ESTIMATION OF THE BENEFITS OF SHIPPERS FROM A MULTIMODAL TRANSPORT NETWORK

Gernot Liedtke: *e-mail: gernot.liedtke@iww.uni-karlsruhe.de*
phone: (+49) – 721 608 - 4415
fax: (+49) – 721 608 – 4963

Hanno Friedrich: *e-mail: hanno.friedrich@iww.uni-karlsruhe.de*
phone: (+49) – 721 608 – 4415
fax: (+49) – 721 608 – 4963

Patrick Jochem: *e-mail: patrick.jochem@iww.uni-karlsruhe.de*
phone: (+49) – 721 608 – 4226
fax: (+49) – 721 608 – 4963

Daniel Keultjes: *e-mail: daniel.keultjes@iww.uni-karlsruhe.de*
phone: (+49) – 721 608 – 4415
fax: (+49) – 721 608 – 4963

Stefan Schroeder: *e-mail: stefan.schroeder@iww.uni-karlsruhe.de*
phone: (+49) – 721 608 – 4782
fax: (+49) – 721 608 – 4963

Affiliation: *Institute for Economic Policy Research (IWW)*
Karlsruhe Institute of Technology (KIT)
Kaiserstr. 12
D-76131 Karlsruhe
Germany

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ABSTRACT

This paper estimates the shippers' reactions and their economic benefits from a multimodal transport network called LOGOTAKT. For this purpose, an econometric shipper model is being estimated in which the major factor influencing logistics decisions – the balance between warehouse and storage cost – is explicitly taken into account. The functional form is being deduced from the first order condition of Total Logistics Cost function minimization. Transport cost is expressed in form of a complex function depending on order size and the transport distance in order capture the effect of economies of scale in transportation. It is estimated based on empirical data of distribution obtained from two major German companies. Simulations show that the new multimodal transportation system has a significant impact on shipment size distributions changing them in favor of smaller shipments. This leads especially to significant reductions in warehouse costs. Finally, some implications of the analytical results on transport policy are provided: To achieve further modal shift from road to rail, public financial support and the regulatory framework must put railways into the position to consolidate shipments and to exhaust economies of scale.

1. INTRODUCTION

The transport logistics sector is characterized by a high degree of competition, cascades of subcontracting and horizontal collaborations. Profit margins are rather low. In such environment, the development of innovative services becomes a crucial condition for logistic service providers in order to survive in the market. The key issue for the success of innovative services lies on the additional benefits offered to the customers. If these incentives met a certain group of customers, an increased willingness-to-pay could be expected.

Up to now in Germany and other surrounding European countries, railways have been concentrating on three types of transport services: Full-trains, single wagon transport and intermodal transports. The market for less-than-truckload transports has been strongly covered by road-based transport logistics providers. Given the already existing high-performance systems of single wagon transports, they could be expanded to single pallets flows, too. In this way, railways could extend their range of services towards logistics demanding transports and become real logistics service providers. For this purpose, multi-modal transshipment facilities should be established exactly at the hubs of the existing single wagon transport networks.

A possibility to implement such a transportation system has been studied in the project LOGOTAKT funded by the German federal ministry of economics. In the project, the economic viability of a transport system for single pallets using the existing transport systems of railways has been analyzed from both, a business and a welfare perspective. The welfare is measured based on a scenario of external cost implementation. Given the wide range of the LOGOTAKT project, we propose to answer only two research questions: How are the shippers' reactions on this new transportation system and which are the potential cost savings for the shippers? For this purpose, an econometric micro-behaviour model has been developed based on the Total Logistic Cost (TLC) approach.

The TLC approach has been widely applied in freight transportation analysis for the last decades (Baumol and Vinod (1970), Beuthe et al. (2004), Liedtke (2006), De Jong et al. (2007)). Unfortunately, only few publications in the literature of TLC models have been empirically calibrated and in general they do not capture complex expressions of transport tariff.

Our proposed TLC-model explicitly treats the shipment-size decisions at a short- and mid-term. Basically, shippers determine their shipment size through the balance between storage and transport cost. Storage cost, such as capital costs in inventory, increases proportionally as the shipment size increases whereas transport cost decreases inversely. Other 'relevant' decisions such as warehouse location choice – significantly influencing the total logistic costs – are set exogenously in this model. This market is defined as all palletized goods and their respective transports with shipment sizes between one and thirty pallets.

The paper is structured as follows. A brief overview on the LOGOTAKT system is presented in Section 2. Then, a TLC model is developed that considers economies of scale in transportation reflecting the tariff structure (Section 3). Section 4 is dedicated to the extraction of the major influencing variable on the TLC-approach which cannot be easily taken from our empirical data on shippers' behavior – storage cost. A simulation of the effects from the introduction of the multimodal transport system and an interpretation of the results closes this paper in Section 5. Policy implications are briefly worked out in the conclusion.

2. SHORT DESCRIPTION OF THE LOGOTAKT SYSTEM

Because of the regulatory framework and the system of financial grants given to the railways, two different types of railway-based freight transportation systems have emerged. On the one hand, there are the intermodal transports. Shuttle trains for containers link about 100 terminals spread all over Germany to the sea-ports (Carrillo Murillo, 2010). On the other hand, there is a transport network for single wagons. The core network consists of eleven big marshalling yards, where trains are dissolved and where the freight cars composed to new trains there are regular train connections between the marshalling yards. Today, on most links, there are more than four departures per day. Since wagons can change their train in marshalling yards, there is also a high transport frequency on all direct and indirect connections on the core network. Furthermore, the national single wagon network system is connected to the single wagon networks of surrounding European countries. Realizing economies of scale in the marshalling yards and profiting from lower transport cost compared to truck transport the main links, the core single wagon network is highly competitive compared to other transport modes, especially for long distances.

However, significant cost occurs when bringing the wagons from and two the sidings of the shippers and recipients. In addition, most manufacturers and warehouses no longer have physical access in form of railway sidings. That is because the industry is the more and more fragmented and the structure of shipments is shifting towards smaller transport lot sizes.
Today, shipments of less-than-one-truck-load are no longer transported by railways. Instead, those shipments are moved by road-based logistics service providers. The formers are either setting up milk-run systems, operating overland transport networks for mixed cargo or establishing partnerships in mixed cargo networks. For those logistics service providers, railways have some fundamental disadvantages: Firstly, the usage of intermodality would create additional transport links between the forwarders' warehouses and the intermodal terminals. Secondly, road-based forwarders have good reasons to use their own trucks on the main runs. Thirdly, there is not a transport with high frequency between intermodal terminals (this is only the case for the connections to the seaports). And finally, there is practically no offer of intermodal transports connecting the terminals except from the hinterland connections. Using the single wagon network is also not a practical option since the operations from the logistics warehouses to the marshalling yards are time consuming, expensive and unreliable.

Before this background, the project LOGOTAKT was launched[1]. The project aimed at studying a new type of transport system that combines elements of existing transport networks. Concretely, it is a combination of single wagon networks, intermodal networks and mixed cargo networks.

For this purpose, warehouses for the transshipment of single pallets should be established within the existing central marshalling yards. They are called Railports. It is planned to use curtain side containers. By this way, single pallets could be transshipped from road to rail within the Railports. But alternatively, also the whole curtain side container could be transshipped using a traditional crane. The system would profit from new automatic technologies for the transshipment of single pallets. Information technology would help to bridge the systems of the different carriers; decision support systems would be used in tour planning and routing.

In this way, railways could become increasingly important in a transportation system offering high-frequency and standardized transport services over long distances for a more and more fragmentized demand all over Europe. Such a transport system – which would be perceived from the shippers as a kind of conveyor band or as a kind of express service for single pallets – could significantly influence logistics behavior and could create additional positive effects for the competitiveness of the European production industry.

The project LOGOTAKT studies different aspects of this transport system. Firstly, a business model must be developed in which forwarders act as horizontal collaborators of the operators of single wagon networks. Secondly, the regulatory framework must be adapted since terminals are considered essential facilities and since single wagon networks constitute natural monopolies. Thirdly, the IT communication infrastructure must be conceived. And finally, a sub-project was studying the economic viability of the whole system. The economic viability comprises the viability for the industry and the effects on total welfare including savings on external cost. Finally, the proof of the economic viability is used to justify possible investment grants to the operators of Railports.

