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Abstract

Although anecdotic evidence suggests that co-location of logistics activities can bring several benefits to the co-located logistics companies and hence, can be important to incorporate in the location decisions of these companies, this is the first paper to empirically research these benefits. This paper contributes to the understanding of spatial concentration of logistics firms by empirically analyzing synergies through co-location and investigates whether spatial concentration of logistics activities indeed results in classical agglomeration economies as well as benefits, which are specific for the logistics sector. Hypotheses related to synergies through co-location of logistics activities are tested based on a survey among managers of 507 logistics establishments in the South of the Netherlands. The findings show that co-located logistics firms more often combine transport and storage capacity, are better accessible, have better availability of repair and maintenance facilities, and have better expansion opportunities than non-co-located logistics firms do. As this research shows that synergies through co-location of logistics activities indeed exist, manager of logistics companies may need to take these benefits into account in location decisions, academics in facility location models, and policy makers in spatial planning.

Keywords: Logistics establishments, Spatial concentration, Co-location, Agglomeration economies, Location decision

1 Introduction

Location decisions of logistics companies play a critical role in the strategic design of supply networks. Hence, the facility location problem received much attention in the supply chain management literature (see e.g. Hale and Moberg, 2003; Melo *et al.*, 2009, for overviews). Besides the availability of many different optimization models that primarily focus on cost factors, there is a trend to incorporate qualitative variables in these location decisions models (Bhatnagar *et al.*, 2003). However, due to the complexity and dynamics of location-decision processes, many of these processes, in practice, are still based on simple rules of thumb, rough estimates, or history (Porter and Rivkin, 2012).

The spatial context in which companies operate got little attention in the literature on supply chains and logistics. This research theme has received widespread attention in management literature, with a focus on potential synergies through spatial concentration of related activities in spatial clusters (see e.g. Alcácer and Chung, 2007; Suire and Vicente, 2008, for examples from the R&D sector). Furthermore, policy makers as well as clustered firms actively invest in cluster competitiveness (Organization for Economic Co-operation and Development, 2007).

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However, cluster benefits have so far hardly been studied specifically for logistics. This is surprising, because anecdotical evidence of logistics parks, in for example Zaragoza and Chicago, and port areas, like in Singapore and Rotterdam, suggests that spatial context for logistics operations is relevant. Furthermore, recent research concluded that logistics firms indeed have the tendency to co-locate (see Bowen, 2008; Jing and Cai, 2010; Van den Heuvel *et al.*, 2011).

Research in economic geography has explained spatial concentration of economic activities in general and in specific industries with several localized synergies, called economies of agglomeration. These economies are related to proximity and distance: the closer firms are together, geographically and organizationally (Torre and Rallet, 2005), the more there are synergies between these firms. This applies regionally (say e.g. on the level of a state in the US), as well as at lower geographical scales (Van Soest *et al.*, 2006; Arauzo-Carod and Viladecans-Marsal, 2009).

Many studies research whether concepts such as local specialization, local diversity, and co-location of vertically related firms result in positive outcomes for the firms involved (e.g. Henderson, 2003; Kukalis, 2010) and the economy at large (e.g. Almeida, 2007). While these concepts can be highly relevant for the logistics sector (Sheffi, 2010), in logistics such research is limited to spatial clustering of port and maritime industries (De Langen, 2004; De Langen and Visser, 2005; Brett and Roe, 2010). In addition, some research has been done on freight villages (e.g. Tsamboulas and Dimitropoulos, 1999; Tsamboulas and Kapros, 2003), but this research does not specifically focus on the spatial concentration of logistics activities.

Given the examples of spatial concentration of logistics activities, classical agglomeration economies are expected to be relevant for logistics firms. Furthermore, spatial concentration of logistics firms is also expected to bring specific benefits that are less relevant in other sectors, such as sharing of transportation and warehousing resources, resulting in an increased efficiency in dealing with demand variability (Sheffi, 2010). This paper contributes to the understanding of spatial concentration of logistics firms by empirically analyzing synergies through co-location and investigates whether spatial concentration of logistics activities indeed results in the classical economies as well as logistics specific benefits. A series of hypotheses is developed with regard to synergies through spatial concentration of logistics activities and these were tested based on a survey of logistics companies in the South of the Netherlands, a region located between Europe's two largest seaports (Rotterdam and Antwerp) and large consumer markets in Germany and France.

The remainder of this paper is structured as follows. Section 2 discusses in more detail the synergies of spatial concentration, and develops a series of hypotheses. Section 3 presents the survey method to analyze these hypotheses. The results of this survey are presented in section 4 and discussed in section 5. Section 6 concludes this paper and presents opportunities for further research.

2 Theoretical framework

This section describes how agglomeration economies are expected to be relevant for logistics. First, the relevance of classical agglomeration economies in the logistics sector is discussed (section 2.1), then specific logistics agglomeration economies are described (section 2.2), and finally, agglomeration diseconomies relevant for the logistics sector are discussed (section 2.3). As firm size can be a possible alternative for co-location, section 2.4 describes for which hypotheses firm size is relevant.

As explained in more detail in section 3, logistics companies in this paper are classified as companies specialized in transport and/or storage activities, as well as wholesale trade companies, as most of these firms also perform many logistics activities (in line with policy studies in the U.S. (see e.g. Southern California Association of Governments, 2004) and the Netherlands (see e.g. TNO, 2009)).

2.1 Classical agglomeration economies

Agglomeration economies are generally divided into localization and urbanization economies (e.g. Henderson, 2003). Localization economies relate to co-location of firms operating within the

same or a related industry and have been researched extensively (e.g. Krugman, 1991; Ellison and Glaeser, 1997; Porter, 2000). Urbanization economies are caused by spatial concentration of employment in general (Jacobs, 1969). These economies describe the advantages of locating close to large urban centers characterized by good access to input and output markets and public facilities (Melo *et al.*, 2010).

Marshall (1956) described three major types of localization economies, namely labor market pooling, knowledge spillovers, and input sharing. These all can be relevant in the case of co-location of logistics activities.

First, co-located firms may have better access to personnel than non-co-located firms. High demand for logistics personnel, due to the spatial concentration of logistics firms, attracts logistics personnel to the region, which results in a high availability of qualified personnel, positively influencing firm performance (Eriksson and Lindgren, 2009). A difference is made between operational personnel, administrative personnel, and truck drivers.

H1. a. Co-located logistics firms experience a higher availability of *operational personnel* than non-co-located logistics firms do.

b. Co-located logistics firms experience a higher availability of *administrative personnel* than non-co-located logistics firms do.

c. Co-located logistics firms experience a higher availability of *truck drivers* than non-co-located logistics firms do.

Second, the degree of knowledge sharing can have a significant influence on firm performance (Zacharia *et al.*, 2009; Grawe *et al.*, 2011). As, everything else being equal, the costs of exchanging information increases with the distance between the firms (Malmberg and Maskell, 1997), knowledge spillovers often result from the co-location of similar firms (Marshall, 1956). This increasingly becomes important for logistics companies, since these increasingly work with highly sophisticated systems, as for example route planning software. As knowledge sharing is relevant in different levels of the organization, a difference is made between management and other personnel.

H2. a. *Managers* of co-located logistics firms more often share knowledge with others than *managers* of non-co-located logistics firms located do.

b. *Non-management personnel* of co-located logistics firms more often shares knowledge with others than *non-management personnel* of non-co-located logistics firms does.

