DEPARTMENT OF TRANSPORT AND REGIONAL ECONOMICS

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Abstract

Due to the globalization and the fragmentation of industrial production processes, the logistics sector, which organizes the linkages between different production plants and the market, is growing fast. This results in an increasing demand for suitable new business locations. Previous research has indicated that accessibility is a key factor in the location decision making process. Though the literature on this subject is extensive, little research has been done to quantify the impact of the different dimensions of accessibility on the location decision process of logistics companies. This paper aims to fill this void in the literature by means of a revealed preference study (using a Geographic Information System (GIS) analysis) and a stated preference study (using a designed discrete choice experiment) in Flanders (Belgium). The results of the revealed preference study served as input to the design of the choice situations in the stated preference study. In this study, the respondents were confronted with a series of choice situations described by means of accessibility variables as well as land rent information. An analysis of the resulting data revealed that land rent is the most important factor in the location choice of logistics companies in Flanders. Access to a port is the one but most important factor, followed by access to a motorway and an inland navigation terminal, and the location in a business park. Finally access to a rail terminal plays no significant role in the location choice of logistics companies in Flanders.

Keywords: logistics, accessibility, transport geography, discrete choice modeling, Belgium

1 Introduction

In recent years, globalization has resulted in an increasing spatial division of production and consumption, and an ongoing fragmentation of production. This evolution has entailed a major growth in the demand for logistics, which causes an even larger fragmentation of production. One key decision in the planning process of the logistics operations is the decision where to locate these activities. This paper aims to provide new insights into the driving factors of location decision and to quantify the relative importance of the different characteristics of potential locations for logistics companies. The focal area for this paper is Flanders, which is a very densely populated area covering the northern part of Belgium. The topic is present-day, as in our survey more than 25% of the logistics companies report to have moved sites or to consider doing so in the near future. Suitable locations are, however, scarce in Flanders. This research will help the Flemish government by uncovering what attributes of logistics sites are the most important to logistics companies and which ones are less important. Logistics are also considered very important for the economy of the European Union, as demonstrated by the words of Siim Kallas (2012), Vice-President and Commissioner for Transport of the European Commission: “Freight transport and the accompanying logistics industry represent one of the most dynamic and important sectors of the European economy, accounting for at least 10% of GDP. Europe is home to several logistics companies which are world leaders. Five of the top 10 global logistics companies are European.” Similarly, the 2011 white paper on transport states that transport is fundamental to our economy and society and enables economic growth and job creation (European Commission 2011). The local importance of logistics should also not be underestimated. According to the National Bank of Belgium, logistics created 7.9% of Belgium’s GDP and 8% of domestic employment in 2005 (Lagneaux 2008). It is safe to say that a large amount of these activities takes place in Flanders due to its high density of logistics gateways, including three international seaports and one international airport.

Logistics companies act as intermediaries that connect all stages of the supply chain. The heterogeneity of logistics firms, however, makes that neither a consistent nor a standardized notion of logistics exists. On its homepage, the Council of Supply Chain Management Professionals (CSCMP 2013) uses the following comprehensive definition: “Logistics is that part of the supply chain that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point-of-origin and the point-of-consumption in order to meet customers’ requirements.” For the purpose of this study, we solely focus on logistics plants dealing with material flows of goods between separate locations and the related storage activities. The reason for this is that logistics plants engaged in these activities require large amounts of land. Logistics providers focusing mainly on services will often find their pick in standard real estate such as office blocks.

Before 2009, eight years of consecutive growth of the take-up of logistics real estate were recorded in Flanders (Jones Lang LaSalle 2010). The sector was hit hard by the global financial crisis in 2009, but the market picked up again in 2011, which was a real bull year for logistics property in Flanders with an important increase of surface occupied by logistics real estate (Jones Lang LaSalle 2010, 2012a, 2012b). Growth declined again in the first half of 2012, but picked up in the second half of the year (Jones Lang LaSalle 2012b, 2013). Despite the general economic climate, the logistics real estate market appears to remain an important factor of growth.

Many global leading logistics groups have a presence in Belgium. Flanders in particular seems to be an attraction pole because of its seaports and its important links to the European hinterland. Within Flanders, the Antwerp region is by far the most important location for logistics activities. Further, the axis between Antwerp and Brussels is also a preferred location for many logistics companies. The Flemish authorities acknowledge the leading position of Flanders in logistics in Europe and the importance of logistics for the economy as a whole. The Flemish government has therefore instigated a process to make Flanders one of the main smart hubs of Europe in terms of sustainable logistics by 2020 (Vlaanderen in Actie, s.d.). This endeavor inspired us to study the location choice decisions of logistics companies. The case study of Flanders may be useful for the other regions that are interested in raising the number of logistics locations.

The location choice decision is a function of the locations' many different characteristics, such as the proximity to ports, highways and railroads, and the cost. A method suitable to quantify the importance of each of these dimensions and to acquire insight into the trade-offs made between the different dimensions is the stated preference method, also known as the discrete choice method (Hensher et al. 2005). Instead of asking respondents directly which attribute they find most important, the discrete choice method combines several attributes in one location profile in order to create a more realistic context. As in Bolis & Maggi (2003), one of the key outputs of the stated preference study we present in this paper is the Willingness to Pay for certain characteristics of a location. The use of stated preference studies is common in transportation (modal choice) and marketing, and increasingly so in health economics and environmental economics. In the choice of locations for logistics businesses, however, the use of stated preference studies is rather uncommon. When conducting a stated preference study, two important challenges are (i) to decide on the attributes of the choice alternatives and the levels of these attributes, and (ii) to determine the exact choice tasks to be performed by the respondents. To determine the attributes and the attribute levels in our study, we built on revealed preferences of logistics companies. To decide on the exact choice tasks, we utilized the optimal experimental design approach advocated by Bliemer & Rose (2010) and Kessels et al. (2009, 2011b-c).

The remainder of this paper is organized as follows. In Section 2, we provide a detailed review of the literature on logistics companies, location, accessibility and discrete choice research. In Section 3, we discuss the stated choice approach in detail. We pay attention to the choice model as well as to the design of the questionnaire and the computation of the Willingness to Pay. A major step in the design of the study was a preparatory GIS exercise to identify the actual accessibility characteristics of existing logistics sites in Flanders. In Section 4, we discuss the results of our stated choice exercise. Finally, in Section 5, we come to a conclusion and articulate some policy recommendations.

2 Literature review

This literature review is built around the four themes that are central to this paper, namely logistics companies/firms/plants, location choice/decision, accessibility and discrete choice/stated choice. While there is an extensive literature on each of these four subjects, few existing studies have combined these four themes.

Good starting points for a study on the location decisions of logistics companies are Rodrigue et al. (2006) and Dicken (2007). Rodrigue et al. (2006) discuss the geography of transport systems in general, and commodity chains and logistics in particular. Dicken (2007) discusses the location of economic activities in general, and the geography of logistics and distribution industries in particular. In neither Rodrigue et al. (2006) nor Dicken (2007), the location of logistics companies is the central focus. According to Hall et al. (2006), there is a need for more empirical research on this topic.

The role of accessibility in the location decisions of companies in general has received substantial attention in the literature. While the early studies all involve revealed preference data, more recent work is based on stated preference data. For instance, Button et al. (1995) used questionnaires which required respondents to rate the importance of several potentially important accessibility factors. Road linkages turned out to be the most important location factor, followed by rental costs. Hayashi et al. (1986) applied an early discrete choice model to study the impact of accessibility (defined here as the distance in kilometer to the nearest motorway junction), and transport and land use policies on location preference of industrial companies in Japan. Accessibility came out as the most important factor in the location decision process of industrial companies. Only the focus on logistics companies is lacking. Hayashi et al. (1986) did not include different levels of the attributes in their stated preference study. The use of attributes with multiple levels in stated preference studies gained popularity after Hensher et al. (1988) pointed out the usefulness of stated preference methods in transportation research after many years of almost exclusively using revealed preference methods. Leitham et al. (2000) also applied a discrete choice model for the location choice of industrial organizations (12% of respondents, or five companies, are specialized in distribution) in the Strathclyde region in Scotland. They found that motorway accessibility and property costs are prime location factors for UK sourced branch sites, while they are unimportant for overseas sourced branch sites. The latter consider workforce and the quality of industrial premises to be of higher importance. Some local firms find road links to be relatively important while others rate them as unimportant. The number of distribution sites in the survey is small and it is therefore difficult to generalize these findings. We have to jump in time to Willigers & van Wee (2011) to find a recent stated preference study on accessibility and location of companies. The study is, however, limited in scope because only rail accessibility of different types of firms is taken into account.

Other work related to the geography of logistics companies was performed by Hesse & Rodrigue (2004), who provided an overview of the emerging transport geography of logistics and freight distribution. They stressed that logistics activities increasingly involve networks of suppliers and subcontractors, so that the geography of the flows, nodes and networks is crucial. Strategic locations are characterized by particular connections to major gateways and hubs, mainly large ports, major airports and motorway intersections with access to a market area. Land constraints and congested traffic arterials limit the expansion of traditional hubs and provide opportunities for the development of inland hubs. Hesse & Rodrigue (2004) also argued that corporate decision makers have to assess advantages and disadvantages of different locations carefully. Hesse (2004) paid special attention to logistics real estate markets and the actors involved, and noted a growing locational competition which resulted in additional land consumption and further dispersal. The importance of land rent in the location decision in the state of New Jersey (USA) is discussed by Holguín-Veras et al. (2005) and Ozmen-Ertekin et al. (2007). Similarly, Nguyen & Sano (2010) found that land rents had significant negative effects on a firm's location decision. Bowen (2008) discussed the changing geography of warehousing in the US due to a more time-sensitive economy, and observed a strong correlation between the growth in the number of warehouses and county-level measures to improve accessibility by air and highway and to a lesser extent by rail networks. O’Connor (2010) analyzed the share of logistics activities in a series of global city regions where the logistics operations compete for land use and mobility. He concluded that infrastructure appears to be a necessary, but not a sufficient explanatory factor of the performance and concentration of freight activity in the global logistics regions. This is in line with Rodrigue & Hesse’s (2007) observations that it is not only the provision of basic infrastructure that drives location decision, but also the capability of regions and cities to allow for flexible and cost efficient physical distribution.

