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# Modelling the interrelation of supply chain structures and freight transport demand – The case of vertical disintegration in the German automotive industry

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Our paper introduces a model to determine possible impacts of changes in supply chain structures on freight transport demand. Examples are centralization or vertical (dis)integration within supply chains. The model first generates a population of establishments and commodity flows in space which is then manipulated according to different scenarios. It uses methods from transport planning and optimization as well as the scenario technique. To demonstrate its applicability a vertical disintegration in automotive supply chain structures in Germany is analysed. The results show that a more educated discussion is needed for such changes since the range of possible impacts is large.

## 1 Introduction

The economy and its spatial and organisational structure permanently evolve to adapt to a continuously evolving environment, e.g. driven by technological, political, or environmental developments. Christopher (1992) emphasises that the relevant economic entities are no longer isolated firms but rather networks of interdependent companies, i.e. supply chains. Examples of industry specific developments of supply chain patterns that directly influence freight transport demand can be found in many sectors. For example, the implementation of new production and procurement principles in the automotive industry, such as modular sourcing, often requires adding additional production stages, i.e. vertical disintegration, to the supply chain. In consequence, existing spatial material flows need to be reorganised as well, directly leading to changes in freight transport demand. **Fehler! Verweisquelle konnte nicht gefunden werden.** illustrates the two different kinds of structural change, i.e. horizontal and vertical, by giving simplified examples for each category of

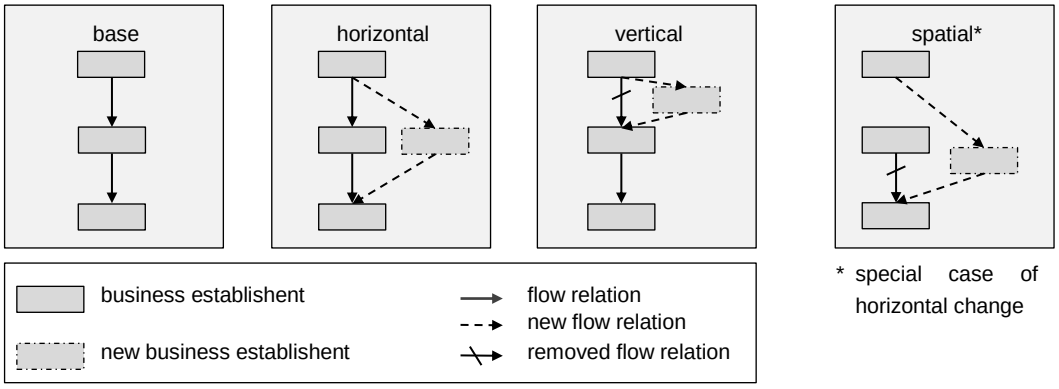


**Figure 1** Categories of changes in supply chain structure with examples

change.

## 2 Literature Summary

Developments on the level of supply chain structures have gained attention from various authors in the area of freight transport research (e.g. Voordijk (1999), Drewes Nielsen et al. (2003), Varschen et al. (2005)). However, studies that quantitatively address the interrelation of supply chain structures and freight transport demand are of aggregate nature ( McKinnon und Woodburn (1996), Jäcker (1997), and Holzapfel und Vahrenkamp (1999)) or focus on effects such as centralisation within logistics structures (e.g. Rodrigue et al. (2001) and Kohn (2005)).

Regarding comprehensive large-scale freight transport models, Tavasszy et al. (1998) present one of the first approaches for integrating entire supply chains including logistics. However, applications of such large-scale models only implicitly capture the interdependency of supply chain structures and freight transport demand by using rather aggregate approaches (e.g. Burgess et al. (2008) and Schubert et al. (2014)). Even in the cases where the developed freight transport models explicitly consider business establishments and the relations between them, they are not applied for estimating the impact of changes in the population of establishments or their linkage, i.e. the supply chain structures (e.g. de Jong und Ben-Akiva (2007) and Samimi (2010)).

Hence, our research question is as follows: How do developments on the supply chain level influence freight transport demand?

## 3 Model

The study at hand addresses this gap by developing a disaggregate model for simulating the impact of change in supply chain structures on the corresponding freight transport demand. For this purpose, the model quantitatively describes spatially disaggregate supply chain structures, consisting of business establishments and commodity flows, on the level of entire sectors.

The developed model consists of two phases. A first phase generates an artificial industry landscape of business establishments and commodity flows according to available aggregate statistics. The generation relies on elements of stochastic simulation and directed choice procedures. The model's second phase simulates change in the supply chain structures from the first phase. Using linear programming, a maximum solution range regarding the impact on freight transport is calculated. Increasing the degree of assumptions, the solution space can be narrowed. Here, the model applies a combination of stochastic simulation, linear programming, and fitting procedures.

The model is applied for analysing vertical disintegration in the automotive industry of Germany. Here, a broad range of data sources is used, e.g. common public statistics on establishment sizes and spatial distribution of employment but also sectoral data, e.g. from industry associations or case studies. The real-world consistency of spatial flow patterns is ensured by assigning commodity flows according to statistical macroscopic flows.

## 4 Results of Model Application

Overall, the simulation results show that an increase in freight transport performance is to be expected for the case of vertical disintegration. However, the maximum solution ranges also indicate that assuming suitable location choice and flow assignment a reduction in freight transport performance is mathematically possible. The analysis also addresses the suitability of state measures for mitigating the impact of changes in the supply chain structure on freight transport demand.

## 5 Conclusions

The described approach is a progress for future analysis of supply chain structure effects such as vertical disintegration. Compared to all existing studies speculating about possible impacts without detailed quantifications, the presented approach makes the discussion more precise. It offers a way to quantify possible effects in space. Using the range logic that considers multiple scenarios, it accounts for the different forms a change in supply chain structure may take in space.

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