Third, Marshall (1956) reasoned that if similar firms co-locate, suppliers of these firms also tend to locate in the same region. As repair and maintenance facilities are one of the major suppliers of logistics firms, it is expected that logistics firms located in logistics concentration areas have better access to this kind of inputs than other logistics firms.

H3. Co-located logistics firms experience a higher availability of repair and maintenance facilities close by than non-co-located logistics firms do.

A classical urbanization economy relevant for logistics companies is the economy of transport density (Mori and Nishikimi, 2002), resulting from well developed infrastructure around (logistics) concentration areas. Better accessibility of the area for freight transport results in lower transport costs and a shorter time to the market (Limão and Venables, 2001). A positive correlation between the number of warehouse establishments and road accessibility in the U.S. (Bowen, 2008), provides evidence for these economies of transport density.

H4. Co-located logistics firms are better accessible by road than non-co-located logistics firms are.

2.2 Logistics agglomeration economies

In addition, spatial concentration of logistics activities is hypothesized to result in benefits which are specific for logistics companies (Sheffi, 2010). First, co-located logistics firms can combine transport flows, which often results in lower transport costs (Jara-Díaz and Basso, 2003), due to a decrease of the average distance between customers (Van Donselaar *et al.*, 1999; Wouters *et al.*, 1999), less repositioning of trucks (Ergun *et al.*, 2007), and a decrease in empty mileage (Cruijssen *et al.*, 2007b, 2010). Besides this opportunity to reduce costs, the combination of transport flows may also result in an increase in the frequency of delivery to customers (Cruijssen *et al.*, 2007b; Hageback and Segerstedt, 2004) and in more flexibility in handling urgent orders. For logistics companies with an in-house transportation department sharing of transport capacity can directly result in cost or service advantages, while for logistics companies that outsource their transport to a third party, these agglomeration economies may result in a lower price for these services and/or more flexibility.

H5. a. Co-located logistics firms more often *send along* cargo with other logistics firms than non-co-located logistics firms do.

b. Co-located logistics firms more often *take along* cargo of other logistics firms than non-co-located logistics firms do.

H6. a. Co-located logistics firms *pay a lower price* for outsourced transportation services than non-co-located logistics firms do.

b. Co-located logistics firms *experience more flexibility* from their carrier(s) than non-co-located logistics firms do.

Second, co-location in logistics may lead to sufficient scale for multimodal transport services. Multimodal transport can hardly compete with road transport unless relatively large volumes can be bundled. When logistics firms co-locate, freight volumes increase, enabling the development of multimodal transport services. Besides that this may reduce transportation costs, it also reduces CO_2 emissions and road congestion, availing for society at large (European Commission, 2011).

H7. a. Co-located logistics firms more often use multimodal transport to and/or from *seaports* than road than non-co-located logistics firms do.

b. Co-located logistics firms more often use multimodal transport to and/or from *European destinations* than non-co-located logistics firms do.

Third, similar to the exchange of transport capacity, inter-establishment storage capacity sharing also increases the productivity of logistics firms (Cruijssen *et al.*, 2007b, 2010). In addition, the market liquidity of warehousing facilities is higher the higher the number of such facilities. Hence, co-located logistics firms may easily buy similar property from logistics firms nearby and expand their operations.

H8. a. Co-located logistics firms *use* more storage capacity of others than non-co-located logistics firms do.

b. Co-located logistics firms *let others use* their storage capacity more than non-co-located logistics firms do.

H9. Co-located logistics firms have better expansion opportunities than non-co-located logistics firms do.

Fourth, and especially relevant for co-located wholesale trade firms is the opportunity for last-minute trade among each other. This increases flexibility in serving customers with volatile demand.

H10. a. Co-located logistics firms more often *purchase* products last-minute to react to last-minute changes in customer order quantities than non-co-located logistics firms do.

b. Co-located logistics firms more often *sell* products last-minute such that their customers can react to last-minute changes in customer order quantities than non-co-located logistics firms do.

2.3 Agglomeration diseconomies

Fujita and Krugman (2004) describe three possible agglomeration diseconomies: immobility, pure external diseconomies, and the increase in land rents. Immobility occurs when firms depend on a specific location, which is not the case in logistics. The last two can be relevant for logistics firms. One of the pure external diseconomies is road congestion in and around concentration areas, due to larger transport volumes to and from these areas. The increase in land rents may be relevant in the logistics sector, since these firms generally need relatively many square meters of land.

H11. Co-located logistics firms experience more road congestion in the direct surroundings than non-co-located logistics firms do.

H12. a. Co-located logistics firms pay a higher *land price* than non-co-located firms do.

b. Co-located logistics firms pay a higher *rent* than non-co-located firms do.

2.4 The effect of firm size

All hypotheses will be tested by testing for differences between firms located in concentration areas (the co-located firms) and firms not located in concentration areas (the non-co-located firms). To avoid conclusions based on spurious relationships, alternative explanations need to be ruled out. Differences in the type and size of logistics companies are plausible alternative explanations.

Differences in the mix of logistics companies in concentration areas and outside these areas may influence the results, as synergies from co-location are different for different types of logistics companies. As table 2 shows, the mix is very similar, with the exception of one type of logistics companies (Transport with own equipment). Deleting those companies does not significantly alter the results. In addition, section 4 shows the results for the group of all respondents, and the two largest subgroups of respondents, from wholesale trade companies and from logistics service providers.

Differences in size can have two effects. On the one hand, large firms may already have certain benefits over small firms, because of their size. On the other hand, small firms may cooperate more with other firms, because they lack the scale needed to efficiently execute certain activities. This may imply that differences in firm size explain differences in results. For hypotheses H1a-H1c, H2a-H2b, H3, H6a-H6b, and H7a-H7b it is expected that large firms score higher than small firms. The first relate to localization economies, that by definition relate to economies of scale (Malmberg *et al.*, 2000; Parr, 2002). As large firms have more bargaining power over their carriers, these probably also score higher on hypotheses H6a-H6b. Finally, for H7a-H7b it is expected that large firms use more multimodal transport than small firms do, as for multimodal transport to be cost-efficient, transport volumes have to be large. Assuming that large logistics firms generate large transport volumes, these firms will more often use multimodal transport than small logistics firms.

For hypotheses H5a-H5b, H8a-H8b, H10a-H10b, and H12a-H12b it is expected that small firms score higher than large firms. Especially small firms probably share transport capacity, since larger firms themselves have the scale to efficiently use their capacity. Similarly, small firms probably interchange more storage capacity and trade more products last-minute than large firms do. Finally, land prices and rents per square meter are expected to be relatively low for larger firms.

As H4, H9, and H11 are related to infrastructure, the size of only one firm does not have an effect on these variables.

To cope with the size difference between co-located and non-co-located firms, three consecutive analyses are conducted. First, differences between co-located and non-co-located firms are tested.

Second, if these are significant, differences between small and large firms are tested. Finally, if these differences are significant as well, differences are tested between both small co-located and small non-co-located firms, and large co-located and large non-co-located firms.

Figure 1 summarizes the relationships that will be tested in this paper.

3 Research methodology

The above described hypotheses were tested based on a survey, using a web-based questionnaire that was sent to managers of logistics establishments. An establishment is one specific company location with a specific address. Firms can have multiple establishments. Respondents were asked to relate the questions to their establishment. Hence, the findings are based on establishments not necessarily firms, as synergies are location specific.