In order to identify the impact of transport on the location decisions of logistics firms in Asia, Hong (2007a-b) used a two-step approach in which logistics firms first had to indicate the city for their preferred location, after which the transport profile for this city was created. Seaports turned out to be the most desirable locations, followed by areas with high rail and road densities. Hong & Chin (2007) also found that seaports and rail and road densities are extremely important in attracting foreign direct investments (FDIs) in China's logistics sector. Similarly, Lu & Yang (2006) emphasized the importance of major seaports when it comes to attracting large logistics firms, not only because they serve as transportation hubs, but also because of the integrated services provided. Recent research by Kim et al. (2010) focused specifically on the location factors important for domestic Korean shipping companies. The relation between location and accessibility was examined using the average travel time between plants and shipping areas as a measure of accessibility. Not surprisingly, Korean domestic shippers prefer locations as near to a shipping area as possible.

Although the study of Kim et al. (2010) utilized revealed preference data, the authors stressed the potential added value of stated preference methods to develop more profound and more accurate policy recommendations. Similarly, Leitham et al. (2000) argued that stated preference methods provide the most realistic simulations of the location choice in terms of accessibility. This, as well as the conclusions of Hesse & Rodrigue (2004) and Hall et al. (2006) that more empirical studies of the driving factors of location decisions of logistics companies are needed, inspired us to carry out a stated preference study to quantify the importance of different attributes of possible locations and to study the trade-offs between different levels of these attributes.

In our study, we focused on Flanders, the northern part of Belgium situated just south of the Netherlands. Flanders is a major logistics hub and an area that was included in the study of O'Connor (2010) in the multiple sea and airports category. In Flanders, there has been a substantial amount of locally disseminated qualitative research based on classic interviews or surveys within companies aimed at identifying the factors that drive the location decisions of logistics companies (Bus et al. 1999; Idea Consult 2001; Reijs et al. 2001; IBM 2004; BCI et al. 2007, 2008; Cabus 2008). According to these studies, the most important factors appear to be accessibility, infrastructure, the availability and cost of land, and labor and market proximity. By far the most important factor is accessibility by road. The increasing importance of multimodal accessibility is often offset by cost, especially for smaller logistics companies. Trade-offs need to be made between the availability of multimodal transport infrastructure and the cost of the location. With this article, we follow up on the qualitative research performed concerning the Flemish logistics sector, and quantify the trade-offs made by key players in their location decision. At the same time, we fill the void in the international literature identified by Hesse & Rodrigue (2004), Hall et al. (2006) and Kim et al. (2010). Our stated preference approach allows us to quantify the importance of accessibility characteristics and the Willingness to Pay for different location types by logistics companies.

3 Setup of the stated choice experiment

We used a stated choice experiment to quantify the trade-offs managers of logistics companies make in choosing between alternative site locations. In our stated choice experiment, we presented respondents with several choice situations involving two alternative site locations. In each choice situation, respondents had to indicate the alternative they preferred. The alternative site locations in a choice situation are described by levels of various attributes. We chose the attributes and attribute levels to be as realistic as possible. In this section, we describe the setup of our stated choice experiment. First, we list the attributes used and present the revealed preference study to identify appropriate levels for the attributes in our stated choice experiment. Next, we explain the experimental design of the study, the complete questionnaire presented and the selection of the respondents. Finally, we describe the model we used to analyze the data and the estimation of the Willingness to Pay (WTP).

3.1 Attributes

In our stated choice experiment, we included four accessibility attributes: 'road access', 'rail access', 'inland navigation access' and 'port access'. In addition, we included 'land rent' as a cost attribute, which is one of the prime location factors in classical location theories (see, e.g., Alonso (1960, 1964), Muth (1969), Mills (1972), Solow (1972) and Beckman (1973) on urban land rent theory, and Fujita & Ogawa (1982), Fujita (1989) and Krugman & Elizondo (1996) on new economic geography). Holguín-Veras et al. (2005), Ozmen-Ertekin et al. (2007) and Nguyen & Sano (2010) provide empirical evidence that land rent drives the location decision of (logistics) businesses. We selected the levels of these five attributes very carefully based on a revealed preference study (see Section 3.2), so as to ensure that the results of our experiment have a high reliability and validity (Earnhart 2001). A sixth attribute we included in our experiment is a 2-level attribute indicating whether or not a site location is in a business park. This is because the Flemish government expressed a desire to evaluate this policy instrument. Business parks are areas designated to commercial real estate with a wide array of different amenities, mainly for the manufacturing industry. Business parks dedicated to logistics are located close to hubs and the manufacturing industry and are characterized by a good accessibility. These parks are usually separated from residential areas, so as to limit the nuisance of industry, to decrease the pressure on land rent and to facilitate entrepreneurship.

In the stated choice experiment, the respondents were forced to make trade-offs between the six attributes. This allows us to identify the attributes that matter most in the location decision process of logistics companies. Moreover, because we included a cost attribute in the experiment, respondents were forced to weigh cost against the other attributes, enabling us to calculate logistics managers' Willingness to Pay (WTP) for an improvement in site location.

3.2 Selection of attribute levels using a revealed preference study

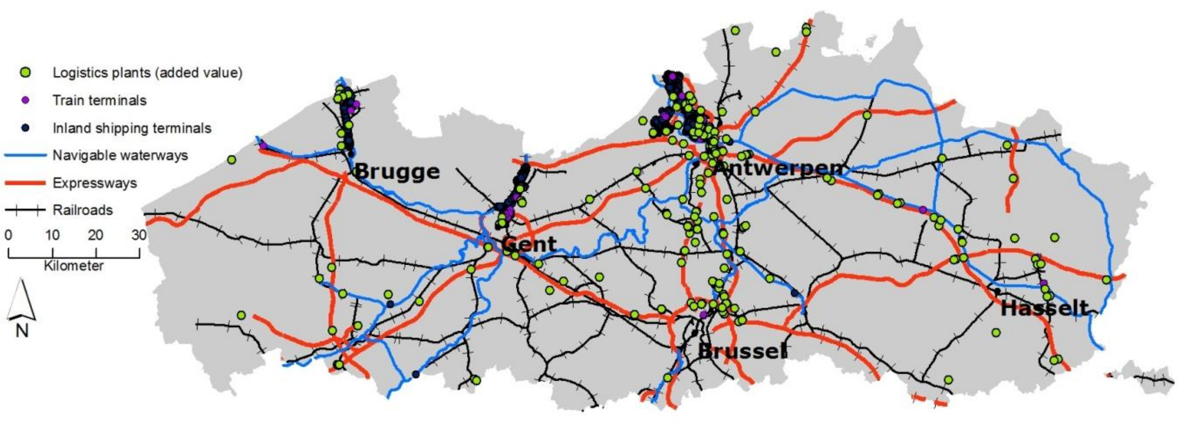
To present respondents with realistic alternative site locations in the stated choice experiment, we performed a revealed preference study to select appropriate levels for the four accessibility attributes 'road', 'rail', 'inland navigation' and 'port', and the attribute 'land rent'. We selected the levels of the accessibility attributes using a GIS (Geographic Information System) analysis that returned actual distances from Flemish logistics sites to motorway junctions, rail and inland navigation terminals and ports. We selected the levels of the attribute 'land rent' by consulting the literature on Flemish real estate for logistics companies.

Using the actual distances from Flemish logistics sites to various transport infrastructures is a very simple measure for accessibility. Throughout the last decade, many researchers (see, e.g., Geurs & van Wee (2004), Lim & Thill (2008) and Thill & Lim (2010)) have developed better accessibility measures. We preferred, however, levels of accessibility that respondents in a stated choice experiment can easily understand and interpret. Many authors, including Birkin et al. (2002), Janssen & Uran (2003), Uran & Janssen (2003), Geurs & van Wee (2004), Vonk et al. (2005) and te Brömmelstroet (2010, 2012) follow the same reasoning and argue that easily understandable measures of accessibility or land use in surveys have a positive impact on understanding, interpretation and communicability.

For the GIS analysis of the revealed preference data, we used the top 200 logistics companies in Flanders in terms of added value, as identified by the National Bank of Belgium. This may seem only a small portion of the almost 11,000 logistics companies active in Flanders, but the vast majority of these companies are (very) small SMEs, including independent truckers (Lagneaux 2008). Hence, by selecting the top 200 logistics companies, only firms with considerable land use and accessibility needs were included. This small number of companies seem to have a substantial influence on the take-up of logistics space (Jones Lang LaSalle 2012b). From the selected companies, we considered only the sites that generate commodity flows, i.e. sites that deliver services such as freight rail transport, freight road transport, freight transport by sea and coastal waters, freight transport on inland waterways, courier services (excluding the national postal services) and storage. This resulted in a representative sample of 235 large logistics sites (one firm may have different sites). Included in the sample are sites of leading international logistics providers such as FedEx, UPS, Caterpillar, Cargill, Vanguard, Brink's, NYK, P&O, MSC, Kuhne+Nagel, Dentressangle, Salvesen, TNT, DHL, PSA and Katoennatie.

