CORRELATION ANALYSES BETWEEN LOGISTICS, BUSINESS AND TRANSPORT DATA TO CHARACTERIZE LOGISTICS HUBS

BASIC EVALUATION TO IDENTIFY KEY RATIOS FOR FREIGHT TRANSPORT DEMAND MODELLING

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ABSTRACT

Logistics hubs are important elements of freight transport generation. They play a decisive role in transport processes. Still, there is little empirical knowledge about those hubs. The authors present their concept to define logistics hubs and their transport volume, which is the basis for their empirical work. The empirical data are used to identify associations between logistics, business and transport characteristics of logistics hubs and networks with high transport volume. The analyses will also be relevant for a better consideration of logistics hubs in freight transport demand modelling.
The starting point is the intention to develop a typology of logistics hubs in terms of their structure and functionalities, which are expected to correlate with the volume of freight going into the hub and starting from there. The typology is created by analysing concrete network structures regarding goods flows, locations and transport volume using existing secondary data sources and data from a previous survey conducted by the authors themselves. The statistical analysis of the data allows for deriving a data-based typology. This will make it possible to integrate logistics hubs as operating systems into freight transport modelling.
Within the developed typology the specific transport network structures of the hubs and their transport volume are identified. The locations according to transportation infrastructure and

transshipment volume are clearly defined and linked with the transport volume. These types of logistics hubs are assigned to typological specific values with respect to transport volume as well as logistics attributes.
This study provides fundamental data of logistics hubs in Germany. This approach serves as a basis for spatially specified transport forecasts as well as transportation planning processes.

Keywords: freight transport; logistics hubs; transport demand modelling; survey.

OBJECTIVE

Freight transport in Germany has shown significant growth rates over time and is predicted to grow even further. Data of the German Federal Statistics Office indicated a freight transport performance in Germany of approximately 630 billion ton-kilometres in 2011 (German Federal Statistical Office 2012). Current forecasts expect an increase in freight transport performance of approximately 40% by 2025 (Drewitz & Rommerskirchen 2012). Due to these growth rates, freight transport should play an essential role in economic and political decisions. Freight transport modelling needs to serve as a tool to support these decision-making processes. But much less research has been undertaken on modelling freight movements than passenger movements. It must be the aim of transport modelling to better understand freight transport patterns (Ortuzar & Willumsen 2011, p. 461).
In reality, logistics hubs are integrated into transport and supply chains. They bundle transport and serve as virtual elements in creating efficient transport chains. However, knowledge gaps exist about logistics hubs and their generation of transport. In addition, logistics hubs are so far not integrated into freight transport modelling.
The aim of the project “Integration of logistics hubs and their specific volume of traffic in freight transport demand modelling” (reference number of the German Research Association (DFG) project: CL 318/12-1 and LE 1137/4-1) is the integration of logistics hubs in freight transport modelling and the typological derivation of characteristic values of the logistics hubs. The project is carried out by the Institute of Transport Logistics at the TU Dortmund University and the Institute for Transport Research at the German Aerospace Centre (DLR). These values shall provide information about specific examples of transport performance and transport volume of logistics hubs. Significant associations for the development of freight transport generation of logistics hubs will be identified and analysed. In this way, the application of a transport demand theory, which includes logistics hubs, should be possible.
Some of the essential steps of the project are:

- the development of a typology of logistics hubs
- the identification and location of logistics hubs in Germany (see Klauenberg & Lenz 2012)
- the analysis of secondary statistics
- an empirical survey (see Thaller et al. 2013)
- the analysis of literature on logistics hubs in freight transport modelling
- the development of key ratios for the traffic generation of different types of logistics hubs

One of the first steps of the project was the methodological systemization of logistics hubs. Individual criteria, suitable for systemizing logistics hubs and their specific transport performance and volume, were defined using system-building methods. Based on that, characteristics and their possible specifications were assigned to the criteria. As a result, a systemization was able to be developed which will be used in the next steps of the project. In the generated typological order, logistics hubs-related aspects as well as transport modes and infrastructure were considered as characteristics. Specific aspects, which describe the companies involved in logistics hubs, were taken into account as well.

Parallel to the development of the typological order of logistics hubs, existing model approaches in freight transport modelling were reviewed and evaluated. Their suitability and transferability for the integration of logistics hubs into demand modelling were examined. On this basis, a new freight transport demand theory, which could implement logistics hubs as autonomous operating systems in freight transport modelling, should be developed.

In this article we want to describe the procedure and development of the primary empirical survey, explain the methods used for analysing the data and present the first results of this study. The content of the survey is based on the typological order of logistics hubs. The collected data base will be analysed by selected statistical methods. The purpose of these analyses is to derive a data-based typology of logistics hubs. Furthermore, the study provides first insights into the correlation analyses between logistics, business and transport data to characterize the logistics hubs. Out of this, the development of key ratios for the traffic generation of logistics hubs for freight transport modelling will be possible.

DEFINITION AND SYSTEMATIZATION OF LOGISTICS HUBS

Logistics hubs are places where goods are exchanged between vehicles or between transport modes. They can be classified as transport logistics hubs and distribution logistics hubs. Transport logistics hubs connect many points of origin with many points of destination. They do not have any dedicated storage function, but the handling function can be connected with a buffer function as a time offset. In contrast to this, distribution logistics hubs are prepared to store goods for longer periods of time and, in general, they connect some few points of origin with many points of destination. Transport logistics hubs are, for instance, airports, seaports, terminals for intermodal transport and handling facilities of freight forwarders. Central or regional warehouses are a typical form of distribution logistics hub. In this project we are focusing on transport logistics hubs, especially on those logistics hubs and networks with high transport volume. Thereby, logistics hubs are defined as parts of a complex freight transport network (de Jong et al. 2004, Clausen et al. 2008).