In the progress of this paper, we will concentrate on the calculation of the benefits for the industry. It is assumed that the providers of the multimodal transport network determine their tariffs according to the principles of activity-based costing. In this case, the benefits for the industry are mainly the benefits of the shippers. Confronted with modified transport tariff systems, they will adapt their warehouse policies and profit from reductions of the logistics cost.

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[1] The LOGOTAKT project is financed by the German Federal Ministry of Economics and Technology. It started 2008 and finishes by the end of 2010. See www.logotakt.de.

3. DEVELOPMENT OF A SIMPLIFIED TLC MODEL WITH ECONOMIES OF SCALE

This section develops a simplified TLC model that considers a complex transport cost function. In most cases, transport cost per pallet is decreasing with an increasing shipment size. We will call this “economies of scale in the transport cost function”. The extended TLC model will be used as the basis for the formulation of an econometric shipper model. This section is organized in three parts: Firstly, a short literature overview is provided. Secondly, the traditional TLC model is being presented. Finally, it is extended with a complex function of transport cost.

3.2. The concept of Total Logistic Cost (TLC)

The idea of total logistics cost (TLC) dates back to Harris (1913). He was the first to develop a minimum cost based Economic Order Quantity model (EOQ model). He identified three main cost drivers of the total logistic costs: purchasing cost, order cost and holding/ warehouse cost. The minimization of the TLC function results in the economic order quantity. This simple approach provides the fundament for many modern lines of researches. In the field of logistics decisions strategies, Beuthe et al. (2004) and Gudehus (2004) described logistics cost drivers in detail and developed a variation of the TLC model. Hensher et al. (2000) used the TLC model to simulate logistic decisions. De Jong et al. (2007) developed a micro-simulation model of shipment sizes for Sweden and Norway, where the following cost drivers were the most relevant: Order costs, transport, consolidation and distribution costs, cost of deterioration and damage during transit, capital costs of goods during transit, inventory costs, capital costs of inventory and stock-out cost. Park (1995) developed a lot-size and mode-choice model based on TLC using a discrete choice model. However, there was no information about the actual lot sizes. Wisentindjawat (2006) developed a micro-simulation model for urban freight movements based on a TLC model. In her study, transport costs were assumed as fixed costs. In the context of setting up a descriptive model explaining the structure of wholesale systems, Friedrich (2010) developed a TLC model able to capture economies of scale in transport by incorporating non-linear cost components.

3.2. Functional form of the simplified Total Logistic Cost model

The total logistics cost function can be represented using a function of the following form:

$$TLC = p \cdot Q + c(q,d) \cdot \frac{Q}{q} + \left(w + p \cdot h\right) \cdot \frac{q}{2} \qquad (1)$$

where:

Q: annual microscopic flow of goods ([pallets])
q: lot size or average order quantity ([pallets])
p: unit value of the good ([EUR/pallet]).
d: distance between sender and recipient of the good.

h: imputed capital cost rate for inventory holding ([%/year]).
w: warehouse storage cost per unit per year ([EUR/pallet/year])
c(q,d): variable transport costs being dependent of q and d.

In extension to the standard model developed by Harris (1913), we have substituted in (1) the fixed ordering costs by the variable transport cost term (second term in the TLC function). It has been assumed that in modern warehouse systems, fixed ordering costs have a relatively low impact on total costs and thus, they could be neglected. The last term in (1) expresses the cost of inventory holding taking into account the storage cost per unit and capital costs of inventory. Capital costs of goods in transit are not taken into account for two reasons: Firstly, lead-times are relatively short in our case and secondly, they do not differ among different choice alternatives. In (1) capital cost occurring for the shipper are excluded. The reason of this is that they do not occur in each delivery relationship depending on the production and logistics processes. In addition, cost terms related to unit handling costs in warehouse, safety stock and uncertainty (such as uncertainty in lead time and uncertainty in consumers' demand) are not incorporated in this simple TLC model[2].

3.3. Variable transport cost

Transport logistics companies normally have a complex tariff structure. Such transport tariff functions enter into the TLC formula of the shippers as variable transport cost. The structure of transport tariffs could be understood by the structure of the existing mixed cargo networks and milk-run systems: They are organised as hub and spoke structures, complex tour patterns and horizontal and vertical collaboration between logistics providers.

Analysing transport tariffs in this market, yields to typical transport cost functions for certain distance categories (see Figure 1). Tariffs usually depend on two factors: transport quantity and distance. Tariff tables reflect a number of cost components such as:

1. Avenue and departure journey (stop-specific costs),
2. consolidation and distribution costs,
3. transshipment costs for the forwarder and
4. a proportion of the overhead cost allocated to different clients of the forwarder.

[2] There is a relationship between lot size and risk. However, if uncertain processes (demand fluctuations, delays) are approximated with Laplace-Gauss distributions, there is only a weak (logarithmic) relationship between risk and lot size in the economic optimum balancing risk and cost. In case studies, the authors have found that in practice safety-stock decisions are not carried out using the "full-blown" TLC approach.

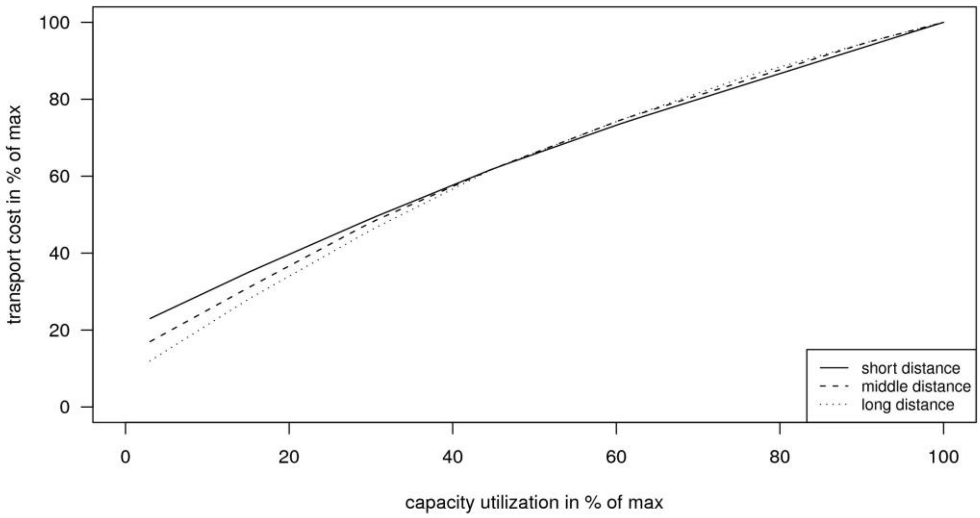


***Figure 1:** Approximated transport cost for a specific distance*

Figure 1 shows typical transport cost functions differentiated by distance. These functions express the percentage of costs (y-axis) in relation to the capacity utilized by the shipper (x-axis). For example, utilizing 30 percent of the capacity causes 50% of the cost of a full-load truck over the same distance.

Transport cost functions can be approximated with analytical functions. Several types of such functions from simple part-wise linear models to various non-linear models (see Keultjes (2009)) have been tested to fit the empirical tariff tables.

In the following, we will focus on a quadratic model for describing the transport cost since it fits very well to the structure of transport tariffs. Since these tariffs are usually given in form of tables differentiating cost per pallet per distance band, the complexity of determining the parameters of an analytical function can be reduced by simply estimating the parameters per each distance band. The quadratic model for the transport cost can be expressed as follows (see Keultjes (2009)):

$$c_t(q,t) = \left(\alpha(d) + \beta(d)\cdot q + \chi(d)\cdot q^2\right)\cdot c_{full}(d) + u \qquad (2)$$

where:

$c_t(q,t)$:	=	transport cost function
q	=	average order quantity
$\alpha(d), \beta(d), \chi(d)$	=	parameters in dependence of transport distance d
$c_{full}(d)$	=	tariff of a full load transport in dependence of distance d
u	=	error term

Estimating the parameters leads to the distance specific models shown in Table 1.

