VIENNA 2018 TRA
A digital era for transport
solutions for society, economy and environment

Proceedings of 7th Transport Research Arena TRA 2018, April 16-19, 2018, Vienna, Austria

The effects of longer trucks on freight transport demand in Germany

Jan-André Bühne[a]*, Robert Burg[b], Marco Irzik [a]

[a] *Federal Highway Research Institute (BAST), Brüderstr. 53, 51427 Bergisch Gladbach, Germany,*
[b] *SSP Consult, Beratende Ingenieure GmbH, Giselastraße 4a, 79183 Waldkirch, Germany*

Abstract

In 2012 the German Federal Government started a five-year field trial with longer trucks. One scientific project focused on empirical data of the logistic and transport processes as well as the modelling of future mileage and market shares of longer trucks. Based on predefined scenarios, potential areas of application and accessible routes for longer trucks were determined using a likelihood approach with particular attention to the different definitions of a longer truck suitable road network. In a second step empirical data covering logistic characteristics collected from participating carriers and forwarders were integrated into a sophisticated transport model in order to estimate transport demand effects and emissions of air pollutants as well as greenhouse gases stemming from longer trucks in normal business operations. The analyses of the traffic demand modelling for the scenarios shows for the reference years 2014 and 2030 that due to logistical constraints and requirements (generally) only a small part of all German heavy good vehicle trips (about 3.0 to 3.2 %) and even a smaller part of all rail and inland waterway transport performance (1.8 and 2.9 %) can be considered as potentially shiftable to longer trucks.

Keywords: longer trucks; freight transport demand; transport modelling; energy efficiency

* Corresponding author. Tel.: +49 2204 43 3203; fax: +49 2204 43 3250.
E-mail address: buehne@bast.de

1. Introduction

Despite of progress in the reduction of the environmental impact of the transport sector in the last couple of years, transport is still responsible for 25 % of European Union (EU) greenhouse gas emissions and contributes significantly to air and noise pollution, and habitat fragmentation (EEA 2015). In order to achieve the European Commission's ambitious goal of a 60 % reduction in greenhouse gas emissions by 2050 while guaranteeing economic growth, new and effective technologies and measures have to be used and implemented (EC 2011).

As one possible solution to address this challenge the introduction of heavy goods vehicles with a higher capacity for freight volume was discussed in many European countries (e. g. Ramberg 2004; Aarts; Honer, 2010; Hellung-Larsen 2011; OECD 2011). With the adoption of the Council Directive 96/53/EC of 25 July 1996 the EU opened up the possibility for the use of overlength vehicles and vehicle combinations (here referred to as "longer trucks") on certain roads and routes based on exemption regulations in the member states (The Council of the European Union 1996). The aim was the creation of a legislative framework in order to benefit from efficiency gains in the road freight transport sector. In 2011, the Federal Ministry of Transport, Building and Urban Development (BMVBS) commissioned the Federal Highway Research Institute (BASt) to conduct a supporting scientific study on a nationwide field trial of longer trucks. Out of over twenty scientific projects within the field test, one project aimed to estimate the market potential of longer trucks in Germany. This study focused on empirical data of the logistic and transport processes as well as the modelling of future mileage and market shares of longer trucks.

This paper is organized as follows: The first section gives a brief description of the framework of the German field trial and the structure of the freight transport demand analysis. After that, the survey design and the according empirical results are outlined. Based on predefined scenarios, potential areas of application and accessible routes of longer trucks were determined using a likelihood approach with particular attention to the different definitions of a longer truck suitable road network (Positive network). In a second step the empirical data from the participating carriers and forwarders were integrated into a sophisticated transport model in order to estimate the transport demand effects and emissions of air pollutants as well as greenhouse gases stemming from longer trucks in normal business operations. In the final section the transport demand effects of longer trucks for the reference years 2014 and 2030 are presented and discussed Based on the defined suitable road network

2. Longer trucks field trial and freight transport demand study

2.1. Description of the field trial

The field trial was launched on 1 January 2012 and was scheduled to run for five years. It is part of the BMVBS's Freight Transport and Logistics Action Plan (BMVBS 2010). The legal basis for the conduct of the field trial is constituted by regulations issued by the Federal Minister of Transport on "Exemptions from Road Traffic Law Provisions governing Overlength Vehicles and Vehicle Combinations" ("the Exemption Regulations") of 19 December 2011 and the relevant amending regulations. Firstly, the Exemption Regulations distinguishes between five different types of longer trucks (BMVBS 2011):

1. Tractor with extended semi-trailer (articulated vehicle), total length not exceeding 17.80 metres
2. Articulated vehicle with centre axle trailer, total length not exceeding 25.25 metres
3. Tractor with dolly and semi-trailer, total length not exceeding 25.25 metres
4. Articulated vehicle with a second semi-trailer (B-Double), total length not exceeding 25.25 metres
5. Tractor-Trailer Combination, total length not exceeding 24.00 metres.