3.1 Methodology

Van den Heuvel *et al.* (2012) developed a method to identify (logistics) concentration areas. With this method, four-digit postal code areas are identified as logistics concentration areas based on both absolute spatial concentration (the number of logistics employees per area) and relative spatial concentration (the location quotient (see e.g. Kim *et al.*, 2000) of the logistics employment per area). Based on this method, the respondents' establishments are categorized as located in or not located in logistics concentration areas. By comparing the answers of respondents of co-located establishments (in logistics concentration areas) with answers of respondents of non-co-located establishments (not in logistics concentration areas), conclusions are drawn about the (dis)advantages of co-location of logistics activities. One-way independent sample t-tests were used to test whether co-located logistics establishments (dis)agree more with the statements than non-co-located logistics establishments. A similar analysis was conducted based on the differences in size; based on the median of the total number of employees per establishment, the establishments were divided into two groups: large and small establishments.

The assumption of t-tests is that samples are randomly drawn from normally distributed populations (Montgomery and Runger, 2003). As sample sizes become larger, nonnormality is less of a concern (Hair *et al.*, 2006). For sample sizes of 30 or more respondents, normal approximations are generally satisfactory (Montgomery and Runger, 2003; Hair *et al.*, 2006). As most responses are not normally distributed, tests conducted on samples with less than 30 respondents are interpreted carefully. Appendix A provides the sample sizes per questionnaire item.

3.2 Data collection

Logistics establishments were selected from the 2009 establishment databases of two provinces in the South of the Netherlands (North Brabant and Limburg) based on the industry codes (Statistics Netherlands, 2012). Establishments with an industry code related to transport, storage, or wholesale trade activities were classified as logistics establishments. Appendix B gives an overview of the industry codes used.

In total, 2634 of the 3991 establishments in the population were contacted by phone to ask whether they were willing to cooperate in this research. Based on these telephone calls, 1463 correct email addresses were gathered, and finally 507 respondents (35% of the people that received an email and 13% of the complete population) fully filled out the questionnaire. The incentive that for every questionnaire fully filled out five euros would be donated to a specific charity fund probably helped to increase the response rate (Manfreda and Vehovar, 2008).

Appendix B shows that the distribution of the respondents over the different types of logistics establishments is similar to that distribution for the whole population. Hence, the respondents are representative for the whole population.

To check for non-response bias, respondents were divided into three different categories: the first group consists of the respondents that filled out the questionnaire based on one telephone

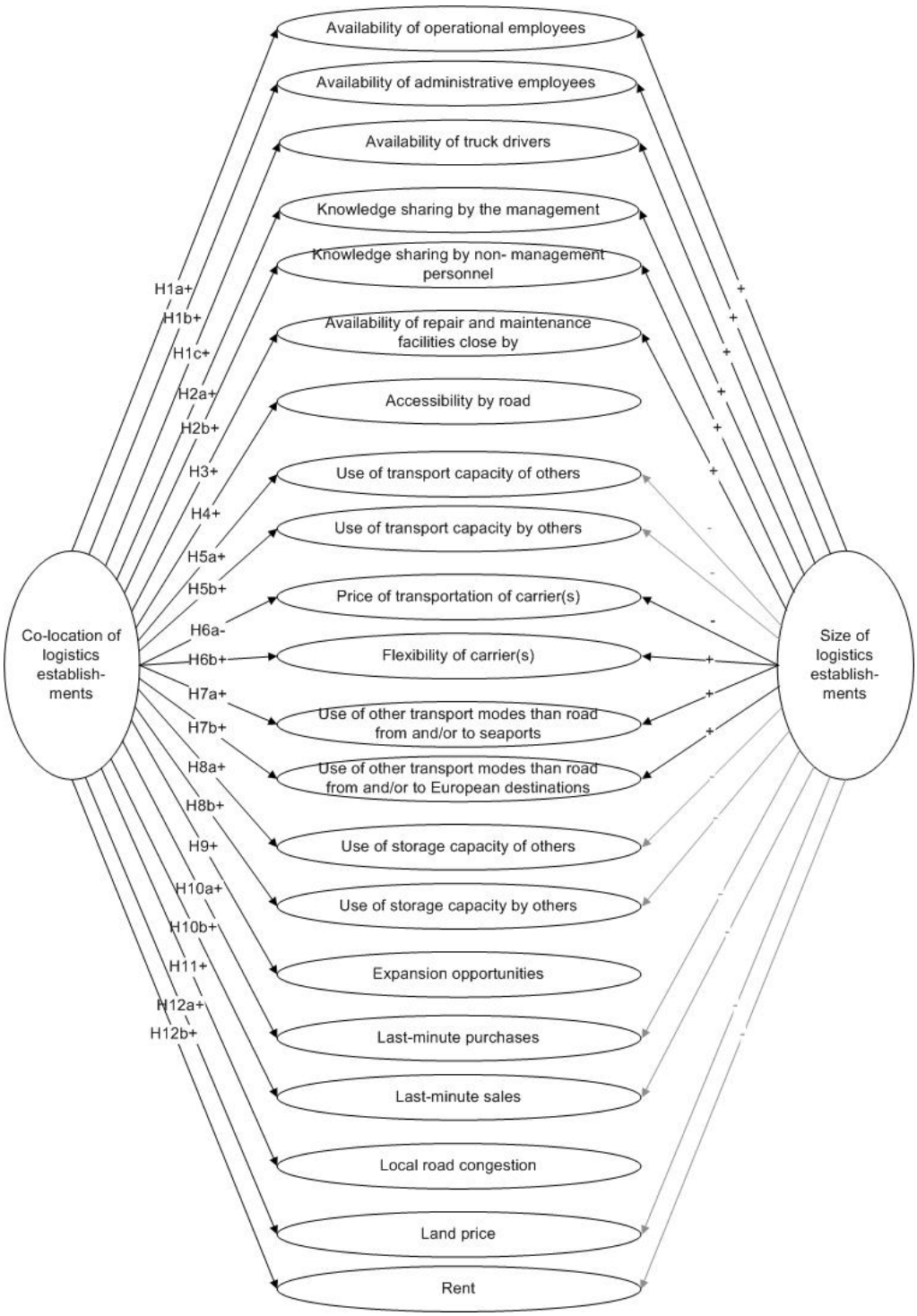

Figure 1: Conceptual model and hypotheses

call and one email inviting them to fill out the questionnaire (48%), the second group are the respondents that replied after a reminder telephone call (14%), and the third group consists of respondents that were reminded by both a telephone call and an extra email (38%). Based on an ANOVA test, no significant differences between the three different categories of respondents were found for all the below described variables (with $\alpha = 0.05$). As late respondents can be used as a proxy for non-respondents (Armstrong and Overton, 1977), which is often used in logistics research to analyze non-response bias (Wagner and Kemmerling, 2010), non-response bias was not considered to be a problem in this study.

3.3 Measurement item development

The C-OAR-SE procedure (Rossiter, 2002) was to develop the questionnaire. Per hypothesis one construct was defined, which was measured using one or more items in the questionnaire. The nature of the construct determines whether the construct is measured with one or more items. For example, the price of the mostly used carrier (related to H6a) can easily be measured with only one item, that can fully cover the construct (Mentzer and Flint, 1997). The availability of operational personnel (related to H1a), however, has to be measured by two items, since this construct consists of two parts, being temporary and full-time personnel. Flexibility of the logistics service provider (related H6b) has to be measured by more items, to ensure that this construct is measured by variables that are interpreted similarly by different persons. To be able to interpret all hypotheses similarly, averages are used to combine different items per construct.