Table 1: *Estimated parameters for the transport-cost function differentiated by distance class*

Distance class [km]	From [km]	To [km]	α	β	χ	c_{full} [€]	R^2	p-value
25	0	50	0,2544708	0,0319615	-0,0002425	235	0,93	$< 2,2e-16$
75	50	100	0,2300638	0,0341254	-0,0002876	283	0,94	$< 2,2e-16$
125	100	150	0,2288866	0,0342789	-0,0002935	327	0,93	$< 2,2e-16$
175	150	200	0,2057484	0,0361682	-0,0003296	351	0,94	$< 2,2e-16$
225	200	250	0,2023297	0,0366008	-0,0003409	396	0,94	$< 2,2e-16$
275	250	300	0,1537941	0,0409876	-0,0004335	475	0,96	$< 2,2e-16$
325	300	350	0,148612	0,0418184	-0,0004553	502	0,96	$< 2,2e-16$
375	350	400	0,1075063	0,0451619	-0,0005205	566	0,97	$< 2,2e-16$
425	400	450	0,082193	0,0474068	-0,0005667	630	0,97	$< 2,2e-16$
475	450	500	0,0569898	0,0495526	-0,0006102	703	0,98	$< 2,2e-16$
525	500	550	0,0571699	0,0496953	-0,0006157	722	0,98	$< 2,2e-16$
575	550	600	0,04	0,051104	-0,000643	775	0,98	$< 2,2e-16$
625	600	650	0,0249332	0,0523779	-0,0006682	828	0,98	$< 2,2e-16$
675	650	700	0,0173217	0,0530737	-0,0006832	874	0,98	$< 2,2e-16$
725	700	750	0,0104854	0,0536987	-0,0006967	921	0,98	$< 2,2e-16$

Figure 2 depicts the relationship between the proportion of the full-truck load cost and the transport lot size.

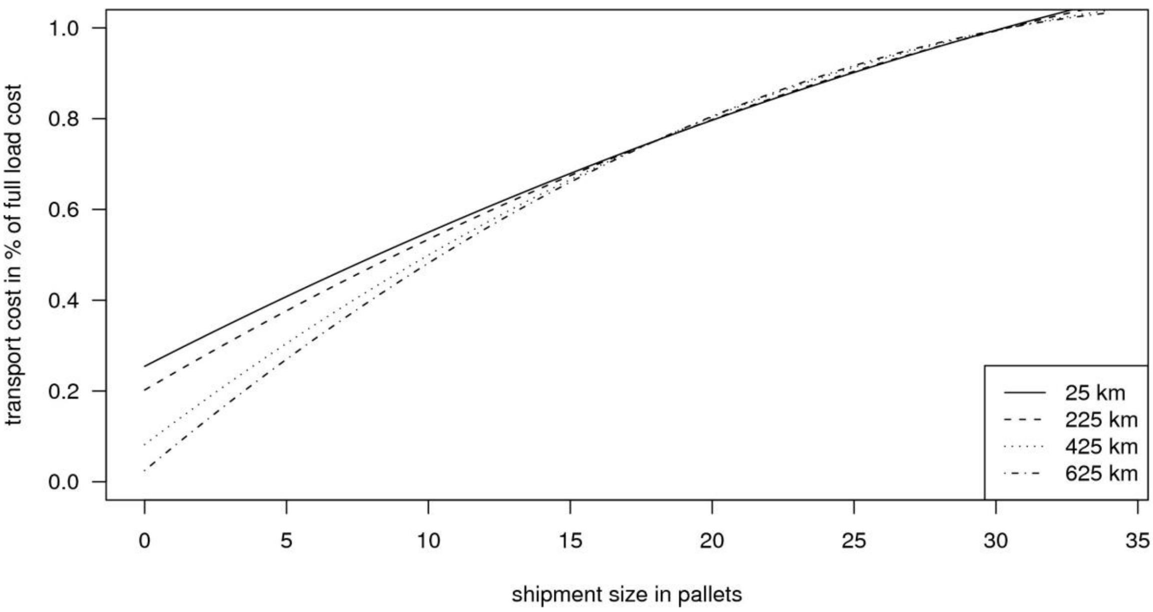


Figure 2: *Proportion of full-truck load cost and lot size*

For instance, when shipping in one trip 15 pallets instead of 30 (approximated truckload capacity) only about 75% of the full-truck tariff has to be paid in almost all cases independently of the forwarding distance. This might have different reasons such as the involvement of only one forwarder and the unused capacity. That is due to the problem of finding adequate additional load. The relative fixed cost compared to the full truckload cost decreases in function of the distance. This can be explained particularly by the fact that very few small shipments are collected by the forwards in the frame of their regular local distribution and collection tours.

Thus, economies of scale are manifested in the fixed cost and in the concave shape of the cost function.

By substituting the second term of Equation (1) with the quadratic model for the transport cost (Equation 2), the following expression is obtained:

$$TLC_{QM} = p \cdot Q + (\alpha(d) + \beta(d) \cdot q + \chi(d) \cdot q^2) \cdot c_{full}(d) \cdot Q/q + (w + p \cdot \mathrm{h}) \cdot q/2 \qquad (3)$$

By determining the first derivative of Equation (3) with respect to q, the ‘economic order quantity’ (EOQ) results in:

$$EOQ_{QM} = \sqrt{\frac{\alpha(d) \cdot 2 \cdot c_{full}(d) \cdot Q}{\chi(d) \cdot Q \cdot c_{full}(d) + (w + h \cdot p)/2}} \qquad (4)$$

Equation (4) could be used to calculate analytically the optimum shipment size. Usually parameters for such normative models are based on company financial and process cost data. But for this study, revealed data describing logistics behavior is available. This data comprises revealed shipment cases of the shippers and this makes possible to estimate the parameters of (4) statistically. By doing so, factors on logistic decision making that are outside the limited scope of a simple TLC minimization could be captured by the behavior model and be considered the economic assessment.

4. ESTIMATION OF A TLC-BASED SHIPPER MODEL

In this section, a TLC model is estimated using revealed shipment data. In a first step, the available data is being presented. In a second step, the influence of the value density of the commodities on shipment size decisions is being analyzed. Then, a linear econometric model is being formulated. Finally, the core explaining variable – the effective perceived warehouse cost rate - is being estimated.

4.1. Description of data base and descriptive statistics

The Shippers’ behavior can be analyzed using detailed historical data of freight transportation cases from two major German companies. The data panel comprises one year of complete information of the transport relation. For each transport case, the origin and destination, the calendar day (e.g. 17. June) and the quantity in terms of pallets (shipment size) transported is available.

Company A belongs to the thermo-technology sector. The dataset of A reflects a typical distribution system, where shipments from several companies are distributed to different local distribution centers. Basically, company A faces the problem to replenish local warehouses. Company B is an automobile producer. The dataset of B contains all deliveries from the suppliers to four distinct automobile factories. Figure 3 shows the geographical distribution of consignors and recipients. When plotting origins and destinations of all transport relations, one can see that senders and receivers of dataset A are geographically distributed all over Germany (see Fig. 3). However, dataset B contains only data from CIP-Code 7 region. In total, we have 682 transport relations for company A and 525 transport relations of company B. Thus, the total observed shipments are 17,458 shipments for company A and 26,165 for company B. The data collected is assumed to be representative for the market subject of analysis. The information included in the data panels are given for different products and various decision levels, .

