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DEVELOPMENTS IN THE DUTCH URBAN SYSTEM

ON THE BASIS OF FLOWS*

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ABSTRACT

In this study, the 1992, 1995, 1999, and 2002 Netherlands National Travel Surveys are employed to examine the change in the configuration of the urban system on the basis of commute and leisure flows between twenty-three Daily Urban Systems (DUSs). The results for commuting flows provide some evidence of smaller differences in the importance of DUSs in the system over the ten-year period in the Dutch urban system. Leisure flows, however, do not reveal clear evidence of such development. We find that the development process occurs very slowly and the developments between DUSs in close proximity to one another take place at a faster pace than between those located further away.

KEYWORDS

Urban system, Urban Flows, Polycentrism, The Netherlands

Le développement du système urbain néerlandais sur la base des flux.

Limtanakool et al.

A partir des enquêtes de 1992, 1995, 1999 et 2002 sur les trajets quotidiens aux Pays-Bas, menées au niveau national, cette étude cherche à examiner l'évolution de l'ossature du système urbain sur la base des migrations quotidiennes entre vingt-trois Daily Urban Systems (DUS; systèmes urbains quotidiens) pour se rendre au travail et au loisir. Pour ce qui est des migrations quotidiennes pour se rendre à la zone de travail. Les résultats laissent voir de faibles différences quant à l'importance des DUS dans le système urbain néerlandais sur une période de dix années. Cependant, les migrations quotidiennes pour se rendre à la zone de loisirs ne font pas preuve d'un tel développement. Il s'avère que le processus de développement évolue très lentement et que les développements entre DUS à proximité évoluent plus rapidement que ne le font ceux qui sont entre DUS à plus grande distance.

Système urbain / Flux urbains / Polycentrisme / Pays-Bas

Classement JEL: R12; R1; R4; R40

Entwicklungen im holländischen urbanen System auf der Grundlage von Strömen

Narisra Limtanakool, Tim Schwanen and Martin Dijst

In dieser Studie werden mit Hilfe der nationalen Verkehrserhebungen in den Niederlanden von 1992, 1995, 1999 und 2002 die Veränderungen in der Konfiguration der urbanen Systeme anhand der Verkehrsströme zu Arbeits- und Freizeitzwecken zwischen 23 Einzugsgebieten untersucht. Die Ergebnisse bei den Verkehrsströmen von Berufspendlern liefern einige Anzeichen für kleinere Unterschiede hinsichtlich der Bedeutung der Einzugsgebiete im System über den zehnjährigen Zeitraum des holländischen urbanen Systems. Bei den Verkehrsströmen zu Freizeitzwecken werden hingegen keine klaren Anzeichen für eine solche Entwicklung sichtbar. Wir stellen fest, dass der Entwicklungsprozess äußerst langsam vonstatten geht und dass sich die Entwicklungen zwischen nahe beieinander liegenden Einzugsgebieten schneller vollziehen als die zwischen weiter voneinander entfernt liegenden Gebieten.

KEYWORDS

Urbanes System
Urbane Verkehrsströme
Polyzentrismus
Niederlande
R12, R1, R4, R40

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Desarrollo en el sistema urbano holandés según los flujos

Narisra Limtanakool, Tim Schwanen and Martin Dijst

Con ayuda de las encuestas nacionales sobre el tráfico en los Países Bajos de 1992, 1995, 1999 y 2002, en este ensayo analizamos el cambio en la configuración del sistema urbano en función de los flujos de desplazamiento por motivos laborales y de ocio entre veintitrés sistemas urbanos de movimientos pendulares diarios. En los resultados de los flujos de desplazamientos por motivos laborales se observan pequeñas diferencias en cuanto a la importancia de los sistemas urbanos diarios en el sistema durante un periodo de diez años en el sistema urbano holandés. Sin embargo, los flujos de ocio no indican una clara evidencia de tal desarrollo. Observamos que el proceso de desarrollo ocurre muy lentamente y los desarrollos entre los sistemas urbanos diarios que están próximos entre ellos tienen lugar a un ritmo más rápido que entre los que están más lejos.