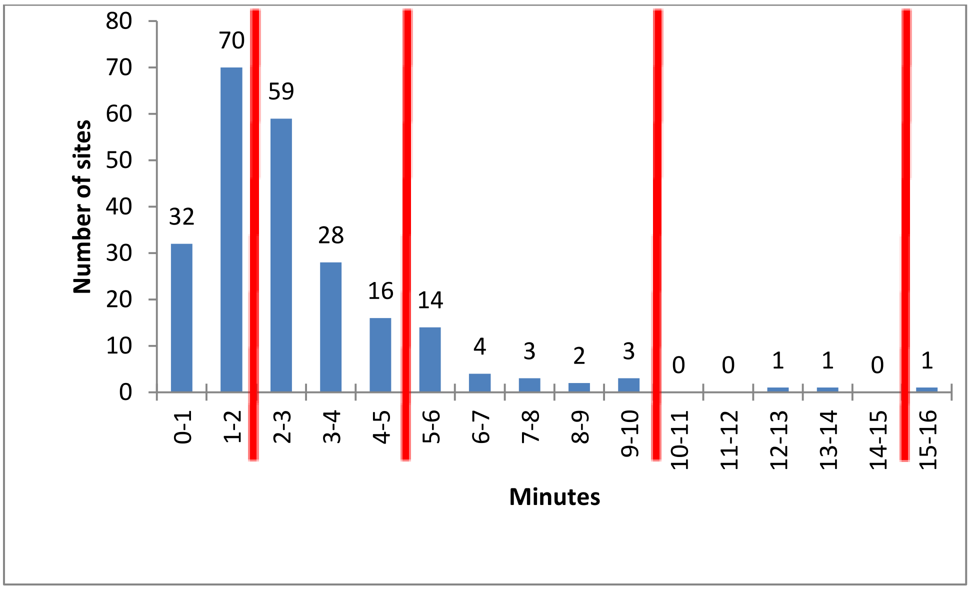
Thomas et al. (2003) showed that there are no major differences between topological accessibility in Belgium expressed in terms of transportation costs and in terms of distances. We therefore started the GIS analysis by geocoding the 235 sites in ArcGIS 10 and calculated driving distances to the transport infrastructures via the shortest route method using the spatial analyst extension. AGIV, the GIS institute of the Flemish government, provided the road maps, including motorway junctions for the network analysis, as well as the shape files of railroads and navigable waterways. We compiled information on rail and inland navigation terminals (including trimodal terminals, i.e. terminals that are suitable for road, rail and inland navigation transport) from freely available data from organizations such as NMBS/SNCB (Belgian national railway operator) and Promotie Binnenvaart (Promotion Inland Shipping). The locations of the selected sites and the different transport infrastructures under study are shown in Map 1.

Map 1: Site locations of the top 200 logistics companies in Flanders and available transport infrastructures.



First, as a measure for 'road accessibility', we calculated the distances between the 235 logistics sites and the nearest motorway junctions in time units (minutes). The average distance to the nearest motorway junction for the 235 logistics sites is 2.7 minutes. Figure 1 shows the distribution of the distances in time for the 235 sites to the nearest motorway junction. The distribution reflects the high density of the Flemish motorway network (Thomas & Verhetsel 1999). The majority of the sites are located within six minutes of a motorway junction. The bold vertical lines in the figure indicate the four levels we selected for the attribute 'road accessibility': 2, 5, 10 and 15 minutes. We selected these four levels because they cover the entire range of distances well.

Figure 1: Distances in minutes to a motorway junction of 235 main logistics sites in Flanders.



Second, as a measure for 'rail accessibility', we calculated the distances in kilometer between the 235 logistics sites and the nearest rail (or trimodal) terminal on the basis of the road network. On average, the 235 sites are located at 8.6 kilometer from a rail connection where they have the ability to load and unload goods. Figure 2 shows the distribution of the distances in kilometer to the nearest terminal. Most sites are located within 10 kilometer of a rail (or trimodal) terminal. This is relatively close, but it does not necessarily imply that the companies take advantage of this proximity. The bold vertical lines in the figure define the four selected levels for the attribute 'rail accessibility': 0, 5, 15 and 30 kilometer. The first level of 0 kilometer means that the site itself has a rail (or trimodal) terminal and hence does not need other transport modes to reach it.

Third, we defined 'inland navigation accessibility' as the distance in kilometer between an inland navigation (or trimodal) terminal and a logistics site. On average, the 235 logistics sites are located at 7.4 kilometer from an inland navigation terminal. Figure 3 shows the distribution of the distances in kilometer to the nearest terminal. This distribution is quite similar to the one in Figure 2 for rail accessibility. Therefore, we selected the same levels for the attribute 'inland navigation accessibility' as for the attribute 'rail accessibility', i.e. 0, 5, 15 and 30 kilometer.

Figure 2: Distances in kilometer to a rail (or trimodal) terminal of 235 main logistics sites in Flanders.

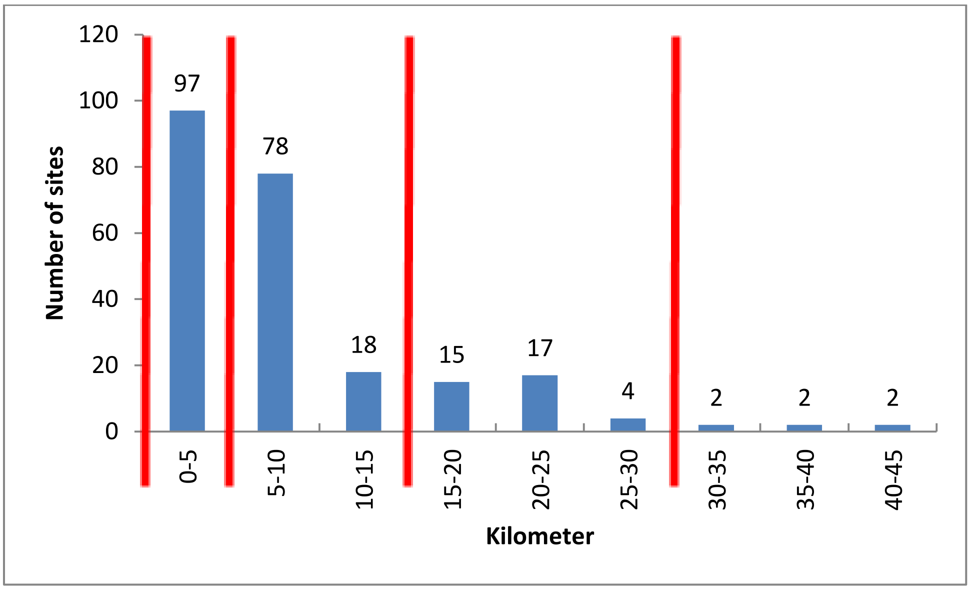
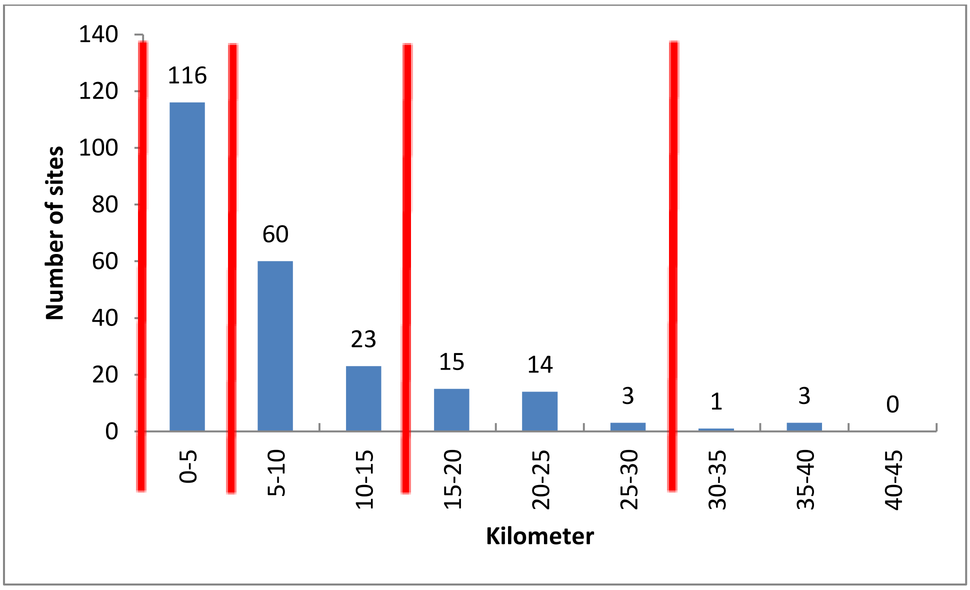
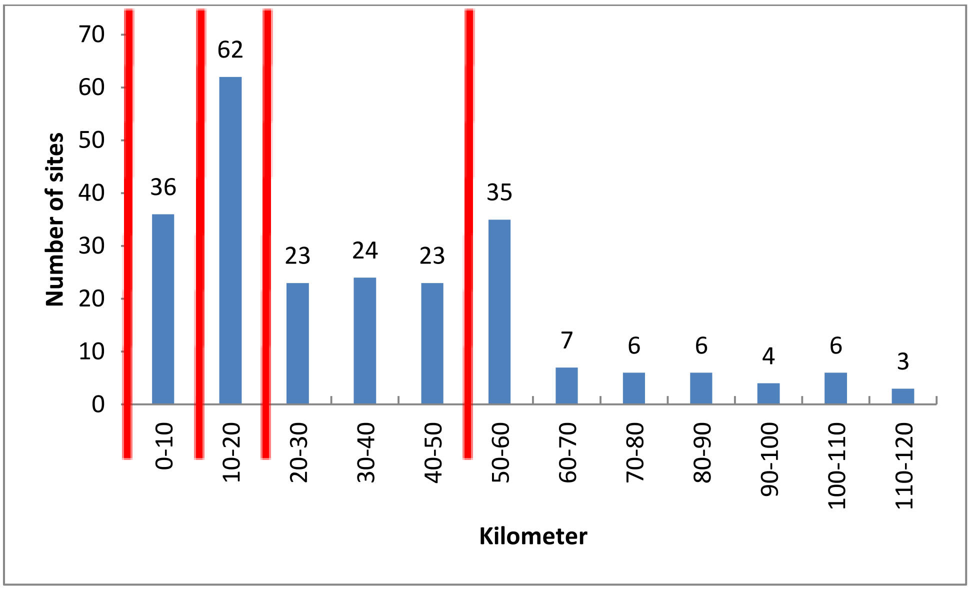


Figure 3: Distances in kilometer to an inland navigation (or trimodal) terminal of 235 main logistics sites in Flanders.