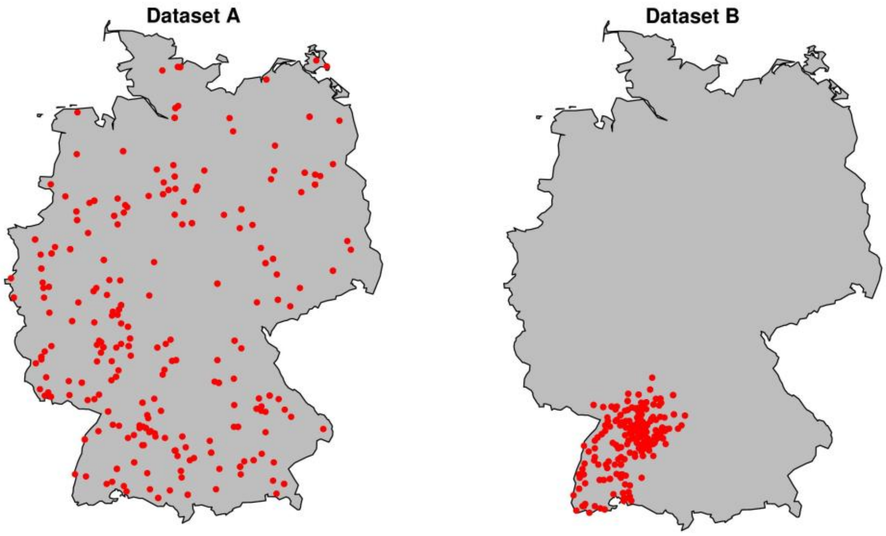


Figure 3: *Spatial distributions of shippers in the two datasets.*

Figure 4 shows the frequency distribution over transported lot sizes in pallets. For both datasets, small lot sizes are dominating.

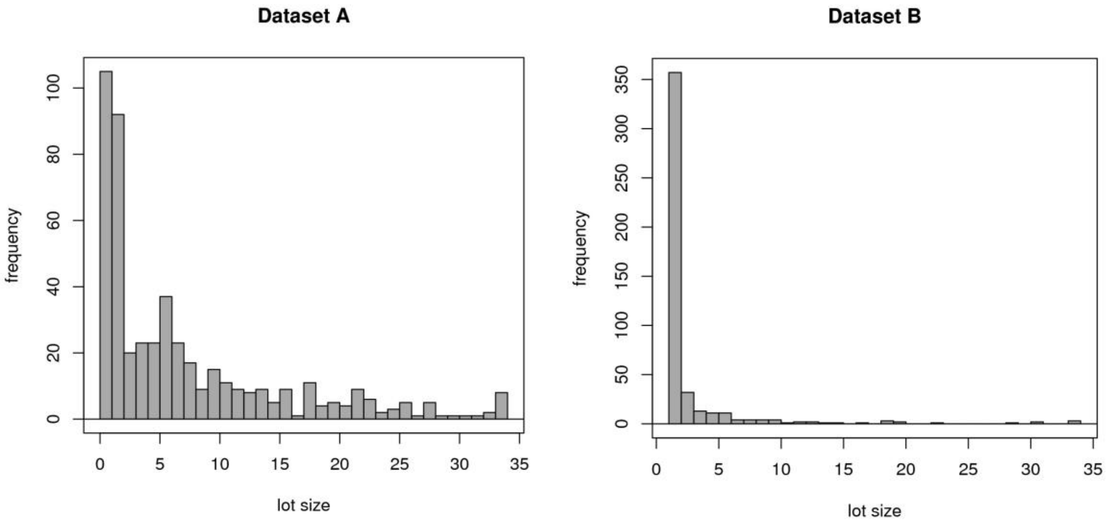


Figure 4: *Frequency distribution of lot sizes*

With regard to our TLC model, we can base our analysis on travelled distance (d), annual shipped quantity (Q), observed lot size (q) and the value per pallet (only for dataset A available).

For the upcoming analysis, all relations with a mean delivery frequency of less than 2 loads per day are excluded (meaning for example a daily delivery). It can be assumed that a significant proportion of these transport flows relates to just-in-time deliveries. Therefore, these shipments are most probably not part of the inbound flows being stocked (or eventually flowing through) in the warehouse facilities. For those cases, the application of a TLC model is no longer justified.

Additionally, all relations having an annual flow of goods less than 10 pallets are excluded from the analysis. As a total result, we only consider transport relations with warehousing activities and subject of a respective warehousing policy. As a result of this process, database A includes 265 relations (17,107 shipments) and database B includes 209 relations (8,427 shipments).

4.2. Determination of explaining variables

The estimation of our TLC model requires the assessment of two parameters: capital cost rate (*h)* and warehouse cost rate (*w)*. Since relation-specific information on the commodity value densities was only indicated in the dataset A, we examined whether the value of the commodity significantly affect shipment sizes as it is generally assumed in TLC models. Figure 5 shows the interdependence between lot size ([pallets]) and the respective value of the pallet. A detailed view on correlations between the variables is given in the Appendix.

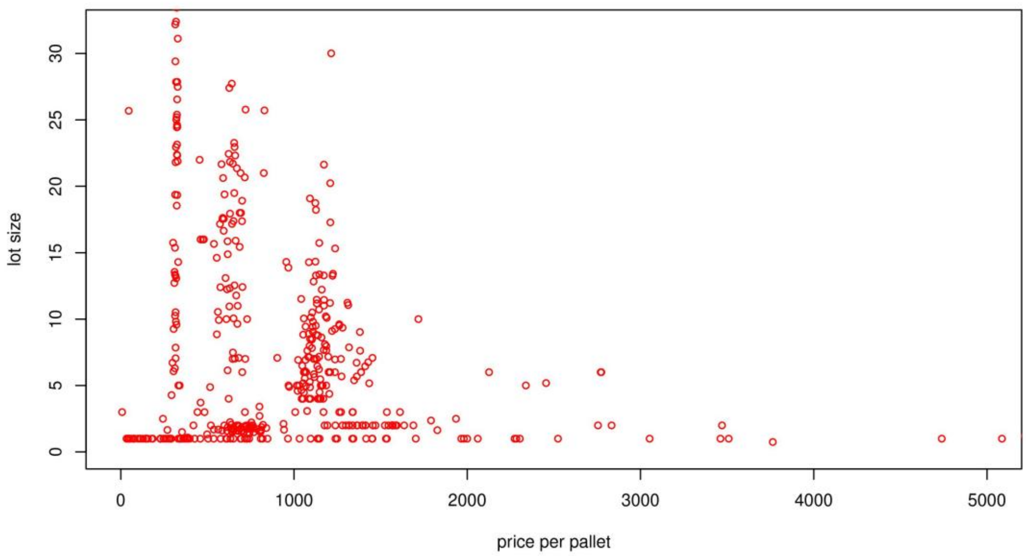


Figure 5: Scatterplot of lot size and value per pallet

At a first glance, it seems that there is no systematic correlation between value density and lot size. This raises the suspicion that the value density is not suited as explaining variable. This question was further examined by analyzing the effect of either including the value density or excluding it in the regression. As it can be seen in Table 4, the F-test and t-test of a simple linear regression show a significant deterioration in the goodness of fit if p is included. According to Backhaus et al. (2006) and Bortz (2005) this means that – in our special case – the value density should be dropped from the set of explaining variables. The results of our tests are indicated in Table 2. The physical characteristics of the transported goods seem to be more important for lot size decisions than capital commitment and cost efficiency.

Table 2: *Effect of including and excluding parameter p in estimation for dataset A*

Model	including parameter p		excluding parameter p	
	F-value	t-value	F-value	t-value
HM	591.686	24.325	1038.276	32.222
QM	116.885*	10.043*	168.069*	12.590*

*=weighted mean

This result means that – in our case – shippers would base their frequency decisions on some kind of "average value" of the shipments. A practical interpretation is that both warehouse and inventory costs are projected into some kind of effective warehouse cost. Therefore, in a further analysis only the annual quantity of goods and the effective average warehouse cost rate are considered as the explaining variables (in dataset B we had no choice since the value densities have not been available due to data privacy reasons).