Secondly, one of the most important parameters of the German field trial was that longer trucks may be designed with a length up to 25.25 m, but a higher gross weight than the currently applicable 40 tonnes (or 44 tonnes on the initial and terminal hauls in combined transport) is not permissible on Germany's roads. Earlier studies conducted by the Federal Highway Research Institute (Glaeser et al. 2006) have already shown that the infrastructure, especially bridge structures, is not designed for vehicles or vehicle combinations with a gross vehicle weight higher than that which is currently permissible (40 t/44 t (CT)). Moreover, the higher kinetic energy associated with an increase in weight would, in the event of an accident, result in a significant deterioration of road safety. Due to this the Federal Government agreed to allow only longer, and not heavier, trucks to be tested in a field trial.

Thirdly, the Exemption Regulations determine the conditions that have to be met by longer trucks to be allowed to use the roads in derogation from the provisions of the Road Traffic Regulations and the Road Vehicles Registration and Licensing Regulations. In particular, they define the requirements to be met by vehicles or vehicle combinations and by drivers. In addition, they list requirements relating to loads, road user behaviour (overtaking) and participation in the supporting scientific research. Finally, although longer trucks also have to meet the turning circle requirements set out in section 32d of the German Road Vehicles Registration and Licensing Regulations (StVZO 2012), experience so far suggests that it might not per se be possible for vehicle combinations, especially those with a length of up to 25.25 m, to operate on all highway facilities. Longer trucks may therefore operate only on suitable origin-destination pairs, i.e. only on roads that have been declared suitable by the competent ministries of the federal states concerned for the operation of longer trucks, that have been notified to the BMVI and that have subsequently been published in the Exemption Regulations. Thus, in accordance with section 2 of the Exemption Regulations longer trucks may only be operated on the routes stipulated in the Annex to the Regulations (authorized network).

Currently the authorized network has a total length of almost 11,600 kilometres with around 70 % federal motorways. This is equivalent to just over 60 % of all federal motorways in Germany. The sections of federal highways, regional roads and district roads approved for use by longer trucks account for only a small percentage of the total length of inter-urban roads (excluding federal motorways) of the federal states participating in the field trial. The proportion of local roads on the authorized network in terms of all local roads in Germany is a few permille. Some federal states refused to allow the operation of longer trucks during the field trial. This resulted in a situation where several federal states were not involved in the field trial at all and thus have not designated any suitable routes for the authorized network (so called Positive network) on which longer trucks may operate.

The purpose of the supporting scientific research was also to bring greater objectivity to the discussions on the issue of "longer trucks" (Irzik et al. 2016). Starting point were the the arguments against longer and heavier trucks by various stakeholders and organisations in the past. The critics expressed concerns regarding the increase in length, which was the only subject addressed in the field trial. Further concerns included a potential shift in freight transport demand. As a result of the likely efficiency enhancement and the associated cost advantages in the road haulage sector, freight traffic would be shifted from the railways to the roads and/or new road traffic would be induced, meaning that ultimately there would be more rather than less road freight traffic. Therefore, the estimation of the scope and dimension of potential demand shifts was the subject of a research project led by an external research institute.

2.1. Approach of the freight transport demand study

The approach of the freight transport demand study (Burg, Schrempp, Röhling, Klaas-Wissing, Schreiner 2016) consisted of three main steps (see figure 1). Basic input for the study was observational empirical data of transport processes collected by a baseline study during the first phase of the field trial (Röhling, Burg, Klaas-Wissing; 2014). In particular the methodology and results of the surveys and the estimated national intra-modal market potential for longer trucks were used in a follow-up study.

To verify the results and to gain possible new insights an additional empirical survey of transport processes of the members of the test trial was conducted. The survey's approach regarding input and objectives were adopted from the former study. Again the main objective was the observation and collection of actual transport data of longer trucks within the test run. These quantitative data were supplemented by qualitative interviews in a parallel survey with participants and also with non-participants of the field trial, e. g. about their assessments of transport demand effects and market opportunities of longer trucks.

In a third step potential areas of application and the accessible routes of longer trucks were determined for predefined scenarios using a likelihood approach with particular attention to the different definitions of a longer truck suitable road network (Positive network). The empirical data from the participating carriers and forwarders were integrated into a sophisticated transport model in order to estimate the transport demand effects and emissions of air pollutants as well as greenhouse gases stemming from longer trucks in normal business operations. Based on the defined suitable road network the transport demand effects of longer trucks were calculated for the reference years 2014 and 2030 via an integrated transport model with special focus on an enhanced mode choice model for longer trucks. A given traffic demand based on the national freight traffic forecast of the BMVI served as the foundation of the analysis.

