; Hess et al., 2008) from both a policy and from a marketing perspective. We estimate the latent class model using the approach of Kamakura and Russell (1989). In order to determine the optimal number of classes, we applied two common fitness measures: the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) (Bhat, 1997; Boxall and Adamowicz, 2002) as follows.

$$AIC = -2LL + 2M \tag{8}$$

$$BIC = -2LL + M \ ln \ N \tag{9}$$

where LL is the convergence value of log-likelihood function, expressing the fit with modelled and observed choice probabilities; M is the number of parameters in the model and N is the sample size. According to Walker and Li (2007), BIC is superior to AIC since BIC is stricter on imposing a penalty for a larger number of parameters in the LC models.

4.4 Empirical results

4.4.1 Results of the MNL and ML models

The results of estimating the MNL and ML models (using Biogeme[2] software release 2.0 (Bierlaire, 2003)) are shown in Table 4 and Table 5, respectively. In the MNL model, all parameters have the expected sign (i.e., positive utilities for increases in control, flexibility, reliability and VAS, and negative utilities for increases in cost and time). The estimated values of cost, time, control and flexibility are significant. The estimated value of the alternative-specific constant (ASC) for the current transportation service is positive and significant, indicating that some shippers may be biased towards their current choice. The estimated value of reliability is not significant at 10% confidence level (although it is significant at 13% level). This could be due to the small range of attribute levels defined for reliability that did not attract (a large proportion of) decision-makers appropriately. However, the LC analysis shows that the estimated value of reliability is significant for a large-size class of shippers (see Section 4.2 for more details).

Table 4. MNL estimation results for the main study

Variable	Main effects model	
	Coefficient	Std. error
Current option	0.435***	4.21
Cost	-10.28***	-5.26
Control	0.863***	2.87
Flexibility	0.382***	3.23
Reliability	0.692	1.50
Time	-1.047***	-4.58
VAS	0.153	1.10
Number of responses	1776	
Number of respondents	296	
Log-likelihood	-1914.267	
McFadden's R^2	0.127	

Note. ***p<0.01, **p<0.05 and *p<0.1 for statistical significance

Table 5 shows the results of the estimation of the main effects ML model. All parameters have the expected sign (e.g., increases in time and cost reduced utilities, and increases in control, flexibility, reliability and VAS raised utilities). While cost, time and control are significant attributes of the logistics service choice, our attention and interest are towards the significant role that *flexibility* plays in the choice of a logistics service. This addresses the RQ1. The relative importance of attributes demonstrates that apart from cost and time as main classic contributors to the utility of shipper firms, flexibility of the logistics service is emerging as the third highest contributor to the shippers' utility. The estimated value of the alternative-specific constant (ASC) for the current transportation service is significant and positive, quantifying the inertia of shippers towards changing their current logistics services or transportation modes.

[2] We applied Biogeme standard settings that are quite common and well documented. For instance, Biogeme assumes a normal distribution to estimate the random parameters in ML models. We used 1000 Hess-Train draws as one of the most common approaches.

Table 5: Coefficients for the Mixed Logit model

Variable	Main effects model		
	Coefficient	Std. error	Relative importance
Current option	0.423	0.129***	16%
Control	0.901	0.203***	7%
Cost	-10.4	2.05***	28%
Flexibility	0.363	0.136***	14%
Reliability	0.664	0.482	
Time	-1.09	0.277***	21%
VAS	0.141	0.152	
Standard Deviation for random effects			
Flexibility	0.677	0.332*	
Number of responses	1776		
Number of respondents	296		
Log-likelihood	-1673.26		
McFadden's R^2	0.237		

***p<0.01, **p<0.05 and *p<0.1 for statistical significance

Although the main effects model reveals shippers' preference for flexible services, it cannot help understanding when they are willing to exploit it. Conditioning the choice tasks on volatile and stable markets enables us to identify whether supply chain managers perceive different utilities under these circumstances. In the interaction model, we find that shippers operating in volatile markets are predominantly willing to apply flexible services (see Table 6 where the interaction term is significant). On the other hand, shippers operating in stable markets favor an undifferentiated logistics service that is efficient enough to addresses their logistical needs (see Table 7). The difference between these two models highlights the critical role that the *context* plays in the choice of flexible services.

Table 6: Interaction model for demand volatility and the choice of flexible services

Variable	Main effects model		Model with interactions	
	Coefficient	Std. error	Coefficient	Std. error
Current option	0.423	0.129***	0.399	0.125***
Control	0.901	0.203***	0.592	0.203***
Cost	-10.4	2.05***	-10	2.14***
Flexibility	0.363	0.136***	0.495	0.133***
Reliability	0.664	0.482	0.458	0.519
Time	-1.09	0.277***	-1.12	0.257***
VAS	0.141	0.152	0.315	0.163**
Demand volatility * Current option			-0.0299	0.125
Demand volatility * Control			0.234	0.335
Demand volatility * Cost			1.15	2.14
Demand volatility * Flexibility			0.246	0.119**
Demand volatility * Reliability			-0.363	0.519
Demand volatility * Time			-0.18	0.257
Demand volatility * VAS			0.335	0.163**
Standard Deviation for random effects				
Flexibility	0.677	0.332**	0.561	0.219**
Number of responses	1776		1776	
Number of respondents	296		296	
Log-likelihood	-1673.26		-1655.715	
McFadden's R^2	0.237		0.245	

***p<0.01, **p<0.05 and *p<0.1 for statistical significance

Table 7: Interaction model for stable demand and the choice of flexible services

Variable	Main effects model		Model with interactions	
	Coefficient	Std. error	Coefficient	Std. error
Current option	0.423	0.129***	0.399	0.125***
Control	0.901	0.203***	0.592	0.203***
Cost	-10.4	2.05***	-10	2.14***
Flexibility	0.363	0.136***	0.495	0.133***
Reliability	0.664	0.482	0.458	0.519
Time	-1.09	0.277***	-1.12	0.257***
VAS	0.141	0.152	0.315	0.163**
Stable demand * Current option			0.0299	0.125
Stable demand * Control			-0.234	0.335
Stable demand * Cost			-1.15	2.14
Stable demand * Flexibility			-0.246	0.119
Stable demand * Reliability			0.363	0.519
Stable demand * Time			0.18	0.257
Stable demand * VAS			-0.335	0.163**
Standard Deviation for random effects				
Flexibility	0.677	0.332**	0.402	0.281
Number of responses	1776		1776	
Number of respondents	296		296	
Log-likelihood	-1673.26		-1655.715	
McFadden's R2	0.237		0.245	

***p<0.01, **p<0.05 and *p<0.1 for statistical significance

The collected data about the characteristics of the shippers' supply chain in the first part of the survey allowed us to investigate whether the impact of shippers' demand volatility on their choice of flexible services is driven by their internal supply chain flexibilities such as volume flexibility. As stated in Section 3.1, we measured the level of internal flexibilities of shipper firms using a Likert scale of 1 to 5 (1:Very low, 2:Low, 3:Medium, 4:High and 5:Very high). For ease and robustness of interpretation, we considered higher scores in the volume flexibility measures (i.e., Likert scales of 4 and 5) as an indicator of having enough volume flexibility in shippers' supply chain. Doing so, we categorized respondents to two groups of enough (or high) volume flexibility and not-enough (or low) volume flexibility and coded them with +1 and -1, respectively, in the dataset for model estimation. Table 8 (Model with interactions (1)) shows the interaction model where only demand volatility and volume flexibility have a significant impact on the managers' choice of flexible services. In particular, when controlling for volume flexibility, shippers operating in volatile (versus stable) markets have a greater preference for flexibility in their logistics service. Besides that, when controlling for a volatile market setting, managers with volume flexibility in their supply chain nodes experience higher utility when exploiting LSP-driven flexible services.
Unlike volume flexibility, other internal supply chain flexibilities, such as product, launch, sourcing and postponement flexibilities do not play a significant role in managers' decision towards LSP-driven flexible services (see Appendix B). As an illustration, the interaction model (2) in Table 8 shows an example of including interaction terms with product flexibility resulting in insignificance of the interaction terms (see further discussions in Section 6 and Appendix B).

Table 8. Interaction model for demand volatility and volume flexibility

Variable	Main effects model		Model with interactions (1)		Model with interactions (2)	
	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
Current option	0.423	0.129***	0.4	0.125***	0.292	0.129**
Control	0.901	0.203***	0.591	0.203***	0.544	0.211***

Cost	-10.4	2.05***	-10	2.15***	-8.99	2.23***
Flexibility	0.363	0.136***	0.497	0.134***	0.462	0.14***
Reliability	0.664	0.482	0.454	0.52	0.532	0.547
Time	-1.09	0.277***	-1.12	0.257***	-0.972	0.266***
VAS	0.141	0.152	0.316	0.164**	0.291	0.169*
Demand volatility * Current option			-0.0243	0.125	-0.048	0.126
Demand volatility * Control			0.213	0.338	0.19	0.339
Demand volatility * Cost			1.06	2.16	1.35	2.17
Demand volatility * Flexibility			0.223	0.134*	0.212	0.125*
Demand volatility * Reliability			-0.349	0.523	-0.333	0.524
Demand volatility * Time			-0.197	0.259	-0.157	0.26
Demand volatility * VAS			0.358	0.235	0.356	0.165**
Volume flexibility * Current option			-0.0433	0.105	0.0756	0.113
Volume flexibility * Control			0.176	0.308	0.281	0.331
Volume flexibility * Cost			0.703	1.98	-0.613	2.14
Volume flexibility * Flexibility			0.186	0.102*	0.235	0.129*
Volume flexibility * Reliability			-0.121	0.468	-0.212	0.5
Volume flexibility * Time			0.117	0.233	-0.0791	0.251
Volume flexibility * VAS			-0.192	0.142	-0.168	0.153
Product flexibility * Current option					-0.362	0.116***
Product flexibility * Control					-0.295	0.34
Product flexibility * Cost					3.74	2.2*
Product flexibility * Flexibility					-0.134	0.134
Product flexibility * Reliability					0.265	0.523
Product flexibility * Time					0.56	0.257**
Product flexibility * VAS					-0.082	0.156
Standard Deviation for random effects						
Flexibility	0.677	0.332**	0.276	0.108**	0.283	0.208
Number of responses	1776		1776		1776	
Number of respondents	296		296		296	
Log-likelihood	-1673.26		-1646.94		-1644.75	
McFadden's R2	0.237		0.249		0.250	

***p<0.01, **p<0.05 and *p<0.1 for statistical significance

As explained in Section 3.2, we need to test for the mediation effect to address RQ3. Firstly, we applied a simple linear regression (i.e., Ordinary Least Squares regression) to test the direct impact of shippers' demand volatility on their volume flexibility. Table 9 (direct effects) shows the results where shippers operating in demand-volatile markets are more in need of building enough volume flexibility in their supply chain. This is supported in the literature by Jack and Raturi (2002), who argue that the main reason and driver of building volume flexibility in a supply chain is existence of volatile demand in the market. Otherwise, supply chain managers do not need to invest on building volume flexibility capabilities when demand is stable. In the second step, we tested the impact of shippers' volume flexibility on their perceived utility of choosing flexible services. As Table 9 demonstrates, the impact of shippers' volume flexibility is significant. The last step is testing for mediation via z-test and bootstrapping. As shown in the second part of Table 9 (indirect effects), the z-test is applied to test the significance of the indirect effect of shippers' demand volatility on their choice of flexible services. The bootstrapping procedure is used to assess the confidence interval for the indirect effect. Using 1000 bootstrapping iterations, the 90% confidence interval of [0.001, 0.046] is obtained for the indirect effect. Since it does not include zero, it shows the significance of the mediation model consistent with the z-test in Table 9. Therefore, we can conclude that the impact of shippers' demand volatility on their perceived utility of flexible service choice is mediated by their volume flexibility in their supply chain. This mediation is partial since the significant indirect effect of shippers' demand volatility on their choice of flexible services (i.e., coefficient of

0.023 in Table 9) could not change the significance of their direct effect (i.e., coefficient of 0.223 in Table 8) to insignificant.

Table 9. The mediation model

	Coefficient	Std. error
Direct effects		
Demand volatility on Volume flexibility	0.125	0.026***
Volume flexibility on Choice of flexible logistics service	0.186	0.102**
Mediation (indirect effects)		
Demand volatility → Volume flexibility→Choice of flexible logistics service	0.023	0.0136*

Note: the adjusted R^2 for the direct effect of Demand volatility on Volume flexibility is 0.82.
***p<0.01, **p<0.05 and *p<0.1 for statistical significance

4.4.2 Results of the Latent class model

We estimated the latent class model using the Latent Gold software v.5.1 (Vermunt and Magidson, 2005). We started estimating models with one to five classes. The model fit of the various models are displayed in Table 10. As expressed in Section 3.2, we need to consider models with the lowest possible AIC and BIC measures to determine the appropriate number of latent classes. When the number of classes increases in Table 10, the AIC decreases, while BIC increases after the third class. Therefore, we choose the latent class model with three classes, which has the lowest BIC and a decent model fit, i.e., McFadden's R^2 of 0.374.

Table 10. Model fit for the latent class choice models

Criteria	Number of classes				
	1 (MNL)	2	3	4	5
Log-likelihood at convergence	-1914.2	-1636.5	-1580.3	-1544.5	-1518.2
McFadden's R^2	0.127	0.2617	0.3744	0.4122	0.4279
Number of parameters	7	21	35	49	63
Number of observations	1776	1776	1776	1776	1776
Akaike information criteria (AIC)	3842.54	3315.13	3230.67	3186.99	3162.41
Bayesian information criteria (BIC)	3868.37	3392.63	3359.83	3367.82	3394.90

We investigated the impact of demand volatility and five internal flexibility types by considering them as covariates in the LC models (see estimation results in Table 11). Taking covariates into account helps clarifying the variability in class memberships by evaluating how the probability of belonging to each class depends on different covariates. The dummy variables of demand volatility and five internal flexibility types are used as segment membership variables. All covariates are nominal in which the data categorized in two groups, e.g., Demand volatility: having demand volatility and not having demand volatility (or having demand stability), coded with +1 and -1, respectively; Volume flexibility: high volume flexibility and low volume flexibility, coded with +1 and -1, respectively. Other internal flexibilities also coded in the same way as Volume flexibility. The reference category for demand volatility is demand stability and, for each of the five internal flexibilities is low internal flexibility, e.g., low volume flexibility.