KEYWORDS

Sistema urbano
Flujos urbanos
Policentrismo
Los Países Bajos

R12, R1, R4, R40

INTRODUCTION

Spatial integration processes play an important part in the evolution of contemporary urban systems. The literature on urban development suggests that spatial integration is a process of change in the relationships among spatial units: the interaction among areas becomes more intense and relationships change from dependent to reciprocal (DAVOUDI, 2003). One consequence of the spatial integration process is the change in urban constellations from monocentric to polycentric urban systems (KLOOSTERMAN and MUSTERD, 2001). This transformation has led the differences in the importance of nodes in the urban systems to become smaller.

The configurations of the urban systems have been examined on a variety of geographical scales, ranging from the global level (DERUDDER et al., 2003), to the European level (BRUINSMA and RIETVELD, 1993), the national level (DEMATTEIS, 1997), and the metropolitan level (CLARK and KUIJPERS-LINDE, 1994). Although it is evident that the configurations of urban systems have evolved over time, few studies take a comparison-in-time perspective and scrutinise the configuration of urban systems at multiple points in time (HALL et al., 2001; HUFF and LUTZ, 1995). In advanced economies, the properties of cities are increasingly determined by flows within systems (DERUDDER and WITLOX, 2005). As yet, the importance of flows has received limited attention in empirical studies: the use of node characteristics (number of inhabitants, for example) to examine changes in the configurations of urban systems (HALL et al., 2001; KOOIJ, 1988) is more common than the use of interaction data (e.g. SMITH and WHITE, 1992; SMITH and TIMBERLAKE, 2001).

The aim of this study was to examine the development of the configuration of the Dutch urban system from 1992 to 2002 based on flows of people between twenty-three Daily Urban Systems (DUSs) (Figure 1). We draw on the concept of polycentrism that has been used in many studies addressing urban systems at the metropolitan level to describe urban configurations at the inter-metropolitan level. Although there are several types of flow (information, money, people, for example) that can be used for studying the interaction between spatial units, we concentrate on human corporeal interaction, because face-to-face relationships continue to be important for the development of urban systems particularly on the national and sub-national scales despite the telecommunication revolution (SMITH and TIMBERLAKE, 2001). Furthermore, the fact that human corporeal interaction faces rather different set of constraints (physical distance, for example) compared to other types of flows such as information and money that are increasingly considered instantaneous (CASTELLS, 1996) also influenced our choice to concentrate specifically on human corporeal flows.

(PLEASE INSERT FIGURE 1 ABOUT HERE)

In this study, we have analysed commuting and leisure trips separately. Studies of urban system development on the metropolitan level have focused mainly on work-related flows such as commuting (e.g. CLARK and KUIJPERS-LINDE, 1994; VAN DER LAAN, 1998); we argue, however, that other mobility flows such as leisure trips should also be examined in this context. Since spatial entities (DUSs, for example) contain and perform multiple functions, partial knowledge may be obtained when considering only work-related aspects of interaction. In fact, it is leisure trips that constitute the greater share in terms of the total number of trips and total distance travelled (SCHWANEN et al., 2001). Furthermore, commuting and leisure travel deserve special attention, because the spatial distribution of employment and leisure opportunities across and within DUSs differ from one another.

Polycentric urban configuration is also important from a policy perspective, particularly in Europe. Policymakers believe that polycentric development will help strengthen the position of Europe in the world economy, since this configuration allows urban nodes to benefit from economies of scale and specialise in particular economic activities (DAVOUDI, 2003). Policymakers in the Netherlands, the target of the current study, also aim to enhance the interaction between DUSs. It has been stated that: 'What is lacking [for the Randstad], however, is the internal interaction between the individual urban agglomerations constituting Randstad Holland. The scattered pattern of urbanisation within the Randstad is a serious drawback. It is limiting the economic basis for mainports and infrastructure. Labour and other markets stay geographically fragmented. The various research potentials are not interlinked and lack economies of scale (REGIO RANDSTAD, 2004).' It is therefore pertinent to gain insight into the developments of urban system at geographical levels beyond that of the DUS and investigate whether a tendency towards polycentrism can be observed.

The remainder of the paper starts with a discussion of the theoretical framework underlying the study. Following this, we describe the methodology and the research design. The empirical results are then presented and the paper concludes with a discussion of the results.