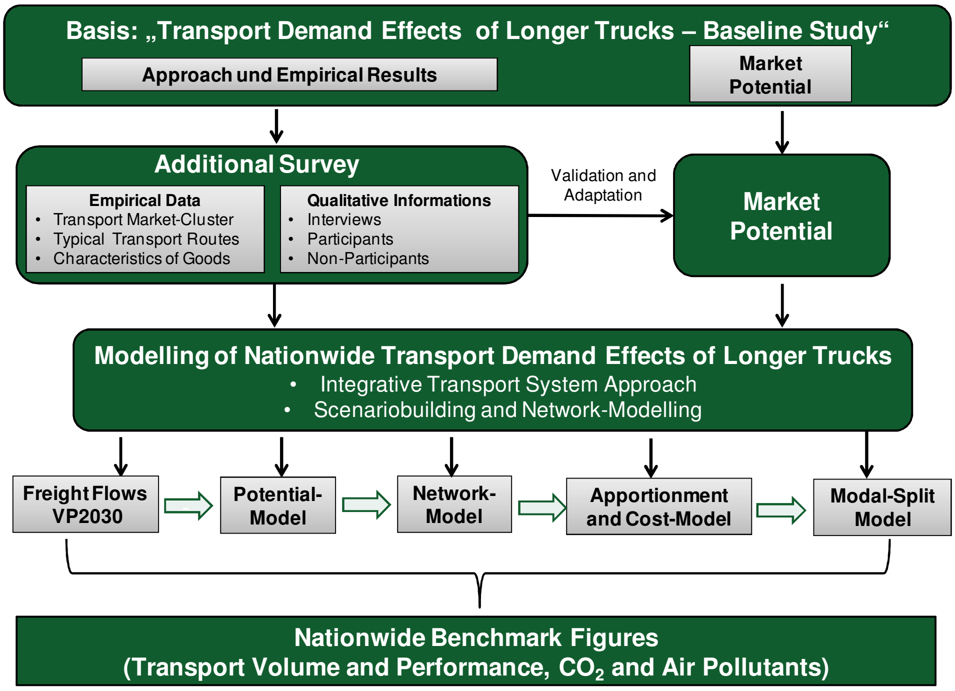

Fig. 1 Approach of the freight transport demand study

The aim/objective of the scenarios was to assess a wide range of impacts regarding the use of longer trucks with different road networks restrictions (Positive network). Therefore, there were two scenarios: the network access according to the 6th network regulation, and an extended network, consisting of a core network including extended catchment area. The detailed definitions of the network scenarios are as followed:

- Scenario A: Limited network according to 6th network regulation for longer trucks Type 2-5
- Scenario B: Enhanced nationwide core network with expanded catchment area for longer trucks type 2-5.

3. Survey

One major focus of this study was to gain empirical data of the logistic and transport processes. During the field test two separate surveys were conducted in order to specify the national intra-modal market potential for longer trucks as well as the logistic characteristics of their typical application areas. The participants of the survey (51 companies with 134 vehicles) were asked to fill in questionnaires about important aspects like the type of carried goods, payload, type of origin, and destination. These quantitative data were then supplemented by qualitative interviews in a parallel survey with participants and also with non-participants of the field trial, e. g. about their assessments of transport demand effects and market opportunities of longer trucks. The main results of the empirical survey of longer trucks can be summarized as follows:

- Type of goods: More than 60% can grouped to the commodities of "Other goods and unidentifiable goods", "grouped goods" and commodities of the automotive industry (without car transport).
- Type of transport: By far the predominant type of transport is directly and permanent rerun trip as a main haulage.
- Type of origin and destination: About three quarters of all trip origins and destinations can be defined as a production or storage location (own or external).
- Payload and utilization: The average payload is between 13 and 14 tons. The share of empty runs is about 6 % and the average utilization rate is more than 85 % (regarding volume as well as loading metres).
- Type of loading unit: About 2/3 of all trips consists of "palletised goods” and only a small proportion of "containers and swap bodies".

It can be concluded that the structure of the companies, the main market areas and logistic patterns of transportation were nearly comparable to the situation of the baseline study (Röhling, Burg, Klaas-Wissing; 2014).

As a main result current national intra-modal market potentials for longer trucks were derived based on national statistical data of heavy good vehicles (see figure 2). As a basis for modelling the transport demand version 2 was used since it was similar to the characteristics of the empirical findings. Flatbed trucks, tip trucks, tank trucks as well as bulk transport were excluded as potential business cases for longer trucks. Furthermore, collecting trips and delivery trips were also neglected for the estimation of the market potential of longer trucks. In version 2 only dedicated trips with general cargo and over 70 % volume utilisation form the basis for the market potential calculations. In total the intra-modal market potential of longer trucks in 2014 amounts to 869 million veh-km (see also chapter 5).