Table 11. Estimation results for the MNL and latent class models

	MNL		LCM					
			Class1		Class2		Class3	
	Estimate	z-value	Estimate	z-value	Estimate	z-value	Estimate	z-value
Class size (%), n=1776			39.6		39.1		21.3	
Taste parameter estimates								
ASC $_{\text{Current option}}$	0.435***	4.21	-0.03	-0.05	-2.44**	-2.51	2.11***	3.14
Cost	-10.28***	-5.26	-28.1***	-5.32	-7.74**	-2.10	-4.75	-1.14
Control	0.863***	2.87	2.37***	2.92	2.81**	2.02	-0.57	-0.83
Flexibility	0.382***	3.23	0.07	0.28	1.56***	2.73	0.14	0.47
Reliability	0.692	1.50	0.24	0.25	3.72***	3.67	-4.48***	-2.94
Time	-1.047***	-4.58	-0.25	-0.45	-4.32***	-2.72	1.01*	1.83
VAS	0.153	1.10	0.29	0.94	-0.82	-1.06	0.41	1.28
R^2 (%)	12.7		30.6		39.5		31	
Class membership functions								
Demand volatility			-0.556	-1.39	1.21***	2.70	Base segment	
Internal flexibility types								
Volume flexibility			0.145	0.38	-0.299**	-1.97		
Product flexibility			0.595	1.45	0.2977	0.66		
Postponement flexibility			-0.145	-0.35	0.1537	0.34		
Launch flexibility			-0.103	-0.25	0.2549	0.56		
Sourcing flexibility			0.162	0.38	0.4133	0.87		
Intercept			-0.814	-1.4	0.259	0.43		

Note. *p<0.1, **p<0.05 and ***p<0.01 for statistical significance

Table 11 shows three distinct classes of shippers and their class membership functions relevant to demand volatility of their products and five internal flexibility types in their supply chain. A large shipper segment (approximately 40% of the population) is the second class of shippers, i.e., Class2, in which firms are distinguishably willing to use flexible transportation services, i.e., the coefficient of flexibility is significant and has the expected sign. Apart from flexibility, the coefficients of cost, time, control and reliability are also significant and have the expected sign indicating that this class of shippers is looking for a quality transportation service with competitive price. The insignificant coefficient of VAS reveals that shippers in the second class are not looking for value-added services, as their desire for basic service performance are more important or have not yet been met. The coefficient of the alternative-specific constant of the current transportation option ($ASC_{\text{Current option}}$) is negative and significant showing potential dissatisfaction of these shippers with the existing transportation services. Looking into the class membership functions, we can identify that the probability of belonging to the second class of shippers is higher for firms operating in demand-volatile markets, i.e., significant coefficient of demand volatility, and firms with high volume flexibility in their supply chains, i.e., the significant coefficient of volume flexibility. However, the insignificance of coefficients of the other internal flexibilities shows that they are not distinguishable for firms of the second class. The results are in line with our findings in Section 4.1.

Unlike the second class of shippers, the first and the third classes are not willing to use flexible transportation services. While the first class of shippers (class size of 38.1%) are very sensitive to the cost and control attributes of the transportation service, i.e., significant coefficients with expected signs, the third class are willing to continue using their current transportation services, i.e., significant coefficient of $ASC_{Current\ option}$. It seems that the first and the third shipper classes do not differentiate their usage of transportation services based on their demand volatility and internal flexibility capabilities, i.e., insignificant coefficients in the class membership functions. One of the important bias signs in a discrete choice experiment is the presence of significant ASC coefficients, usually originating in non-trading behavior of respondents, i.e., selecting a particular alternative in all choice situations. Such behavior could indicate a reluctance to consider (a) particular alternative(s), misunderstanding or fatigue during the stated choice exercise or political/strategic behavior towards particular alternative(s) (Hess et al. 2010). To examine how this bias affects our results, we investigated our dataset, which shows that only 3% of respondents selected the first alternative in all choice tasks, against 1.3% and 12.5% for the second and third alternatives, respectively. These figures still fall well within DCE's acceptable standards (Johnson et al. 2007), so it is unlikely that respondents were confused by the choice modelling exercise. Although these data could be removed from the analysis, some scholars suggest keeping them (e.g., Lancsar and Louviere, 2006) if they fall within acceptable DCE standards and within utility maximization assumption. We prefer to keep this data in our analysis, since, based on our investigation, they mainly demonstrate utility maximizing behavior of our respondents (Hess et al. 2010).

Another important bias is *self-selection* bias which happens because of incomplete observational data due to sampling from a population. Restricting data analysis to a sample of respondents (not the whole population) leaves us with a *self-selected* sample (Dubin and Rivers, 1989). Using a self-selected sample to find relationships between variables may not be sufficient to establish causality (Mokhtarian and Cao, 2008) and could lead to misleading and biased interpretations (Dubin and Rivers, 1989). To robustly infer causality, at least four kinds of evidence are needed: association (a statistically significant relationship), causal mechanism (a logical explanation showing why the supposed cause should produce the observed effect), time precedence (cause precedes effect), and nonspuriousness (a relationship that cannot be attributed to another variable) (Schutt, 2004; Singleton and Straits, 2005; Mokhtarian and Cao, 2008).

We think that self-selection bias is not a major concern in our study because of the following evidences needed for a robustly causality inference. Taking our dataset and results into account, the evidence for association is proved statistically significant relationships throughout Section 4. The causal mechanism exists since one of the main reasons for developing and utilizing flexibility in supply chains is existence of uncertainties such as demand volatility (see Tachizawa and Thomsen, 2007; Angkiriwang et al, 2014; Sreedevi and Saranga, 2017, among all). Regarding time precedence, it is clear from the operations management literature that until the causes, e.g., demand volatility, have not happened the effects, e.g., building flexibility capabilities, would not happen since building flexibility capabilities in transportation and supply chain are quite time-consuming and capital-intensive (see for example, Jack and Raturi, 2002, among all). It is also obvious that flexibility capability could not cause demand volatility. Considering nonspuriousness, since addressing uncertainties such as demand volatility needs to make a change in the supply chain, e.g., change delivery location/time/volume, by definition the only attribute that can support changes in transportation service components is flexibility.

We also investigated our dataset with respect to the self-selection bias. According to Thomson Reuters business classification (2012) there are 9 relevant business sectors to our study. Having respondents from all 9 sectors (see Table 3) shows none of them are missed in our dataset. Considering the fact that our respondents are from Global fortune 500 companies which are often industry leaders, we think that the preferences of these global leader shippers will be a good representative of the preferences across their industry. Therefore, we think that having a high self-selection bias is not likely with respect to the results of this study.

4.4.3 Willingness to pay measures

After addressing our research questions using both ML and LC models in Sections 4.2 and 4.3, it would be useful for LSPs to know about willingness to pay (WTP) of shippers for different attributes of the transportation service. Similar to the approach adopted by Arencibia et al. (2015) and Khakdaman et al. (2020), we measure WTP to offer guidelines to LSPs who are willing to improve their transportation services, and to policymakers who evaluate different improvement policies. WTP is the ratio of marginal utility of the attribute and the marginal utility of the transportation cost (McFadden, 1981). We applied the Latent Gold software to obtain the WTP for each attribute in the MNL and LC models, as shown in Table 12.

Table 12. Willingness to pay and its confidence interval for the MNL and LC models

Attribute	MNL		LCM			
			Class1		Class2	
Control (€/service level)	8.39**	[1.63 ; 15.15]	8.45***	[2.12 ; 14.78]	36.38	[-23.95 ; 96.71]
Flexibility (€/service level)	3.71***	[1.15 ; 6.28]	-	-	20.19**	[1.16 ; 39.22]
Reliability (€/delivery times)	-	-	-	-	48.13**	[4.66 ; 91.61]
Time (€/day)	10.17***	[5.06 ; 15.29]	-	-	55.8	[-22.28 ; 133.89]

Note. Confidence intervals of WTP in [;], *p<0.1, **p<0.05 and ***p<0.01 for statistical significance

While point estimates for WTP are informative, it is important to measure confidence intervals for each point estimate, in particular for random variables of the ML model, i.e., Flexibility. In order to calculate the confidence intervals for WTP, we applied the *Delta* method (see further details in Hole, 2007) as a suitable approach for studies with large sample sizes, i.e., N>100 (Hole, 2007 and Gatta et al., 2015). The main assumption of the Delta method is that WTP is normally distributed and thus symmetrical around its mean. Hole (2007) emphasized that when a model is estimated using a large sample and the estimate of the coefficient for the cost attribute is sufficiently precise, it is likely that WTP is approximately normally distributed. Gatta et al. (2015) argued that the normality assumption of the Delta method limits its accuracy for small sample sizes, however, they showed that when sample size is large and coefficient of variation for the cost coefficient is low, i.e., as in our study, the Delta method also produces similar results to other methods, e.g., the Fieller method or Bootstrap.

We calculated the WTP figures and the associated confidence intervals only for parameters that are significant and have the expected sign. When the confidence interval does not include zero for an attribute, a positive WTP is likely to exist among shippers. Besides that, we assumed that the average shipment cost of one TEU container is €100. Taking the MNL model into account, the average WTP for a day's reduction in the end-to-end transportation time is estimated at €10.17 ranging between €5.06 and €15.29. Shippers' WTP for control and flexibility is approximately €8.39 [1.63;15.15] and €3.71 [1.15;6.28], respectively, for one level enhancement of control and flexibility. Regarding the latent class model, Shippers in Class1 are willing to pay €8.45 [2.12;14.78] for control attribute for one level of service improvement. Shippers in Class2 are willing to pay €20.19 [1.16;39.22] and €48.13 [4.66;91.61] for flexibility and reliability, respectively, for every unitary improvement in these service dimensions. Compared to the other latent classes, shippers in Class2 indicate the highest intention for WTP for flexible transportation services.

4.5 Practical implications and Conclusions

4.5.1 Main findings

In this research we discussed flexible logistics services as one of the service requirements in modern era of logistics services. We conducted a large experiment among global shipper companies to understand how they appreciate flexibility of freight logistics services. We demonstrated how their choice of LSP-driven flexible services differs when they operate in markets with highly volatile demand, from the situation in stable markets. Having a better understanding of customers' requirements in different business conditions will support LSPs in the design of customized logistics service packages, with the potential of improving their and their client's competitive advantage. We also demonstrated the influence of shippers' internal supply chain flexibility on their choice of flexible logistics services. While shippers with volume flexibility are willing to use LSP-driven flexible services as a supplementary external flexibility, the ones with other internal flexibilities i.e., product, launch, sourcing and postponement, do not seem to be willing to utilize flexible services.

4.5.2 Practical implications

The willingness of LSPs' customers to use flexible services especially for volatile markets highlights new opportunities for LSPs to develop and offer service packages with different levels of flexibility. Identifying seasonal products of their customers, for instance, LSPs can provide service packages with higher flexibility levels to address highly fluctuating demand of shippers' seasonal products. The results of the LC analysis show that a certain degree of willingness among specific leading shipper firms exists to derive value from flexible transportation services. Since main characteristics of these shippers are operating in demand-volatile markets and having high volume flexibility in their supply chains, LSPs managers could design tailor-made flexible services based on the level of the internal volume flexibility in their customers' supply chain. In the long run, the approach of LSPs' customers to use traditional ways of addressing demand volatility, e.g., high inventory levels, could shift towards utilizing premises of LSP-driven flexible services, when LSPs provide accurate flexible logistics services.

In order to make the flexibility capability in the logistics services, LSPs may need to change their business operations to adapt to customers' changing preferences. To this end, LSPs may need to have access to lots of locations to be able to expand their logistics network whenever needed. Instead of owning and managing many locations, LSPs can create an extensible network with operators providing on-demand warehousing and fulfilment services with available capacity in every market location (FLEXE, 2020). This allows LSPs to (1) add locations to improve the last mile of delivery for their shipper customers, (2) secure additional capacity to address shippers' peak-season requirements or new product rollouts and (3) resolve shippers' unexpected inventory overflow situations. In addition to locations, LSPs may also need to have access to different modes of transportation to improve utilization of transportation capacity and to address extreme weather events and political decisions regarding international free trade agreements (e.g., lowering the capacity of international shipping) by switching between different modes of transportation in real-time. Having access to multiple transportation modes can be achieved by using services of different transport operators, complementing the LSPs' own transport modes and services.

Offering flexible transportation services will have consequences for the business models of LSPs. Flexibility in logistics services will become more relevant in the value proposition of LSPs (FLEXE, 2020). Operationalizing flexible services will need changing three major functions in the business model: service package design, revenue management, and supply and capacity planning. The service design function should introduce different levels of flexibility to address the requirements of various customer segments. In their revenue management systems LSPs will need to differentiate prices for different flexibility service levels. This price differentiation could be based on shippers' WTP for flexibility and range between the minimum and maximum points in the WTP's confidence interval. Price differentiation should also be aligned with the value that flexibility creates for customers to ensure that LSPs' pricing strategy is appropriately competitive in the market of freight transportation services. Supply and capacity planning will need to be equipped with sophisticated resource allocation algorithms, to enable fulfilling changes in orders while maintaining control over the utilization of resources. In addition, shipper firms could also establish collaborative practices with their LSPs. Many initiatives have been taken recently to improve supply chain responsiveness in volatile markets, resulting in strategic volume flexibility and mix flexibility. Shipper firms could initiate different levels of partnership with LSPs as suppliers of the logistics function, to strengthen their delivery/logistics flexibility (Purvis et al., 2014).

Insights provided in this research could be used by public policymakers to make long-term decisions for improving flexibility capabilities of national and international transportation networks. As logistics flexibility is an important service requirement of a large share of shippers, existing infrastructure and service investments should be enhanced, to enable LSPs to provide flexible services. This could be done by establishing scalable warehousing locations and transportation modes as well as providing advanced logistics information systems. Finally, provision and utilization of flexible logistics services at the international scale also needs proper adaptation of the international rules and regulations.

4.5.3 Future research directions

This study opens several new research opportunities for enrichment of the knowledge on service choice in transportation and logistics. Willingness of shipper firms towards flexibility of logistics services could be assessed for specific industry types, e.g., retail and apparel. Choice studies could be conducted to understand the impact of other business circumstances, e.g., supply and process uncertainty, on the choice of flexible services. These dynamics in service choice could be compared for different industries to highlight which ones need higher levels of flexibility. Requirements and obstacles of global LSPs in order to be able to provide flexible services for shippers also could be comprehensively identified.