Fourth, as a measure for 'port accessibility', we calculated the distance to a seaport as the distance in kilometer of a logistics site to a central point in the nearest Flemish seaport. This analysis took into account the ports of Antwerpen (Antwerp), Gent (Ghent) and Zeebrugge (port of Bruges). Because the distances of the 235 sites are calculated to only these three points, the average distance of 34.6 kilometer to a port is substantially higher than the average distances to any of the other transport infrastructures. As a result, Figure 4, which contains the distribution of the distances in kilometer to a port, shows a different pattern than Figures 1, 2 and 3. To cover the range of distances to a seaport of most of the logistics sites, we selected the levels 0, 10, 20 and 50 kilometer for the attribute 'port accessibility'.

Figure 4: Distances in kilometer to a port of 235 main logistics sites in Flanders.



Finally, as a last step in our revealed preference study, we identified five suitable levels for the attribute 'land rent'. Little information is available from scientific or administrative sources. We therefore had to rely on publications of the main players in the Flemish real estate market for logistics companies. The land rent estimates of these companies are quite similar. According to CBRE (2007), land rents for logistics companies on the Antwerp-Brussels axis ranged from 34 up to 48 EUR/m²/year, while land rents of 38 up to 43 EUR/m²/year were observed in other areas with an expanding logistics sector. Cushman & Wakefield (2010, 2011a) estimated that land rent for logistics real estate in 2010 and 2011 would average to 46 EUR/m²/year in Brussels, to 42 EUR/m²/year in Antwerp, to 36 EUR/m²/year in Ghent, and to 35 EUR/m²/year in the Hasselt-Genk region. According to Jones Lang LaSalle (2010), land rents for logistics real estate in 2010 ranged from 43 to 60 EUR/m²/year on the Antwerp-Brussels axis, and from 40 to 45 EUR/m²/year on the Antwerp-Ghent and Antwerp-Hasselt-Genk axes. In 2012 land rents evolved from 48 to 55 EUR/m²/year on the Antwerp-Brussels axis, from 42 up to 46 EUR/m²/year on the Antwerp-Ghent axis and from 40 up to 45 EUR/m²/year on the Antwerp-Hasselt-Genk axis (Jones Lang LaSalle 2012b). These land rents for logistics real estate are very low compared to those of neighboring countries (see Cushman & Wakefield (2011b, 2011c, 2011d) and Jones Lang LaSalle (2010)). The land rent deviations between the different axes seem to be realistic and reflect the differences in accessibility between them (Thomas et al. 2003). To cover a wide range of possible land rents, we selected 10 EUR/m²/year, 35 EUR/m²/year, 50 EUR/m²/year, 65 EUR/m²/year and 90 EUR/m²/year as the levels for the attribute 'land rent' in the stated choice experiment. The highest level, 90 EUR/m²/year, then represents the high land rents in the top logistics regions in the neighboring countries (e.g. Amsterdam, Frankfurt, Munich, Paris and London). The one but highest level, 65 EUR/m²/year, represents the land rent for the best logistics real estate possible in Belgium, 50 EUR/m²/year is the average land rent for very good logistics locations, 35 EUR/m²/year is the lowest observed land rent in the core logistics areas of Flanders, and 10 EUR/m²/year would be the land rent for an area which is very unattractive to logistics providers.

The revealed preference study resulted in the selection of four levels for the four accessibility attributes and five levels for the attribute 'land rent'. Table 1 provides an overview of the six attributes in our study, including the attribute 'business park', and their levels.

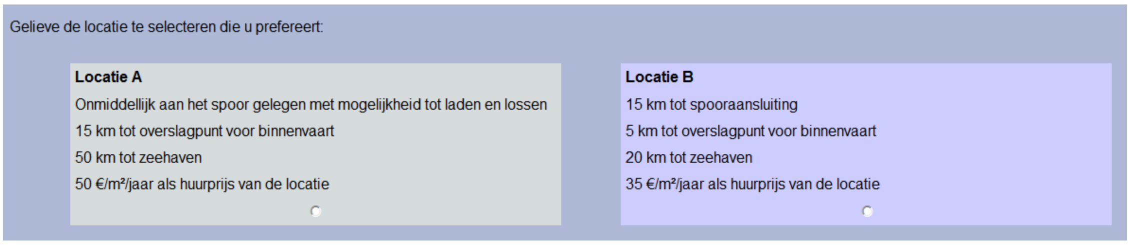
Table 1: The six attributes and their levels in the stated choice experiment.

Attribute	Level 1	Level 2	Level 3	Level 4	Level 5
Road	2 min	5 min	10 min	15 min	
Rail	0 km	5 km	15 km	30 km	
Inland navigation	0 km	5 km	15 km	30 km	
Port	0 km	10 km	20 km	50 km	
Land rent	10 EUR	35 EUR	50 EUR	65 EUR	90 EUR
Business park	Yes	No			

3.2 Experimental design

Our stated choice experiment presented each respondent with 20 choice situations involving two alternative site locations, called profiles. For each choice situation, respondents were asked to indicate the profile they preferred. The alternative site locations or profiles are combinations of levels of the attributes in Table 1. However, to limit the cognitive burden imposed on the respondents, we included only four of the six attributes in each choice situation. The resulting profiles are called partial profiles (Green 1974; Kessels et al. 2011a, 2012). Figure 5 shows an example of a choice situation where respondents had to choose between two site locations A and B, described by four of the six attributes.

Figure 5: Screenshot of a choice set used in the stated choice experiment.



Example of a choice situation involving one alternative (Locatie A) which has immediate access to a rail terminal, is located at 15 km from an inland navigation terminal and at 50 km from a sea port, and has an annual cost of 50 EUR/m^2/year and another alternative (Locatie B) located at 15 km from a rail terminal, at 5 km from an inland navigation terminal and at 20 km from a sea port, and has an annual cost of 35 EUR/m^2/year.

To maximize the information content of the stated choice experiment, we created two different surveys by constructing a partial profile design involving 40 choice situations and dividing it into two sets of 20 choice situations. Appendix A shows the two surveys. We ensured that each survey was filled out an equal number of times. As pointed out by Sándor & Wedel (2005), using 40 instead of 20 different choice situations results in a larger amount of information on the respondents' preferences and therefore in more precise estimates of the relative importances of the attributes and attribute levels as well as better estimates of the Willingness to Pay. Each choice situation of the partial profile design in Appendix A varies the levels of four of the six attributes. These varying attributes differ from choice situation to choice situation. We determined the varying attributes in every choice situation using the variance-balance partial profile design approach developed for attributes with differing numbers of levels (Kessels et al. 2012). The variance balance approach yields more informative designs for stated choice experiments than the classical attribute balance method that varies all attributes an equal number of times (Green 1974; Kessels et al. 2011a). Each of the two surveys varies the 2-level attribute ‘business park’ in eight choice situations, each of the 4-level accessibility attributes in 14 choice situations and the 5-level attribute ‘land rent’ in 16 choice situations. An immediate advantage of the partial profile design in Appendix A is that the respondents never have to make complicated trade-offs between six different attributes. Instead, they have to consider four different attributes in every choice situation. This limits the cognitive burden and reduces respondent fatigue toward the end of the experiment as well the likelihood that respondents will resort to undesirable choice behavior. As a matter of fact, a concern of stated choice experimenters is that respondents will focus on the levels of just one attribute whenever the choice situations they face are cognitively too demanding. The use of partial profiles prevents this from happening.

The variance balance approach of Kessels et al. (2012) builds on the rich literature on Bayesian D-optimal or D-efficient stated choice designs, which are increasingly considered the state of the art (Rose & Bliemer 2009; Bliemer & Rose 2010; Kessels et al. 2011b-c, 2012). A key feature of the Bayesian D-optimal partial profile designs is that they take into account prior knowledge concerning the respondents’ preferences. The usefulness of prior information when setting up stated choice experiments was first recognized by Huber & Zwerina (1996). For our experiment, we know that respondents prefer low land rents over high ones, and prefer to be closer to the motorway, a rail or an inland navigation terminal and a sea port. Additionally, we took into account expert information which led us to believe that the four accessibility attributes are potentially equally important to the population of logistics companies, and that the attribute land rent would most likely turn out to be the most important attribute. For the 2-level attribute business park, however, we did not obtain any prior information about respondents’ preferences. In a technical Appendix B, we explain how we cast all available prior information as well as the uncertainty regarding that information in a prior distribution. The design optimized over that distribution is called a Bayesian D-optimal design, where the adjective ‘Bayesian’ is statistical jargon which signifies that prior information is taken into account when designing the stated choice experiment. The adjective ‘optimal’ is used because the alternatives or profiles appearing in the choice situations are selected so that, roughly speaking, the statistical model and quantities such as Willingness to Pay can be estimated which maximum precision. One major benefit of Bayesian D-optimal designs for stated choice experiments is that, using a proper prior distribution, they do not involve choice situations in which one profile is dominating the other profile(s) on every attribute (Crabbe & Vandebroek 2012).

For each respondent, the final questionnaire consisted of two parts. The first part contained general questions on the characteristics of the logistics plants, such as turnover, removals, logistics services offered on site, annually transported tonnage by mode and land rent. The first part of the questionnaire was identical for each respondent. The second part of the questionnaire contained the actual stated choice experiment, comprising one of the two different surveys we created (see Appendix A). We distributed the two versions of the questionnaire online using Sawtooth's survey software SSI Web, version 8.1 (Sawtooth Software, Orem, UT, USA). The questionnaire language was Dutch. Respondents to the questionnaire were managers from logistics plants involved in location decisions. To obtain reliable results, our goal was to collect data from at least 100 managers. Initially, we only recruited respondents from the 235 sites studied in the GIS exercise, but because this was not sufficient to reach the desired number of 100 respondents, we eventually also contacted other, smaller logistics firms.