Table 1 gives an overview of the items used per hypothesis. Flexibility of the carrier was measured with four different items (developed by Stank and Daugherty, 1997). Based on a Cronbach's alpha of 0.841, these four items measured one construct, called flexibility of the carrier. For the other multi-item constructs, Cronbach's alpha is not useful, as these have formed attributes, while flexibility has eliciting attributes (Rossiter, 2002).

Respondents were mostly asked to indicate the level of agreement per item based on a 7-point Likert scale. Creating different scales per item would result in unnecessary complexity of the questionnaire, which increases the respondent's burden to fill out the questionnaire (Manfreda and Vehovar, 2008). The questionnaire was in Dutch.

The questionnaire was tested with five logistics managers using the method developed by Jansen and Hak (2005). Based on these test interviews, some questions were changed, to make their interpretation easier.

Table 1: Questionnaire items per hypothesis

Hypotheses and statements		**N**	**Mean**	**SD**
Availability of labor				
H1a	Average score for the ease of fulfilling vacancies for operational personnel	499	4.29	1.41
	- A vacancy for a temporary operational employee (for example order picker or lift truck driver) can be fulfilled quickly	499	4.38	1.59
	- A vacancy for a full-time operational employee can be fulfilled quickly	502	4.21	1.52
H1b	Average score for the ease of fulfilling vacancies for administrative personnel	498	4.34	1.40
	- A vacancy for a temporary administrative employee can be fulfilled quickly	498	4.36	1.54
	- A vacancy for a full-time administrative employee can be fulfilled quickly	500	4.31	1.48

Table 1 continued

Hypotheses and statements		N	Mean	SD
H1c	Average score for the ease of fulfilling vacancies for truck drivers	281	4.01	1.51
	- A vacancy for a temporary truck driver can be fulfilled quickly	282	4.01	1.68
	- A vacancy for a full-time truck driver can be fulfilled quickly	283	4.01	1.61
Knowledge sharing				
H2a	The management of our firm often (informally) shares information / has contact with managers of competitive colleague firms	465	3.95	1.76
H2b	Other employees of our firm often (informally) share information / have contact with employees of competitive colleague firms	464	3.67	1.68
Availability of repair and maintenance facilities				
H3	The facility level of repair and maintenance firms within 2 kilometers of our firm is good	495	4.85	1.76
Accessibility by road				
H4	The road accessibility of our location is good	496	5.72	1.47
Exchange of transport capacity				
H5a	Our firm often sends along less-tan-truck-load freight with competitive colleague firms	454	2.43	1.99
H5b	Our firm often takes along less-than-truck-load freight of competitive colleague firms	305	2.39	1.91
Carrier(s)				
H6a	The transport price of our carrier(s) is much lower than the average price in the South of the Netherlands	326	3.91	1.55
H6b	Average score for flexibility of the carrier used most (Stank and Daugherty (1997); Cronbach's alpha is 0.841)	332	5.35	1.17
	- The carrier we use most is flexible in response to requests	333	5.54	1.34
	- The carrier we use most can readily adjust its operations to meet unforeseen circumstances	332	5.21	1.37
	- The carrier we use most handles change well	333	5.24	1.4
	- The carrier we use most can provide emergency services	333	5.41	1.58
Use of multimodal transport				
H7a	Transport volume from and/or to seaports in 2010	421	9.19	20.07
H7b	Transport volume from and/or to European destinations in 2010	424	22.33	33.65
Interchange of storage capacity				
H8a	Our firm makes much use of storage capacity of competitive colleague firms (among other things as temporary rent)	331	2.00	1.77
H8b	Competitive colleague firms make much use of our storage capacity (among other things as temporary rent)	330	1.92	1.57
Expansion opportunities				
H9	The possibilities to expand at our current location are good	497	3.70	2.08
Last-minute purchases				
H10a	Our firm often purchases products last-minute from competitive colleague firms to fulfil last-minute order changes of customers	205	2.03	1.55
H10b	Our firms often sells product last-minute to competitive colleague firms, such that they can fulfil last-minute order changes of their customers	203	2.13	1.57
Local congestion				
H11	During rush hour the road within a distance of 10 kilometers from our firm are very busy	496	4.37	1.85

Table 1 continued

Hypotheses and statements		N	Mean	SD
Land price / rent				
H12a	The current value of our land is high, compared to the average price in the South of the Netherlands	219	4.08	1.18
H12b	The rent we have to pay at our location is high, compared to the average rent in the South of the Netherlands	125	3.58	1.48

Note: Respondents were asked to indicate the level of agreement with the statement measured using a 7-point Likert scale, where 1 = completely disagree and 7 = completely agree. Only for H7a-H7b, respondents were asked to indicate the share of multimodal transport as percentage of the transport volume in both categories.

4 Analysis and results

4.1 Descriptive statistics

The average size (in number of full-time employees) of the respondents' establishments is 47, with a standard deviation on 118 and a median of 20. Table 2 gives an overview of the characteristics of the respondents. The median of the number of full-time employees of the respondents' establishments (20) is used to make a distinction between small and large establishments. Wholesale trade (35%) and transport as logistics service providers (26%) are the most important activities of the respondents' establishments. On average 33% of the respondents are located in logistics concentration areas. As this is 31% for all logistics establishments in the population, respondents are representative for the total population. Respondents of establishments with as most important activity transport with own equipment are significantly less located in concentration areas than respondents in general. Deleting those companies does not significantly alter the results.

Table 2: Location and size of the different types of logistics establishments

Most important activity	Total		In concentration area				Employees (FTE)			
			Yes		No		≤ 20		> 20	
	N	%	N	%	N	%	N	%	N	%
Wholesale trade	178	35%	60	34%	118	66%	89	51%	85	49%
Storage	29	6%	12	41%	17	59%	13	52%	12	48%
Transport with own equipment (shipper)	48	9%	9	19%**	39	81%	21	51%	20	49%
Transport as logistics service provider	132	26%	41	31%	91	69%	74	62%	46	38%*
Value added logistics (VAL) services	12	2%	4	33%	8	67%	4	36%	7	64%
Organization of the shipment of freight, without storage and transport	20	4%	9	45%	11	55%	11	55%	9	45%
Other services	59	12%	14	48%	15	52%	14	50%	11	50%
Total	507	100%	168	33%	339	67%	253	54%	217	46%

* Significantly smaller than the total for all respondents (last row) with $\alpha = 0.1$, ** Significantly smaller than the total for all respondents (last row) with $\alpha = 0.05$, based on normal approximations to the binomially distributed variables (Montgomery and Runger, 2003).