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Appendices

Appendix A. The MNL estimation results for the pilot study

We conducted a pilot study to get priors for designing our D-efficient design experiment. We developed an orthogonal fractional factorial design (Kocur et al., 1982) for the pilot study in which 18 choice tasks are blocked in 2 choice sets, where each one contained 9 choice tasks and was included in a web-based survey using an online survey platform (Surveygizmo, 2017). Each survey is sent via email to 131 respondents which were selected from 56 randomly selected firms out of the list of 556 firms (in total 262 executives were contacted). We received 19 and 22 complete responses from pilot survey 1 and 2, respectively (average response rate of 15.6%). Aggregating the results, 19 choice sets each one containing 18 complete choice tasks

(342 observations) are applied to estimate model parameters. The results of estimating the MNL model (using Biogeme software release 2.0 (Bierlaire, 2003)) on the pilot study data, is shown in Table A1.

Table A1. Estimation results for the pilot study (orthogonal design)

Variable	Main effects model	
	Coefficient	Std. error
Current option	0.591***	3.11
Control	0.789**	1.98
Cost	-10.1***	-5.39
Flexibility	0.102*	1.69
Reliability	0.328***	3.01
Time	-1.06*	-1.74
VAS	0.153	1.36
Number of responses	342	
Number of respondents	38	
Log-likelihood	-338.448	
McFadden's R^2	0.138	

Note. ***p<0.01, **p<0.05 and *p<0.1 for statistical significance

Appendix B: insignificance of four internal flexibility types with demand volatility

Table B1. The interaction model for demand volatility and product flexibility

Variable	Main effects model		Model with interactions	
	Coefficient	Std. error	Coefficient	Std. error
Current option	0.423	0.129***	0.297	0.129***
Control	0.901	0.203***	0.562	0.21***
Cost	-10.4	2.05***	-9.03	2.23***
Flexibility	0.363	0.136***	0.485	0.139***
Reliability	0.664	0.482	0.507	0.545
Time	-1.09	0.277***	-0.972	0.265***
VAS	0.141	0.152	0.275	0.168
Demand volatility * Current option			-0.0381	0.125
Demand volatility * Control			0.229	0.336
Demand volatility * Cost			1.25	2.15
Demand volatility * Flexibility			0.244	0.134*
Demand volatility * Reliability			-0.36	0.52
Demand volatility * Time			-0.168	0.258
Demand volatility * VAS			0.332	0.164**
Product flexibility * Current option			-0.333	0.109
Product flexibility * Control			-0.191	0.317
Product flexibility * Cost			3.49	2.05
Product flexibility * Flexibility			-0.0474	0.125
Product flexibility * Reliability			0.184	0.49
Product flexibility * Time			0.526	0.239
Product flexibility * VAS			-0.144	0.146
Standard Deviation for random effects				
Flexibility	0.677	0.332**	0.378	0.336
Number of responses	1776		1776	
Number of respondents	296		296	
Log-likelihood	-1673.26		-1642.56	
McFadden's R2	0.237		0.251	

***p<0.01, **p<0.05 and *p<0.1 for statistical significance

Table B2. The interaction model for demand volatility and launch flexibility

Variable	Main effects model		Model with interactions	
	Coefficient	Std. error	Coefficient	Std. error
Current option	0.423	0.129***	0.403	0.132***
Control	0.901	0.203***	0.489	0.22**
Cost	-10.4	2.05***	-9.95	2.34***
Flexibility	0.363	0.136***	0.548	0.144***
Reliability	0.664	0.482	0.273	0.563
Time	-1.09	0.277***	-1.02	0.276***
VAS	0.141	0.152	0.315	0.174*
Demand volatility * Current option			-0.0295	0.125
Demand volatility * Control			0.222	0.336
Demand volatility * Cost			1.17	2.15
Demand volatility * Flexibility			0.251	0.134*
Demand volatility * Reliability			-0.379	0.52
Demand volatility * Time			-0.173	0.257
Demand volatility * VAS			0.334	0.164**
Launch flexibility * Current option			0.00748	0.113
Launch flexibility * Control			-0.412	0.333
Launch flexibility * Cost			0.112	2.16
Launch flexibility * Flexibility			0.124	0.13
Launch flexibility * Reliability			-0.452	0.509
Launch flexibility * Time			0.229	0.25
Launch flexibility * VAS			0.00432	0.152
Standard Deviation for random effects				
Flexibility	0.677	0.332**	0.439	0.675
Number of responses	1776		1776	
Number of respondents	296		296	
Log-likelihood	-1673.26		-1647.60	
McFadden's R2	0.237		0.2487	

***p<0.01, **p<0.05 and *p<0.1 for statistical significance

Table B3. The interaction model for demand volatility and sourcing flexibility

Variable	Main effects model		Model with interactions	
	Coefficient	Std. error	Coefficient	Std. error
Current option	0.423	0.129***	0.2	0.18
Control	0.901	0.203***	0.729	0.228***
Cost	-10.4	2.05***	-7.64	2.44***
Flexibility	0.363	0.136***	0.581	0.147***
Reliability	0.664	0.482	-0.254	0.587
Time	-1.09	0.277***	-0.92	0.292***
VAS	0.141	0.152	0.26	0.178
Demand volatility * Current option			-0.0295	0.125
Demand volatility * Control			0.231	0.336
Demand volatility * Cost			1.18	2.15
Demand volatility * Flexibility			0.249	0.134*
Demand volatility * Reliability			-0.371	0.521
Demand volatility * Time			-0.178	0.257
Demand volatility * VAS			0.334	0.164**
Sourcing flexibility * Current option			-0.2	0.18
Sourcing flexibility * Control			0.442	0.333
Sourcing flexibility * Cost			4.5	2.15
Sourcing flexibility * Flexibility			0.166	0.122
Sourcing flexibility * Reliability			-1.37	0.533
Sourcing flexibility * Time			0.376	0.268

Sourcing flexibility * VAS			-0.106	0.142
Standard Deviation for random effects				
Flexibility	0.677	0.332**	0.262	0.281
Number of responses	1776		1776	
Number of respondents	296		296	
Log-likelihood	-1673.26		-1644.75	
McFadden's R2	0.237		0.25	

***p<0.01, **p<0.05 and *p<0.1 for statistical significance

Table B4. The interaction model for demand volatility and postponement flexibility

Variable	Main effects model		Model with interactions	
	Coefficient	Std. error	Coefficient	Std. error
Current option	0.423	0.129***	0.341	0.136***
Control	0.901	0.203***	0.483	0.229**
Cost	-10.4	2.05***	-9.06	2.45***
Flexibility	0.363	0.136***	0.532	0.151***
Reliability	0.664	0.482	0.371	0.593
Time	-1.09	0.277***	-0.882	0.287***
VAS	0.141	0.152	0.224	0.179
Demand volatility * Current option			-0.033	0.125
Demand volatility * Control			0.224	0.336
Demand volatility * Cost			1.23	2.15
Demand volatility * Flexibility			0.25	0.134*
Demand volatility * Reliability			-0.374	0.52
Demand volatility * Time			-0.164	0.258
Demand volatility * VAS			0.329	0.164**
Postponement flexibility * Current option			-0.127	0.117
Postponement flexibility * Control			-0.358	0.35
Postponement flexibility * Cost			1.94	2.28
Postponement flexibility * Flexibility			0.0697	0.138
Postponement flexibility * Reliability			-0.157	0.54
Postponement flexibility * Time			0.474	0.262*
Postponement flexibility * VAS			-0.189	0.158
Standard Deviation for random effects				
Flexibility	0.677	0.332**	0.093	0.088
Number of responses	1776		1776	
Number of respondents	296		296	
Log-likelihood	-1673.26		-1644.09	
McFadden's R2	0.237		0.2503	

***p<0.01, **p<0.05 and *p<0.1 for statistical significance

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5 Alignment of transportation strategy with supply chain strategy in global supply chains

Khakdaman, M., Rezaei, J., & Tavasszy, L. A. (2021). Alignment of transportation strategy with supply chain strategy in global supply chains. International Journal of Logistics Research and Applications, (Submitted)

Abstract
Alignment of core supply chain functions with corporate supply chain strategy is one of the key success factors for firms. However, the alignment of transportation (as a key supply chain function) strategy with supply chain strategy is not investigated in the Operations Management literature. It is not clear which transportation strategies should be developed by different industries to make an alignment between transportation strategy and supply chain strategy. We investigate the alignment of transportation strategy with supply chain strategy among Global Fortune 500 companies. Our results highlight several misalignments between transportation strategy and supply chain strategy of global supply chains, if we solely rely on the current theories in the Operations Management literature. We also demonstrated relevant transportation strategies for different supply chain strategies. Counter-intuitive to the existing literature, our analyses show that only a customized transportation strategy can provide a right alignment between transportation strategy and supply chain strategy.

5.1 Introduction

Strategic fit between business strategy and supply chain strategy is essential to the operations management (Qi, Zhao, & Sheu, 2011). Once a firm's supply chain strategy is determined, core functions of the supply chain need to align their strategies with the targeted supply chain strategy (Chopra & Meindl, 2007). Decisions taken within each core supply chain function should be mutually consistent and converge with the overall supply chain and business strategy (Joshi, Kathuria, & Porth, 2003; Sun & Hong, 2002). The likely effect of misalignment is development of disconnected practices that reproduce imperfections and flaws along the supply chain. This can compromise achieving the business goals and consequently deteriorate overall supply chain performance and increase total supply chain cost (Joshi et al., 2003; de Carvalho Borella and Padula, 2010). The alignment of transportation strategy (TS) with the supply chain strategy (SCS) is one of the primary strategic fits for every supply chain to make smooth movement and delivery of materials/goods/services throughout the supply chain. An effective TS fits the movement of goods to the corporate SCS (LTD management, 2020). Lack of strategic fit or misalignment between TS and SCS could make transportation as the weakest function in the supply chain which leads to deteriorating performance of the whole supply chain as established by the Theory of Constraints (TOC) (Goldratt and Cox, 1986) that "a chain is no stronger than its weakest link". However, to what extent this strategic fit exists in global supply chains and how firms can achieve this alignment is by-and-large ignored in the operations management (OM) literature.

It is not clear in the OM literature how to devise a TS that makes a proper alignment with SCS. From the first introduction of “What is the right supply chain for your product?” by Fisher (1997), i.e., efficient SCS for functional products (i.e., predictable demand) and responsive SCS for innovative products (i.e., uncertain demand), scholars such as Lee (2002) and Christopher, Peck, and Towill (2006) also introduced different SCS types, i.e., efficient, risk-hedging, responsive and agile SCSs by Lee (2002) and lean, agile and leagile SCSs by Christopher et al (2006), by adding supply uncertainty and supply lead time of products to demand uncertainty, respectively. However, when it comes to devise a proper TS for SCSs, it is not clear what TS should be used for each of these SCSs. Does an efficient TS always mean a low-cost one or it could mean a lower transportation time, or better modal control for some industries? A common interpretation is that efficiency means lower cost. However, when it comes to transportation operations, an efficient TS could mean a fast TS, that secures lower total supply chain costs by responding effectively to demand fluctuations. This promotes an outside-in perspective to redefine proper TS(s) with regards to various SCSs in supply chains.

The relationship between SCS and TS is rarely investigated (theoretically and practically) in the existing literature. Existing studies mainly focus on TS-related factors and ignored its alignment with SCS (e.g., Ke, Windle, Han, & Britto, 2015). Lagoudis, Lalwani, Naim, and King (2002) concerned sea transportation and investigated which sea shipping vessel should be applied relevant to the TS of a supply chain. The authors considered different transportation-related factors (e.g., supply volume, product cost, shipping distance) in their case study analysis and concluded that when cost-efficient transportation is needed, conventional shipping vessels should be applied, while high-speed vessels should be used when transportation flexibility is the market winner. Orcao and Perez (2014) investigated how the fitness of transport and logistics into the production network could provide major Spanish retailors with competitive advantage. They indicated that efficient logistics and sufficiently fast transportation have enabled Spanish fast fashion companies (i.e,. Zara) with short lead times needed to fulfill demand in economically and geographically very disparate markets. Zhang, Lam, and Huang (2014) applied Fishers’ SCS categories (Fisher, 1997) to study the link between port strategy and SCS in the port of Hong Kong and highlighted the importance of this alignment in supporting shippers with agile/responsive SCS. Using the US trade and manufacturing datasets, Ke et al. (2015) showed the impact of several industry characteristics (i.e., the cost of capital, contribution margin ratio, demand uncertainty and competition) on the freight transportation modal choice of supply chains. Their results indicated the importance of strategic alignment between industry characteristics and transportation modal mix in different supply chains.

Scholars developed several frameworks that can be applied for assessing alignment of TS with SCS. While Fisher (1997) initially introduced what SCS is right for different product natures, his framework only considers demand uncertainty (predictability) and ignores supply uncertainty (Lee, 2002). Lee’s model comprehensively introduced four SCSs with regards to both demand and supply characteristics of products. Other scholars, e.g., Christopher et al. (2006) also introduced similar taxonomies. While any of these frameworks, amongst all, can be applied to evaluate the alignment of different supply chain functions i.e., procurement, production, transportation, with SCS (see, for example, Qi, Boyer, & Zhao, 2009, amongst all), alignment of TS with SCS is ignored in the OM literature. The existing literature about TS solely investigates the impact of some transportation-related factors that may involve in development of TS within the supply chain (e.g., product and shipping characteristics (Lagoudis et al., 2002), industry characteristics (Ke et al., 2015), network types (Haial, Berrado, & Benabbou, 2016), port strategy (Zhang et al. 2014), distribution center operations (Baker, 2004), logistics system design (Orcao and Perez, 2014). While these factors do impact development of TS in supply chains, a systematic understanding of how TS should be characterized and aligned to the SCS is missing in the existing literature.

To address this research gap, we formulate the research questions: "*How strong is the alignment between transportation strategy and supply chain strategy in global supply chains?*" and "*how should firms align their TS to their SCS?*". The first research question sheds light on the current state of the TS and SCS alignment. This will provide a better understanding of how firms decide about their TS relevant to their SCS. This understanding will then help addressing the second research question by identifying pathways to align TS with SCS relevant to the characteristics of different industries with different nature of products and operations. Supply chains can use these guidelines to align their TS to their SCS based on different factors. In addition, supply chains can ask their logistics service providers (LSPs) to provide tailor-made transportation services that implements their TS.