3.3 Statistical model

We used the multinomial logit (MNL) model to analyze the data from our stated choice experiment. The model employs random utility theory which describes the utility a respondent attaches to alternative j (j = 1, 2) in choice situation s (s = 1, …, 20) as the sum of a systematic and a stochastic component (Hensher et al. 2005):

$$U_{js} = \mathbf{x}'_{js}\boldsymbol{\beta} + \varepsilon_{js}.$$

In the systematic component $\mathbf{x}'_{js}\boldsymbol{\beta}$, $\mathbf{x}_{js}$ is a k x 1 vector containing the coded attribute levels of alternative j in choice situation s. In our analysis, we initially assumed that all six attributes are categorical, so that our initial model involved k = 17 parameters and $\mathbf{x}_{js}$ and $\boldsymbol{\beta}$ are 17 x 1 vectors. The vector $\boldsymbol{\beta}$ is the vector of parameter values indicating the importance of the different attribute levels to the respondents. The stochastic component ε_{js} is the error term capturing the unobserved sources of utility. Under the assumption that the error terms are independently and identically Gumbel distributed, the MNL probability that a respondent chooses alternative j in choice situation s is

$$p_{js} = \frac{\exp\left(\mathbf{x}'_{js}\boldsymbol{\beta}\right)}{\exp\left(\mathbf{x}'_{1s}\boldsymbol{\beta}\right) + \exp\left(\mathbf{x}'_{2s}\boldsymbol{\beta}\right)}.$$

To estimate the parameter vector $\boldsymbol{\beta}$, we used a maximum likelihood estimation approach which maximizes the probability of obtaining the responses from the selected data sample (Hensher et al. 2005). We computed the overall significance and the relative importance of the six attributes by means of likelihood ratio (LR) tests and present the marginal utility values of the attribute levels. Because we used effects-type coding for the attribute levels, the marginal utility values for all but the last level of each attribute correspond to the elements of the vector $\boldsymbol{\beta}$, while the marginal utility for the last level of each attribute is computed as minus the sum of all other marginal utilities for that attribute. Absolute values of the marginal and total utility values have no direct interpretation, since, in choice models, only differences in utility values matter. A positive marginal utility value has a positive effect on the total utility, whereas a negative marginal utility value has a negative impact.

An interesting feature of stated choice analysis is the possibility to calculate the Willingness to Pay (WTP) for an improvement with respect to one or more attributes (Hensher et al. 2005). For our study, this involves calculating how much managers of logistics plants are willing to pay for an improvement in site location. The condition for being able to calculate a WTP value is that at least one attribute is expressed in a monetary unit and modeled using linear coding. In our stated choice model, the attribute 'land rent' is expressed in EUR/m²/year. In our initial analysis, we used effects-type coding, a commonly used nonlinear kind of coding, for the land rent attribute, but, by means of a LR test, we investigated whether this type of coding provides added value when compared to the simpler linear coding.

We carried out the entire data analysis using the Choice Modeling platform in the statistical software package JMP, version 10 (SAS Institute, Cary, NC, USA).

4 Results

We first describe the general characteristics of the logistics sites whose managers participated in the stated choice experiment. Next, we present the results of the MNL model estimation and the corresponding WTP estimates.

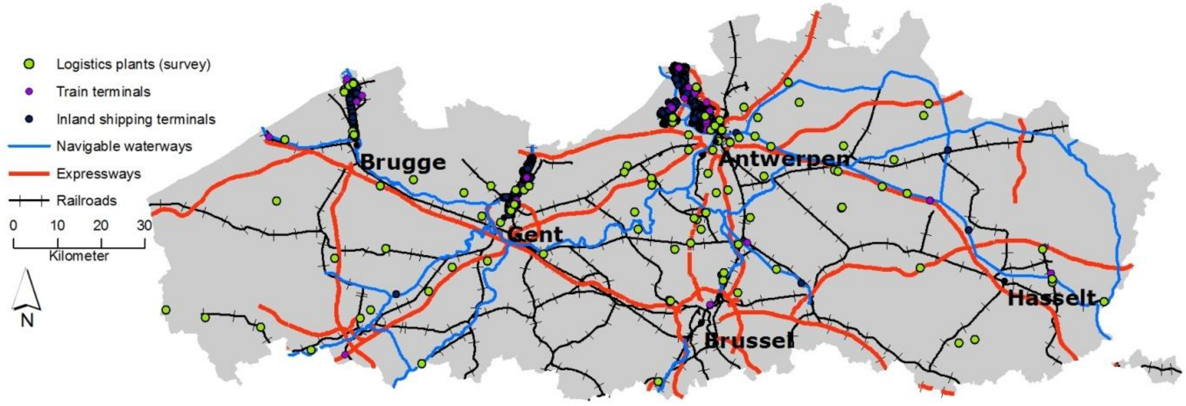
4.1 Respondent characteristics

The first part of the online questionnaire was intended to collect information concerning the 100 respondents. This includes information on the surface area of the sites where the respondents are employed, address information of the sites, transport activities offered on site, the way goods are actually transported, and whether the company has moved sites in the past five years or is considering doing so in the near future.

The average surface area of the sites is 15,000 m², the median is 5,000 m², and the largest site covers 340,000 m². In terms of added value, the respondents show a good spread of large-, medium- and small-sized companies. Concerning the actual transport modes offered (which do not only include road and rail transport, inland navigation, and transport over sea, but also air transport), 56 respondents indicated they are only occupied with road transport. A total of 25 respondents use at least two transport modes, one of which may be road, and 19 of them offer at least three transport modes. In addition, 39 plants specialize in palletized goods, while 16 exclusively deal with containers and 14 transport both. The remaining 31 sites transport goods in another fashion, e.g. as parcel, general commodity or bulk.

Map 2 shows the site locations of the 100 respondents in combination with the different transport infrastructures under study. Most sites are clustered around the three major seaports and along the Antwerp-Brussels axis. A comparison of Map 2 with Map 1 shows that the spatial distribution of the companies in these maps is quite similar. It turns out that 62 respondents are within a radius of 2.5 kilometer from at least one of the sites used in the revealed preference analysis. Increasing the radius to 5 and 10 kilometer, the number of respondents within these radii increases to 71 and 92, respectively. In the last five years, 17 plants changed location. The reasons for this are as diverse as the need for a new premise and/or space for expansion, the need for a more profitable location, the need to be located closer to home, the need to avoid high land rent and a takeover. Another 10 plants indicated they were planning to move within the next five years. The most important reasons mentioned are expansion and/or restructuring plans. The fact that 27% of the respondents in our survey have moved sites or expressed the desire to do so shows that our stated choice study is timely and relevant.

Map 2: Site locations of the 100 respondents in the stated choice experiment in Flanders and available transport infrastructures.



4.2 MNL modeling results

First, we estimated a full MNL model that includes all six attributes used in the stated choice experiment. As mentioned above, we initially used effects-type coding, hereby treating all attributes as categorical. This enabled us to capture possible nonlinear relationships between the utility of an alternative site location and the attribute levels. We call the resulting model the *initial MNL model*. We then simplified the model by retaining only the significant terms and testing for linearity in the attribute 'land rent' to calculate WTP values. We call the resulting model the *final MNL model*.

Table 2 shows the marginal utility values of the attribute levels and the significances of the attributes' effects obtained from likelihood ratio (LR) tests for the *initial MNL model*. The LR tests indicate that all attributes are significant at the 0.05 level except for rail accessibility. In other words, we did not find evidence that rail access affects the location choice of the respondents. Therefore, we dropped the attribute 'rail access' from the model. This is in line with research presented by Hilmola (2007), Nash & Rivera-Trujillo (2007) and Vassallo & Fagan (2007), who reported that freight rail transport in Europe is inefficient due to the prioritization of passenger transport, a lack of interoperability of the different national rail networks, poor service quality, high rates and a lack of government incentives. Deville & Verduyn (2012) confirm these results for Belgium. This negative image of freight rail services is thus reflected in the results of our stated choice experiment.

The six attributes in Table 2 are ranked in order of importance, where the importance of an attribute is measured by –log(p-value of the LR test). Figure 6 shows the importances of the different attributes relative to the importance of the attribute 'land rent', which is the most important attribute. The attribute 'port accessibility' ranks second, followed by 'business park', 'road accessibility' and 'inland navigation accessibility', which are about equally important. The location for logistics plants is thus primarily determined by the cost of the available sites. Naturally, the lower the cost, the more favorable the location. At first sight, the superior importance of land rent over accessibility may be surprising. However, an extensive body of literature on the impact of land rent on location supports this finding (see, e.g., Alonso (1960, 1964), Muth (1969), Mills (1972), Solow (1972), Beckman (1973), Fujita & Ogawa (1982), Fujita (1989) and Krugman & Elizondo (1996) for a technical appraisal, and see, e.g., Holguín-Veras et al. (2005), Ozmen-Ertekin et al. (2007) and Nguyen & Sano (2010) for empirical evidence on the relationship between land rent and the location decision of (logistics) businesses). The result that 'port accessibility' is the most important accessibility attribute is also in line with the existing literature (see, e.g., Lu & Yang (2006), Hong (2007a-b), Hong & Chin (2007) and Kim et al. (2010)) and could have been expected since there are three seaports in Flanders which generate a large demand for transport. Somewhat surprising though is that the attributes 'business park' and 'road accessibility' are about as important as 'inland navigation accessibility'. This is in contrast with the findings in the local literature, which stresses the impact of road accessibility (Bus et al. 1999; Idea Consult 2001; Reijs et al. 2001; IBM 2004; BCI et al. 2007, 2008; Cabus 2008). We therefore expected this attribute to play a more prominent role. A possible explanation for the lower relative importance of road accessibility is the high density of motorways and motorway junctions in Flanders, i.e. one never has to drive far to access a motorway (Thomas & Verhetsel 1999). In most cases the journey from the logistics site to the motorway constitutes only a very small fraction of the total journey.