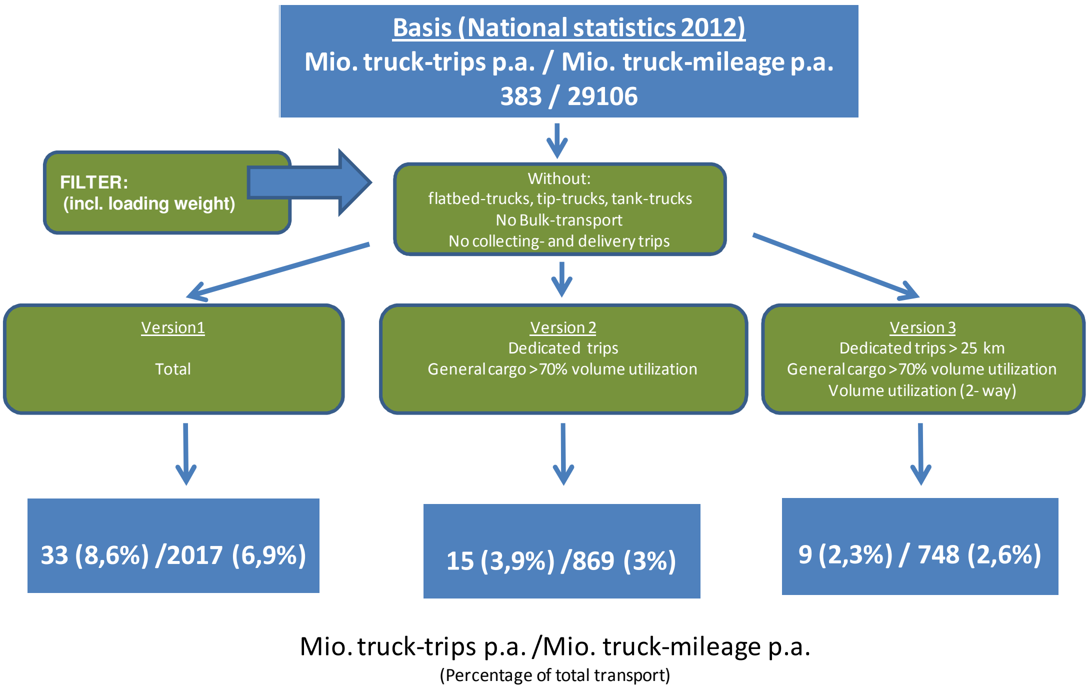

Fig. 2 Potentials for longer trucks

4. Model approach

The basic model approach was mainly designed in two levels:

- Integrated transport model with special focus on enhanced mode choice model for longer trucks
- Spatial pattern model: Likelihood approach for the determination of potential areas of application and accessible routes of longer trucks with particular attention to the different definitions of a longer truck suitable road network (Positive network).

4.1. Transport model

Based on the defined suitable road network the transport demand effects of longer trucks were calculated for the reference years 2014 and 2030 via an integrated transport model with special focus on an enhanced mode choice. A given traffic demand, based on the national freight traffic forecast of the Federal Ministry of Transport and Digital Infrastructure (Intraplan 2014), served as the foundation of the analysis. Modelling tools from SSP-Freight were used as a basis for modelling the traffic post-fractions, in particular the effects in the investigated scenarios.

The SSP-Freight model, which is the general basis for the modelling approach, is a five-step approach with feedback iterations. SSP-Freight is a collection of specific modules which are combined by well-defined interfaces. It can be used for the estimation of current transport flows as well as for the forecast of future transport patterns applying different scenarios. Based on the integrated vehicle model the approach provides an assignment of traffic flows for all modes within the network and analyses route-choice and bottlenecks. Mainly the following modules have been used:

- Network assignment model for trucks
- Cost models
- Vehicle and potential analysis model for longer trucks
- Mode-Choice model.

The network assignment model provides the routes and the characteristics for transport time and distance for normal trucks as well as longer trucks. These transport characteristics serve as input for cost models which calculate transport costs for all relations, distinguished between commodity groups and transport types. This part of the model responds sensitively to scenario-specific network configurations (positive network for longer trucks) and provides scenario-specific costs of longer truck per relation as input for the Mode-Choice model..

As the *stateoftheart* for calculating costs and services for transport and logistics companies, business costs for road and rail freight traffic are used as a basis for the reference year 2014. Neither economic cost elements such as external environmental costs, nor market prices are integrated in the cost calculation. In addition to the pure transport costs all transport chain-specific elements are taken into account. The cost elements are generally subdivided into fixed (time based) and variable (performance based) costs components.