In this study, we consider transportation as a service that combination of its attributes (i.e., cost, time, reliability, flexibility and so on) reflects the TS of a (customer) firm. Firms' TS determines (and is directly related to) their transportation service choice (Bolis and Maggi, 2003). As customers, firms usually ask for freight transportation services from LSPs such as third-party logistics providers (3PLs), careers and forwarders. LSPs are considered as the main actors of the global freight transportation network that flow goods among different nodes of the international supply chains (i.e., suppliers, manufacturers, distribution centers, retailers and customers). As a strategic decision in a supply chain, once a firm's TS is determined, the main characteristics of its TS is reflected in the long-term contracts with the LSPs as attributes of the transportation/logistics services delivered by the LSP at the operational daily basis. The combination of different service attributes shows what type of TS the firm is seeking from the LSP.

In order to understand the extent to which firms' TS is aligned with their SCS, we first combine the main attributes of a transportation service, as representative of firms' TS. Second, we apply Lee's framework (Lee, 2002) to categorize firms based on different product types, demand and supply uncertainties, and SCSs. Third, we assess the alignment of TS and SCS of international supply chains using a structured multi-criteria decision making (MCDM) method called Best-Worst Method (BWM) (Rezaei, 2015; Rezaei, 2016). BWM is one of the recent developments in MCDM which requires less data and produces more reliable results (Rezaei, Nispeling, Sarkis, & Tavasszy, 2016). To depict a global perspective about the alignment of TS with SCS, we conducted our study among Global Fortune 500 companies (Fortune magazine, 2017) and major customer firms of the 40 largest global LSPs (Logistics Quarterly magazine, 2011), including various industries and commodity types that account for the majority of global transportation volume and value (Khakdaman, Rezaei, & Tavasszy, 2020). These companies are usually leading firms in their industry with international supply chain operations and rely heavily on LSPs' logistics services for flowing their goods globally (Khakdaman et al., 2020).

We advance the OM literature via the following contributions: (i) We assess the alignment between TS and SCS for global supply chains considering different contextual factors such as industry characteristics, commodity types, shipment sizes and product types. This highlights the importance of TS and SCS alignment for improving overall supply chain performance. (ii) We define TS in conjunction with different transportation service attributes and demonstrate which TS(s) should be applied to achieve better fit with SCS in various industries. (iii) We conduct our study among global supply chains, while earlier studies are limited in their geographical diversity, operational complexity and sample size. Following this section, we present the research methodology, including the BWM, survey design and data collection. Results of the study and associated discussions are presented in Section 3. Section 4 proposes right TSs for different SCSs. Section 5 provides conclusions and future research directions.

5.2 Methodology

In order to assess the alignment of TS with SCS, we develop a multi-stage methodology. First, we select a known framework for evaluation of TS and SCS alignment. To this end we choose the framework introduced by Lee (2002) since it considers both demand and supply uncertainties of products to comprehensively introduce four SCSs (i.e., efficient SCS for products with low demand and supply uncertainty, and responsive SCS for products with low supply uncertainty and high demand uncertainty). Then, we take into account the configuration of transportation service attributes as a reflection of firms' TS and identify main relevant attributes in the literature (Section 2.1). Second, we design a survey to identify firms' demand/supply uncertainty characteristics and SCSs. Using the same survey, we also recognize firms' TS preferences using BWM (Sections 2.2, 2.3). Third, we describe the necessary calculations and evaluations to obtain a valid model (Section 2.4) and present results of our analysis in Section 3.

5.2.1 Transportation service criteria for a transportation strategy

Taking into account studies by Swafford, Ghosh, and Murthy (2006), Ben-Akiva, Bolduc, and Park (2008), Roso, Woxenius, and Lumsden (2009), Arencibia, Feo-Valero, García-Menéndez, and Román (2015) and Khakdaman et al. (2020), among all, we include three sets of criteria for identifying configuration of a transportation service: (i) the common criteria for choosing a transportation service, such as transportation cost, time and reliability, (ii) transportation modal control, as a criterion for observing whether firms consider specific transportation mode(s) in their TS or they have a service choice attitude, and (iii) criteria to observe how firms would like to change their TS adaptive to their business circumstances, such as transportation flexibility, and how value-adding operations beyond the main transportation service is considered in firm's TS, i.e., value-added services (VAS). The attributes are defined as follows:

- End-to-end cost is the total amount of money paid for shipping, for example, one TEU (20-foot container) from origin to destination.
- End-to-end transportation time is the duration from the shipment's first origin to its final destination.
- Reliability is the on-time delivery of freight/goods at the destination.
- Modal Control is the importance of having control over determining the mode of transportation by firms.
- Flexibility is transportation service capability to effectively fulfil a shipper firm's required changes in service components before finalizing the booking of the transportation service, and while goods are on their way towards their destination. Examples include changing in delivery time/location, shortening or extending lead

times, and aggregating or disaggregating volume/variety via warehouses or cross-docking terminals.

- Value-added services (VAS) are ancillary services including tracking and tracing, storage and handling, customs and packaging offered by the LSP beyond the main transportation service.

5.2.2 Survey design and data collection

We designed a web-based survey questionnaire using the Surveygizmo platform (Surveygizmo, 2017). The survey consists of 21 questions in two sections. The first section introduces the objective of our study and asks respondents about their sociodemographic information of the respondents (e.g., position, job function) and their company's operations (e.g., company's industry type, size (number of employees), annual revenue and product types; and so on). Then, we asked them to choose one of their products/materials and reveal the level of demand and supply uncertainty for that product. In the second section we asked respondents to reflect their preferences for transportation service attributes based on the BWM method.

In order to make a comprehensive perspective about the alignment of TS with SCS, we chose to sample from international supply chains with high operational influence on the global production and trade of goods, including firms with high overall revenues and firms that manage large freight flows. The former type of companies was identified via the Global Fortune 500 list (Fortune magazine, 2017). The latter category was found via the list of major customer firms of the 40 largest LSPs worldwide (Logistics Quarterly magazine, 2011). This magazine presents between 5 to 10 leading customer shippers for each LSP. 556 unique companies were identified by combining these lists. Then, we targeted top (c-level) and senior/middle level managers who lead supply chain/logistics/transportation functions in these firms. We sent the web-based survey via email to 2490 managers (e.g., vice-president of operations, director of logistics, head of supply chain). After three follow-up rounds, 324 usable responses were collected from 209 unique firms. This implies a response rate of 13% and 38% among individuals and companies, respectively. Demographics of respondent firms are depicted in Table 1.

Table 1. Profile of the respondents and their companies

Respondent Position	*%*	*Company size (#employees)*	*%*	*Annual Revenue*	*%*	*Economic sector*	*%*
C-level/Top Management	21%	<99	4%	<$100 Mn	10%	Basic Materials	13%
Senior/Middle Management	79%	100- 249	7%	$100-250 Mn	8%	Consumer Cyclicals	18%
		250-999	6%	$250 Mn-1 Bn	13%	Consumer Non-Cyclicals	21%
		1000-9999	19%	$1-10 Bn	19%	Energy	4%
		10000-49999	26%	$10-50 Bn	27%	Healthcare	12%
		> 50000	38%	> $50 Bn	23%	Industrials	7%
						Technology	15%
						Telecom Services	9%
						Utilities	2%

5.2.3 Calculating attribute weights using best-worst method

In order to solve decision (or evaluation) problems with a set of criteria, several MCDM methods have been developed that have their own advantages and disadvantages. A recently developed MCDM method by Rezaei (2015) is called Best-Worst method (BWM) which is getting more attention among scholars. As a pairwise comparison-based method, BWM offers a structured way to make the comparisons. Rezaei (2020) illustrates several salient features of BWM. Unlike MCDM methods that use a single vector (e.g., Swing and SMART family) or a full matrix (e.g., AHP), BWM uses two pairwise comparisons vectors formed based on two opposite references, i.e., the best and the worst criteria (or the alternatives). While in the single vector MCDM methods, using one vector for the input data requires less time of the decision maker, the consistency of the provided pairwise comparisons cannot be checked. The main drawback of the full matrix MCDM methods is their time(and data)-inefficiency, besides the fact that asking too many questions from the decision maker might even contribute to the confusion and inconsistency of the decision maker. Furthermore, identifying the best and the worst criteria before conducting the pairwise comparisons among the criteria, makes a clear understanding of the range of evaluation for the decision maker which could lead to more reliable and consistent pairwise comparisons as shown in the original study of Rezaei (2015). This could mitigate possible anchoring bias that the decision maker might have during the process of conducting pairwise comparisons. The aforementioned features of BWM makes it as the most data (and time)-efficient method which, at the same time, allows for checking the consistency of the provided pairwise comparisons (See Rezaei (2020) for more details).

BWM is applied in several OM areas such as supplier selection (Gupta & Barua, 2017; Rezaei et al., 2016), transportation disruptions in supply chain (Fartaj, Kabir, Eghujovbo, Ali, & Paul, 2020), supplier segmentation (Rezaei et al., 2016), LSP selection (Paul, Moktadir, & Paul, 2019), sustainable supply chain (Ahmadi, Kusi-Sarpong, & Rezaei, 2017), optimal bundling configurations in ground transport of air freights (Rezaei, Hemmes, & Tavasszy, 2017), to name a few. Because of advantages of BWM, we applied this method to identify the level of alignment between TS and SCS of international supply chains through finding the criteria weights of 323 responses in our study. In this study we use the linear BWM (Rezaei, 2016) as follows.

Step 1: Determine a set of n decision (or assessment) criteria $\{C_1, C_2, \dots, C_n\}$.

Step 2: The decision-maker/expert selects the best criterion (e.g., the most important/influential one) and worst criterion (e.g., the least important/influential one) among the available set of criteria identified in Step 1.

Step 3: The decision-maker/expert conducts pairwise comparisons between the best criterion and other criteria. To this end, the decision-maker applies a number between 1 and 9 (where 1 is ‘equally important’ and 9 is ‘extremely more important’) in order to determine preference of the best criterion over other criteria. This will result in the following vector:

$$A_B = (a_{B1}, a_{B2}, \dots, a_{Bn}) \quad (1)$$

where a_{Bj} represents the preference of the best criterion C_B over criterion C_j, $j = 1, 2, \cdots, n$.

Step 4: The decision-maker/expert carries out pairwise comparisons between the other criteria and the worst criterion in a similar way to the third step using a number between 1 and 9. The resulting vector of this comparisons would be:

$$A_W = (a_{1W}, a_{2W}, \dots, a_{nW}) \quad (2)$$

where a_{jW} represents the preference of criterion C_j over the worst criterion C_W, $j = 1, 2, \cdots, n$.

Step 5: Determine the optimal weights of the criteria $(w_1^*, w_2^*, \dots, w_n^*)$ and ξ^{L*} by minimizing the maximum absolute differences $\{|w_B - a_{Bj}w_j|$ and $|w_j - a_{jW}w_W|\}$ via the following model:

$$\min \max_j \{|w_B - a_{Bj}w_j|, |w_j - a_{jW}w_W|\}$$

s.t.

$$\sum_j w_j = 1$$

$w_j \geq 0$, for all j. (3)

This model can be transferred to the following linear programming model:

$min\, \xi^L$

s.t.

$$\left|w_B - a_{Bj} w_j\right| \leq \xi^L$$

$$\left|w_j - a_{jW} w_W\right| \leq \xi^L$$

$$\sum_j w_j = 1$$

$$w_j \geq 0, \text{ for all } j. \quad (4)$$

Solving this problem results in finding the optimal weights $(w_1^*, w_2^*, \ldots, w_n^*)$ and ξ^{L*}.

Reliability of BWM Results

Before using the result of BWM for investigating our research questions, we tested for reliability of obtained criteria weights. Although we use the linear version of BWM to find the results (Rezaei, 2016), we are still able to check the consistency of the provided pairwise comparisons by individual experts using the input-based consistency measure and the thresholds developed by Liang, Brunelli, and Rezaei (2020). Checking all the findings per individual expert, the input-based consistency ratio of 81 responses among our 323 are above the thresholds (hence, not acceptable). Thus, we excluded those 81 responses from our analysis which resulted in using 242 (sufficiently) consistent responses for further analysis.

5.3 Results and discussion

5.3.1 Assessing alignment of transportation strategy with supply chain strategy

We assess the alignment of TS with SCS using product and supply chain alignment model introduced by Lee (2002) (see Figure 1). To this end, we first obtained weight of each transportation service attribute for each respondent using BWM. We then incorporated these weights in the context of Lee's model by calculating the average weight (geometric mean) for each service attribute relevant to each SCS as shown in Table 1.

		Demand uncertainty	
		Low (Functional products)	***High (Innovative products)***
Supply uncertainty	***Low (Stable process)***	Efficient supply chains	Responsive supply chains
	High (Evolving process)	Risk-hedging supply chains	Agile supply chains

Figure 1. Supply chain strategy with product characteristics alignment model by Lee (2002)

Table 1. Assessment of TS and SCS alignment based on Lee's model

	Demand uncertainty													
	Low (Functional products)							***High (Innovative products)***						
Supply uncertainty	*Cost*	*Control*	*Flexibility*	*Reliability*	*Time*	*VAS*	*# Resps.*	*Cost*	*Control*	*Flexibility*	*Reliability*	*Time*	*VAS*	*# Resps.*
Low	0.192	0.142	0.133	0.253	0.199	0.082	51	0.196	0.153	0.143	0.228	0.192	0.088	40
High	0.233	0.129	0.127	0.210	0.198	0.101	99	0.216	0.122	0.120	0.200	0.236	0.104	52

As can be seen in Figure 1, for products with low demand uncertainty, i.e., predictable demand (functional products) and low supply uncertainty, i.e., stable process, an efficient SCS is the best match (Lee, 2002). Considering same situation in Table 1, we expect to recognize an *efficient* TS, i.e., focusing mainly on minimizing transportation costs, to be aligned with the efficient SCS. However, we see that transportation reliability and time are the most important decision criteria (i.e., they have the highest weights among all attributes) in determining TS of companies in this group, while transportation cost is the third important criterion when these companies align their TS with their SCS. This mismatch between TS and SCS also exists for responsive and agile SCSs, where transportation cost is the second most important criterion after transportation reliability and transportation time, respectively.

One can argue that these are not necessarily misalignments, since transportation cost is always important for every SCS even if it is an agile SCS, and transportation reliability is important for efficient SCSs. However, Ke et al. (2015) argue that in order to understand how TS could be aligned with SCS, industry characteristics as a vital factor should be taken into account. To this end, we investigate TS and SCS alignment in different industries based on the Thomson Reuters business classification (2012) which classified all industries into nine industry sectors. Since we already used this comprehensive industry classification in our survey design phase, we are able to investigate all industry sectors in our analysis as shown in Table 2.