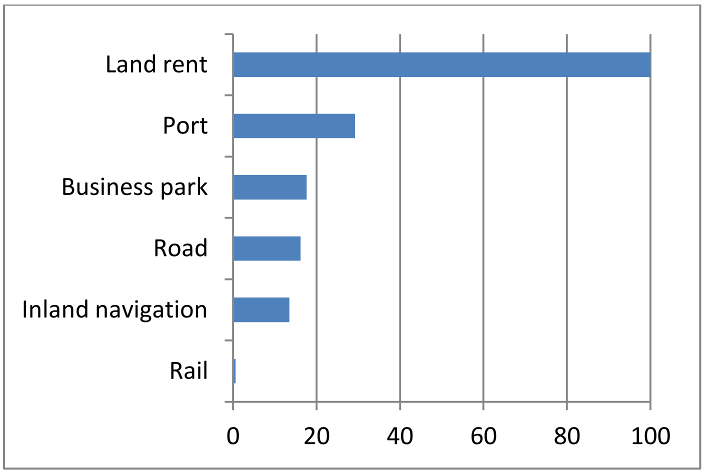
Table 2: Marginal utility values of the attribute levels and significances of the attribute effects obtained from likelihood ratio (LR) tests for the initial MNL model.

Attribute with level	Marginal	L-R ChiSquare	DF	P-value
Land rent [10 EUR]	1.378	462.499	4	<0.0001*
Land rent [35 EUR]	0.739			
Land rent [50 EUR]	-0.105			
Land rent [65 EUR]	-0.682			
Land rent [90 EUR]	*-1.330***			
Port [0 km]	0.721	136.491	3	<0.0001*
Port [10 km]	0.211			
Port [20 km]	-0.057			
Port [50 km]	*-0.875***			
Business park [yes]	0.372	74.776	1	<0.0001*
Business park [no]	*-0.372***			
Road [2 min]	0.389	76.910	3	<0.0001*
Road [5 min]	0.395			
Road [10 min]	-0.134			
Road [15 min]	-0.650**			
Inland navigation [0 km]	0.423	64.658	3	<0.0001*
Inland navigation [5 km]	0.088			
Inland navigation [15 km]	0.087			
Inland navigation [30 km]	*-0.598***			
Rail [0 km]	-0.043	4.035	3	0.2578
Rail [5 km]	-0.025			
Rail [15 km]	0.141			
Rail [30 km]	*-0.073***			

* Significant at 5% level.

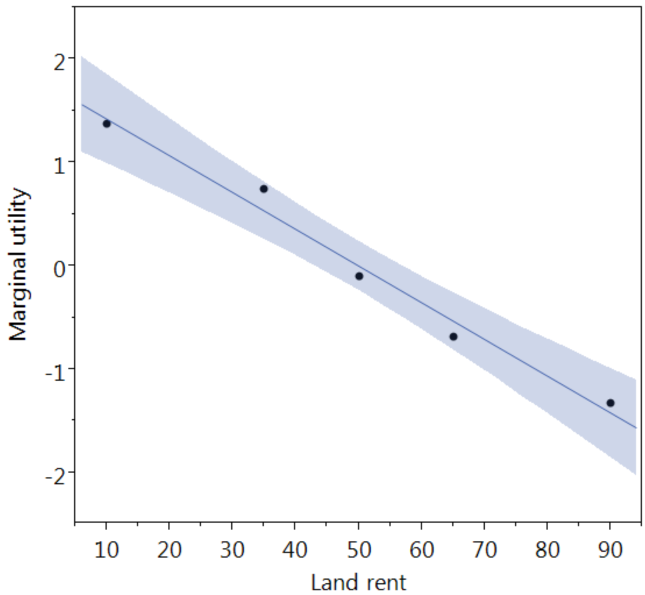
** Marginal utility values corresponding to the last level of each attribute are indicated in italic to stress that they are calculated as minus the sum of all other marginal utility values of that attribute.

Figure 6: Importance of the six attributes in the initial MNL model relative to the most important attribute ‘land rent’.



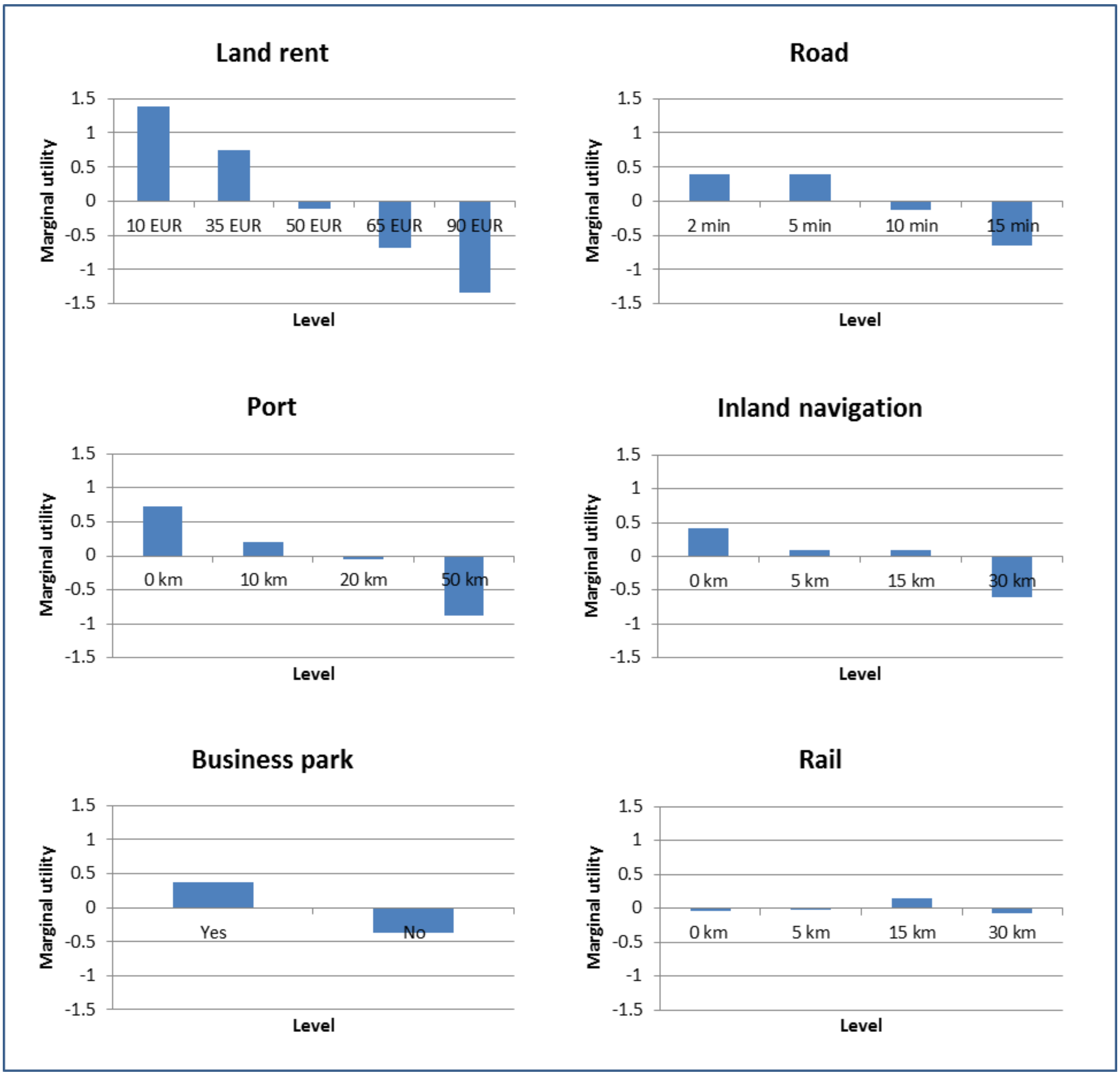
To be able to compute WTP values, the utility of a site location has to have a linear relationship with the attribute ‘land rent’. Figure 7 shows the result of a simple linear regression of the estimated marginal utility values of the five levels of the attribute ‘land rent’ to the land rent values shown during the stated choice experiment. It is clear that assuming a linear relationship is perfectly reasonable, and that switching from effects-type coding to linear coding is justified here.

Figure 7: Relationship between the estimated marginal utility values of the levels of the attribute ‘land rent’ and the actual land rents shown in the stated choice experiment.



Our study of the most important attribute ‘land rent’ showed that the utility of a site location decreases linearly with the land rent. Similarly, the utility of a site location decreases linearly with the distance to a port. This is shown in Figure 8, which also shows the marginal utility values of the levels of the other attributes. For the attribute ‘business park’, respondents value a site that is located in a business park substantially higher than a site that is not located in a business park. Hence, logistics managers appreciate the existing benefits of a business park. These benefits stem from the amenities provided, which generate agglomeration effects. For the attribute ‘road accessibility’, the marginal utility values of the levels ‘road [2 min]’ and ‘road [5 min]’ are similar. A LR test confirmed that these values are not significantly different (p-value = 0.940). This means that logistics managers do not differentiate between locations within 2 or 5 minutes from a motorway junction. They do, however, differentiate between locations within 2 or 5 minutes, on the one hand, and locations within 10 minutes, on the other hand, and between locations within 10 minutes and within 15 minutes from a motorway junction. Therefore, in the final model, we combined the levels ‘2 minutes’ and ‘5 minutes’ of the attribute ‘road accessibility’ into one single attribute level labeled ‘2-5 minutes’. Figure 8’s panel labeled ‘Inland navigation’ shows that the marginal utility values of the levels ‘5 km’ and ‘15 km’ are also very similar. A LR test confirmed that also these values are not significantly different (p-value = 0.934). Respondents are thus indifferent between locations at 5 or 15 kilometer of an inland navigation terminal. An onsite inland navigation terminal, however, has a substantially higher utility value, while a location with the nearest inland navigation terminal at 30 kilometer results in a substantially lower utility. In the final model, we combined the attribute levels ‘5 km’ and ‘15 km’ into a single attribute level, ‘5-15 km’. The very small marginal utility values in the bottom right panel of Figure 8 confirm the results from the LR test for the attribute ‘rail’ in Table 2, which revealed that ‘rail’ does not have significant explanatory value. Therefore, we did not include this attribute in the final model.

Figure 8: Marginal utility values of the attribute levels derived from the initial MNL model in Table 2.