THEORETICAL FRAMEWORK

In this study, an urban system refers to a set of interdependent DUSs connected to one another via flows of people. In theory, configurations of urban systems may range from a fully monocentric constellation (in which opportunities are concentrated in only one or at most just a few nodes) to a fully polycentric system that lacks truly dominant nodes, because the opportunities are evenly distributed across nodes in the system. Thus, polycentrism is a state of the urban system at a given point in time; polycentrism refers to a situation in which several nodes are interdependent and interact with one another via various types of flow of information, money, goods, and people, for example (HALL and HAY, 1980; PARR, 2004). A system develops towards a fully polycentric configuration as nodes participate more intensely in the system of interaction and the differences in participation across nodes become smaller over time. We are confident that an assessment on the extent to which the role and dominance of individual nodes have evolved within the system can contribute to our understanding of the development of the configurations of an urban system. To this end, we have employed and extended a framework previously proposed by Limtanakool and colleagues (LIMTANAKOOL *et al.*, 2007) and examined the pattern of interaction at different points in time (cf. SMITH and TIMBERLAKE, 2001). Taking a relational perspective, we have studied the configurations of the urban system through the 3 S-dimensions, namely strength, symmetry, and structure. These three dimensions are presented schematically in Figure 2.

(PLEASE INSERT FIGURE 2 ABOUT HERE)

The dimension *strength of interaction* concerns the intensity of interaction between areas; it is one of the defining characteristics of urban systems (BOURNE and SIMMONS, 1978). When nodes are intensely interrelated, changes, new ideas, innovations, and so forth can be transmitted from one node to another more readily (SMITH, 2003). Nodes that interact intensively with other nodes in the wider system are considered dominant, because the strength of interaction also indicates a node's ability to control or influence activities throughout the system. In this study, we extend the dimension of strength from the employed framework by taking into account the differences in the level of intensity across different links. The reason for this extension is the fact that the dominance of a node depends on the extent of the power it wields in controlling or dominating activities in multiple nodes in the system (IRWIN and HUGHES, 1992). In a fully polycentric system, we expect intense interaction between all DUSs and even distribution of the level of interaction across all links, because this case refers to the situation in which all nodes in the system are equally important.

In real-life situations, the interaction between DUSs can range from completely asymmetrical (that is, a unidirectional relationship) to fully symmetrical (that is, a bidirectional relationship with equally large flows in both directions). For flows of people, the interaction from A to B does not necessarily have the same meaning as the interaction from B to A (VAN DER LAAN, 1998), because many trips are undertaken for acquiring goods and services that are tied to specific geographical locations. In such cases, it is important to take into account the direction of flows; DUSs receiving many trips are considered dominant in the system, because they contain opportunities sought by people residing in other DUSs in the system (ALDERSON and BECKFIELD, 2004). In this study, the directionality of flows is captured through the dimension of the *symmetry of interaction*. In a fully polycentric system, where urban nodes tend to be equally important, reciprocal or fully symmetrical rather than dependent relationships between DUSs are expected (VAN DER LAAN, 1998).

With the first two S-dimensions having been assessed, insight can be gained into the third dimension, the *structure* of the urban system; this can range from a hierarchical structure (as in a fully monocentric system) to a non-hierarchical structure (as in a fully polycentric system) (Figure 2). The former is characterised by the presence of (a) node(s) that strongly dominate(s) the system by attracting considerable flow from other nodes. In the extreme case, this pattern corresponds to a set of asymmetrical flows from other nodes in the system towards the dominant node(s) (system A from Figure 2). A considerable gap between the importance of the dominant and non-dominant nodes suggests a strong hierarchical structure of the monocentric system. In contrast, every node in a fully polycentric or non-hierarchical system is equally important when every link is equally strong and the interaction fully symmetrical, indicating a reciprocal relationship (system C from Figure 2). We can say that the hierarchical structure in the urban system decreases as the urban system develops towards a fully polycentric system.

SPATIAL INTERACTION INDICES

In this section, we introduce a set of interaction indices to measure the 3 S-dimensions of spatial interaction. A set of indices rather than a single index was used, since to the best of our knowledge the latter does not exist (Table 1).

The strength of interaction was measured through the *Relative Strength Index* (RSI_{ij}) and the *Dominance Index* (DII_i); both indices are relative measures. The RSI_{ij} concerns the magnitude of unidirectional interaction between nodes as a proportion of the total interaction within the system. The RSI_{ij} values for all links in the system thus sum to unity. The DII_i indicates the importance of a node in terms of the magnitude of flow it receives in relation to the average size of flow received by other nodes in the system. The higher the dominance index value, the more dominant is the node. In a fully polycentric system in which every node is equally important, every node has a DII_i value of one and every link has the same RSI_{ij} value. For both indices, the smaller the differences in the values across nodes and links, the closer is the system to a fully polycentric configuration.