Table 2. Assessment of TS and SCS alignment based on Lee's model considering industry characteristics

			Demand uncertainty													
			Low (Functional products)							***High (Innovative products)***						
			Cost	*Control*	*Flexibility*	*Reliability*	*Time*	*VAS*	*# Resps.*	*Cost*	*Control*	*Flexibility*	*Reliability*	*Time*	*VAS*	*# Resps.*
Supply uncertainty	***Low***	Basic Materials	0.198	0.122	0.172	0.260	0.181	0.066	10	0.184	0.143	0.121	0.278	0.199	0.074	2
		Consumer Cyclicals	0.182	0.170	0.096	0.309	0.167	0.077	7	0.250	0.123	0.163	0.280	0.104	0.079	7
		Consumer Non-Cyclicals	0.202	0.216	0.113	0.235	0.164	0.069	8	0.175	0.193	0.143	0.142	0.270	0.077	9
		Energy	0.350	0.146	0.080	0.223	0.172	0.028	3							
		Healthcare	0.136	0.122	0.149	0.332	0.201	0.060	10	0.090	0.160	0.146	0.301	0.214	0.090	6
		Industrials	0.132	0.138	0.135	0.178	0.275	0.142	4	0.134	0.089	0.092	0.413	0.102	0.170	2
		Technology	0.192	0.096	0.146	0.203	0.203	0.161	6	0.223	0.162	0.149	0.151	0.171	0.143	7
		Telecommunications	0.270	0.097	0.110	0.115	0.332	0.076	3	0.252	0.138	0.134	0.236	0.204	0.035	7
	High	Basic Materials	0.210	0.120	0.102	0.226	0.234	0.107	17	0.110	0.127	0.106	0.380	0.161	0.115	2
		Consumer Cyclicals	0.237	0.125	0.109	0.198	0.196	0.135	17	0.211	0.100	0.112	0.202	0.295	0.081	13
		Consumer Non-Cyclicals	0.242	0.117	0.135	0.210	0.198	0.098	28	0.171	0.110	0.084	0.225	0.306	0.104	5
		Energy	0.172	0.101	0.098	0.234	0.285	0.110	7							
		Healthcare	0.313	0.211	0.144	0.138	0.141	0.053	8	0.174	0.128	0.111	0.342	0.154	0.090	5
		Industrials	0.213	0.202	0.160	0.228	0.128	0.070	6	0.165	0.166	0.102	0.200	0.207	0.160	4
		Technology	0.291	0.111	0.112	0.173	0.214	0.099	7	0.284	0.134	0.115	0.170	0.194	0.103	16
		Telecommunications	0.220	0.121	0.173	0.213	0.149	0.124	6	0.193	0.130	0.196	0.098	0.276	0.107	6
		Utilities	0.126	0.085	0.208	0.375	0.162	0.044	3	0.202	0.036	0.202	0.083	0.238	0.238	1

As can be seen from Table 2, some of the firms with efficient SCS have chosen a TS that is not necessarily cost-efficient (e.g., industries such as consumer non-cyclicals, healthcare and industrials). As an illustration, the healthcare industry seeks a reliable, fast and flexible TS (i.e., these three criteria compose almost 70% of the total criteria weight) and regards transportation cost as one of the least important factors for functional products in the context of efficient SCS. Taking consumer non-cyclicals industry with efficient SCS into account, their preferred applied TS is mainly based on seeking transportation reliability since maintaining the efficient SCS needs optimal integration of production and distribution of materials/goods throughout the supply chain (Lee, 2002), which requires highly on-time transportation to enable implementing end-to-end tight production-distribution schedules. In another example, while based on the Fisher's framework, a common understanding in the OM community is that a responsive/agile SCS needs to have a fast, reliable and/or flexible TS for best alignment of its end-to-end operations, Table 2, conversely, illustrates that firms with an innovative product and agile SCS apply a cost-efficient TS, i.e., technology and telecommunications industries. This shows that the TS approach of some industries towards alignment with SCS is not necessarily the same.

Although considering industry characteristics improves our understanding of how firms align TS with SCS, it also reveals several misalignments in real-world circumstances based on the current TS definitions in the existing literature. This highlights the incompleteness of current definitions of TS and how it should be aligned with SCS. Taking these new findings into account, in section 4 we develop relevant TSs to be aligned with each SCS based on our dataset. We think that decisions of global supply chains for devising a proper TS relevant to their SCS in the context of this study could advance our understanding about right alignment of TS with SCS.

5.3.2 The role of shipment size in the alignment of transportation strategy with supply chain strategy

In this section we dig deeper into the analysis of TS and SCS alignment by incorporating shipment size as a key decision factor when firms devise their TS. Shipment size relates transportation/distribution operations to production operations when firm's production strategy and TS need to be synchronized to better align with the overall SCS of the firm (Chopra & Meindl, 2007). For example, when a firm operates on an efficient SCS for some of their products, they may need to optimally and efficiently synchronize the flow of raw material, semi-finished products and finished products among nodes of their supply chain network (i.e., suppliers, manufacturing plants, distribution centers and retailers) in a way that each of these products arrives at the targeted node on the right time based on the overall integrated production-distribution plan of the supply chain. To achieve the maximum efficiency, each node in the supply chain network needs to send/receive the planned shipment size on-time via the LSP's transportation network. Considering the fact that many firms have more than one SCS due to their various product portfolios, the complexity of synchronizing different shipment sizes with production and distribution plans will directly impact how firms devise their TSs.

In order to understand the impact of shipment size on choosing relevant TSs for each SCS, we used our dataset to incorporate two amount of shipment sizes, i.e., below 25 TEU and above 25 TEUs, as small and large shipment sizes into our framework for TS and SCS alignment. Table A1 (see Appendix1) shows how the TSs of global supply chains are influenced by the amount of their shipment sizes when they operate within various SCSs. For example, taking into account the basic materials industry, while according to Table 2 they prefer a CRT TS for their efficient SCS, when it comes to shipment sizes above 25 TEUs (see Table A1) their preference shifts to a flexible TS, i.e., FCR TS, to better align their TS with SCS. This can be done via, for example, synchronizing their operations by distributing large shipment sizes into their supply chain network when they rely significantly on a flexibility-oriented TS by utilizing their LSP's flexibility capability to change transportation service components such as destinations, lead times and shipment volumes based on changes in their business circumstances. Similar shifts to a more flexible TS for large shipment sizes can also be identified for healthcare industry in the context of responsive SCS and telecommunications industry in the context of risk-hedging SCS.

Shipment size can also have huge impacts on firm's TS alignment with SCS. For instance, a significantly different TS is followed by technology industry for small shipment sizes when operating with innovative products in the context of responsive SCS. While the technology industry achieves a responsive SCS through a modal-control-oriented TS, i.e., MCF, for large shipment sizes, they prefer a VAS-oriented TS, i.e., VRT, for small shipment sizes. This change in TS reveals how the importance of determining transportation mode can be ignored when shipment size is changed. While several other examples of the impact of shipment size on devising proper TS can be found in Table A1, there are also cases in which shipment size has a neutral role. For example, taking both consumer cyclicals and non-cyclicals industries into account, it seems that shipment size has almost no significant impact on TS when these industries experience high supply uncertainty no matter how much demand volatility they experience in the downstream of their supply chain (i.e., when they follow bot risk-hedging and agile SCSs). This could highlight a more static view to the alignment of TS with SCS relevant to the shipment size.

5.4 Developing transportation strategies for supply chain strategies

A right TS is the one that can best align transportation operations to the objectives of the SCS. The right alignment between TS and SCS creates high synergy between transportation operations and supply chain operations and improves overall business performance. Illustrations in section 3 show the right alignment of TS with SCS not only does not mean pursuing same approach for determining TS and SCS, it also means more than one proper TS strategy might be needed for each SCS depending on the nature of industry. In practice, industries with the same SCS apply different TSs to make right alignment between their TS and SCS with the aim of minimizing total supply chain landed cost[1]. When a Fortune company adopts a responsive TS for an efficient SCS, this will improve total supply chain landed cost for their specific industry while when another company selects an efficient TS for their efficient SCS they also seek to decrease total landed cost of the supply chain via different configurations between production, transportation and distribution operations. We identified four major TSs that are applied by major global supply chains to best align their TS with SCS and depicted in Figure 2. Considering results presented in Table 2, we arrived at these strategies considering three transportation service attributes that usually contribute to approximately 70% of the overall weight of a TS for every industry in each SCS. Following this we define these TSs.

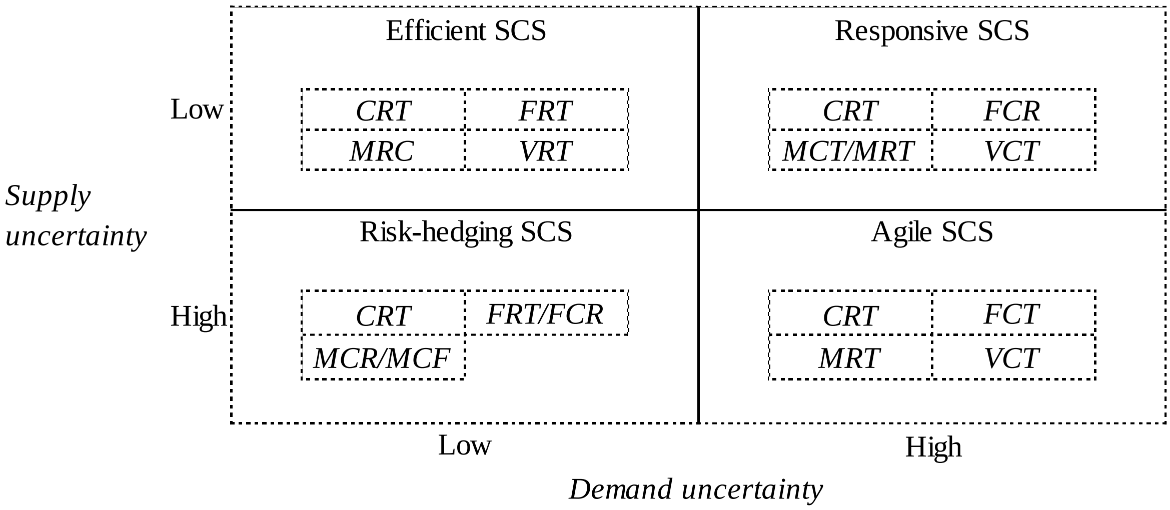

Figure 2. Fitting transportation strategies for alignment with supply chain strategy

Cost-efficient, fast and reliable transportation (CRT strategy): Many firms use this conventional TS. Firms with this TS mainly focus on minimizing transportation costs while improving transportation time and reliability. For example, firms operating in the energy industry (see Table 2) apply a CRT strategy for their efficient SCS where 75% of the decision criteria weight in their TS is composed of transportation cost (i.e., criterion weight of 0.35), transportation reliability and time. Consumer cyclicals industry is another case where firms follow a CRT strategy for their agile SCS.

[1] Total supply chain landed cost of a product includes all of the visible and hidden costs incurred along the supply chain in order to make the product available for consumption. This includes the costs of sourcing and manufacturing, quality, transportation, inventory, taxes, duties, insurance and other trade costs, repackaging, returned goods, risk mitigations, lost sales, and others (Supply chain link, 2015).

Flexibility-oriented transportation (FRT and FCT/R strategies): A flexibility-oriented TS is applied when firms need to address different uncertainties within their end-to-end supply chain (i.e., demand fluctuations) by utilizing capabilities of LSPs' flexible transportation services such as changing transportation destination, increasing or decreasing transportation lead time, aggregation or disaggregation of shipment quantity and so on. Mason and Nair (2013) report that LSPs' clients e.g., shipper firms, seek flexibility in the logistics services as a valuable competency for addressing uncertainties in their competitive markets. TSs that consider adaptability of transportation service components as a main decision criterion are getting more popular among firms (Khakdaman et al, 2020). We identified two main flexibility-oriented TSs as follow:

Flexible, reliable and fast transportation (FRT): In this TS, the majority of weight for the decision criteria composed of transportation flexibility, time and reliability while cost-efficiency is among the least decision factors. For instance, healthcare companies with an efficient SCS adopt a FRT strategy for best alignment of their TS with SCS. Another example is utilities industry which applies the FRT transportation strategy to mitigate different risks in their risk-hedging SCS. Firms with low demand uncertainty and high supply uncertainty (i.e., utilities industry) adopt a risk-hedging SCS to pool and share resources in their supply chain in order to share risks among supply chain actors when supply disruptions happen (Lee, 2002). Using a FRT transportation strategy by firms in the utilities industry helps mitigating supply chain risk by, for example, consolidating (or deconsolidating) the quantity of a key component from alternative supply sources when the main supply source is disrupted.

Flexible, cost-efficient and fast/reliable transportation (FCT/R): Firms adopting this TS have a stricter view to the costs of a flexible transportation service by including cost-efficiency besides flexibility and reliability (or time) as main decision criteria (i.e., at least 70% of criteria weight). For example, firms pursuing a responsive SCS for innovative products in consumer cyclicals industry adopt a FCR transportation strategy to respond demand fluctuations via on-time and adaptive deliveries while maintaining minimum transportation costs. Another case is telecommunications industry with agile SCS which adopts a FCT strategy to address volatilities in their demand and supply.

Modal-control-oriented transportation (MRT,MCT/R and MCF strategies): While firms usually decide about transportation mode when asking LSPs for transporting their goods (Tongzon, 2009), inclusion of modal control as a main decision criterion for developing TS reflects vital importance of modal control for some industries that need to avoid risks associated with losing control and visibility over transportation of their goods by LSPs (Tsai, Lai, Lloyd, & Lin, 2012; Khakdaman et al, 2020). We identified three main modal-control-oriented TSs as follow:

Mode-specific, reliable and fast transportation (MRT): Firms pursuing this strategy as their TS need to utilize a reliable and fast transportation service that is operating within specific pre-determined mode(s) of transportation. As an illustration, in order to ensure safe transportation of some pharmaceutical products, healthcare companies adopting a responsive SCS need to determine mode of transportation in advance. Other examples are supply chains operating with agile SCS in industrials and basic materials industries.

Mode-specific, cost-efficient and fast/reliable transportation (MCT/R): This TS is applied by industries that need to control transportation mode while concerning transportation cost and time/reliability as typical attributes of a transportation service. Firms producing consumer non-cyclical products adopt MCT/R strategy when pursuing both efficient and responsive SCSs. MCT/R is also applied by consumer cyclicals industry when adopting an efficient SCS.