4.3. Formulation of a linear econometric model and parameter estimation

Since we do not have information about the actual total logistic cost in our empirical data, we assume that shippers are cost optimizers and thus, the shipment size minimizing logistic costs can be determined with the first order condition of the TLC expression leading to the "economic order quantity". These "optimum" shipment sizes are expressed in equation (5) for the standard Harris model (HM). Equation (6) shows the same expression for the quadratic transport cost function. In both expressions, "$w + p \cdot h$" is substituted by "γ"

HM: $$EOQ_{HM}{}^2 = 2 \cdot Q \cdot c_{full} \cdot 1/\gamma \qquad (5)$$

QM: $$(\alpha/EOQ_{QM}{}^2 - \chi)^{-1} = 2 \cdot Q \cdot c_{full} \cdot 1/\gamma \qquad (6)$$

In this context, the substitution variable γ could be understood as the resulting and effective warehouse cost rate perceived by the logistics decision-maker. This variable expresses all kind of factors opposed to inventory holding such as inventory cost for the shipper, warehouse-space scarcity, inventory holding cost or incentives by the upper management towards the reduction of circulating assets.

Equations (5) and (6) serve as regression function and are linear in their parameters. The estimated values for the yearly warehouse costs per pallet are listed in table 3.

Table 3: *Estimation results of effective perceived warehouse cost per pallet and year*

Model	Dataset	Estimated γ [Euro]	R^2	p-value (t)
HM	A	3,587	0.68	≤ 2.2e-16 ***
QM	A	1,320	0.78	0.0018 **
HM	B	5,136	0.30	≤ 2.2e-16 ***
QM	B	1,689	0.57	0.03 *

The regression results shows, that all the extended EOQ models fit to the data. All p-values are lower than 0.04 which leads to a falsely rejection of the null hypothesis – that Q has no systematic impact on lot sizes – by less than 4%. Comparing the coefficient of determination, the fit for Dataset A is much better than for Dataset B. A possible reason for this result can be found in the structure of the lot size distribution. In Dataset B small lot sizes are more dominating and the range of different lot sizes per annual order quantity is high. This causes high residual values in the lower lot size region. The result of the regression is plotted in the figures in the appendix, which show observed data and predicted values for lot sizes over quantity of yearly pallets.

It is difficult to compare the results with reference values from the literature. While being aware of the logical error, we could relate the warehouse cost to the average value of the commodities. The values per palette are given in the dataset B while the average value for the dataset B can be deduced by a comprehensive market research (Friedrich, 2003) where pallet prices were calculated for specific industrial sectors. The imputed resulting warehouse rate per Dataset and model indicated in Table 4.

Table 4: *Estimated effective perceived warehouse cost rates*

Model	Dataset	Value per pallet*	Warehouse rate(*)
HM	A	2634	136.2%
QM	A	2634	50.1%
HM	B	2288	224.5%
QM	B	2288	73.8%

(*) Estimated warehouse rates in relation to the average monetary value per pallet.

Similar values have been found by Park (Park, 1995) .Using a total logistic cost model with fixed transport cost, Park estimates a warehouse rate of 45.6% which is similar to our result[3]. In a second step Park introduced quality parameters of the railways reducing the estimated warehouse cost rates by about 50%. In our case, however, this extension of the model is not possible since we are dealing only with one truck-based transport market (mixed cargo and partial loads). It might be that the introduction of quality parameters punishing rail and thus, large shipment sizes, gives raise to fallacious regression results since the poorer quality of

[3] In our case we have only considered the storage cost of either the recipient or the shipper. A TLC model for both sides of the supply relationship would provide 50% of the warehouse cost rates. In this case the results of our study and Park's initial values are quite similar.

railway transport services makes the same effect on the lot-size structure as an increased warehouse cost rate.

5. SIMULATION OF THE EFFECT OF LOGOTAKT ON WAREHOUSE POLICIES

Using the results of our estimated lot-size model and thus having fixed our reference case, we can study the effects of the sketched multimodal and high-frequency alternative transport service. There are two scenarios Scenario A relates to the distributing company, Scenario B relates to the sourcing company. In this section, firstly, the transport cost function of LOGOTAKT is worked out. Then, the logistics micro models of the two scenarios are confronted with the modified transport cost function and the resulting warehouse policies and their cost is being computed.

5.1. Transport cost function of LOGOTAKT

In order to determine the transport cost function of LOGOTAKT according to the principles of activity based costing, its main processes and the differences to existing transport systems are shown. The new transport network of the LOGOTAKT project is characterized as follows:

1. High-performance transshipment points at central locations – especially at the big marshalling yards of the railways which are the nodes of the single wagon transport system. They are called “Railports”.

2. High-frequency transports on the main links of the transport system (for instance, as additional loads on the existing block trains).

3. Regular tours connecting the Railports with shippers and recipients.

4. Intelligent combination of pickups and deliveries on the same tour.

5. Synchronization of transport service taking into account the demand for such transport services.

Analyzing the transport costs of LOGOTAKT, it becomes clear that the following reasons lead to cost reductions:

1. The time needed for loading or unloading the regularly operating trucks can be reduced because regular and high-frequency business processes can be established.

2. The transshipment cost within the transport network can be reduced through automation. It is therefore crucial that the system has a certain critical mass of turnover.

3. The distances between firms on the delivery and collection tours are reduced since the Railports have much more turnover than the existing mixed cargo networks.

4. Because of the high transport frequency on the main links, regular transport and logistics processes could be set up. Supported by advanced planning systems an intelligent and regular combination of delivery and collection tours is possible.

5. Shippers can combine shipments intended to several recipients on one truck.

Transport cost is calculated based on a full-cost approach. All occurring cost is allocated to the shipments according to the transport-activities induced by these shipments according to the principles of activity-based costing. Thereby, tariff tables for different distance classes are calculated. They could then be transformed into the transport cost functions.

Figure 6 exemplarily shows the initial tariff curve S1 (reference case) and the resulting tariff curve for the multimodal transport network S2 for a transport distance of 400 km.

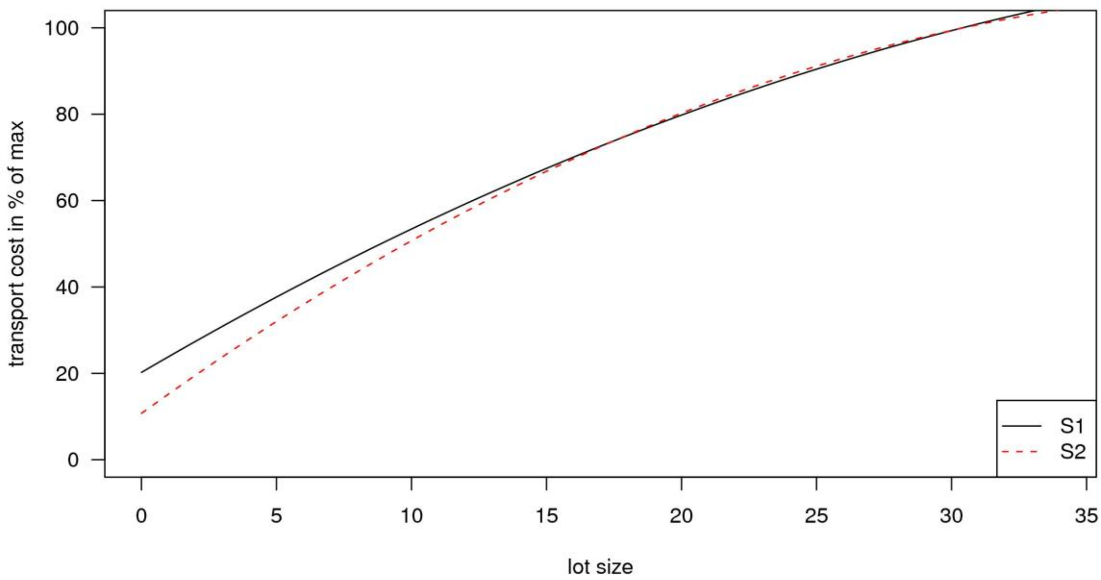


Figure 6: *Change in transport cost curve from S1 to S2*

For both scenarios, the impact of the modified tariff tables on shipment sizes, transport and warehouse cost are calculated. The results are shown in Table 5. Table 6 provides the relative changes of the cost components.