We retained only the relevant attributes and attribute levels to build the *final MNL model*. Table 3 shows the marginal utility values of the attribute levels and the significances of the five remaining attributes in the *final MNL model*. The attributes are ranked in decreasing order of importance. The relative importances of the attributes are shown in Figure 9. They are almost identical to those in Figure 6. Note, however, that in the final model, we obtained a single estimate of -0.036 for the attribute 'land rent'. This is due to the fact that, in this final model, we used linear coding for the land rent attribute.

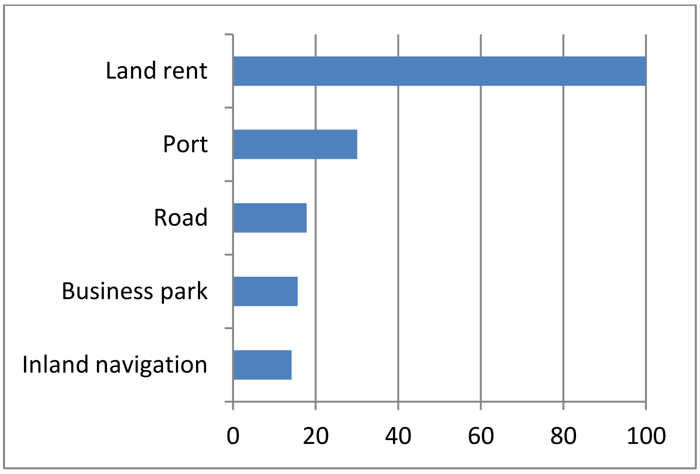
Table 3: Marginal utility values of the attribute levels and significances of the attribute effects computed by likelihood ratio (LR) tests for the final MNL model.

Attribute with level	Marginal	L-R ChiSquare	DF	P-value
Land rent (linear coding)	-0.036	553.219	1	<0.0001*
Port [0 km]	0.733	172.880	3	<0.0001*
Port [10 km]	0.223			
Port [20 km]	-0.066			
Port [50 km]	*-0.890*			
Road [2-5 min]	0.544	99.885	2	<0.0001*
Road [10 min]	-0.007			
Road [15 min]	*-0.537*			
Business park [yes]	0.393	82.829	1	<0.0001*
Business park [no]	*-0.393*			
Inland navigation [0 km]	0.471	79.417	2	<0.0001*
Inland navigation [5-15 km]	0.110			
Inland navigation [30 km]	*-0.581*			

* Significant at 5% level.

** Marginal utility values corresponding to the last level of each attribute are indicated in italic to stress that they are calculated as minus the sum of all other marginal utility values of that attribute.

Figure 9: Importance of the five attributes in the final MNL model relative to the most important attribute 'land rent'.



4.3 Willingness to Pay

A key output of our analysis is a set of WTP values for changes in the various attributes of site locations. We calculated the WTP value for a change in the level of an attribute by dividing the difference in marginal utility of two attribute levels by the absolute value of the land rent effect on the utility. For example, the WTP value for moving from a site location with a motorway junction within 15 minutes to one within 10 minutes is

$$\frac{\beta_{road[10min]} - \beta_{road[15min]}}{-\beta_{landrent}} = \frac{-0.007 - (-0.537)}{0.036} = 14.722.$$

Hence, logistics managers are willing to pay an additional land rent of 14.722 EUR/m²/year for a location within 10 minutes from a motorway junction instead of one within 15 minutes.

Tables 4 to 7 contain the WTP values for all possible changes in the levels of the accessibility attributes and the attribute ‘business park’. The rows show the possible attribute levels at the initial location, while the columns depict the attribute levels at the new location. Positive values indicate the increase in land rent (expressed in EUR/m²/year) logistics managers are willing to accept in exchange for a location which shows improvement with respect to the attribute under consideration, while negative values indicate the decrease in land rent required for logistics managers to move their site to a location that is less attractive in terms of that attribute. Tables 4, 5 and 6 show that logistics managers are willing to pay about 30 EUR/m²/year to move from a location at 50 kilometer from a port to one at 10 kilometer, to move from a location within 15 minutes from a motorway junction to one with an almost direct connection, and to move from a location at 30 kilometer from an inland navigation terminal to one at a canal or river. Table 7 reveals a substantial WTP value for sites located in a business park.

Table 4: Willingness to Pay (WTP) estimates for port accessibility.

To/from	**Port [0 km]**	**Port [10 km]**	**Port [20 km]**	**Port [50 km]**
Port [0 km]	/	-14.167	-22.194	-45.083
Port [10 km]	14.167	/	-8.028	-30.917
Port [20 km]	22.194	8.028	/	-22.889
Port [50 km]	45.083	30.917	22.889	/

Table 5: Willingness to Pay (WTP) estimates for motorway accessibility.

To/from	**Road [2-5 min]**	**Road [10 min]**	**Road [15 min]**
Road [2-5 min]	/	-15.306	-30.028
Road [10 min]	15.306	/	-14.722
Road [15 min]	30.028	14.722	/

Table 6: Willingness to Pay (WTP) estimates for inland navigation accessibility.

To/from	**Inland navigation [0 km]**	**Inland navigation [5-15 km]**	**Inland navigation [30 km]**
Inland navigation [0 km]	/	-10.028	-29.222
Inland navigation [5-15 km]	10.028	/	-19.194
Inland navigation [30 km]	29.222	19.194	/

Table 7: Willingness to Pay (WTP) estimates for business park.

To/from	**Business park [yes]**	**Business park [no]**
Business park [yes]	/	-21.833
Business park [no]	21.833	/

To calculate WTP values for improvements in a location with respect to more than one attribute, we sum WTP values from different tables. For example, assume that a site is located at 20 kilometer from a port, 15 minutes from a motorway junction, 5 kilometer from an inland navigation terminal and outside a business park. For a relocation to a site at 10 kilometer from a port, 2-5 minutes from a motorway junction, situated at an inland navigation terminal and within a business park, a logistics company would be willing to pay an additional 8.028 + 30.028 + 10.028 + 21.833 = 69.917 EUR/m²/year, according to our results.

5 Conclusion

The logistics sector is a major stakeholder in the fragmentation of industrial production processes due to globalization. The organization of the spatial networks of logistics companies is one of the most important strategic decisions they have to make. The quest for suitable plant locations is crucial in this context. The research described in this paper was carried out in response to the need for new locations for logistics operations. The research, which focused on Flanders (Belgium), is unique in its use of a stated choice experiment in combination with a discrete choice model for identifying the key factors in the search for suitable locations for logistics sites, quantifying their impact on the choices made by logistics managers and determining the Willingness to Pay for improvements in location. The literature on site location in general shows that the accessibility of transport infrastructure and land rent costs are considered the most important location factors for companies. This is even more true when focusing on logistics plants. In the past, traditional questionnaires have been extensively used to study location factors. We break this status quo by adopting a stated choice experimental approach, where respondents are forced to choose between different alternative locations.

In the stated choice experiment, important location factors emerging from a thorough literature review were included. More specifically, the importance of accessibility (in terms of distance to major transport infrastructures) and land rent costs was investigated. The location of a site inside or outside of a business park was also incorporated in the stated choice experiment, since the Flemish government was very interested in feedback concerning the added value of these subsidized facilities. For the stated choice experiment we used the distance to a motorway junction, to a sea port, to a rail terminal and to an inland navigation terminal as indicators of accessibility. Our GIS exercise showed that the largest logistics plants in Flanders are predominantly located at short distances of the available transport infrastructure. These distances were used as input to determine the attribute levels utilized in the stated choice experiment. An acceptable share of the respondents of the stated choice study belongs to the group of large logistics plants in Flanders, but SMEs, which are typical for Flanders, are also included in the pool of respondents. One in four respondents moved location during the last five years or is preparing a move. This demonstrates that location issues are continuously present in the strategic management considerations of logistics companies.

The outcome of the stated choice experiment confirms the classical urban economic theories, with land rent being by far the most important location factor for logistics sites. Our research shows that the access to seaports is the one but most important location factor. A seaport is preferably located within 10 kilometer of one's site. Flanders, being served by three major seaports (Antwerpen, Gent, Zeebrugge), therefore offers a substantial number of attractive locations for logistics companies. Furthermore, locations within 5 minutes of a motorway junction and within 15 kilometer from an inland navigation terminal are considered attractive as well. The amenities in business parks, a factor rarely included in location research, are also considered to be very attractive. The distance to a rail terminal, on the other hand, had no significant impact in our study. However, because of recent EU decisions concerning major investments in rail infrastructure and a more efficient management of rail, we would still recommend including rail accessibility in future research.

The results of our stated choice experiment provide valuable input to government agencies that need to identify locations in Flanders suitable for developing new logistics sites. New business parks nearby seaports, well connected by road and within reach of inland shipping terminals would be ideal candidates for further development. Our results indicate a strong preference for locations that lend themselves to intermodal and multimodal transport. This is of crucial importance in densely urbanized regions, like Flanders and many other seaport areas worldwide, where land for extensive developments is scarce and, consequently, land rents are high. The results of our Willingness to Pay study show that logistics companies are willing to pay a substantially larger annual land rent for attractive locations, so that, from a private as well as from a public viewpoint, developments on more expensive, highly accessible locations are preferable to developments on cheap locations with poor accessibility.

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Appendix A: Bayesian D-optimal partial profile design consisting of two surveys for the stated choice experiment.

The entire stated choice experiment involved two surveys of 20 choice situations which appear in Tables A.1 and A.2. Each survey was taken by 50 respondents. The surveys contain the alternative site locations shown in the different choice situations. Asterisks indicate attributes not used in the choice situations. The last line under each survey indicates how often each attribute appears in the choice situations of that survey. Attributes that have many levels are used more often than attributes with fewer levels.

Table A.1: Survey 1 of the Bayesian D-optimal partial profile design.