Mode-specific, cost-efficient and flexible transportation (MCF): The MCF transportation strategy is applied when firms need to control transportation mode(s) and costs while favoring transportation flexibility to address their supply chain uncertainties. Risk-hedging SCS is a good example where several healthcare firms adopt a MCF strategy to mitigate their operational risks along the supply chain.

VAS-oriented Transportation (VRT and VCT/R strategies): This TS is concerned mainly by industries that technological/operational value-added service, i.e., packaging, tracking and tracing, and storage and handling, derive particular value to the operations alignment in their supply chain. We identified two main VAS-oriented TSs as follow:

VAS-oriented, reliable and fast transportation (VRT):This TS belongs to firms that apart from transportation reliability and time value VASs as an effective attribute of their TS to align their supply chain operations. For instance, firms operating with industrial products in the context of efficient SCS are willing to apply VASs to track their freight from origin to destination or to do packaging of goods via LSPs' VAS services while their goods are on the way toward the destination.

VAS-oriented, cost-efficient and fast/reliable transportation (VCT/R): Firms with this TS seek a typical cost-efficient, reliable and/or fast transportation while benefiting from value-added services. Two examples in this regard are firm operating with responsive SCS in industrials sector and firm operating under an agile SCS in utilities industry.

Considering preferences of leading supply chain firms to adopt a variety of TSs for each SCS show that only a *customized* TS can provide a right alignment between TS and SCS.

5.5 Conclusions and future research directions

In this research we investigated the alignment between transportation strategy (TS) and supply chain strategy (SCS) of global supply chains. We assessed this alignment based on the Lee's framework by considering products' demand volatility and supply uncertainty, and firm's relevant SCSs and TSs for different products. We carried out our investigation among different industry sectors by sampling from Global Fortune 500 companies all around the world. The results of our investigation suggest limits to the validity of conventional understandings (usually based of Fisher's framework) in the operations management community about what a right TS for a SCS is, i.e., a right TS for best alignment with an efficient (a responsive) SCS is an efficient (a responsive) TS. We found several counter-intuitive examples within leading international supply chains that shows lots of misalignments between firms' TS and SCS if we solely account on the current state-of-the-art of the knowledge in the operations management literature.

We then depicted a new perspective towards what a right TS for a SCS could be by developing right TSs for each of the Lee's four well-known SCSs, i.e., efficient (lean), responsive, risk-hedging and agile SCSs. We showed that more than one TS would be needed for a firm depending on the industry characteristics, nature of products and transportation shipment sizes. We demonstrated that the conventional match between efficient (responsive) SCS and efficient (responsive) TS is no longer a valid assumption and only a *customized* TS can provide a right alignment of TS with SCS in today's advanced supply chains with complex operations, value chains and customer preferences. We think that since we sample form industry leaders their TS can be applied as a benchmark for firms operating in the same industry. Supply chains can ask their logistics service providers to provide tailor-made transportation services consistent with their required TS.

Research on how best firm's TS can be aligned with their SCS is still underdeveloped and several research can be conducted based on the findings of this study. The alignment of TS with SCS for particular industries can be investigated in more details via testing frameworks of Fisher, Lee and Christopher as well as case study research approaches. One could investigate how the alignment of TS with SCS can impact alignment of other major supply chain functions such as production strategy, procurement strategy and distribution strategy. Another research direction is shedding light on organizational criteria of the alignment between TS and SCS, since we mainly focused on operational criteria here. More theory-building and theory-testing research is needed in the area of SCS alignment to advance the operations management literature.

Appendix1

Table A1. Assessment of TS and SCS alignment based on Lee's model considering industry characteristics and shipment size

			Demand uncertainty													
			Low (Functional products)							***High (Innovative products)***						
		Shipment size	*Cost*	*Control*	*Flexibility*	*Reliability*	*Time*	*VAS*	*# Resps.*	*Cost*	*Control*	*Flexibility*	*Reliability*	*Time*	*VAS*	*# Resps.*
Supply uncertainty – ***Low***	Basic Materials	>25 TEU	0.172	0.130	0.340	0.162	0.127	0.069	2							
		<25 TEU	0.205	0.121	0.131	0.285	0.195	0.065	8	0.184	0.143	0.121	0.278	0.199	0.074	2
	Consumer Cyclicals	>25 TEU	0.302	0.258	0.111	0.077	0.194	0.058	3	0.278	0.078	0.238	0.261	0.079	0.067	3
		<25 TEU	0.092	0.104	0.084	0.482	0.147	0.091	4	0.230	0.157	0.107	0.294	0.123	0.089	4
	Consumer Non-Cyclicals	>25 TEU	0.424	0.204	0.088	0.123	0.123	0.039	1	0.163	0.180	0.177	0.129	0.264	0.087	7
		<25 TEU	0.171	0.218	0.117	0.251	0.170	0.074	7	0.214	0.240	0.022	0.189	0.292	0.043	2
	Energy	>25 TEU	0.362	0.114	0.078	0.228	0.188	0.030	2							
		<25 TEU	0.327	0.211	0.084	0.211	0.141	0.026	1							
	Healthcare	>25 TEU								0.051	0.129	0.199	0.325	0.188	0.108	3
		<25 TEU	0.136	0.122	0.149	0.332	0.201	0.060	10	0.129	0.190	0.093	0.276	0.239	0.072	3
	Industrials	>25 TEU	0.120	0.105	0.198	0.185	0.270	0.122	2	0.175	0.105	0.131	0.419	0.131	0.039	1
		<25 TEU	0.144	0.171	0.071	0.170	0.281	0.163	2	0.093	0.073	0.053	0.407	0.073	0.301	1
	Technology	>25 TEU								0.322	0.177	0.182	0.120	0.095	0.104	3
		<25 TEU	0.192	0.096	0.146	0.203	0.203	0.161	6	0.149	0.151	0.125	0.174	0.229	0.172	4
	Telecommunications	>25 TEU	0.344	0.060	0.083	0.139	0.344	0.030	1	0.185	0.464	0.106	0.093	0.106	0.046	1
		<25 TEU	0.233	0.115	0.123	0.103	0.326	0.100	2	0.263	0.084	0.139	0.260	0.220	0.033	6
Supply uncertainty – ***High***	Basic Materials	>25 TEU	0.165	0.096	0.105	0.262	0.246	0.126	8							
		<25 TEU	0.250	0.141	0.100	0.195	0.224	0.090	9	0.110	0.127	0.106	0.380	0.161	0.115	2
	Consumer Cyclicals	>25 TEU	0.211	0.131	0.109	0.214	0.196	0.140	13	0.193	0.107	0.102	0.197	0.290	0.111	7
		<25 TEU	0.322	0.107	0.108	0.143	0.199	0.121	4	0.232	0.092	0.123	0.207	0.301	0.046	6
	Consumer Non-Cyclicals	>25 TEU	0.216	0.113	0.155	0.170	0.214	0.133	11	0.182	0.119	0.086	0.186	0.308	0.119	4
		<25 TEU	0.260	0.119	0.122	0.236	0.188	0.075	17	0.127	0.076	0.076	0.381	0.297	0.042	1
	Energy	>25 TEU	0.137	0.100	0.089	0.264	0.249	0.161	4							
		<25 TEU	0.218	0.102	0.109	0.195	0.333	0.043	3							
	Healthcare	>25 TEU	0.325	0.234	0.169	0.090	0.111	0.072	4	0.219	0.146	0.146	0.109	0.340	0.040	1
		<25 TEU	0.302	0.188	0.119	0.186	0.171	0.034	4	0.163	0.124	0.103	0.400	0.108	0.103	4

Industrials	>25 TEU	0.216	0.145	0.189	0.286	0.082	0.083	4							
	<25 TEU	0.207	0.316	0.101	0.111	0.222	0.044	2	0.165	0.166	0.102	0.200	0.207	0.160	4
Technology	>25 TEU	0.213	0.048	0.128	0.091	0.128	0.392	1	0.269	0.134	0.122	0.152	0.210	0.113	6
	<25 TEU	0.304	0.121	0.110	0.187	0.229	0.050	6	0.294	0.133	0.111	0.181	0.185	0.097	10
Telecommunications	>25 TEU	0.216	0.128	0.258	0.098	0.192	0.107	3	0.166	0.141	0.125	0.095	0.331	0.142	4
	<25 TEU	0.223	0.114	0.088	0.328	0.106	0.141	3	0.247	0.109	0.337	0.105	0.165	0.037	2
Utilities	>25 TEU	0.126	0.085	0.208	0.375	0.162	0.044	3	0.202	0.036	0.202	0.083	0.238	0.238	1
	<25 TEU	0.172	0.130	0.340	0.162	0.127	0.069	2							

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6 Conclusions and recommendations

This thesis has addressed the role new service attributes and contextual factors of freight demand play in the adoption of innovative freight transportation services. The main research goal is *to measure the role of innovative logistics-related service attributes in the demand for freight transportation services.* The first study identified drivers of demand for innovative freight transportation services (Chapter 2). The next two studies are conducted to investigate how shipper's choice is influenced by new service attributes such as modal control delegation, flexibility and value-adding services (Chapters 3 and 4). The impacts of contextual factors of demand such as shippers' demand volatility and internal flexibilities are also explored in Chapter 4. The role of supply chain strategy as another major contextual demand factor is examined in the fourth study (Chapter 5). The main findings of this thesis are presented in the following. Then, recommendations for research are drawn. This chapter is closed with managerial and policy recommendations.

6.1 Key research findings

First set of research questions (Chapter 2):

- *What new service attributes drive the choice of shipper firms for innovative freight transportation services?*
- *What factors in the shipper firms' business context drive their choice for innovative freight transportation services?*

We identified three new transportation service attributes that drive the choice of shipper firms for innovative freight transportation services, i.e., modal control delegation, service flexibility and value-added services. Modal control delegation involves transferring the transportation mode choice decision from shippers to the LSPs. Flexibility allows the shipper to change the service specification after the first agreement, until the final fulfilment of the service. Value-added are ancillary services including tracking and tracing, storage and handling, customs and packaging offered by the LSP beyond the main transportation service. We also recognized important contextual factors of demand that influence shippers' choice for innovative freight transportation services. These contextual factors include shippers' supply chain strategy, demand volatility, internal flexibilities and industry nature. We also present the concept of service choice approach in freight transportation and discussed how a better understanding of freight demand characteristics could improve service package design, including subsequent direct benefits for the supply chain.

This study has some limitations. While it discusses several new service features based on the recent transportation innovations, it has not considered the nature and dynamics of operations in particular shipper industries which could potentially reveal some new service features. Another limitation is having access to a limited number of LSP's managers responsible for designing innovative service packages. This limitation also could constraint our identification of emerging service features of innovative transportation services.

Second set of research questions (Chapter 3):

- *Under which circumstances and to what extent are shippers willing to give mode and route selection authority to the LSPs?*

We find that over two-thirds of the shippers may be willing to relinquish control over transportation modes and routes, if they are rewarded by better services or lower costs. We find four different market segments for cost and service level improvements toward the global community of LSPs, freight forwarders and carriers. The first and largest segment is called *high service-level seekers*, who have high willingness to use synchromodal services and delegate modal control, provided LSPs are able to secure high-quality transportation in terms of service time, flexibility and reliability. The first category of shippers are most likely large companies with more than 10,000 employees and annual revenues in excess of more than US$ 10 billion. The *cost-sensitive risk-taking* shippers make up the second largest segment. They are mainly willing to relinquish modal control in exchange for cheaper transportation services. Large firms with 10,000-50,000 employees and annual revenues of US$ 1 to 10 billion are more likely to belong to the second class of shippers. The third shipper segment is called *ancillary service seekers* who are to a large extent willing to delegate modal control by shifting towards synchromodal services that provide the value-added services they are looking for in a transportation service. This class of shippers most probably includes small to medium-sized fortune companies with fewer than 1000 employees and up to US$ 1 billion USD in annual revenues. The fourth segment contains the *risk-averse* shippers who are not willing to relinquish modal control and prefer using the transportation services they are currently using.

Since this study is the first to identify modal control delegation and assess its role in shippers' service choice, it has some limitations. The first limitation is that it ignores some service attributes such as safety and security, trust and collaboration between shippers and LSPs. Another limitation is that some shipment characteristics like distance or commodity value are not taken into account. The last limitation is that this study has not focused on specific industries, geographical areas or commodity types to investigate in more detail the requirements and conditions of shippers when it comes to applying synchromodal transportation.

Third set of research questions (Chapter 4):

- *How strong is the willingness of shipper firms towards using LSP-driven flexible logistics services?*
- *How different is the choice of shippers for LSP-driven flexible logistics services when they operate within a volatile demand and a stable demand business setting?*
- *Which shippers' internal supply chain flexibilities mediate the effect of demand-volatile market setting on their choice of LSP-driven flexible logistics services?*

We find that about 40% of shipper firms are specifically willing to use LSP-driven flexible transportation services. We find that shippers operating in markets with highly volatile demand are willing to choose LSP-driven flexible services to strengthen their capability to address

demand uncertainties. We also find that there is no particular interest for transportation flexibility among shippers operating in markets with stable demand. Regarding the mediation role of internal flexibilities in shippers' supply chains, we find that shippers choosing flexible transportation services will themselves exhibit high volume flexibility in their supply chain, and to a lesser extent other internal flexibilities i.e., product, launch, sourcing and postponement flexibility. This indicates that shippers see LSP-driven flexible transportation services as a tool to strengthen volume flexibility.
This study has also limitations. The first limitation is that this study is mainly focused on demand uncertainties and does not consider supply and process uncertainties when examining the willingness among shippers to use flexible logistics services. Uncertainties in supply side of the supply chain also could trigger shippers to use flexible logistics services. Another limitation is having insufficient data per each industry to discover which level(s) of flexibility, i.e., low, medium or high, is desirable for each industry in different business settings.