A vehicle model is applied based on the Origin/Destination freight flows of the traffic forecast 2030 (Intraplan et. al. 2014). Depending on the type and distance-specific average utilization rates from the (annual) freight flows, the daily vehicle flows are determined. The acquisition of back-loading has been taken into account. In addition a potential analysis model is used for longer trucks based on special logistical patterns derived from the field survey (detailed description in chapter 3). In some cases, these patterns can be assigned to the commodity groups (for example, no bulk goods), some of them are transport type based patterns, e.g. collection/distribution transport versus Point-to-point transport, which requires a new segmentation. This segmentation is part of the potential model for longer trucks which was determined within the first transport demand study (Röhling, Burg, Klaas-Wissing, 2014).

The aggregated mode–choice model is one of the main elements of the modelling approach. It regards all transport means within a commodity group and a distance class as "logistically" equivalent. In consideration of the results of the potential analysis model the original mode-choice model differentiates between truck, rail and inland waterway transport. An aggregated logit model is applied for the estimation of mode shift effects from rail - differentiated according to the production modes single wagon load and combined transport - and the inland waterway vessel (container) to longer trucks. This model approach supports a detailed, group-specific comparison of individual modes of transport, which is related to individual transport relations, and thus also reflects the international state-of -the-art in freight transport modelling (for example: BVU 2014, Tavasszy 2013, Ben-Akiva 2013, De Jong 2012).

The Logit model has the following formulation:

$$p_v = \frac{exp\,(U_v)}{\sum_k exp\,(U_k)} \qquad (1)$$

with

$$U_{v;i,j} = \alpha_{v;i,j} + \beta_k BC\left(K_{v;i,j,}\gamma_k\right) + \beta_T BC\left(T_{v;i,j,}\gamma_T\right) \qquad (2)$$

In which:

pv	Likelihood to select the transport mode v
i,j	Relation i->j
α	Parameter to adjust the as-is Modal-Split
β_K,β_T	weighting parameter
γ	Parameter for the Box-Cox Transformation
K	Transport costs
T	Transport times
BC	Box-Cox Transformation

This approach is based on the assumption that mode choice is determined by the relative supply characteristics of the competing carriers taking into account the different weighted decisions based on commodity segments and type of transport. The required transport characteristics in the main haulage of the alternative modes are provided as a result of the network assignment models distinguished by commodity groups and transport type (e.g. container transport). To ensure the integration of longer trucks as a separate transport mode, the original logit approach is enhanced by a "nested" stage. Within this stage the transport mean “truck transport” distinguishes between the subsegments of conventional trucks and longer-trucks.

Within the intramodal mode-choice approach, which describes the potential shift from conventional to longer trucks, generalized costs (joint consideration of transport costs and travel time) between the alternatives are compared. Potential areas of application and accessible routes of longer trucks with particular attention to the different definitions of a longer truck suitable road network (Positive network) are taken into account in a later model stage (see chapter 1.2). In comparison to that mode choice models based on generalized price elasticities of demand are not appropriate for a determination of mode shift effects on this level of detail.

Another key input of mode choice modelling is the quantification of the increased efficiency of longer trucks, expressed as an efficiency factor. In the mode choice model, two efficiency components are distinguished: Firstly, the efficiency influences mode choice directly by decreasing cost components, and secondly efficiency affects the mileage (in truck km) replaced by longer trucks. The efficiency factor is derived based on the smallest used loading unit (Euro-Pallet). In contrast to the economic view, which represents the substituted number of journeys without taking into account the actual capacity utilization, this macroscopic approach builds on the relational substitution of the actually transported volumes of goods in Germany.

4.2. Spatial pattern model

The spatial pattern and road network model are important elements of the general model design. For the modelling of the spatial pattern a grid model developed by SSP Consult was used, which is based on an intersection of industrial real estate areas with a 500 m x 500 m grid in Germany. In order to keep the number of grid elements in a performable format, these grid elements were combined into a 1.5 km x 1.5 km grid model. Furthermore, a limit value of 5 ha was defined for industrial real estate per grid element. This results in approximately 31,000 grid elements (see figure 3). Only with this elaborate model approach it is possible to model transport demand on a detailed level.