The systematization of logistics hubs was based on a literature review. The analysis showed that although scientific approaches exist which examine distribution and transport networks, they often deal only indirectly with logistics hubs (e.g. Becker et al. 2003, Beuthe & Kreutzberger 2001). The selected approaches describe the relations between logistics concepts or aspects and traffic induced (Drewes Nielsen et al. 2003, McKinnon & Woodburn 1996, Clausen & Iddink 2009). However, there was no approach for the comprehensive description of logistics hubs available. A framework for the development of a new systematization was given by Klaus and Krieger (2004) where the focus was put on one type of hub. The studies of Hesse and Rodrigue (2004) were a suitable basis for systemizing logistics hubs. Within these studies, relevant characteristics of logistics hubs were identified. Using descriptions and classifications of other types of hubs (Glaser 1995, Rimienė & Grundey 2007), this approach was extended to a systematization of logistics hubs, emphasizing hub-related aspects, characteristics and values of transport volume and transport performance as well as the companies located in the logistics hubs and their customers. Within these three main categories the following sub-categories were used to systemize the logistics hubs at a second level:

1. Logistical master data
2. Hub integration in network structures and transport chains
3. Transport and transshipment objects
4. Transport modes and transport infrastructure
5. Organizational structure of the logistics hub

The categories at the second level were specified in detail, obtaining a list of characteristics to describe logistics hubs in-depth. Each characteristic was connected with characteristic values. (see Table 1)
In the next step this preliminary work was used to analyse the real network structures of logistics hubs in Germany and their connecting networks with regard to goods flows, locations, transport volume and transport performance. For this, handling facilities of freight forwarders, seaports, inland ports, airports, terminals for intermodal transport and similar logistics hubs were analysed using official statistics and public sources. This step will not be further described in this paper. Further details of this step were described in detail in Thaller et al. (2013).

METHODOLOGY OF THE SURVEY

The developed systematization of logistics hubs with the theoretical prepared characteristics and characteristics' values is the basis for the design of the survey for the primary data collection. In the survey transport hubs and networks with high transport volume and high transport performance were taken into account:

- Hubs of networks of freight forwarders (forwarding)
- Hubs and depots of courier, express and parcel services (CEP-services)
- Rail freight centres
- Freight villages (GVZ – Gueterverkehrszentren)[1]
- Terminals for intermodal transport
- Inland ports
- Seaports
- Airports

Within the questionnaire, hub-related aspects, characteristics and values of transport volume and transport performance as well as the companies located in the logistics hubs and the user-side were considered. Within these three main categories, the sub-categories and characteristics are shown in Table 1. They are used in the developed questionnaire to

[1] GVZ are settlements of transport-oriented (independent) companies, logistics service providers and logistics intensive trade and production enterprises in a commercial area (Nobel 2004).

systemize logistics hubs and to derive associations between logistics-related aspects, transport-specific attributes and the user-side.

Table 1 – Typological order of logistics hubs as a basis for structuring the questionnaire (Source: Thaller et al. 2013)

Characteristics of the logistics hubs		
Logistical master data	Hub integration in network structures and transport chains	Transport and transshipment objects
• Size of the total area • Size of the transshipment area • Size of the storage area • Maximum handling capacity • Total transshipment volume in previous year • Number of ramps for local and long-distance transport	• Geographical position of the location • Interface between local and long-distance transport • Number of further locations • Network density • Network structure	• Type of goods handled • Handling equipment used and volume • Loading units entry/exit and volume
Characteristics of transport volumen and transport performance		
Transport modes and transport infrastructure • Connections to transport modes • Vehicle type used per transport mode • Transport volume per transport mode • Transport performance per transport mode • Maximum and average transport distance for delivery in local and long-distance traffic • Intra-day distribution of in- and outbounds • Load factor of transportation means • Share of empty trips		
Characteristics of the demand side		
Organizational structure of the logistics hub • Type of enterprise (type of logistics hub) • Industrial sector of the customer(s) • Organisational structure • Revenue of the location • Size of enterprise (Number of employees at the location) • Number of involved enterprises		

In the first and second quarter of 2012 a standardized, web-based and written survey was carried out. The target groups were companies located at logistics hubs and operators of logistics hubs. They were contacted by post and e-mail. The questionnaire contains mainly closed questions, which align with the characteristic categories of the typological order developed.

The basic population of the gross sample of N=2,395 is comprised by the business sites of all located companies and operators at hubs in Germany. The disproportional stacked random sample was chosen, as all strata was to be included, with the same chance, irrespective of their share of the basic population, of deriving statements on or comparisons between the single strata (Kohn 2005, p. 29). The above-mentioned target groups and the number of contacts of these groups are presented in Table 2.

Table 2 – Basic population of the sample (Source: Thaller et al. 2013)

Logistics companies and operator of hubs	Number of contacts
Freight forwarders	1,560
CEP-service providers	354
Freight villages	38
Terminals of intermodal transport	243
Inland ports	144
Seaports	32
Airports	24
Basic population of the gross sample	**2,395**

As official registers do not exist to draw a sample, the research team reverted to available and prepared lists at the DLR of business sites in Germany and prepared registers of logistics hubs and CEP-services. In addition, research for the most relevant logistics companies were carried out by ITL, thereby the most important logistics providers or freight forwarders in Germany with their locations could be identified via 13 forwarding networks established in Germany (e.g. DB Schenker, CargoLine GmbH, System Alliance GmbH). Further relevant logistics providers with their contact details are found in "TOP 100 der Logistik" (Klaus et al., 2011).

Statistical Methods for Evaluation

The data analysis, especially the detailed description of the empirical survey, is done by the use of different uni- and multivariate methods. The application of these methods enables a structural simplification and bundling of the single data as well as the identification of patterns, associations and dependencies. The starting point of the analyses is the uni- and multivariate descriptive analyses. Frequency distributions and measures of location scales (arithmetic mean, median) as well as dispersion measures (standard deviation) are also used for the evaluations.