Fourth set of research questions (Chapter 5):

- *How strong is the alignment between transportation strategy and supply chain strategy in global supply chains?*
- *How should firms align their transportation strategy to their supply chain strategy?*

We found several counter-intuitive examples within leading international supply chains that suggest misalignments between the transportation strategy and supply chain strategy of firms. The results of our investigation indicate possible limits to the validity of conventional understandings (usually based of Fisher's framework (Fisher, 1997)) about what a right transportation strategy for a supply chain strategy is, i.e., a right transportation strategy for best alignment with an efficient (a responsive) supply chain strategy is an efficient (a responsive) transportation strategy. We propose a new perspective by developing transportation strategies for each of the four well-known supply chain strategies introduced by Lee (2002), i.e., efficient (lean), responsive, risk-hedging and agile supply chain strategies. We propose that only a *customized* transportation strategy can provide a right alignment of transportation strategy with a supply chain strategy, depending on the shipper firms' industry characteristics, nature of products and transportation shipment sizes.
A limitation of this study is that less attention is paid to the organizational criteria for assessing alignment between transportation strategy and supply chain strategy, since we mainly focused on operational criteria. Another limitation is that we have insufficient data for industry sectors to differentiate weights between industry sectors.

6.2 Recommendations for research

In this section we first present future directions for research according to each of the four studies in chapters 2 to 5. We then introduce some other avenues for research.
Study 1 (Chapter 2):

- A key research direction for the future entails the continued identification and measurement of new service attributes/components, relevant to modern logistics requirements.
- For transportation, a shift of mind-set from a mode choice approach to a service choice approach allows to make the link to the supply chain context. As the main connector of all the nodes in the supply chain network, transportation can play a key role in success of shipper firms when its potential for addressing shippers' needs is identified by academicians and practitioners. These potentials could be more deeply explored in research.

- Apart from the attributes and contextual factors discussed in this study, new ones could be identified, based on the nature and dynamics of operations in different industries, and future innovations in freight transportation that are yet to appear in our line of sight.

Study 2 (Chapter 3):

- Scholars can focus on specific industries, geographical areas or commodity types to reveal how the modal control delegation paradigm is emerging.
- In the design of choice experiment important attributes that could be considered include safety and security, trust and collaboration between LSPs and supply chain actors, as well as cost and profit sharing among LSPs and shippers.
- Some shipment characteristics, like distance or commodity value, can be used to model the shippers' choice.
- Requirements and conditions of shippers when it comes to applying synchromodality could be identified.
- The identification of customer segments presents opportunities for differentiated planning, scheduling, network design, revenue management and real-time decision-making.
- Business cases could drive forward more detailed studies involving supply chain resilience and flexibility, demonstrating the value of delegated modal control in the face of network disruptions or sudden demand changes.

Study 3 (Chapter 4):

- One research avenue would be to examine the willingness among shippers to use flexible logistics services in specific industries, for instance retail and apparel.
- Choice studies could be conducted to examine the impact of other business circumstances, e.g., supply and process uncertainty, on the choice of flexible services, and the dynamics involved could be compared for different industries to determine where higher levels of flexibility may be required.
- Research could help identify the requirements and obstacles global LSPs face in their quest to provide more flexible services to shippers.

Study 4 (Chapter 5):

- The alignment of transportation strategy with supply chain strategy for particular industries can be investigated in more details via testing frameworks of Fisher, Lee and Christopher as well as case study research approaches.
- One could investigate how the alignment of transportation strategy and supply chain strategy can impact alignment of other major supply chain functions such as production strategy, procurement strategy and distribution strategy.
- Another research direction is shedding light on organizational criteria of the alignment between transportation strategy and supply chain strategy, since we mainly focused on operational criteria here.

Apart from the abovementioned research directions, we introduce several new interesting directions in the following.

An interesting research topic is investigating the role of innovative transportation services in the business performance of shipper firms. Since new service attributes are introduced in this thesis, several in-depth case study research can be conducted to explore how using these new attributes will impact shipper firms' financial performance, i.e., profit margin, and environmental sustainability (e.g., carbon emissions). This can be done using methods such as Structural Equation Modeling (Hoyle, 1995). For instance, scholars can investigate the question of "how using flexible transportation services to address supply chain uncertainties, e.g., supply disruptions and demand fluctuations, will impact financial, environmental and social indicators of shipper firms?"

Another valuable topic is developing demand forecasting models for innovative logistics systems such as synchromodality. An illustrative example is forecasting the number of containers shipped via seaports in synchromodal transportation system in short-term. Using methodologies such as time series regression methods, and Bayesian regression (Bishop and Tipping, 2003), scholars could come up with models for short-term forecast of synchromodal freight volume (in terms of container quantity) with multiple attributes.
When working on forecasting and modeling freight demand, revenue management (Cross, 2011) can be considered as an interesting area of research since it is primarily based on dynamics in demand and price. Here, scholars could conduct research on the impact of shippers' preferences and forecasted demand on the LSPs' revenue management. To this end, operational research methods could be applied. In particular, when there are uncertainties in supply and demand, methods for optimization under uncertainty such as stochastic and robust optimization could be applied. Another relevant topic here is forecasting changes in long-term freight transportation demand in presence of LSPs' different revenue management strategies. To achieve this goal, one can simulate revenue management strategies for the long-term business strategy of an LSP using, for example, scenario planning and/or system dynamics approaches. Then, optimization models could be used to measure the impacts of applying different revenue management strategies on long-term freight demand. For both above examples, a logistics innovation such as synchromdal transportation could be applied as case study.
A crucial research topic associated with freight demand is investigating required changes in the business models of LSPs when they want to establish innovative freight transportation services. To this end, the following research question could be considered: What would change in terms of business models if the LSPs start providing flexible services/synchromodal services/value-adding features? How should LSPs change their business to adapt to the shippers' changing preferences? If LSPs are going to collaborate with shippers to create innovative transportation services, what changes in their business models need to be done? What are viable collaborate strategies with competitors in order to establish tailor-made services for shippers? What sustainable business models could help LSPs developing effective logistics innovations?
Finally, scholars need to take a dynamic perspective into account with respect to future logistics services. As shippers' attitudes and preferences evolve over time according to the technological developments, LSPs need to identify new preferences and adapt their business models and services accordingly. Scholars could apply simulation methodologies such as system dynamics (Sterman, 2002) to measure and reflect the dynamic impacts of technological, regulative, environmental and social changes on the long-term performance of logistics innovations as they become mainstream in global logistics network. Finally, it is also interesting to investigate the co-evolution of technological aspects and behavioral patterns in the stakeholders of the transportation system. Such an investigation can be done by agent-based modelling.

6.3 Managerial and Policy recommendations

Results of four studies in this thesis provides insights for three main stakeholders of the global logistics system, i.e., customers of freight transportation (shipper companies, such as, BMW and Zara), suppliers of freight transportation (LSPs such as UPS and DSV) and the system-level agents that these customers and suppliers are operating within it (government, or industry organizations). Below we discuss managerial and policy recommendations for each stakeholder.

Considering the shipper firms, an important insight derived from our results for policy making is to align the overall transportation strategy with the corporate supply chain strategy. Since in practice shippers have different supply chain strategies due to the variety of product types they produce/trade, and the dynamics in their markets, it is important to devise transportation strategies aligned with each supply chain strategy to ensure effective demand fulfillment in different markets. This means that shippers need to expect LSPs for tailor-made transportation strategies for each supply chain strategy according to demand volatility of their products and market dynamics. While each of these tailor-made transportation strategies have its own main service attribute(s), they overlap in some service features such as transportation flexibility which could address several uncertainties in different markets at the aggregate level. In case of unavailability of such tailor-made transportation services, shippers could establish collaborative operations management practices with their LSPs, in order to develop the capabilities of their transportation service suppliers, i.e., LSPs. This could be in the form of different partnership levels with LSPs, to develop strategic logistical capabilities for long-term alignment of their supply chain and transportation strategies which ultimately improves their competitiveness.

Taking the perspective of LSPs into account, the first and foremost insight drawn from our results is the existence of a certain degree of eagerness and need among leading shippers to derive much more value from transportation services, with the aim of sustaining supply chain competitiveness. From a strategy and policy making perspective, this thesis suggests LSPs to perform two major changes in their business: shifting from a supply-driven to a more demand-driven business strategy and develop innovative service propositions. For the earlier change, LSPs need to promote a service choice approach over the conventional mode choice approach by designing and operationalizing mode-free high-quality innovative services tailored with the supply chain strategies of shipper firms. Doing this will shift shippers' mindset from a mode-choice to a service choice approach in the long run which provides enough room for LSPs to improve efficiency of their resources the logistics network. For the latter change, LSPs should design customized service solutions for diverse supply chain strategies and segments of shippers. Considering global shippers' interest to new service attributes identified in this thesis, i.e., modal control, flexibility and value-added services, could provide a firm ground for LSPs to develop more fitting transportation service packages. In the long run, however, it is of a crucial importance for LSPs to monitor challenges in the business context of their shipper customers carefully and try to predict what new logistics service attributes might be required by shippers in near and long-term future. This will help developing competitive service portfolios supporting their long-term competitive advantage.

Considering the global shippers' requirements and interests for innovative logistics services, public policymakers have a crucial role in promoting logistics innovations from three perspectives: logistics operations, ICT infrastructures and rules/regulations. With respect to the logistics operations, public policymakers need to enhance the existing infrastructure and service investments to enable LSPs to provide innovative logistics service packages for shipper firms. This could be done via, for example, supporting regional transportation networks that allow switching between transportation modes, and establishing more warehousing/mode-volume switch locations in the logistics network. The next important category is supporting the uptake of ICT infrastructure required by LSPs and shippers for real-time support to innovative logistics systems. Another major role of public policymakers is in the adopting proper international rules and regulations to pave the way for a true provision and utilization of innovative logistics services internationally. Public policy makers can also use financial or non-financial incentives for encouraging LSPs and shippers to improve integration of global logistics network. This will help satisfying the share of transportation in achieving global sustainability visions such as UN Paris agreement (Agora, 2019) and EU Green Deal (European Commission, 2020).

Finally, since the results and insights of our studies in this thesis are gained from our study among Global fortune 500 companies (Fortune magazine, 2017) which are often industry leaders, we expect that the preferences of these global leader shippers will at some point become widespread within the industry. This could ensure LSPs' practitioners and public policymakers that there would be sufficiently fertile ground to innovate logistics and transportation services in the long run.

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Summary

Several innovations during the last decades have impacted freight transportation as one of the major drivers of global economic development. Both demand and supply of freight transportation services have been transformed through major recent logistics' innovations such as globalization dynamics, freight network integration, mass-individualized logistics services, digitalization and advanced transportation technologies. Changes in the service deployment of logistics service providers (LSPs) will ultimately transform characteristics of their logistics service packages resulting in the emergence of new service features for their customers i.e., shipper firms. These new features not only influence business operations of the customer firms directly or indirectly, but also change shipper firms' expectations in the long run. While a deep understanding of customers' needs is one of the key factors to sustain competitive advantage of firms, in freight transportation less attention is being paid to understand beforehand whether an innovation is appreciated and will be utilized by customers. The innovations in freight transportation services are offering shippers new choices and service offerings which claim big advantages for shippers. However, no one has yet tried to measure these advantages. This lack of knowledge makes it difficult for LSPs to compose multi-dimensional service packages and to set prices in the market. Fulfilling this practical need requires a major research effort, to formulate and empirically model the demand for these services.

Considering the existing limitations in understanding customers' attitudes towards innovative freight transportation services, this thesis aims to measure the role of innovative logistics-related service attributes in the demand for freight transportation services. To this end several research questions are introduced and addressed mainly using two methodologies: Discrete choice modelling (DCM) and Multi-criteria decision-making (MCDM). More specifically, DCM methods such as multinomial logit, mixed logit and latent class modelling, and an MCDM method called Best-Worst Method (BWM), are applied. All the model estimations are based on stated preference (SP) data from our survey among Global Fortune 500 companies and major customer firms of the 40 largest global LSPs, including all different industries and commodity types that account for the majority of global transportation volume and value.

Following an introductory chapter (Chapter 1), in Chapter 2, three new transportation service attributes are identified which drive the choice of shipper firms for innovative freight

transportation services, i.e., modal control delegation, service flexibility and value-added services. Modal control delegation involves transferring the transportation mode choice decision from shippers to the LSPs. Flexibility allows the shipper to change the service specification after the first agreement, until the final fulfilment of the service. Value-added are ancillary services including tracking and tracing, storage and handling, customs and packaging offered by the LSP beyond the main transportation service. The important contextual factors of demand that influence shippers' choice for innovative freight transportation services are also discussed. These contextual factors include shippers' supply chain strategy, demand volatility, internal flexibilities and industry nature. The concept of service choice approach in freight transportation is also discussed to highlight how a better understanding of freight demand characteristics could improve service package design, including subsequent direct benefits for the supply chain.

In Chapter 3, the willingness among shippers to delegate their mode choice authority to the LSPs is examined. Considering the global shippers' agreement/permission to fully delegate modal control authority to LSPs as an emerging paradigm in transportation and logistics, this paradigm is validated in the context of synchromodal transportation, since decisions regarding transportation mode/route selection are made by LSPs in real-time.

The findings of this study reveal that over two-thirds of the shippers may be willing to relinquish control over transportation modes and routes, if they are rewarded by better services or lower costs. Four different market segments for cost and service level improvements are identified. The first and largest segment is called high service-level seekers, who have high willingness to use synchromodal services and delegate modal control, provided LSPs are able to secure high-quality transportation in terms of service time, flexibility and reliability. The first category of shippers are most likely large companies with more than 10,000 employees and annual revenues in excess of more than US$ 10 billion. The cost-sensitive risk-taking shippers make up the second largest segment. They are mainly willing to relinquish modal control in exchange for cheaper transportation services. Large firms with 10,000-50,000 employees and annual revenues of US$ 1 to 10 billion are more likely to belong to the second class of shippers. The third shipper segment is called ancillary service seekers who are to a large extent willing to delegate modal control by shifting towards synchromodal services that provide the value-added services they are looking for in a transportation service. This class of shippers most probably includes small to medium-sized fortune companies with fewer than 1000 employees and up to US$ 1 billion USD in annual revenues. The fourth segment contains the risk-averse shippers who are not willing to relinquish modal control and prefer using the transportation services they are currently using.

In Chapter 4, the willingness of shipper supply chains to utilize flexible logistics services is investigated. Knowing more about the relevant shippers' characteristics e.g., shipper firms' market environment such as demand volatility, would help LSPs to understand the extent their customers seek a flexible logistics service to address uncertainties in their competitive markets. This study explores the impact of shipper firms' market environment such as demand volatility, as well as internal supply chain flexibilities such as volume, product, launch, sourcing and postponement flexibilities on the shippers' choice of flexible transportation services.