Note: The totals are larger than the summations of the different categories, because respondents did not fill out all questions

Figure 2 compares the size of the respondents' establishments with the location of these establishments. Based on a binomial distribution test, small establishments are significantly *less* often ($p = 0.003$) and large firms are significantly *more* often located in logistics concentration areas

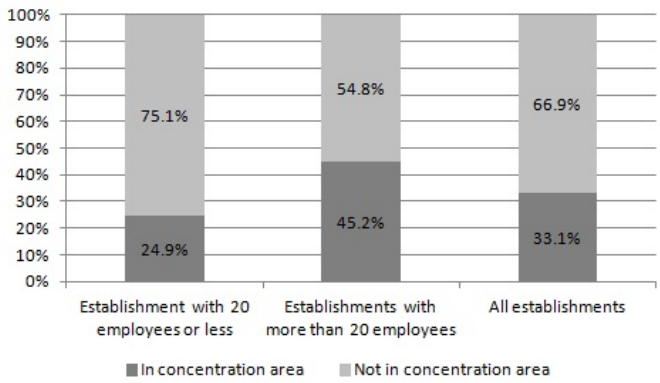

Figure 2: Size of logistics establishments in and outside concentration areas

($p \leq 0.000$) than logistics establishments in general are. This means that for the hypotheses for which co-located establishments are expected to have benefits over non-co-located establishments and for which large firm are expected to have benefits over small firms (see section 2.4), it has to be checked whether the differences between co-located and non-co-located establishments are caused by differences between small and large establishments. This holds for hypotheses H1a-H1c, H2a-H2b, H3, H6a-H6b, and H7a-H7b.

4.2 Comparison of co-located and non-co-located logistics establishments

Table 3 shows the average levels of agreement for respondents of establishments in concentration areas and respondents of establishments not in these areas. Table 4 shows the average levels of agreement for respondents of large and small establishments for the hypotheses for which this difference was considered relevant. Both tables show results to test the hypotheses presented in section 2. These tests are all based on a significance level α of 0.05. Both tables present results for all logistics establishments, and the two largest subgroups, wholesale trade establishments, and logistics service providers. Figure 3 (at the end of this section) summarizes the results.

H1a to H1c stated that co-located logistics firms experience a higher availability of operational personnel, administrative personnel, and/or truck drivers, respectively, than non-co-located logistics firms do. Table 3 shows that vacancies for operational personnel and truck divers can be filled significantly more easily in logistics concentration areas than outside these areas. For administrative personnel, there is no significant difference (with a significance level α of 0.05).

To test whether differences between co-located and non-co-located establishments are not spurious, table 4 shows the outcomes of the t-tests based on differences between small and large establishments. As vacancies for truck drivers are not more easily filled by large establishments than by small establishments, the conclusion is that co-located logistics establishments indeed can more easily fill vacancies for truck drivers than non-co-located logistics establishments can. This especially is the case for logistics services providers (LSPs), for which this type of personnel is relatively important.

Vacancies for operational personnel can be filled significantly more easily by large establishments than by small establishments. Hence, it was tested whether small (large) co-located logistics establishments can more easily fill these vacancies than small (large) non-co-located logistics establishments. Both differences are not significant. Hence, it cannot be concluded that vacancies for operational personnel can be filled more easily by co-located logistics establishments than by non-co-located logistics establishments.

To conclude, hypothesis H1c is supported, while hypotheses H1a and H2b are not supported.

H2a and H2b stated that management and non-management personnel, respectively, of co-located logistics firms more often shares knowledge with others than similar personnel of non-

Table 3: Differences in mean scores for establishments in and not in concentration areas

	All			Wholesale trade			Logistics service providers		
	Mean		p-value	Mean		p-value	Mean		p-value
	In	Not in	(one-sided)	In	Not in	(one-sided)	In	Not in	(one-sided)
Availability of labor									
H1a	4.47	4.20	0.003**	4.56	4.39	0.224	4.57	3.83	0.003**
H1b	4.45	4.28	0.099*	4.38	4.35	0.162	4.68	4.06	0.005**
H1c	4.34	4.84	0.004**	4.28	4.13	0.354†	4.43	3.44	0.001**
Knowledge sharing									
H2a	4.11	3.87	0.082*	4.05	4.08	0.466	4.41	3.62	0.017**
H2b	3.75	3.63	0.228	3.54	3.65	0.339	3.97	3.67	0.150
Availability of repair and maintenance facilities									
H3	5.13	4.70	0.004**	4.98	4.99	0.486	5.15	4.38	0.026**
Accessibility by road									
H4	6.02	5.56	0.000**	6.00	5.65	0.033**	6.03	5.24	0.004**
Exchange of transport capacity									
H5a	2.88	2.21	0.001**	1.49	4.62	0.253	4.27	3.07	0.003**
H5b	2.81	2.17	0.005**	1.59	1.48	0.351†	3.85	2.74	0.003**
Carrier(s)									
H6a	4.03	3.83	0.130	4.04	4.03	0.491	3.63	3.64	0.492†
H6b	5.42	5.31	0.217	5.37	5.35	0.471	5.17	5.16	0.489†
Use of multimodal transport									
H7a	12.17	7.82	0.033**	6.65	7.42	0.400	16.56	9.91	0.121
H7b	21.89	22.53	0.428	18.17	23.76	0.165	21.50	27.12	0.224
Interchange of storage capacity									
H8a	2.30	1.82	0.011**	2.05	1.68	0.088*	2.20	2.10	0.425†
H8b	2.01	1.87	0.216	1.37	1.52	0.187	3.40	2.05	0.011**†
Expansion opportunities									
H9	3.93	3.59	0.043**	3.69	3.73	0.447	3.31	3.19	0.382
Last-minute purchases									
H10a	2.42	1.85	0.012**	2.42	1.83	0.016**		*Not relevant*	
H10b	2.30	2.05	0.143	2.29	2.05	0.176		*Not relevant*	
Local congestion									
H11	4.31	4.40	0.301	4.45	4.33	0.327	4.23	4.51	0.234
Land price / rent									
H12a	4.17	4.03	0.211	4.30	3.96	0.111†	4.32	3.81	0.073*†
H12b	3.66	3.52	0.211	3.17	3.44	0.282†	4.00	3.29	0.055†

* Significant with $\alpha = 0.1$; ** Significant with $\alpha = 0.05$

† Sample size of at least one of the groups is smaller than 30 (see Appendix A)

Table 4: Differences in mean scores for large and small establishments for relevant hypotheses

	All			Wholesale trade			Logistics service providers		
	Mean		p-value	Mean		p-value	Mean		p-value
	Large†	Small††	(one-sided)	Large†	Small††	(one-sided)	Large‡	Small‡‡	(one-sided)
Availability of labor									
H1a	4.53	4.16	0.003**	4.53	4.34	0.197	4.45	3.85	0.006**
H1b	4.61	4.14	0.000**	4.47	4.26	0.162	4.63	3.97	0.002**
H1c	4.15	3.91	0.101	4.11	4.26	0.354	3.94	3.63	0.148
Knowledge sharing									
H2a	4.25	3.71	0.001**	4.27	3.83	0.055*	4.47	3.33	0.001**
H2b	3.97	3.47	0.001**	3.95	3.25	0.004**	4.22	3.54	0.017**
Availability of repair and maintenance facilities									
H3	4.92	4.89	0.432	4.93	5.08	0.254	5.07	4.25	0.017**
Carrier(s)									
H6a	3.93	3.93	0.496	3.99	4.08	0.358	3.58	4.18	0.168
H6b	5.32	5.40	0.293	5.31	5.40	0.323	4.99	5.61	0.082*
Use of multimodal transport									
H7a	10.05	8.62	0.239	6.37	7.94	0.293	11.37	12.51	0.400
H7b	21.61	24.25	0.219	20.40	24.26	0.240	22.35	31.85	0.088*

† More than 20 employees (based on the overall median being equal to the median of wholesale trade establishments)

†† 20 employees or less (based on the overall median being equal to the median of wholesale trade establishments)

‡ More than 13 employees (based on the median of logistics service providers)

‡‡ 13 employees or less (based on the median of logistics service providers)

* Significant with $\alpha = 0.1$; ** Significant with $\alpha = 0.05$

co-located logistics firms does. Only for LSP establishments, significant differences were found between levels of agreement of respondents of co-located establishments and respondents from non-co-located establishments with the statement that the management of the establishment often shares information with competitive colleagues (see table 3). This may be spurious, as differences between different sized establishments are also significant (see table 4). Finally, small co-located LSP establishments agree significantly more with this statement than small non-co-located LSP establishments do ($p = 0.028$); large co-located LSP establishments do not agree more with this statement than large non-co-located LSP establishments do. However, the former result has to be interpreted carefully, as the group of small co-located LSP establishments only consists of ten respondents. Hence, hypotheses H2a and H2b are not supported.