Depending on the different scale levels of the characteristic features, suitable structure verifying methods are used, for example regression and correlation analyses, to test research relevant hypotheses.

In this paper selected data from this survey are presented. In this context, we concentrate on characteristics with regard to logistics master data, integration in network structure and transport chains as well as description of the organization or user-side. We try to identify dependencies and associations between these features by multivariate methods and different mathematical correlation analyses.

RESULTS

In total the net sample amounts to N=627 participants, a response rate of 26.1% could be reached in comparison to gross sample of N=2,395. After data cleaning of non-usable cases a net sample of 393 usable questionnaires was included in the assessment of the survey. Consequently, the utilization rate was 16.4% (393 out of 2,395 enterprises). Due to a high number of early drop-outs in the first survey wave, the questionnaire was shortened and adjusted for the second survey wave. The success of this measure was a higher percentage of usable questionnaires:

- 1st survey wave: 167 usable questionnaires out of 321 responses – 52%
- 2nd survey wave: 226 usable questionnaires out of 306 responses – 74%

The distribution of the 393 companies included in the analyses is shown in Figure 1. The distribution approximately reflects the general market share of the enterprises discussed. Here, the companies are classified in the different *types of logistics hubs*. Forwarding and road freight transport dominate with nearly 55%, followed by inland ports, courier, express and parcel service providers (CEP-service providers) and terminals of intermodal transport. The number of firms in the field of sea ports and airports is very low, so the statements on these types of hubs are only partially reliable. Other types of hubs are even less well represented; hence, these data allow no derivation of conclusions about these businesses. This should be taken into account when interpreting the results evaluated.

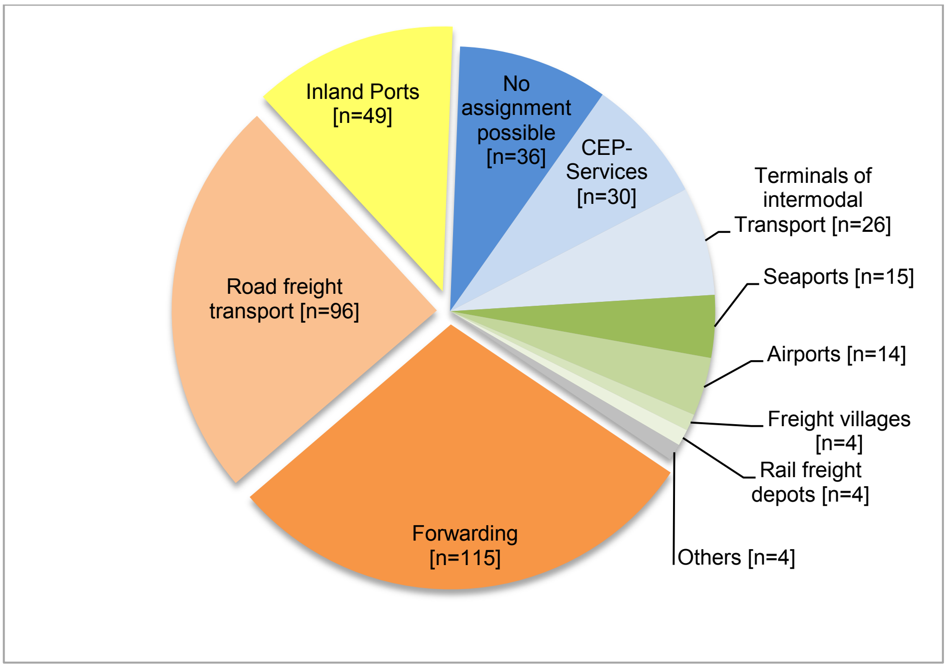

Figure 1 – Categorizing the net sample by the characteristic types of logistics hubs (N=393) (Source: own research)

Descriptive analyses

Concerning the *type of business unit* 41% of 393 evaluated responders reported that they are individual enterprises; nearly 13% are main offices and 31% are branch offices. 15% did not specify their type of business unit.

Each individual company has on average 3 further locations and is connected with 18 logistics hubs at national level. The main offices have 21 further locations and connections to 12 hubs in Germany. The branch offices have on average 39 further locations and are in a network of 25 enterprises.

According to *the size of enterprises*, nearly 27% are small-sized enterprises (with less than 50 employees). Medium-sized companies account for 47%. Micro enterprises (less than 10 employees) with 10% and large scale companies (more than 249 employees) with 14% have only low shares.

Regarding *the network structures*, 27% of the 393 firms are integrated in a corporate system or network. Out of these 108 enterprises, about 18% belong to a direct transport network, about 16% to hub and spoke networks, and in more than 60%, direct transport is combined with hub and spoke networks.

Over 70% of the investigated hubs (N=393) are connection points between regional and long distance transport. Almost 28% of the logistics hubs stated to be a hub location, over 47% are depots. On average, the share of hub transport accounts for 39% on hub locations; on depots hub transport stands at 32%.

Concerning *the characteristics of the business sector,* the general evaluation of multiple answers shows that the clients of the responding enterprises (N=275) are mainly from the logistics and transportation sector, other industry and economic services as well as food industry with each case nearly 10%, followed by the sectors trade, automotive industry, chemical industry and construction industry. Further sectors account for a smaller share of up to 6% (see Figure 2).