Choice set	Road	Rail	Inland navigation	Port	Land rent	Business park
1	*	5 km	*	10 km	65 EUR	Yes
1	*	0 km	*	0 km	50 EUR	No
2	*	30 km	5 km	*	65 EUR	No
2	*	15 km	30 km	*	50 EUR	Yes
3	*	15 km	0 km	0 km	*	No
3	*	0 km	30 km	50 km	*	Yes
4	*	5 km	5 km	20 km	*	No
4	*	30 km	0 km	10 km	*	Yes
5	*	5 km	0 km	10 km	50 EUR	*
5	*	0 km	5 km	0 km	65 EUR	*
6	*	0 km	0 km	20 km	65 EUR	*
6	*	30 km	5 km	10 km	35 EUR	*
7	15 min	*	*	10 km	90 EUR	No
7	5 min	*	*	50 km	65 EUR	Yes
8	2 min	*	15 km	50 km	90 EUR	*
8	5 min	*	30 km	10 km	65 EUR	*
9	2 min	*	30 km	0 km	50 EUR	*
9	10 min	*	0 km	50 km	35 EUR	*
10	5 min	*	5 km	50 km	50 EUR	*
10	10 min	*	30 km	20 km	10 EUR	*
11	5 min	*	15 km	20 km	10 EUR	*
11	2 min	*	30 km	0 km	35 EUR	*
12	2 min	*	5 km	20 km	50 EUR	*
12	5 min	*	15 km	0 km	10 EUR	*
13	15 min	15 km	*	*	10 EUR	Yes
13	5 min	5 km	*	*	65 EUR	No
14	5 min	5 km	*	0 km	10 EUR	*
14	2 min	0 km	*	20 km	65 EUR	*
15	2 min	15 km	*	50 km	10 EUR	*
15	10 min	0 km	*	10 km	35 EUR	*
16	2 min	15 km	*	10 km	65 EUR	*
16	15 min	30 km	*	0 km	35 EUR	*
17	10 min	15 km	5 km	*	*	Yes
17	5 min	30 km	30 km	*	*	No
18	10 min	30 km	5 km	*	*	Yes
18	15 min	15 km	30 km	*	*	No

19	5 min	15 km	15 km	*	50 EUR	*
19	2 min	5 km	30 km	*	90 EUR	*
20	5 min	15 km	0 km	*	90 EUR	*
20	10 min	30 km	30 km	*	10 EUR	*
Frequency	*14*	*14*	*14*	*14*	*16*	*8*

Table A.2: Survey 2 of the Bayesian D-optimal partial profile design.

Choice set	**Road**	**Rail**	**Inland navigation**	**Port**	**Land rent**	**Business park**
1	*	0 km	*	10 km	35 EUR	Yes
1	*	30 km	*	0 km	50 EUR	No
2	*	15 km	*	50 km	90 EUR	No
2	*	5 km	*	20 km	50 EUR	Yes
3	*	0 km	5 km	10 km	*	No
3	*	5 km	0 km	50 km	*	Yes
4	*	30 km	0 km	10 km	90 EUR	*
4	*	0 km	15 km	50 km	35 EUR	*
5	*	0 km	15 km	50 km	50 EUR	*
5	*	15 km	5 km	20 km	35 EUR	*
6	*	30 km	15 km	20 km	65 EUR	*
6	*	0 km	30 km	50 km	10 EUR	*
7	15 min	*	*	0 km	65 EUR	Yes
7	10 min	*	*	20 km	10 EUR	No
8	2 min	*	15 km	*	35 EUR	No
8	10 min	*	5 km	*	90 EUR	Yes
9	5 min	*	5 km	*	90 EUR	Yes
9	10 min	*	15 km	*	65 EUR	No
10	10 min	*	0 km	50 km	*	No
10	15 min	*	15 km	20 km	*	Yes
11	15 min	*	0 km	10 km	50 EUR	*
11	5 min	*	30 km	0 km	90 EUR	*
12	10 min	*	15 km	0 km	90 EUR	*
12	15 min	*	5 km	50 km	10 EUR	*
13	2 min	30 km	*	*	10 EUR	Yes
13	15 min	5 km	*	*	35 EUR	No
14	2 min	30 km	*	20 km	35 EUR	*
14	15 min	0 km	*	10 km	65 EUR	*
15	5 min	0 km	*	20 km	90 EUR	*
15	10 min	15 km	*	0 km	65 EUR	*
16	15 min	5 km	15 km	*	10 EUR	*
16	10 min	0 km	30 km	*	50 EUR	*
17	2 min	30 km	0 km	*	35 EUR	*
17	10 min	5 km	5 km	*	50 EUR	*
18	2 min	0 km	15 km	*	90 EUR	*
18	5 min	15 km	30 km	*	35 EUR	*
19	15 min	5 km	0 km	0 km	*	*
19	5 min	15 km	15 km	10 km	*	*
20	2 min	5 km	15 km	10 km	*	*
20	15 min	0 km	0 km	20 km	*	*
Frequency	*14*	*14*	*14*	*14*	*16*	*8*

Appendix B: Multivariate normal prior parameter distribution used to construct the Bayesian D-optimal partial profile design for the stated choice experiment.

This appendix describes the prior distribution used for constructing the Bayesian D-optimal partial profile design for the stated choice experiment, shown in Appendix A. The prior distribution is a 17-variate normal distribution, because the initial modeling approach treated every attribute as categorical. As a consequence, the total number of parameters in the initial choice model equals the sum of the numbers of levels of all attributes minus the number of attributes. As explained in the main text, this enabled us to capture possible nonlinear effects of the attributes on the perceived utility of a site location.

In this article, we use effects-type coding for the attribute levels, which means that the levels of every 2-level attribute are coded as 1 and -1, the levels of every 4-level attribute as [1 0 0], [0 1 0], [0 0 1] and [-1 -1 -1], and the levels of every 5-level attribute as [1 0 0 0], [0 1 0 0], [0 0 1 0], [0 0 0 1] and [-1 -1 -1 -1]. This is not only important for interpreting the estimates of the parameters of the MNL model, but also for specifying the prior distribution of these parameters when constructing the design of the stated choice experiment.

To construct the Bayesian D-optimal partial profile design, we used the 17-variate normal prior distribution $N\left(\boldsymbol{\beta}\middle|\boldsymbol{\beta}_0,\boldsymbol{\Sigma}_0\right)$, with prior mean vector

$$\boldsymbol{\beta}_0 = \left[0.483, 0.167, \text{-}0.15, 0.483, 0.167, \text{-}0.15, 0.483, 0.167, \text{-}0.15, 0.483, 0.167, \text{-}0.15, 0.5, 0.2, 0, \text{-}0.2, 0\right]'$$

and prior variance-covariance matrix

$$\boldsymbol{\Sigma}_0 = \begin{bmatrix}
0.09 & -0.03 & -0.03 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-0.03 & 0.09 & -0.03 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-0.03 & -0.03 & 0.09 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.09 & -0.03 & -0.03 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -0.03 & 0.09 & -0.03 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -0.03 & -0.03 & 0.09 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0.09 & -0.03 & -0.03 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & -0.03 & 0.09 & -0.03 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & -0.03 & -0.03 & 0.09 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.09 & -0.03 & -0.03 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -0.03 & 0.09 & -0.03 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -0.03 & -0.03 & 0.09 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.09 & -0.02 & -0.02 & -0.02 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -0.02 & 0.09 & -0.02 & -0.02 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -0.02 & -0.02 & 0.09 & -0.02 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -0.02 & -0.02 & -0.02 & 0.09 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.09
\end{bmatrix}.$$

In order to understand the meaning of the prior mean vector $\boldsymbol{\beta}_0$, it is important to realize that the vector's first three elements correspond to the prior utility values of the first three levels of the attribute 'road accessibility'. The next three sets of three elements correspond to the prior utility values of the first three levels of the attributes 'rail accessibility', 'inland navigation accessibility' and 'port accessibility'. The next four elements correspond to the prior utility values of the first four levels of the attribute 'land rent' and the final element corresponds to the utility value of the first level of the attribute 'business park'. Attributes for which the utility values are larger in absolute value than other attributes are considered more important for the location choice experiment, a priori.

The land rent attribute has the largest absolute value in the prior mean $\boldsymbol{\beta}_0$, namely 0.5, so that we assumed that this attribute was the most important when setting up the experiment. We also assumed that the four accessibility attributes 'road', 'rail', 'inland navigation', 'port' and 'land rent' are equally important (as witnessed by the fact that the prior utility values in $\boldsymbol{\beta}_0$ for all these attributes are 0.483, 0.167 and -0.15).

The prior distribution also expresses our prior belief that logistics managers generally prefer immediate access to a motorway junction, a train terminal, an inland navigation terminal and a port, and that they also generally prefer a lower land rent. This is because the first element in $\boldsymbol{\beta}_0$ for each of the four accessibility attributes and the land rent attribute has the largest value. The next few elements for each attribute have lower values, indicating that the other levels of the attributes are less attractive.

The prior mean vector $\boldsymbol{\beta}_0$ does not contain the utility values for the last level of the attributes. The implied utility of an attribute's last level equals minus the sum of all other utility values of that attribute. The implied utility value for the highest land rent, for instance, is -0.5, indicating that a site location with a high cost is unattractive.

Finally, for the 2-level attribute 'business park', we had no prior information about the logistics managers' preferences. In other words, prior to the stated choice experiment, we did not know whether they desired to be located in a business park or not. Therefore, we specified a zero prior utility value for the first level of the attribute 'business park' when setting up the stated choice experiment. This explains why the final element of the prior mean vector $\boldsymbol{\beta}_0$ is zero. The implied prior utility value of the second level of the business park attribute is then also zero.

For the prior variance-covariance matrix $\boldsymbol{\Sigma}_0$, we specified 17 variances that express our uncertainty about the prior utility values contained within the prior mean vector $\boldsymbol{\beta}_0$. The variances are all equal to 0.09, because this preserves the natural rank order of the levels of the first five attributes in most cases. This means that the difference between two consecutive prior utility values for each of these attributes is usually larger than or equal to the standard deviation of 0.3. We also specified negative covariances between the utility values corresponding to a single attribute. If L_i denotes the number of levels of attribute i, we computed these covariances using a correlation coefficient of $-1/(L_i - 1)$. As explained by Kessels et al. (2008), this ensures that the variances of all prior utility values corresponding to a given attribute are the same, meaning that the variance associated with the implied utility of the last level of each attribute also equals 0.09.