H3 stated that co-located logistics firms experience a higher availability of repair and maintenance facilities close by than non-co-located logistics firms do. Both based on the complete sample and based on the sample of LSPs, co-located establishments indeed experience a higher availability of these facilities than non-co-located establishments do (see table 3). In addition, large LSP establishments experience a higher availability of these facilities than small LSP establishments do; no significant differences between large and small establishments were found in the complete sample (see table 4). Separate tests in the groups of small LSP establishments and large LSP establishments do not show significant differences between co-located and non-co-located LSP establishments. Hence, hypothesis H3 is supported based on the complete sample, but not based on the specific sample of logistics service providers.

H4 stated that co-located logistics firms are better accessible by road than non-co-located logistics firms are. Since for all logistics establishments as well as the separate categories of wholesale trade establishments and LSP establishments, respondents from co-located establishments agreed more with this statement than respondents from non-co-located establishments (see table 3), hypothesis H4 is supported.

H5a (H5b) stated that co-located logistics firms more often send (take) along cargo with other logistics firms than non-co-located logistics firms do. With both statements used to test these hypotheses, respondents of co-located logistics establishments agreed more than respondents of non-co-located logistics establishments (see table 3). The difference in levels of agreement is even larger for LSPs, for which this hypothesis is especially relevant. Hence, hypotheses H5a and H5b are supported.

H6a stated that co-located logistics firms pay less for outsourced transportation than non-co-located logistics firms do. No significant differences were found between the price paid to carriers by co-located establishments and by non-co-located establishments (see table 3). **H6b** stated that co-located logistics firms experience more flexibility from their carrier(s) than non-co-located logistics firms do. Similarly to the price of the carrier, the flexibility of the carrier is not affected by co-location of its customers (see table 3). As it may make a difference for both hypotheses whether the carrier itself is also located in the same concentration area, it was also tested whether there was a difference between co-located and non-co-located establishments of which their carrier is located within a distance of two kilometers (59 establishments of which 22 are located in concentration areas). However, also here no significant differences were found ($p = 0.251$ and $p = 0.067$ for H6a and H6b, respectively). Hence, hypothesis H6a and H6b are not supported.

H7a and H7b stated that co-located logistics firms more often use multimodal transport to and/or from seaports and European destinations, respectively, than non-co-located logistics firms do. Table 3 shows that there is no difference between the use of multimodal transport to and/or from destinations in Europe, but co-located logistics firms do use significantly more multimodal transport to and/or from seaports than non-co-located logistics establishments do. There are no significant differences between large and small establishments on these statements (see table 4). Hence, hypothesis H7a is supported, while hypothesis H7b is not supported.

H8a (H8b) stated that co-located logistics firms use more storage capacity of others (let others use their storage capacity more) than non-co-located logistics firms do. Respondents from co-located establishments agree significantly more with the statement that they use storage capacity of competitive colleague firms than respondents from non-co-located establishments do (see table 3). This especially is true for wholesale trade establishments. For the statement that other logistics

firms make use of the respondent's storage capacity, only LSPs located in logistics concentration areas agree significantly more with this statement than LSPs located outside logistics concentration areas (although sample sizes are relatively small for these categories). Hence, hypothesis H8a is supported, while hypothesis H8b is not supported.

H9 stated that co-located logistics firms have better expansion opportunities than non-co-located logistics firms do. As the average level of agreement with this statement of logistics establishments in logistics concentration areas was significantly higher than that of logistics establishments in other areas (see table 3), hypothesis H9 is supported. As the absolute difference in average response was small, no significant differences were found for the smaller subgroups of wholesale trade establishments and LSPs.

H10a (H10b) stated that co-located logistics firms more often buy (sell) products last-minute to react to last-minute changes in customer order quantities than non-co-located logistics firms do. Both establishments for which wholesale trade is their most important activity as well as establishments for which wholesale trade is one of their activities (the category of all establishments in table 3) in logistics concentration areas buy significantly more often last-minute products with competitive colleague firms than these establishments in other areas do (see table 3). For the last-minute sales no difference was found (see table 3). This is probably due to the fact that companies do not know whether they sell products to a customer such that last-minute demand can be fulfilled compared to regular demand. Hence, hypothesis H10a is supported, while hypothesis H10b is not supported.

H11 stated that co-located logistics firms experience more road congestion in the direct surrounding than non-co-located logistics firms do. Table 3 shows that there is no difference in traffic during rush hour around concentration areas and around other areas, both based on the answers of all respondents and based on the answers of LSPs (whom concerns this most). Hence, hypothesis H11 is not supported.

H12a (H12b) stated that co-located logistics firms pay higher land prices (rent) for their location than non-co-located firms do. As no significant differences were found for these hypotheses (see table 3), these are not supported.

4.3 Additional results

4.3.1 Less-than-truckload shipments

One of the results is that logistics establishments located in logistics concentration areas relatively often exchange transport capacity. As the exchange of transport capacity is especially interesting if customer order sizes are relatively small (Cruijssen *et al.*, 2007a), it is expected that establishments with relatively small average customer order sizes locate relatively often in logistics concentration areas.

Respondents were classified in two groups, based on the percentage of the transport volume generated by the respondents' establishments that concerns less-than-truckload (LTL) shipments per delivery address. Figure 4 gives an overview of the location of establishments for which LTL shipments are 25 percent or less of their transport volume and of establishments for which LTL shipments are more than 25 percent of their transport volume. This percentage (25%) was the smallest percentage for which the created subgroups are large enough to use normal approximations. While establishments with relatively few LTL shipments locate significantly less often in logistics concentration areas than logistics establishments in general do ($p = 0.048$), establishments with relatively many LTL shipments do not locate significantly more often in logistics concentration areas than logistics establishments in general do ($p = 0.078$).