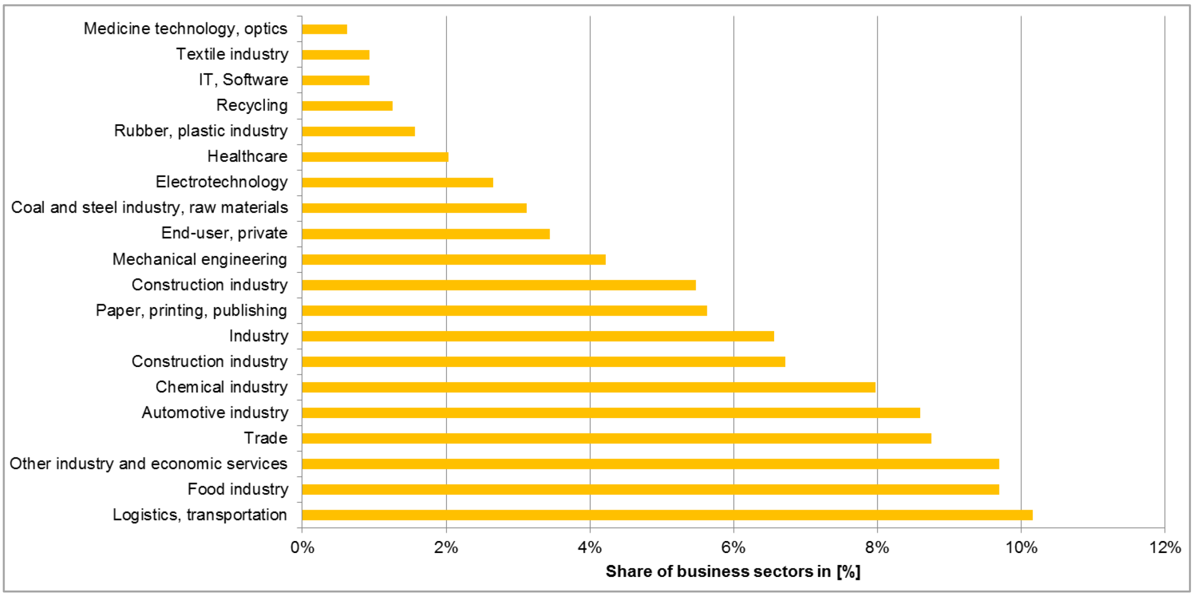

Figure 2 – Clients' business sector of enterprises (N=275) (Source: own research)

Concerning *the infrastructure connectivity* of the logistics hubs, 80% of them are within 10km of an Autobahn, only 10% of them are more than 10 km from one. 87% of the enterprises are connected to an ordinary highway nearby their locations (maximum distance of 10km). Over 27% of them have their own rail link, whereas 40% are within 100km of a rail port. Furthermore, 23% of the hubs are directly linked to an inland port and further 33% are located nearby an inland port (less than 50km). Only 7% of the enterprises have a direct connection to seaports, in comparison nearly 50% of the locations are more than 100km far from a seaport. 7% of the enterprises are located at an airport. Most of them (40%) have a link to an airport in a distance of less than 50km.

Bivariate Analyses

The bivariate analyses are carried out to compare the different *types of logistics hubs* with selected characteristics. The division into *types of logistics hubs* by *the size of enterprises* (number of employees) in Figure 3 shows that most of the logistics operators at airports are large scale companies (more than 249 employees) with a share of 50%. Mainly medium-sized companies are present in seaports (50%), CEP-services (57%), forwarding (59%) and road freight transport (57%). Mostly micro and small-sized companies are identified at inland ports (76%) and terminals of intermodal transport (54%). The different types of logistics hubs could thus be categorized into three different groups by the size of company.

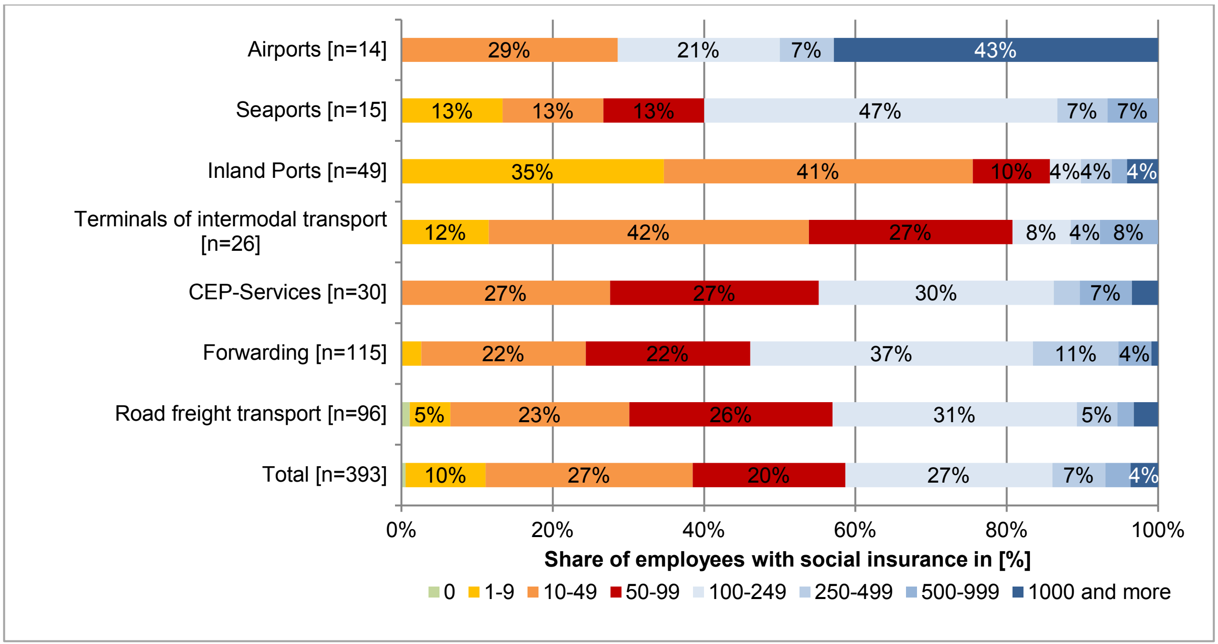

Figure 3 – Number of employees of each type of logistics hubs (Source: own research)

In Figure 4 the distribution of *the types of logistics hubs* concerning *the transport modes* used is shown. The diagram clearly illustrates the transport characteristics of the examined logistics hubs. Operators at airports mostly use the modes air and road transport. Seaports are hubs, which combine the various modes sea, inland waterway, rail and road transport. Inland ports primarily utilize inland waterway, rail and road transport. Terminals of intermodal transport are tri-modal terminals with road, rail and a lower share of inland waterway transport. CEP-services are dependent on road transport in more than 96.7% of all cases. Additionally, 50% of those hubs use air transport. Forwarders and companies for road freight transport mainly use road transport for goods distribution. Within this analysis the associations between the locations of the different types of logistics hubs can be derived. The types of logistics hubs use spill-over effects of the others and move to locations where they are able to efficiently handle the goods transported.