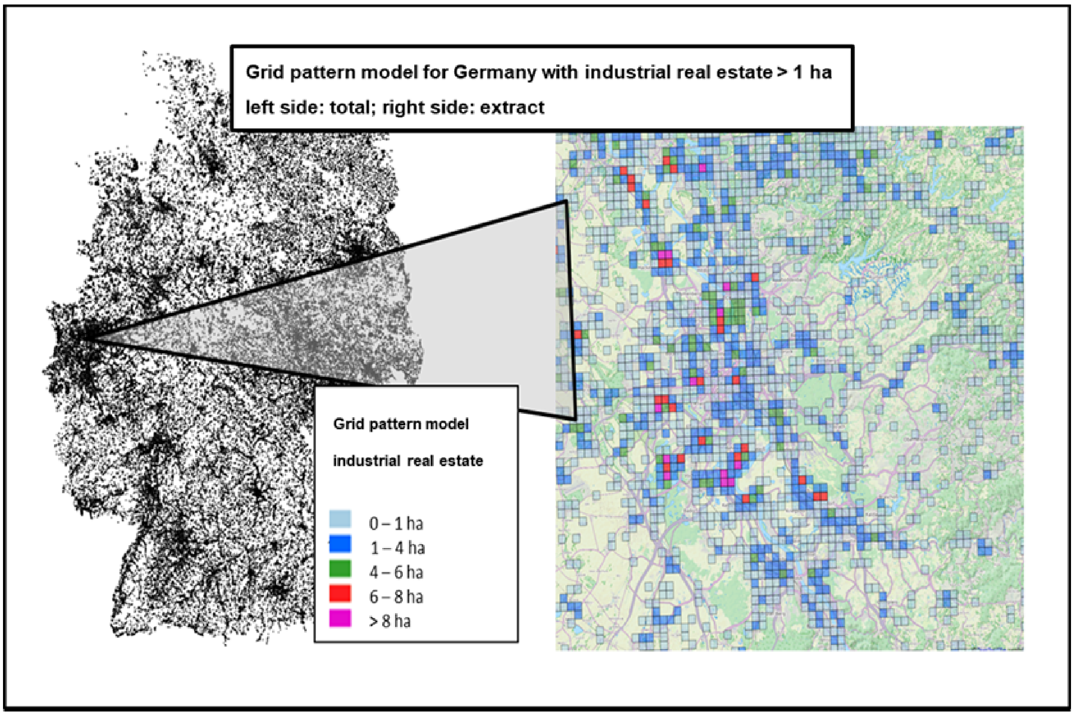

Fig. 3 Grid pattern model for industrial real estate in Germany as basis for the spatial pattern of the model

The road network model used here covers the German main road network from motorways to the municipal roads. In addition, the route information was supplemented in a very elaborate procedure to the 6th Positive network regulation. Network models for rail and inland waterway transport have been used based on the national freight traffic forecast of the Federal Ministry of Transport and Digital Infrastructure (Intraplan 2014). This is the basic input for modelling the potential areas of application and the accessible routes for longer trucks. Therefore different scenarios have been defined (see chapter 2.1) and analysed based on a suitable likelihood and approximation approach that takes into account that a wide definition of a maximum positive network for longer truck in Germany is far beyond the current situation. This approach defines the accessibility of the individual grid elements for longer trucks as follows: For individual routes or road categories, likelihood values will be gathered that these routes can be driven by longer trucks. Criteria for this are road category, the number of lanes, control speed and adjacent residential areas. Since the likelihood will be multiplied for sequent stretches the likelihood approach for homogeneous stretches can be defined as:

$$w(l) = exp^{-\alpha * l} \quad (3)$$

In which:

w	Likelihood that a longer truck could drive on an homogenous road path
l	the length of the path (per km)
α	path specific Model parameter .

With that the parameter α can be construed as "half amplitude length" L(1/2). With each half-length of a stretch

$$L_{\frac{1}{2}} = \frac{ln(2)}{\alpha} \sim \frac{0,7}{\alpha} \quad (4)$$

the likelihood of a route´s accessibility for longer trucks is cut in half. The parameter selection of α = 1 corresponds to a half amplitude length of approximately 700 meters, α = 0.1 corresponds to 7 km. The following table shows the likelihood based half amplitude length dedicated to the relevant road categories. The outcome of this is a core network for longer trucks, which consists of highways and comparable roads with at least two lanes per direction and without direct crossings of residential areas that could be accessible without any restrictions. For all other categories and combinations a likelihood-gradation of the accessibility for longer trucks will be defined.