In addition, respondents with relatively many LTL shipments agreed significantly more with the statement that they often take along freight of competitive colleague firms than respondents with relatively few LTL shipments (related to H5b; $p = 0.021$). If only the group of establishments with relatively many LTL shipments is considered, the difference in the level of agreement of respondents in concentration areas and not in concentration areas is highly significant for both statements (for H5a, $p \leq 0.000$ and for H5b, $p = 0.005$). For the group of establishments with relatively few LTL

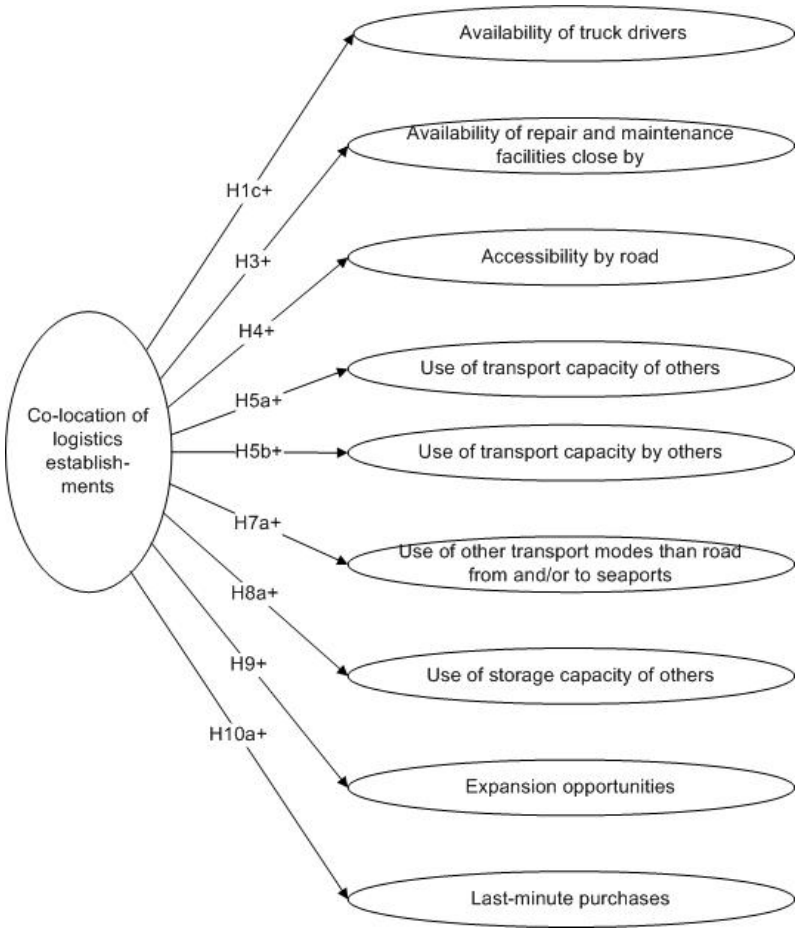

Figure 3: Graphic summary of the research findings

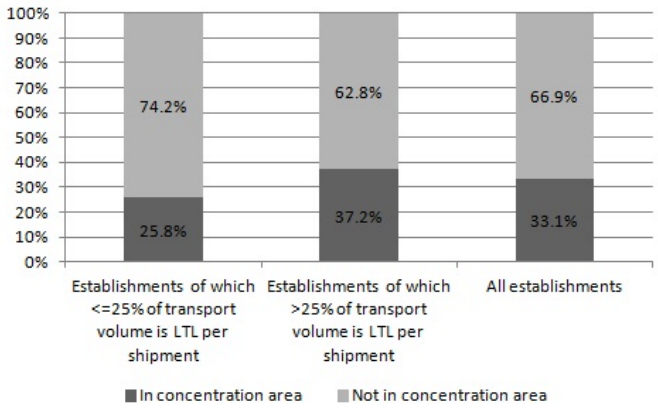

Figure 4: Location of establishments with relatively many and few less-than-truckload shipments

shipments, no significant differences were found. Hence, establishments with relatively many LTL shipments indeed have more advantage of being close to other logistics establishments as these establishments more often use the opportunity to exchange transport capacity than establishments with relatively few LTL shipments have.

4.3.2 Intermodal terminals

Co-located logistics establishments more often use multimodal transport from and to seaports than non-co-located establishments do. As the efficiency of multimodal transport heavily depends on the distance between the intermodal terminal and the logistics establishment, it is highly likely that there is a relation between the distance to a terminal and the use of multimodal transport. Figure 5 presents the average agreement levels of respondents in and not in logistics concentration areas with and without intermodal terminals.

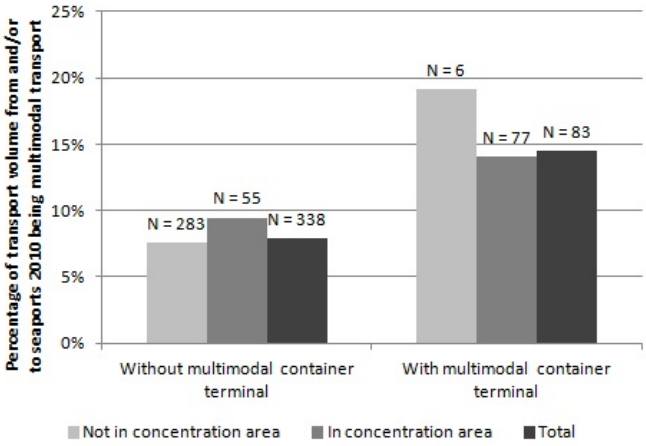

Figure 5: Percentage of transport volume from and/or to seaports being multimodal transport

The presence of an intermodal terminal in a concentration area completely explains the difference in the percentage use of multimodal transport between co-located and non-co-located establishments. The percentage of the transport volume to and/or from seaports of establishments in areas with intermodal terminals (14.46%) is significantly higher ($p = 0.014$) than the percentage of the transport volume to and/or from seaports of establishments in areas without intermodal terminals (7.89%). Whether logistics concentration areas attract intermodal terminals or whether intermodal terminals attract that logistics activities, is outside the scope of this paper.

5 Discussion and implications

The findings of this survey show that proximity matters for logistics companies. As this research is the first to empirically analyze the effects for logistics companies to be located in logistics concentration areas, it both makes contributions to literature and to practice.

5.1 Conceptual implications

This research shows that some classical agglomeration economies also hold for logistics firms and furthermore, that co-location of logistics activities results in special benefits relevant in the logistics sector. Of the three well know localization economies (Marshall, 1956), input sharing is most important for logistics companies as the availability of repair and maintenance facilities was found to be better in logistics concentration areas than in other areas. Labor market pooling turned out to be only relevant in the market of truck drivers and not in the market of administrative and

operational workers. As these last two are very general job types, these can probably be found evenly easy across areas. No support was found for the proposition that co-located logistics firms more often share knowledge with other logistics firms.

Besides classical localization economies, one specific urbanization economy, road accessibility, is relevant for logistics companies. This research empirically showed that economies of transport density (Mori and Nishikimi, 2002) are related to co-location of logistics activities. Whether it is the case that logistics companies are attracted by locations with good road accessibility or that policy makers take into account logistics concentration areas in their investment decisions is hard to say based on the cross-sectional data used in this study, but the fact is that co-located logistics companies experience a better road accessibility than non-co-located logistics companies.

An especially interesting outcome of this paper is that spatial concentration of logistics activities does not only result in commonly discussed classical agglomeration economies, but also results in *sector specific* advantages for the co-located companies. The analyses of this paper empirically show that co-location of logistics companies result in more efficient use of transport and storage capacity, as these companies more often share resources with other companies than non-co-located logistics companies do. In addition, co-located logistics companies relatively often use multimodal transport to seaports and have relatively good expansion opportunities.