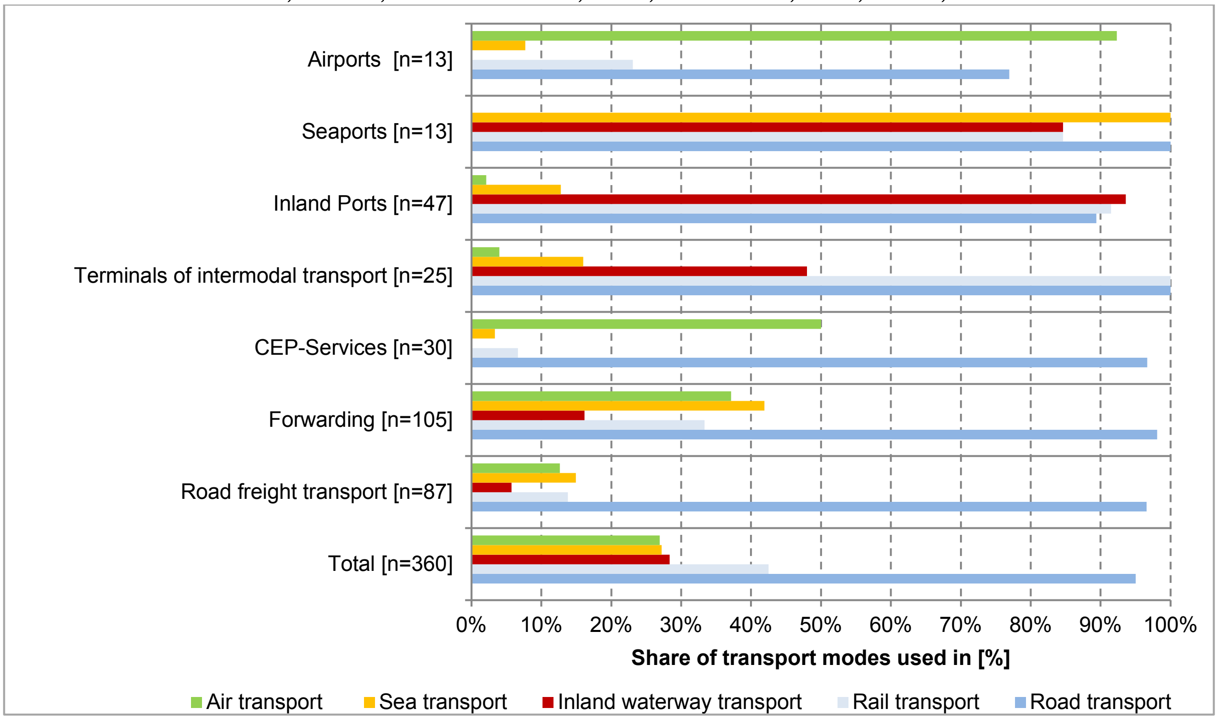

Figure 4 – Transport modes used of each type of logistics hubs (Source: own research)

Figure 5 shows an evaluation of area data concerning enterprises surveyed. The size of the total area and the size of the transshipment area are compared to the type of logistics hubs and are presented in a logarithmic scale.

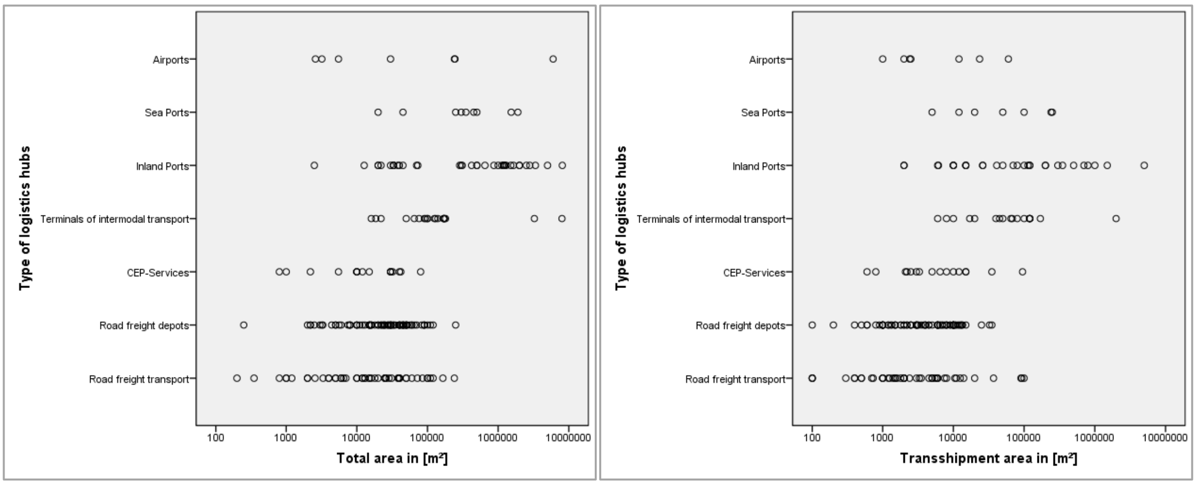

Figure 5 – Size of total area (left) and size of transhipment area (right) of each type of logistics hubs (Source: own research)

Furthermore, a comparison with the size of the total area shows that the transshipment area represents a very high percentage of the total area of the enterprises surveyed. This result is in concert with the goal of the survey to investigate transport network hubs with transshipment as main function instead of storage. In an investigation of distribution network hubs it could be expected that the storage area, in contrast to the transshipment area, would take up a greater share.