Table 5: *Cost structure for S1 and S2*

Dataset / Scenario	Transport cost [tsd. Euro]	Warehouse cost [tsd. Euro]	Total cost [tsd. Euro]
A / S1	3,537	1,668	5,206
A / S2	3,566	1,383	4,950
B / S1	2,665	1,228	3,894
B / S2	2,583	1,020	3,603

Table 6: *Percentage of cost change for A and B compared to the reference case*

Dataset	Variation of Transport cost	Variation of Warehouse cost	Variation of Total Logistics Cost
A	+1%	-17%	-5%
B	-3%	-17%	-7%

In both cases – recall that case A is a distribution system and B a sourcing system in production – the new type of transport service leads to a reduction of the total logistics cost of about 5% - 7%. However, the detailed adaptation mechanisms of the two companies differ significantly from each other.

.Since the transport cost is reduced by LOGOTAKT, company A increases delivery frequencies significantly (see Figure 7). This effect is also reflected in the results of table 6: Although, the transport tariffs are lower than in the existing systems, A's transport cost increases by 1%. Company B also increases frequencies (see Figure 8). These changes also go into the direction of smaller lot-sizes. But still, company B reduces its transport expenses. In both cases it turns out that the cost savings mainly result from a reduction of warehouse cost and not from reduced transport cost.

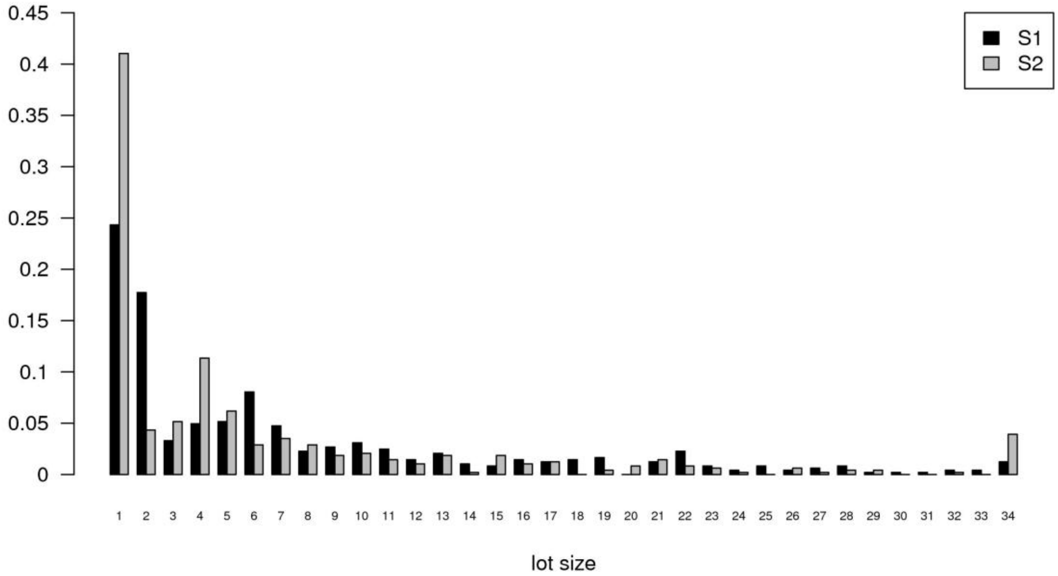


Figure 7: *Changed lot size distribution for A*

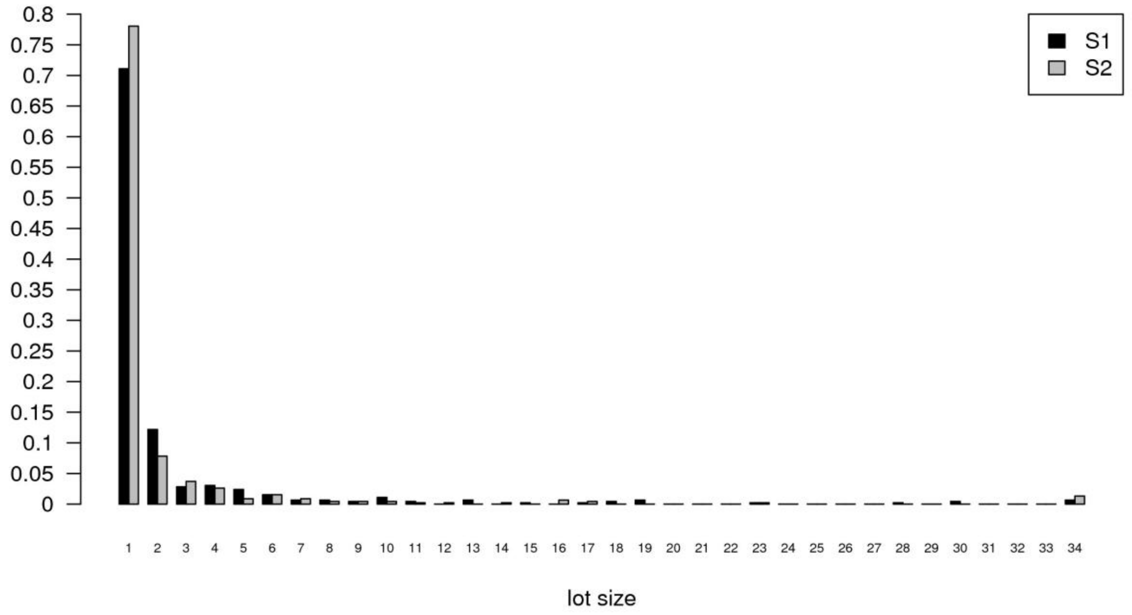


Figure 8: *Changed lot size distribution for B*

CONCLUSION

When opening the existing transport systems for single railway cars to palletized cargo, railways could profit from the prospering markets of less-than-truckloads and single pallets transported over a national or even continental scale. This was the main idea of the project LOGOTAKT. On the main links of the conceived multimodal transport network, railways carry consolidated transports of many shippers realizing economies of scale and profiting from lower transport cost. Additionally, LOGOTAKT offers regular and high frequency connections between shippers and recipients on a national basis and in a second stage on a European scale. LOGOTAKT is designed to offer services to those customers operating in the general cargo market, especially those transporting high value goods in relatively small shipment sizes.

For the demonstration of economic viability of such a system and for the justification of investment grants supporting the development of intermodal infrastructure, an integrated behavior and assessment model has been estimated. To deal with the specific characteristics of this market (no mode-choice, continuous range of lot sizes), a continuous choice model has been developed. Using the 1st order condition of the TLC optimization problem as functional approach, it was possible to set up a relationship between the annual flow of goods as well as shipment size and frequency respectively. By doing so, we included the main drivers of shippers' logistic behavior – logistic cost reductions by using economies of scale in transport as well as by balancing out transport- and inventory cost. To study explicitly the effects and the willingness-to-pay resulting from a variation of the transport cost, the presented model expresses transport cost as a complex function that reflects the decreasing marginal transport costs (quadratic model of the transport cost).

Estimating the model with two empirical datasets, we deduced annual warehouse cost rates of about 1300-1700 EUR per pallet. This value resumes the set of costs including:

- The scarcity of warehouse space,
- the calculated warehouse cost (including capital cost and running expenses),
- the perceived cost of "complexity",
- the risk that commodities will not be entirely consumed,
- the wish of the company's higher management to reduce the capital stock and
- the imputed capital cost of the stocks.

Relating the warehouse cost rates only to the average monetary value of the commodities, effective storage cost rates of about 50 percent and 70 percent per year were deduced.