Table 1. Parameters of the likelihood approach (Positive-network)

Category of road	Number of lanes	Control speed (km/h)	Adjacent residential areas	Half amplitude length
A (motorway)	All	-	All	∞
B (federal road)/L (rural road) or S (state road)	>=2	-	No	∞
		-	Yes	20 km
B (federal road)	1	-	No	20 km
		-	Yes	8 km
L (rural road) or S (state road)	1	-	No	15 km
		-	Yes	5 km
K/G (municipal road)	>=2	-	No	20 km
		-	Yes	5 km
	1	-	No	10 km
		-	Yes	1 km
F (ferry)	All	-	All	0
Other	>=2	≥60	No	20 km
			Yes	5 km
		<60	No	5 km
			Yes	1 km
	1	-	No	2 km
		-	Yes	0.5 km

5. Modelling results

The analyses of the freight transport demand modelling for the scenarios shows that generally only a small part of all German heavy good vehicles runs (about 3.0 % (2014; 869 m. veh-km) to 3.2 % (2030; 1,179 m. veh-km)) and even a smaller part of all rail and inland waterway transport performance (1.7 and 2.9 %) can be seen as shiftable intra-modal or inter-modal potentials to longer trucks in both scenarios due to logistical constraints and requirements (see table 2). These shiftable potentials do not mean an actual shift of intra-modal or inter-modal transport demand. The decision about the scheduling of transport routes is rather determined by transport cost differences as well as accessibility considerations. Therefore, a detailed and scenario-based analysis of the actual transport demand shifts has to be conducted. In scenario A estimations of the actual vehicle mileage of longer trucks amount to approximately 9.6 m. veh-km in 2014 and 15.1 m. veh-km in 2030 respectively. These numbers account for about 1 % of the sum of the intra-modal and inter-modal longer truck potential. In scenario B approximately 70.2 m. veh-km (2014) and 97.8 m. veh-km (2030) account for 7 % (2014) and 6 % (2030) respectively of the total longer truck potential.

Table 2. Results of the transport modelling.

Year 2014 vehicle mileage millions (veh-km)	Scenario A	Scenario B
Overall road freight transport	29,450	29,450
Overall rail transport/inland water vessels*	10,118	10,118
Intra-modal potential	869	869
Inter-modal potential	176	176
Longer trucks intra-modal	9.1	68.4
Longer trucks inter-modal	0.5	1.8
Longer trucks total	9.6	70.2
Conventional trucks	856.7	769.0
Trucks total	866.4	839.2
Year 2030 vehicle mileage millions (veh-km)	Scenario A	Scenario B
Overall road freight transport	37,402	37,402
Overall rail transport/inland water vessels*	13,541	13,541
Intra-modal potential	1,179	1,179
Inter-modal potential	390	390
Longer trucks intra-modal	13.9	93.9
Longer trucks inter-modal	1.2	3.9
Longer trucks total	15.1	97.8
Conventional trucks	1,159.4	1,040.9
Trucks total	1,174.5	1,138.7

*as longer truck vehicle-km equivalent

As mentioned above a maximum of 1.7 % (2014) and 2.9 % (2030) of the railway and inland waterway transport performance can potentially be shifted to longer trucks. Actually, in scenario A 0.5 m. veh-km (2014) and 1.2 m. veh-km (2030) are estimated to be intermodally shifted. This freight transport demand shift amounts to 0.3 % of the total inter-modal mileage potential only. For Scenario B the results are similar. In comparison to the total German transport amount of rail and inland waterway transport performance, model based derived inter-modal shifts to longer trucks are nearly non-existent and thus negligible(Scenario A: 0.05 ‰ in 2014; Scenario B: 0.3‰ in 2030). The comparison of the results of both scenarios shows that the vehicle mileage (veh-km) of all trucks would in total be about 3.1 % lower in 2014 and 3.0 % in 2030 respectively due to the expanded network in scenario B. An additional reason for this decrease besides the growing routes of longer trucks lies within the possibility to avoid detours due to the previous networks constraints. Associated with the changes of the freight transport demand the emissions of CO_2 and air pollutants (NO_X, particles) decreases around 0.4 % in 2014/2030 for scenario A and around 3.2 % (2014)/ 3.0 % (2030) for scenario B compared to the longer trucks emission potential.

6. Conclusion

In general it can be summarized that the use of longer trucks in normal operation currently generates a positive overall transport demand effect regarding the reduction of driven truck mileage and accordingly a reduction of greenhouse gas emissions and air pollutants. This positive effect will be enhanced by a possible extension of the road infrastructure that is allowed to use (Positive network). Intermodal shifts from the railways and inland waterways to longer trucks were not apparent in the empirical observations nor are they considered likely given the logistical and freight structures and characteristics observed in the deployment of longer trucks. This assessment is backed up by the transport demand modelling which also shows that modal shift effects from rail and inland waterway transport are very small and almost negligible. On the other hand, the results also clearly show that the operation of longer trucks is not solely the solution for reducing freight traffic growth and the associated negative environmental effects. But in certain market segments there are economic and traffic demand-side benefits. Finally, some questions cannot be answered by either field trials or by experimental or theoretical model studies. To forego the limits of the methodology used in this paper future research should evaluate the topic by the observation and analysis of real world operation data from several years.