Inductive Analyses

By testing the formulated research hypotheses, associations between different variables will be identified. The specified maximum of α-probability of errors, which are defined by convention, is used to reject a null hypothesis (α < 5% (significant) and α < 1% (highly significant)) (Bortz 2006, p.494). For the hypothesis tests in this empirical study we defined 5% for the significance level to reject a null hypothesis. The selection of the test methods is done depending on the scale level of the variables. The following analyses are conducted by statistics software IBM SPSS Statistics Standard.
First, we used the Chi-square test to determine the association between two nominal scaled variables or between one nominal and one ordinal scaled variable. Additionally, the Chi-square test is used to investigate whether the measures of association observed between two variables can be applied to the basic population. According to the Chi-square test by PEARSON, the significance value p is compared with the defined significance level and the hypothesis is thus tested. The contingence coefficient Cramér's V is a measure of association and is used to test the strength of association. The coefficient is suitable for nominal scaled variables with more than two characteristics.
On the basis of the comparison of the mean values by the *t*-test for paired samples, the association between nominal and metric variables can be tested. The correlation analysis can be applied to investigate the strength and direction of associations. A prerequisite for this is that the variables are at least ordinal scaled. In contrast to proportionality the association represents only a statistical correlation. That means the determined coefficients serve for evaluation of the associations. Depending on scale level, the correlation coefficient is calculated either by SPEARMAN (ordinal scaling) or by PEARSON (metric scaling). Thereby, the correlation coefficient ϒ is representative for both of the mentioned correlation analyses, which are interpreted as being identical (see Table 3). The linear regression analysis enables a measurement of dependencies between two or more variables. In distinction to bivariate analysis by Chi-square test and correlation analysis, multivariate analysis can be performed with the regression (multiple regression analysis). Furthermore, the value of a dependent variable can be derived from an indicator variable.

Table 3 – Interpretation table for correlation coefficient ϒ (Source: Bühl 2012, p. 269)

Values of the correlation coefficient ϒ	**Interpretation**
0 < ϒ ≤ ± 0.2	Very low association
± 0.2 < ϒ ≤ ± 0.5	Low association
± 0.5 < ϒ ≤ ± 0.7	Medium association
± 0.7 < ϒ ≤ ± 0.9	High association
± 0.9 < ϒ ≤ ± 1	Very high association

Often it is necessary to examine the association between metric and ordinal scaled variables. As linear regression analysis can only be applied for metric scaled dependent variables, a distinction needs to be made between dependent and independent variables. The independent variables can also be ordinal scaled. If the dependency is not clearly ascertainable, a correlation analysis is performed instead of the regression analysis. During further proceedings, however, a correlation analysis by PEARSON is performed in advance

for the investigation of two variables with metric scale level. The regression, though, is directly used to analyse multiple associations. (Bühl 2012)
In this respect, in this study it is analysed in an explorative way, as so far it is not known which characteristics can be used as defining features. Based on the preliminary considerations described above further hypotheses are substantiated in the following. The hypothesis tests are selected by different methods.
In the further chapters the results of the hypothesis tests will be presented. Thereby, the associations between logistical, business and transport-specific characteristics of logistics hubs will be identified and validated. In detail, the further characteristics will be analysed:

- Type of logistics hubs
- Size of enterprises (number of employees)
- Choice of transport modes
- Size of areas of logistics hubs (total and transshipment area)
- Maximum handling capacity
- Total transshipment volume
- Transport volume (number of trips per year)

T-tests for Paired Samples

In the following the associations between metric scaled and nominal scaled variables are tested. Due to this, a *t*-test for paired samples is applied to test the associations between the variables. Thereby, the significance is simultaneously calculated. Within this procedure the null hypotheses should be falsified.
It shall be substantiated that there are associations between the following:

- Type of logistics hubs and size of total area
- Type of logistics hubs and size of transshipment area
- Type of logistics hubs and transport volume (number of trips per year)

In addition, the null hypotheses are formulated thus:

- H_{01}: No association between type of logistics hubs and the size of total area exists
- H_{02}: No association between type of logistics hubs and the size of transshipment area exists
- H_{03}: No association between type of logistics hubs and transport volume exists

The determined values of the tests are summarized in Table 4 and 5.

Table 4 – Associations for paired samples (Source: own research)

	N	ϒ	*Sig.*
Type of logistics hubs & total area	246	-.331	.000
Type of logistics hub & transshipment area	232	-.213	.001
Types of logistics hubs & transport volume	216	-.164	.016

Table 5 – Test for paired samples (Source: own research)

	T	*df*	*Sig. (2-sided)*
Type of logistics hubs – total area	-4.684	245	.000
Type of logistics hubs – transshipment area	-2.914	231	.004
Type of logistics hubs – transport volume	-3.744	215	.000

Table 4 presents the results for testing the associations between the nominal and metric scaled variables investigated. In Table 5 the indicators are shown if the results can be applied to the basic population.

In the case of an association of r = - 0.331 and a highly significant result, a low association between *type of logistics hubs and size of total area* can be assumed. The null hypothesis can be rejected as the significance value is p = 0.000 < 0.5. There exists also a highly significant association between type of logistics hubs and total area.

The association r between *type of logistics hubs and size of transshipment area* is with the significant value of p = 0.001 highly significant. The null hypothesis can be rejected according to the test for paired samples as a highly significant association between the two variables is assessed.

The association (r = -0.164) between *the type of logistics hubs and transport volume* is significant with a value of p = 0.016. There are interdependencies between these two variables.

In conclusion, the variable combinations tested by the t-test for paired samples have each a statistical correlation and can be applied to basic population.