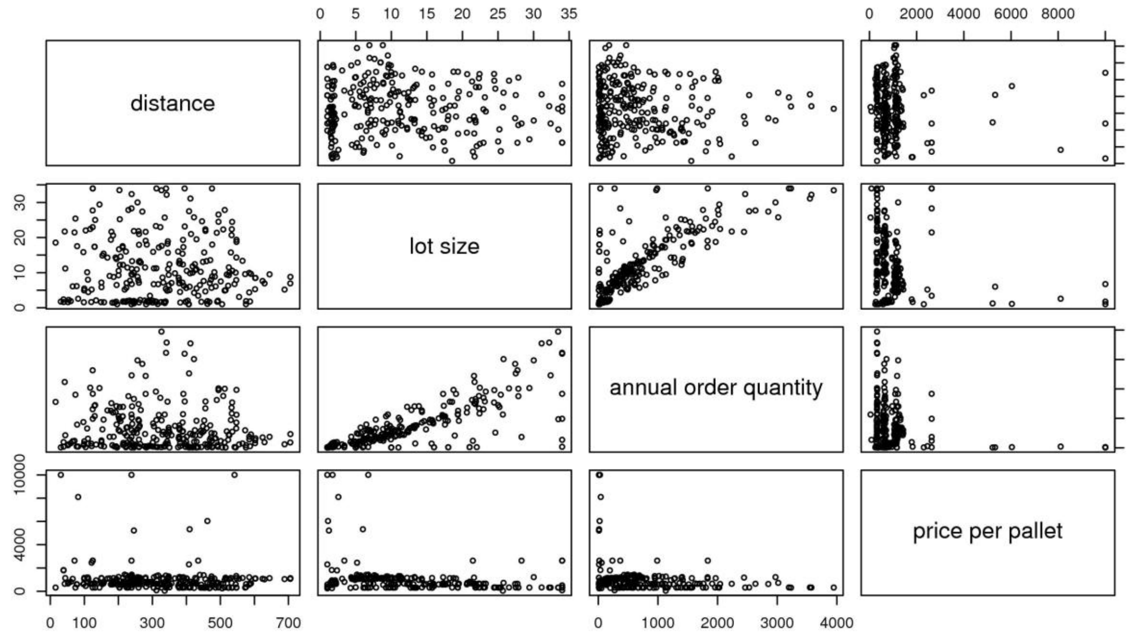
Applying our model to the new multimodal transport system 'LOGOTAKT', the analysis reveals interesting implications for the examined type of companies. Company A distributing commodities to points of sale can significantly reduce total logistic costs by shipping smaller lot sizes with LOGOTAKT. Company A's transport cost increases by 1 percent but reduces its warehouse costs by 17 percent. At the same time, Company B, being the manufacturing company, reduces both, transport cost by 3 percent and warehouse cost by 17 percent.

For policy making, our analysis implies that the modal share of railways can only be influenced positively if railway operators could enter into the market of standardized and regular single pallet transports. For this purpose railways must be set into the position of handling efficiently – and thus economically – small lot sizes. Therefore, a competitive rail transport system requires a strong alliance with road freight operators closing the gap between rail networks and customers. LOGOTAKT could be an example for this kind of alliance where railways can beneficially operate the main link between two Railports. But also road operators can make use of intelligent planning solutions for consolidating shipments in collection and distribution tours respectively. Especially, if such a transport system could be extended to operate on a European scale, the benefits become even higher.

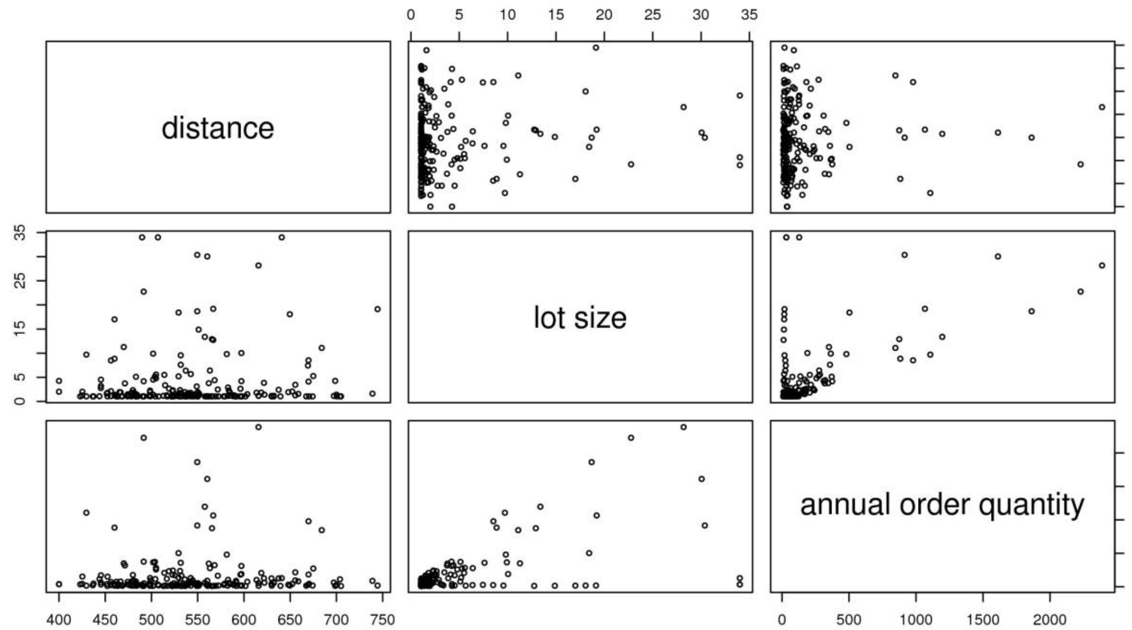
However, high investment expenses for the multimodal transshipment infrastructure are needed. This induces the risk of sunk costs. If railway companies cannot manage the risk, policy should support these companies. This may be very beneficial for the manufacturing and distribution industry, the railways and the environment.