A scientific implication of the relevance of agglomeration economies for logistics companies is to reconsider the basic assumption of most location decision models in supply chain literature (see e.g. Hale and Moberg, 2003; Melo *et al.*, 2009, for overviews). Most of these models assume that minimization of the sum of the distances between the own location and the locations of customers and suppliers is equivalent to the minimization of transport costs. The research presented in this paper shows that locating in a logistics concentration area brings the opportunity to combine transport flows with other logistics companies. As this decreases transport costs, especially for companies with relatively many less-than-truckload shipments, it may well be the case that this location is preferred over another one based on costs, while distances to customers and suppliers are not minimized. Hence, incorporating synergies of co-location of logistics companies in location decision models of these companies is an interesting topic for future research.

5.2 Managerial implications

In practice, many location decisions are still based on simple rules of thumb, rough estimates, or history (Porter and Rivkin, 2012). This paper allows to propose a new rule of thumb: unless there are major reasons to not to, logistics companies should locate in a logistics concentration area, as agglomeration economies can lead to increased efficiency of logistics processes.

Co-location of logistics companies results in more efficient use of transport and storage capacity, as these companies more often share resources with other companies than non-co-located logistics companies do. In a follow-up question, respondents were asked why they send shipments with competitive colleague firms close by. Almost 40% of the respondents indicated that this reduces logistics costs and another 31% indicated that this increases customer service. Hence, exchange of transport capacity can result in major benefits for logistics companies, especially those with many less-than-truckload shipments. Furthermore, it also results in environmental advantages, as a better use of transport capacity results in less freight traffic, which decreases road congestion and CO_2 emissions. This is a relevant insight for both managers from logistics companies as well as policy makers.

The study also showed that if an intermodal terminal is located close by a logistics concentration area, these concentration areas result in more use of multimodal transport, due to large transport volumes, needed for multimodal transport to be cost-efficient. Hence, while single companies may not have the transport volume to make use of multimodal transport, co-located companies have. This brings cost efficiency and greener supply chains.

Companies located in concentration areas for which storage is not their core activity (e.g. wholesale trade firms), use (extra) storage capacity of companies that do have storage as a core activity (LSPs). Hence, co-located wholesale trade firms can economize on in-house storage capacity. Furthermore, there may also be unexplored opportunities to commercialize temporary excess

storage capacity.

In addition, tradionally mentioned disadvantages of spatial concentration (Fujita and Krugman, 2004) were not found in the logistics sector. First, it was tested whether roads in the direct surroundings of the co-located companies were more congested than the roads in the direct surroundings of non-co-located companies. This was not the case; it apparently is the case that economies of transport density described above decrease this possible diseconomy. Another explanation for this is that congestion (in the Netherlands) is primarily caused by commuter traffic. Second, while a high land price (rent) was expected to be one of the major disadvantages of being located in a logistics concentration area, this was not supported by the respondents. A possible explanations would be that land prices are not only dependent on demand from the logistics sector, but are primarily related to total (industrial) demand. As non-co-located logistics companies are located in other industrial areas, land prices do not differ between these locations and locations in logistics concentration areas.

In sum, spatial proximity results in synergies for logistics establishments. This probably explains in part why managers of co-located logistics establishments are significantly more satisfied with their location than managers of non-co-located logistics establishments (this question was part of the questionnaire, but not discussed before as we only presented survey results of questions directly related to the hypotheses).

6 Conclusions and limitations

The research empirically showed that co-located logistics companies do have advantages over non-co-located logistics companies. The most important ones are general advantages, like better availability of repair and maintenance facilities and better road accessibility in logistics concentration areas, and logistics specific advantages, like the opportunities to exchange transport and storage capacity with other logistics companies and better expansion opportunities. Hence, based on the outcomes of this paper, managers of logistics companies that have to make a new location decision as well as scientists are advised to consider the benefits of co-location for logistics companies in location decision models developed for these companies. Besides advantages for logistics companies, exchange of transport capacity also results in societal benefits, as CO_2 emissions and road congestion are reduced. This is an important argument for (regional) policy makers to stimulate the development of logistics concentration areas.

Several issues related to the research conducted for this paper deserve some discussion. First, as with any business survey conducted based on questionnaires, all conclusions are based on the perception of managers of logistics companies. Although the real research theme (co-location of logistics activities) was not presented to the respondents and questionnaire statements were based on actual actions, not on options of actions, an analysis into the actual activities of the companies would have resulted in more reliable conclusions. However, as data needed for this kind of analysis are hard to collect, the survey developed for this paper is a good first step.

Second, a concern with every survey is the degree to which one can generalize the findings. The population for this survey was defined as all logistics establishments located in the South of the Netherlands. One result from this specific population is that (almost) no very large logistics establishments were included in the analyses. Furthermore, logistics concentration areas were defined on a very low spatial aggregation level. To be able to generalize the outcomes, replicating the study, on e.g. a county level in the U.S., could potentially yield relevant insights.

This paper analyzed synergies resulting from spatial concentration of logistics activities. Based on the findings, it is concluded that co-location brings advantages for logistics firms. Considering (sector specific) agglomeration economies in location decisions helps logistics managers to reduce costs and increase flexibility.

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Appendices

A Sample sizes

Table A.1 gives an overview of the number of respondents per questionnaire statement, based on the complete sample, the sample of wholesale trade establishments, and the sample of logistics service providers.

Table A.1: Sizes of the samples of establishments in and not in concentration areas

	All		Wholesale trade		LSPs	
	In	Not in	In	Not in	In	Not in
PER1	167	332	60	118	41	86
PER2	168	330	60	116	41	86
PER3	97	185	27	40	37	83
KNO1	157	308	56	103	37	85
KNO2	157	307	55	103	37	85
FAC1	164	331	58	116	39	89
ACC1	163	333	58	116	39	91
TRA1	150	304	59	115	41	89
TRA2	106	199	29	44	41	89
CAR1	123	203	54	97	24	22
CAR2	125	207	54	99	25	22
TRM1	132	289	52	114	32	79
TRM2	133	291	53	114	32	81
STO1	125	206	59	115	25	21
STO2	125	205	59	115	25	20
EXP1	164	333	58	116	39	91
PUR1	66	139	59	115		
PUR2	66	137	59	113		
COG1	164	332	58	116	39	90
LOC1	70	149	27	47	19	48
LOC2	50	75	12	32	11	14

B Definition of logistics establishments

To identify logistics establishments, the standard Dutch industry classification code, the *Standaard BedrijfsIndeling (SBI)* code (Statistics Netherlands, 2012), is used. Table B.1 presents the SBI codes used for the definition of the logistics sector in this paper (similar to Van den Heuvel *et al.*, 2012).

Table B.1 also shows that the respondents are representative for the complete population based on distribution of the different types of logistics establishments in the population and of the respondents.

Table B.1: SBI codes (2008) for the categories of logistics establishments used in this paper

Wholesale trade establishments			Percentage in population	Percentage of respondents
G	46	Wholesale trade and commission trade (except of motor vehicles and motorcycles)	50%	51%
Excl.	461	Wholesale on a fee or contract base		
	4623	Wholesale of live animals		
	4651	Wholesale in computers, computer peripheral equipment, and software		
Freight transport, storage, and other logistics establishments			Percentage in population	Percentage of respondents
H	4920	Freight transport via railways	0%	0%
H	4941	Freight transport by road (except for removal transport)	38%	36%
H	5121	Air freight transport	0%	0%
H	52101-52109	Storage and warehousing	4%	5%
H	52242	Cargo handling	1%	1%
H	52291-52292	Other supporting transport activities	8%	7%

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