Chi²-tests and Cramér's V

Within the further tests the potential associations between two nominal scaled variables or between one nominal and one ordinal scaled variable are verified by Chi²-tests.

The strength of the associations should be derived by the measure of association Cramér's V between respective scaled variables. The associations between the following were assessed:

- Size of enterprises (number of employees) and choice of transport modes
- Type of logistics hubs and choice of transport modes
- Type of logistics hubs and size of enterprises (number of employees)

Therefore, the null hypotheses are:

- H_{04}: No association between size of enterprises and choice of transport modes exists
- H_{05}: No association between type of logistics hubs and choice of transport modes exists
- H_{06}: No association between type of logistics hubs and size of enterprises exists

The results are shown in the following tables.

Table 6 – Chi²-tests of size of enterprises and choice of transport modes (Source: own research)

	Value	*df*	*Asymptotic Sig. (2-sided)*
Chi² by Pearson	50.810	32	.019
Number of valid cases	393		

The result is significant with an overall probability value smaller than 0.05. According to this significant value, an association between *size of enterprises* and the *choice of transport modes* exists (see Table 6). The null hypothesis can be falsified with an error probability of 1.9%. An association is thus assumed. The Cramér's V-value 0.180 also validates a significant result of 0.019 with a weak association.

Table 7 – Chi²-tests of type of logistics hubs and choice of transport modes (Source: own research)

	Value	*df*	*Asymptotic Sig. (2-sided)*
Chi² by Pearson	357.54	48	.000
Number of valid cases	350		

Table 7 shows that the association between *type of logistics hubs* and *choice of transport modes* exists and is highly significant. According to this highly significant value, an association between these two variables is proven. The Cramer-V-value 0.505 indicates a medium association between these variables. In this case, the result is highly significant with a probability of 0.00. Thereby, the null hypothesis can also be rejected with the distinct Cramer-V-value.

Table 8 – Chi²-tests of type of logistics hubs and size of enterprises (Source: own research)

	Value	*df*	*Asymptotic Sig. (2-sided)*
Chi² by Pearson	410.80	96	.000
Number of valid cases	393		

The association between *type of logistics hubs* and *size of enterprises* is highly significant with an overall probability value of 0.00 (see Table 8). The strength of the association is with a value of 0.361 by Cramer's V medium and highly significant. The null hypothesis is rejected.

Linear Regressions and Correlation Analyses by SPEARMAN

In the following are presented the analyses of the interdependencies between:

- Transport volume and size of enterprises
- Size of total area and size of enterprises

The defined null hypotheses are:

- H_{07}: No association between transport volume and size of enterprises exists
- H_{08}: No association between size of total area and size of enterprises exists

Due to the ordinal and metric scaling of the criterion variables investigated, interdependence analyses can be performed by linear regressions. Thereby, the ordinal scaled variable *size of enterprises* is the independent variable in both cases. Thus, the linear regression takes place according to the inclusion method.

Table 9 – Coefficient hypothesis – Inclusion method – Transport volume and size of enterprises (Source: own research)

Model		*T*	*Sig.*
1	*(Constant)*	1.264	.207
	Size of enterprises	.249	.804

According to the model of *transport volume* and *size of enterprise*s, the value R = 0.017 shows a very weak association. In consequence of determination coefficient R^2, it is indicated that 0.0% of the variation of transport volume is explained by the predictor variable size of enterprises. The standardized coefficient Beta (0.162) shows clearly that the size of enterprises has only a low influence in transport volume. The results are not significant with a value of 0.804 (see Table 9). A further correlation test by SPEARMAN (N=227) is applied. Although the correlation coefficient by SPEARMAN defined a medium association (0.533), the association is highly significant (2-sided), at a level of 0.01. Therefore, the null hypothesis can be rejected as a demonstrable association between transport volume and size of enterprises exists.

Table 10 – Coefficient hypothesis – Inclusion method – Size of total area and size of enterprises (Source: own research)

Model		*T*	*Sig.*
2	*(Constant)*	-.662	.509
	Size of enterprises	1.329	.185

Concerning the regression analysis between *size of total area* and *size of enterprises*, the identified association is very weak with R = 0.082. On the basis of the R^2-value, only 0.7% of the variation of total area is determined by the predictor variable size of enterprise. The Beta value clearly indicates that the size of enterprises has a low influence on the total area. The significance level of the regression parameter has a distinctly higher value than 0.05 and thus is not significant (see Table 10). Since the association and the significance have not been verified, a further correlation analysis by SPEARMAN (N=262) is applied. On the one hand, the correlation coefficient by SPEARMAN shows a weak association with the value of 0.263, but on the other, the association is highly significant (p = 0.01). For this reason, the association between these two variables can be confirmed and the null hypothesis can be rejected.

Correlation Analyses by PEARSON and Linear Regressions

The following shows correlation analyses between:

- Size of total and transshipment area
- Total transshipment volume and maximum handling capacity
- Size of transshipment area and maximum handling capacity
- Size of total area and transport volume

Thereby, the null hypotheses are defined as:

- H_{09}: No association between size of total and transshipment area exists
- H_{10}: No association between total transshipment volume and maximum handling capacity exists

- H_{11}: No association between size of transshipment area and maximum handling capacity exists
- H_{12}: No association between size of total area and transport volume exists

For the further tests, the correlation analysis by PEARSON for the examination of two metric scaled variables is initially applied (see Table 11). If the correlation coefficient ϒ is positively correlated and significant at a level of 0.05, a linear regression analysis by an inclusion method can be conducted afterwards.