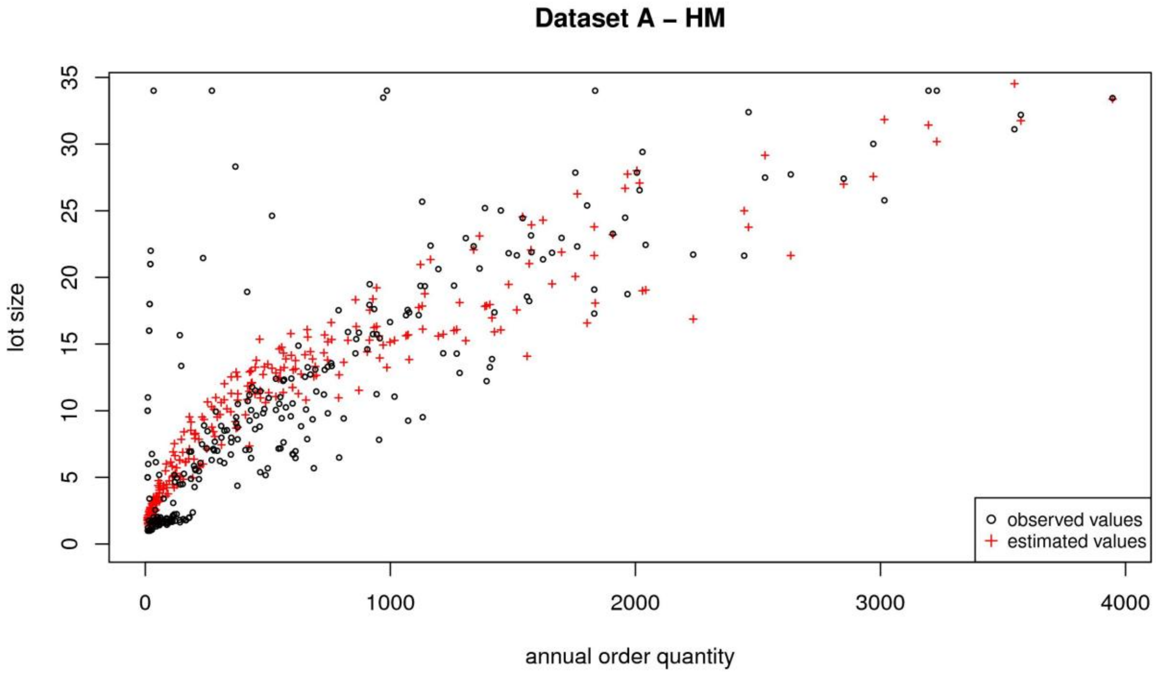
APPENDIX

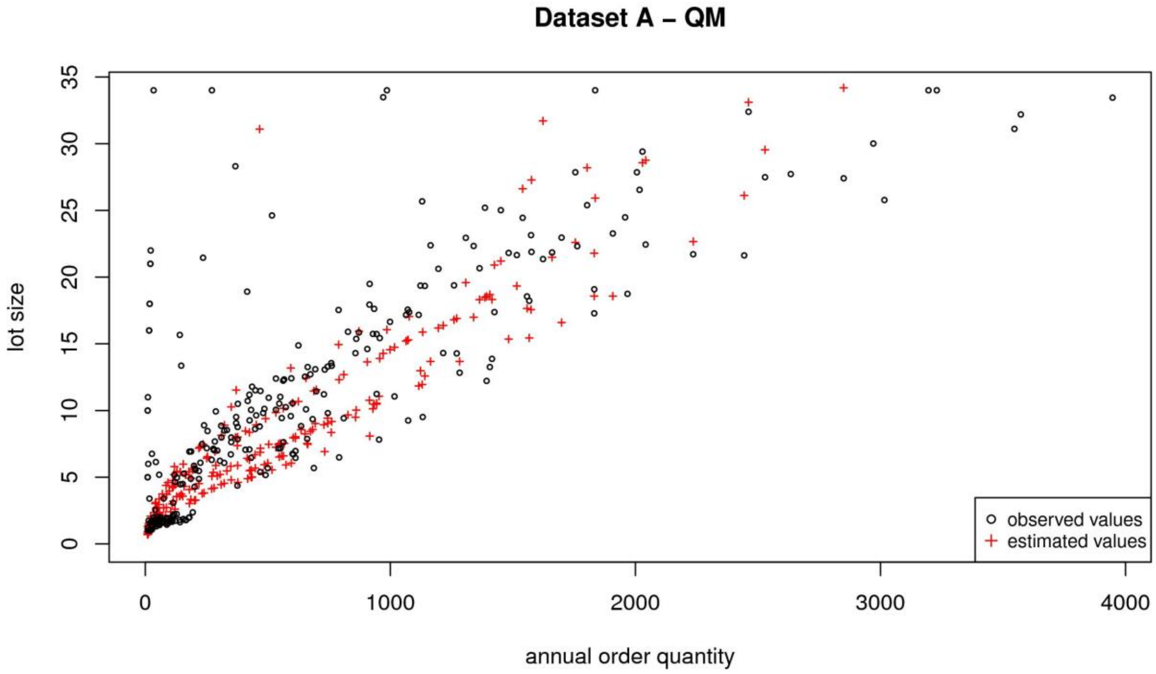
Scatterplot matrix for dataset A

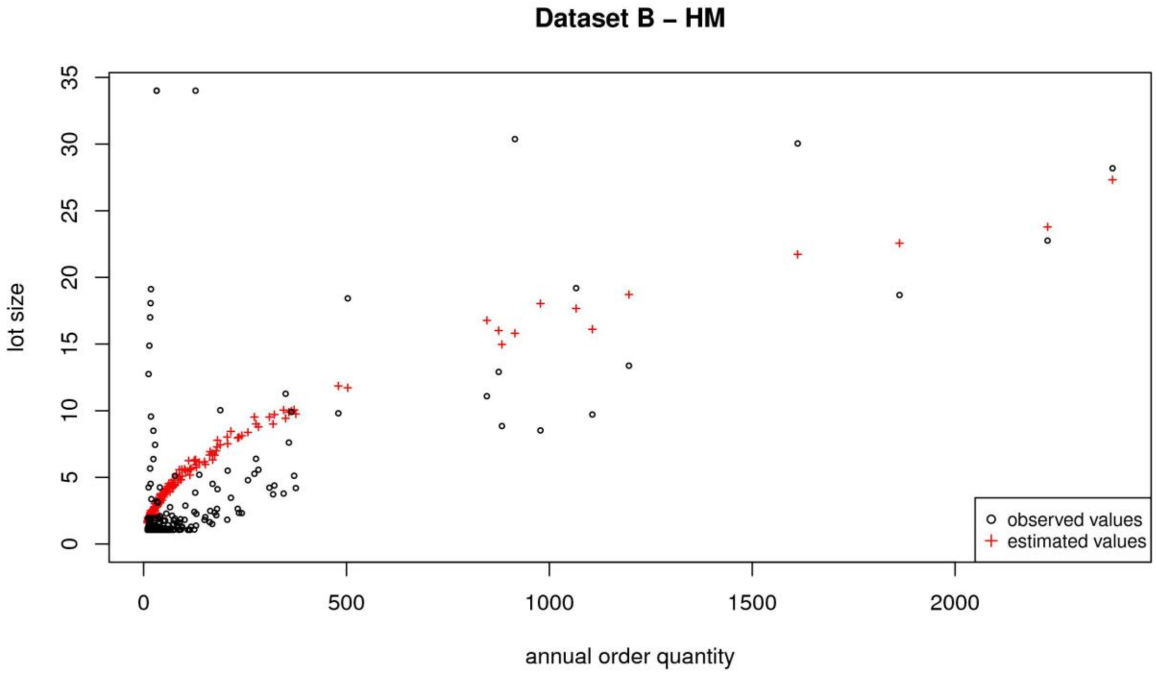


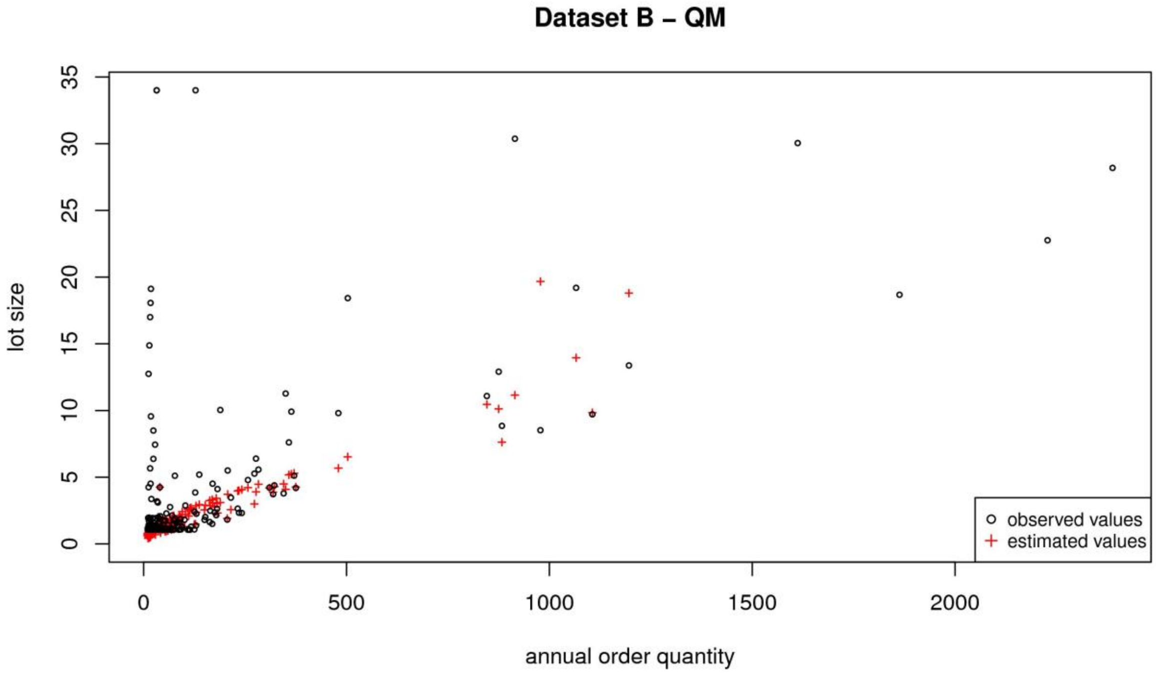
Scatterplot matrix for dataset B




Dataset A – HM
lot size
annual order quantity
0
5
10
15
20
25
30
35
0
1000
2000
3000
4000
observed values
estimated values


Dataset A – QM
lot size
annual order quantity
0
5
10
15
20
25
30
35
0
1000
2000
3000
4000
observed values
estimated values


Dataset B – HM
lot size
annual order quantity
observed values
estimated values


Dataset B – QM
lot size
annual order quantity
observed values
estimated values

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