Acknowledgements

The research work presented in this paper was carried out during the scientific monitoring of the German field test on longer trucks between 2012 and 2016. This paper is inspired by two R&D projects (FE-Nr. 89.0273/2012; 89.0315/2015) financed by the Federal Ministry of Transport and Digital Infrastructure (BMVI) and commissioned by the Federal Highway Research Institute (BASt). Responsibility for the content of this paper lies with the authors.

References

Aarts, L., Honer, M. 2010. Längere und Schwerere Lastkraftwagen (LZVs) in den Niederlanden – Einblicke und Erfahrungen im Zeitraum 1995–2010. Rijkswaterstaat – Dienst Verkeer en Scheepvaart, Herausgegeben vom Ministerie van Verkeer en Waterstaat, Den Haag.

Ben-Akiva, M., Meersman, H., Van de Voorde, E., 2013. Recent developments in freight transport modelling. In: Moshe Ben-Akiva, Hilde Meersman, Eddy Van de Voorde: Freight Transport Modelling.

BMVBS – Federal Ministry of Transport, Building and Urban Development 2010. Aktionsplan Güterverkehr und Logistik – Logistikinitiative für Deutschland, Berlin.

BMVBS – Federal Ministry of Transport, Building and Urban Development 2011. Verordnung über Ausnahmen von straßenverkehrsrechtlichen Vorschriften für Fahrzeuge und Fahrzeugkombinationen mit Überlänge (LKWÜberlStVAusnV). https://www.ebundesanzeiger.de in the "Official Section" of the Federal Gazette, date of publication 21 December 2011.

Burg, R., Schrempp, S., Röhling, W., Klaas-Wissing, T., Schreiner, S. 2016. Verkehrsnachfragewirkungen von Lang-Lkw. Final report on R&D project 89.0315/2015, Waldkirch, St. Gallen.

BVU 2014. Entwicklung eines Modells zur Berechnung von modalen Verlagerungen im Güterverkehr für die Ableitung konsistenter Bewertungsansätze für die Bundesverkehrswegeplanung, Freiburg.

de Jong, G., Vierth, I., Tavasszy, L., Ben-Akiva, M. 2012. Recent developments in national and international freight transport models within Europe. Transportation. Volume 40, Issue 2, pp 347- 371.

EC – European Commission 2011. White Paper - Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, COM(2011) 144 final, European Commission. Brussels, 28.3.2011.

EEA – European Environment Agency 2015. SOER 2015 European briefings – Transport, Copenhagen.

Glaeser, K.-P., Zander, U., Lerner, M., Roder, K., Weber, R. Wolf, A., Zander, U. 2006. Auswirkungen von neuen Fahrzeugkonzepten auf die Infrastruktur des Bundesfernstraßennetzes. Federal Highway Research Institute, Bergisch Gladbach.

Hellung-Larsen, M. 2011. Evaluation of Trial with European Modular System – Danish Experience. In: Conference paper, 12th International Symposium on Heavy Vehicle Transportation Technology, The Danish Road Directorate.

Intraplan et. al. 2014. Verkehrsverflechtungsprognose 2030. Los 3: Erstellung der Prognose der deutschlandweiten Verkehrsverflechtungen unter Berücksichtigung des Luftverkehrs, München.

Irzik, M., Kranz, T., Bühne, J.-A., Glaeser, K.-P., Limbeck, S., Gail, J., Bartolomaeus, W., Wolf, A., Sistenich, C., Kaundinya, I., Jungfeld, I., Ellmers, Kübler, J., U., Holte, H., Kaschner, R. 2016. Feldversuch mit Lang-Lkw, Bergisch Gladbach.

OECD 2011. Moving Freight with Better Trucks: Improving Safety, Productivity, and Sustainability. International Transport Forum, Paris

Ramberg, K. 2004. Three Short become Two Long, if the EU follows the example set by Sweden and Finland. Fewer trucks improve the Environment. Confederation of Swedish Enterprise.

Röhling, W., Burg, R., Klaas-Wissing, Th., 2014. Verkehrsnachfragewirkungen von Lang-Lkw – Grundlagenermittlung, Waldkirch/St. Gallen.

StVZO 2012 – German Road Vehicles Registration and Licensing Regulations in the version promulgated on 28 September 1988 (Federal Law Gazette I, p.1793), as amended by Article 6 of the Regulations of 13 January 2012 (Federal Law Gazette I, p. 103).

Tavasszy, L., De Jong, G, .2013. Modelling Freight Transport, Elsevier.

The Council of the European Union 1996. Council Directive 96/53/EC of 25 July 1996, laying down for certain road vehicles circulating within the Community the maximum authorized dimensions in national and international traffic and the maximum authorized weights in international traffic, Brussels.