Table 11 – Correlation by PEARSON (Source: own research)

	ϒ	*Sig. (2-sided)*	*N*
Size of total area – size of transshipment area	.804	.000	242
Total transshipment volume – maximum handling capacity	.904	.000	177
Maximum handling capacity – size of transshipment area	.156	.047	164
Transport volume – size of total area	,225	,002	180

Table 12 – Coefficient hypothesis – Inclusion method – Size of total and transshipment area (Source: own research)

Model		*T*	*Sig.*
	(Constant)	-.483	.629
3	*Size of total area*	20.91	.000

Correlation analysis for the investigation of the two variables *size of total and transshipment area* shows that the association between these two variables is high and significant (see Table 11). The linear regression confirms these results with R = 0.804. The coefficient of determination R^2 amounts to 0.646 and therefore nearly 65% of the criterion variable size of total area can be explained by the predictor variable transshipment area. Consequently, there is interdependency between these variables. The statistical correlation is verified by the correlation coefficient. The null hypothesis can be rejected by a highly significant result (see Table 12).

Table 13 – Coefficient hypothesis – Inclusion method – Total transshipment volume and max. handling capacity (Source: own research)

Model		*T*	*Sig.*
4	*(Constant)*	.017	.986
	Max. handling capacity	27.92	.000

Table 11 shows that the correlation coefficient by PEARSON for the variables *total transshipment volume* and *maximum handling capacity* is very high. The association between these variables is significant at a level of 0.01. On the basis of linear regression conducted, a similar result can be derived with R = 0.904. At over 81% maximum handling capacity is dependent on total transshipment volume (R^2=0.817). The null hypothesis can be rejected due to a high significance (see Table 13).

Table 14 – Coefficient hypothesis – Inclusion method – Max. handling capacity and size of transshipment area (Source: own research)

Model		*T*	*Sig.*
5	(Constant)	4.314	.000
	Size of transshipment area	2.005	.047

Within correlation analysis by PEARSON a weak association between *maximum handling capacity* and *size of transshipment area* can be presented. The association is significant at a level of 0.05 (see Table 11). The linear regression shows the same tendencies with R = 0.156. The value R^2 = 0.024 testifies a low influence of maximum handling capacity on size of transshipment area. For this reason, the null hypothesis can be rejected and the hypothesis can be confirmed with a significant result at a level of 0.05 (see Table 14).

Table 15 – Coefficient hypothesis – Inclusion method – Transport volume and size of total area (Source: own research)

Model		*T*	*Sig.*
6	*(Constant)*	2,736	,007
	Size of total area	3,085	,002

According to the variables *transport volume* and *size of total area,* a weak association with a significant result at a level of 0.01 is verified (see Table 11). By linear regression the correlation coefficient R = 0.225 also suggests a weak association and the value R^2 = 0.051 indicates a low influence of transport volume to size of total area. Nevertheless, the null hypothesis can be falsified with a high significance (see Table 15).

In conclusion, the hypothesis tests show that the variables *type of logistics hubs, size of enterprise, transport volume* and *size of total area* are related to the transport-related and enterprise-specific characteristics of the logistics hubs (see Figure 6).

CONCLUSION

The survey design for the primary data collection was developed on the basis of the theoretical systemization of logistics hubs. Transport hubs and networks with high transport volume and performance in Germany were examined. Transport volume, performance and demand side were collected using the standardized survey characteristics of the transport hubs. Out of 2,395 contacts of different logistics companies, we reached in total 26% of them for our survey. Afterwards, we analysed the data base obtained by uni- and multivariate methods. For this investigation we focused on characteristics of the logistics hubs and their transport volume and logistical master data.
Within uni- and bivariate analyses we could define and characterize the single transport hubs with their specific features. Furthermore, the hypotheses were tested with selected statistical methods (Chi²-test, *t*-test, correlation, linear regression). In conclusion, we were able to confirm several hypotheses and identified associations as shown in Figure 6. What was noteworthy here was the fact that logistical, transport and business-related characteristics are mainly dependent on the four variables *type of logistics hubs*, *size of enterprises*, *size of areas* (*total and transshipment area*) and *transport volume*.

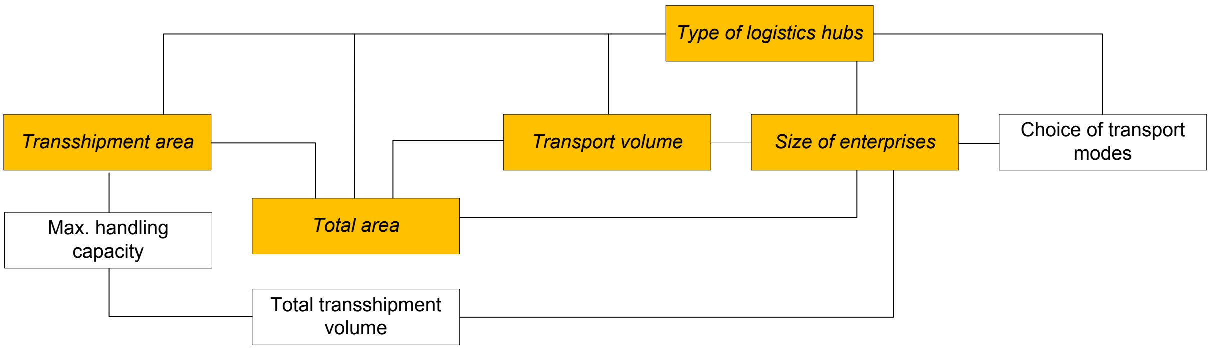

Figure 6 – Confirmed associations between selected characteristics of logistics hubs (Source: own research)

Finally, this paper presents the first overview of detailed information about logistics hubs and their specific transport volume. In the next steps, the data base could serve for further investigations in-depth. Using this data base, we could analyse special issues related to the individual types of hubs (e.g. freight forwarders, terminals of intermodal transport, CEP-service providers). The information obtained could be used for freight transport modelling and for deriving freight transport forecasts.

ACKNOWLEDGEMENT

The authors gratefully acknowledge funding of this work by the German Research Association (DFG) under reference number CL 318/12-1 and LE 1137/4-1.

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