Finding of this study show that about 40% of shipper firms are specifically willing to use LSP-driven flexible transportation services. In particular, shippers operating in markets with highly volatile demand are willing to choose LSP-driven flexible services to strengthen their capability to address demand uncertainties. This study also finds that there is no particular interest for transportation flexibility among shippers operating in markets with stable demand. Regarding the mediation role of internal flexibilities in shippers' supply chains, the findings express that shippers choosing flexible transportation services will themselves exhibit high

volume flexibility in their supply chain, and to a lesser extent other internal flexibilities i.e., product, launch, sourcing and postponement flexibility. This indicates that shippers see LSP-driven flexible transportation services as a tool to strengthen volume flexibility.
Chapter 5 focuses on investigating the impact of an important contextual factor of freight demand, i.e., supply chain strategy of shipper firms, on the attributes of innovative freight transportation services that represent a shipper's transportation strategy. One of the key success factors for shipper firms is how their transportation strategy is aligned with their corporate supply chain strategy. This study also investigates suitable transportation strategies to make an alignment between transportation strategy and supply chain strategy.
Several counter-intuitive examples within leading international supply chains are found that suggest misalignments between the transportation strategy and supply chain strategy of firms. This indicates possible limits to the validity of conventional understandings about what a right transportation strategy for a supply chain strategy is, i.e., a right transportation strategy for best alignment with an efficient (a responsive) supply chain strategy is an efficient (a responsive) transportation strategy. This study proposes a new perspective by developing transportation strategies for each of the four well-known supply chain strategies i.e., efficient (lean), responsive, risk-hedging and agile supply chain strategies. It is concluded that only a customized transportation strategy can provide a right alignment of transportation strategy with a supply chain strategy, depending on the shipper firms' industry characteristics, nature of products and transportation shipment sizes.
In conclusion, this thesis contributes to the research on freight transportation demand taking into account logistics-related innovations. This thesis has addressed the role new service attributes, i.e., modal control delegation, transportation flexibility, and value-added services, and contextual factors of freight demand, i.e., shippers' internal flexibility capabilities, end-consumer demand volatility and underlying supply chain strategies, play in the adoption of innovative freight transportation services. In addition, the thesis shows the importance of moving from mode choice to service choice approach to pave the way for adopting various new innovations in freight transportation. Furthermore, this research evaluates the alignment of transportation strategy and supply chain strategy in global supply chains and recommend fitting strategies for improving overall supply chain performance. Hence, the contributions of this research motivate future research to understand the underlying complexities in shippers' attitude towards freight transportation innovations.

Samenvatting

Verschillende innovaties hebben in de afgelopen decennia invloed gehad op het vrachtvervoer als een van de belangrijkste motoren van de mondiale economische ontwikkeling. Zowel de vraag als het aanbod van vrachtvervoersdiensten zijn getransformeerd door belangrijke recente logistieke innovaties zoals de globaliseringsdynamiek, netwerkintegratie, massa-geïndividualiseerde logistieke diensten, digitalisering en geavanceerde transporttechnologieën. Logistieke dienstverleners (3PL'ers) veranderen uiteindelijk ook de eigenschappen van hun logistieke services, leidend tot nieuwe servicefuncties voor hun klanten, d.w.z. verladers. Deze nieuwe functies hebben niet alleen korte termijn invloed op de bedrijfsactiviteiten maar veranderen ook de verwachtingen van verladers op de lange termijn. Hoewel een diepgaand begrip van de behoeften van klanten een van de sleutelfactoren is om het concurrentievoordeel van bedrijven te behouden, wordt in logistiek onderzoek weinig aandacht besteed aan de vraag of een innovatie wordt gewaardeerd en door klanten zal worden gebruikt. Hoewel innovaties in logistieke diensten verladers allerlei nieuwe keuzes bieden en grote voordelen claimen, worden deze voordelen nauwelijks gemeten. Dit gebrek aan kennis maakt het voor 3PL'ers moeilijk om multidimensionale servicepakketten samen te stellen en passende prijzen in de markt vast te stellen. Het vervullen van deze praktische behoefte vereist een grote onderzoeksinspanning, in het bijzonder om de vraag naar deze diensten te kwantificeren en empirisch te modelleren.

Dit proefschrift heeft als doel het meten van het effect van innovatieve servicekenmerken op de vraag naar logistieke diensten. Daartoe worden verschillende onderzoeksvragen geïntroduceerd en beantwoord, voornamelijk met behulp van twee methodologieën: discrete keuzemodellen (DCM) en Multi-Criteria Decision-Making (MCDM). Meer specifiek worden DCM-methoden zoals multinomial logit, mixed logit en latent class modelling, en een MCDM-methode genaamd Best-Worst Method (BWM) toegepast. Alle modelschattingen zijn gebaseerd op gegevens van stated preference (SP) uit een grote enquête onder ‘Global Fortune 500’-bedrijven en grote klanten van de 40 grootste wereldwijde logistieke dienstverleners. Deze bedienen samen de industrieën en grondstoftypen die het grootste deel van het wereldwijde transportvolume en -waarde voor hun rekening nemen.

Na een inleidend hoofdstuk (hoofdstuk 1), worden in hoofdstuk 2 drie nieuwe kenmerken van transportdiensten geïdentificeerd, d.w.z. delegatie van modale controle, serviceflexibiliteit en toegevoegde waarde-diensten. Het delegeren van modale controle houdt in dat de beslissing over de keuze van de transportmodaliteit tijdens de uitvoering van de dienst wordt overgedragen van verladers naar de 3PL'ers. Deze flexibiliteit stelt de verlader ook in staat om de servicespecificatie te wijzigen na de eerste overeenkomst, totdat de uitvoering van de service heeft plaatsgevonden. Toegevoegde waarde-diensten betreffen ondersteunende diensten, waaronder tracking en tracing, opslag en afhandeling, douane en verpakking, aangeboden door de 3PL'er naast de belangrijkste transportdienst. De belangrijke contextuele vraagfactoren die de keuze van verladers voor innovatieve vrachtvervoersdiensten beïnvloeden, worden ook besproken. Deze contextuele factoren omvatten de bevoorradingsketen-strategie van verladers, de volatiliteit van de vraag, interne flexibiliteit en de aard van de branche. Het concept van dienst keuze aanpak in vrachtvervoer wordt ook besproken om te benadrukken hoe een beter begrip van de kenmerken van de vraag naar vracht het ontwerp van servicepakketten zou kunnen verbeteren, met inbegrip van de daaropvolgende directe voordelen voor de toeleveringsketen. In hoofdstuk 3 wordt de bereidheid van verladers onderzocht om hun moduskeuzebevoegdheid te delegeren aan de 3PL'ers. Gezien de overeenkomst/ toestemming van de wereldwijde verladers om modale controlebevoegdheid volledig te delegeren aan 3PL'ers als een opkomend paradigma in transport en logistiek, wordt dit paradigma gevalideerd in de context van synchromodaal transport, aangezien beslissingen met betrekking tot transportwijze/ routes in werkelijkheid door 3PL'ers worden genomen. -tijd.

De bevindingen van deze studie laten zien dat meer dan twee derde van de verladers bereid zou zijn om de controle over transportmodaliteiten en routes op te geven, als ze worden beloond met betere dienstverlening of lagere kosten. Er worden vier verschillende marktsegmenten voor verbeteringen van kosten en serviceniveaus geïdentificeerd. Het eerste en grootste segment worden “high service-level seekers” genoemd, die een hoge bereidheid hebben om synchromodale services te gebruiken en modale controle te delegeren, op voorwaarde dat 3PL'ers in staat zijn om kwalitatief hoogstaand transport te garanderen in termen van servicetijd, flexibiliteit en betrouwbaarheid. De eerste categorie verladers zijn grote bedrijven met meer dan 10.000 werknemers en een jaaromzet van meer dan 10 miljard dollar. De kostengevoelige, risicovolle verladers vormen het op een na grootste segment. Ze zijn vooral bereid de modale controle op te geven in ruil voor goedkopere transportdiensten. Grote bedrijven met 10.000-50.000 werknemers en een jaaromzet van 1 tot 10 miljard dollar behoren eerder tot de tweede klasse van verladers. Het derde verladerssegment wordt “ondersteunende dienst-zoekers” genoemd. Deze verladers zijn in hoge mate bereid zijn om over te schakelen op diensten die de specifieke toegevoegde waarde leveren waarnaar ze op zoek zijn in een vervoersdienst. Deze klasse van verladers omvat hoogstwaarschijnlijk kleine tot middelgrote fortuinbedrijven met minder dan 1000 werknemers en tot 1 miljard USD aan jaarlijkse inkomsten. Het vierde segment bevat de risicomijdende verladers die niet bereid zijn de modale controle op te geven en liever gebruik maken van de transportdiensten die ze momenteel gebruiken.

In hoofdstuk 4 wordt de bereidheid van toeleveringsketens van verladers onderzocht om gebruik te maken van flexibele logistieke diensten. Deze studie onderzoekt de impact van de marktomgeving van verladersbedrijven, zoals de volatiliteit van de vraag, evenals de flexibiliteit van de interne toeleveringsketen, zoals volume-, product-, lancerings-, inkoop- en uitstelflexibiliteit op de keuze van de verladers voor flexibele transportdiensten. Naarmate meer bekend is over de kenmerken van de relevante verladers, bijvoorbeeld de marktomgeving van verladersfirma's en de volatiliteit van de vraag, kunnen 3PL'ers beter begrijpen in hoeverre hun klanten een flexibele logistieke dienst zoeken om de onzekerheden in hun concurrerende markten aan te pakken.

Uit deze studie blijkt dat ongeveer 40% van de verladersbedrijven specifiek bereid is om gebruik te maken van 3PL'er-aangedreven flexibele transportdiensten. Met name verladers die actief zijn in markten met een zeer volatiele vraag, zijn bereid om 3PL'er-gestuurde flexibele diensten te kiezen om hun vermogen om de vraagonzekerheden aan te pakken, te versterken. Uit deze studie blijkt ook dat er geen bijzondere interesse is voor transportflexibiliteit bij verladers die actief zijn in markten met een stabiele vraag. Met betrekking tot de bemiddelende rol van interne flexibiliteit in de toeleveringsketens van verladers, geven de bevindingen aan dat verladers die kiezen voor flexibele transportdiensten, zelf een hoge volumeflexibiliteit zullen vertonen in hun toeleveringsketen, en in mindere mate andere interne flexibiliteit, d.w.z. flexibiliteit van product, lancering, bevoorrading en uitstel. Dit geeft aan dat verladers 3PL'er-gestuurde flexibele transportdiensten zien als een instrument om volumeflexibiliteit te versterken.

Hoofdstuk 5 richt zich op het onderzoeken van de impact van een belangrijke contextuele factor van de vraag naar goederen, d.w.z. de bevoorradingsketen-strategie van verladers, op de kenmerken van innovatieve vrachtvervoersdiensten die de transportstrategie van een verlader vertegenwoordigen. Een van de belangrijkste succesfactoren voor verladersbedrijven is hoe hun transportstrategie is afgestemd op hun corporate bevoorradingsketen-strategie. Deze studie onderzoekt ook geschikte transportstrategieën om een afstemming te maken tussen de transportstrategie en de bevoorradingsketen-strategie.

Er worden verschillende contra-intuïtieve voorbeelden gevonden binnen toonaangevende internationale toeleveringsketens die wijzen op een verkeerde afstemming tussen de transportstrategie en de toeleveringsketenstrategie van bedrijven. Dit geeft mogelijke grenzen aan de geldigheid van conventionele inzichten over wat een juiste transportstrategie voor een bevoorradingsketen-strategie is, dat wil zeggen, een juiste transportstrategie voor de beste afstemming met een efficiënte (een responsieve) bevoorradingsketen-strategie is een efficiënte (een responsieve) transportstrategie. Deze studie stelt daarom een nieuw perspectief voor door transportstrategieën te ontwikkelen voor elk van de vier bekende bevoorradingsketen-strategieën, d.w.z. efficiënte (mager), responsieve, risicoafdekking en agile bevoorradingsketen-strategieën. Er wordt geconcludeerd dat alleen een op maat gemaakte transportstrategie een juiste afstemming van de transportstrategie met een bevoorradingsketen-strategie kan bieden, afhankelijk van de branchekenmerken van de verladers, de aard van de producten en de omvang van transportzendingen.

Concluderend draagt dit proefschrift bij aan het onderzoek naar de vraag naar logistieke diensten. Dit proefschrift behandelt specifiek de rol van nieuwe servicekenmerken, d.w.z. delegatie van modale controle, transportflexibiliteit en diensten met toegevoegde waarde. Hierbij blijken contextuele factoren van de vraag naar diensten, d.w.z. de interne flexibiliteitscapaciteiten van verladers, de volatiliteit van de vraag van eindgebruikers en onderliggende bevoorradingsketen-strategieën, mee te spelen in de adoptie van deze diensten. Bovendien laat het proefschrift zien hoe belangrijk het is om van modaliteitskeuze naar servicekeuze-benadering over te gaan om de weg vrij te maken voor het adopteren van verschillende nieuwe innovaties in het vrachtvervoer. Tenslotte evalueert het onderzoek de afstemming van de transportstrategie en de bevoorradingsketen-strategie in wereldwijde toeleveringsketens en beveelt het passende strategieën aan om de algehele prestaties van de toeleveringsketen te verbeteren. Wij hopen dat dit onderzoek ook zal leiden tot meer en nieuwe inspanning om de vraag van verladers naar innovatieve logistieke diensten beter te begrijpen.

About the author

Masoud Khakdaman was born on 11 September 1981 in Qom, Iran. He obtained his bachelor degree in industrial engineering from Yazd University in iran. He then worked for six years in automotive and textile industries in Iran. Inspired by challenges in supply chain management area, he continued his studies in two master programs of industrial engineering at the Malaysia University of Technology and supply chain management at the MIT-Malaysia institute for supply chain innovation. He then worked for Schlumberger and AirAsia to expand his knowledge and experience in oil & gas and airline industries as well. His passion in applying state-of-the-art of the knowledge in addressing real-world complex SCM challenges resulted in wining prestigious awards in academia e.g., MIT-MISI (Best thesis award for proposing innovative solution strategies for Starbucks supply chain) as well as industry e.g., AirAsia (Ancillary Revenue & Merchandising Award for designing optimized bundle of products in air travel service packages using gigantic airline data sets), among all. He then started his Ph.D. at the Delft University of Technology working on the impact and value-addition of new logistics innovations such as Synchromodal transportation. Even before finishing his Ph.D. he was offered a postdoc position at Vrije Universiteit Amsterdam working on sustainable supply chain management.

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