(PLEASE INSERT TABLE 1 ABOUT HERE)

The differentiation in the intensity of interaction is measured by two indices, namely the Entropy Index of the system (EI) and the Entropy Index of the node (EI_i).

The *EI* measures the degree to which the magnitude of interaction on each link is equal across all links in the system. This index varies from zero to one: a value of zero indicates that the interaction in the system concentrates on only one link, given that there is more than one possible link in the system, while a value of one indicates that the distribution of interaction across all links in the system is even. Thus, a fully polycentric system possesses an *EI* value of one. The differentiation in the intensity is also analysed at the node level. The EI_i measures the evenness of the distribution of the incoming interaction across all links associated with a node. The EI_i also varies from zero to one, with a value of one indicating that the interaction on all links associated with a node is equally strong. It therefore follows that, in a fully polycentric system, every node has an EI_i value of one.

The Node Symmetry (NSI_i) and the Link Symmetry (LSI_{ij}) indices involve the dimension of symmetry. At the node level, the NSI_i measures the difference between the incoming and the outgoing flow to and from the node in question. The NSI_i can take on values from -1 to +1; a positive net interaction suggests that the node is primarily a receiver and a negative value that it is more important as a sender. At the link level, the LSI_{ij} describes the extent to which the unidirectional interaction equals the interaction in the other direction between pairs of nodes. This index varies from zero to one: a value of one shows that the interaction is fully symmetrical (the amount of interaction from node *i* to *j* is exactly the same as that from *j* to *i*), while zero indicates completely asymmetrical interaction. In sum, with respect to the symmetry dimension, the system is fully polycentric when all nodes and links are fully symmetrical.

Taking all dimensions into account, we can say that the urban system is more polycentric if the values of dominance, entropy (for both the system and node), and link symmetry indices are close to one (for every link); the node symmetry index for every node is close to zero; and there is little variability in the values for the relative strength index for different links. A fully polycentric system is of course an ideal-type configuration. The extent to which actually occurring interaction patterns approximate to this ideal type can be assessed from the means, medians, and standard deviations, as well as the complete distributions of index values, for configurations actually observed. We would expect an urban configuration to developing into a fully polycentric system to have values for interaction patterns that become more similar to this ideal configuration over time.

RESEARCH DESIGN

Data description

The data used for the empirical analysis are taken from the 1992, 1995, 1999, and 2002 Netherlands National Travel Surveys (NTSs). This survey was started in 1979 and has been conducted annually ever since. The travel data includes information on the purpose, self-reported distance and time, mode (excluding airplanes), and the geographical location of origin and destination (measured at the municipal level) of all trips for a single day; overnight trips have not been included in the data. Statistics Netherlands have calculated weight factors for all the years to make the data representative of the whole population of the Netherlands. The weights are based on a number of variables and some of their interactions: the degree of urbanisation, age, gender, household size, car ownership, fuel type, and the month in which households participated in the survey (more details in STATISTICS NETHERLANDS, 2002). The sample size was increased between 1993 and 1995 and in 1999 a new data collection method was implemented (the use of the municipality as a sampling unit and telephone calls to encourage respondents, for example). To make the data from all years comparable, Statistics Netherlands provided correction factors to correct for the differences in data sampling and data collection methods. In 1992, around (unweighted) 77,000 trips were recorded in the database. The number of (unweighted) trips increased to about 610,000 in 1995. However, owing to a drop in response rates, the number of trips recorded in comparison with 1995 fell by 30 percent and 50 percent in 1999 and 2002 respectively. To make the data comparable across all years, we applied the weight and the correction factors provided by Statistics Netherlands.

The current analysis concentrates on commuting and leisure trips between DUSs. Leisure trips are undertaken for shopping, sports, hobbies, and other recreational activities. Trips undertaken for visiting family and friends are not included, because these are not directly associated with the use of facilities located in the DUSs. Although a distinction cannot be drawn between non-daily shopping trips and grocery shopping trips in the NTS, we believe that, since we have only analysed trips between DUSs, most grocery shopping trips are filtered out, because they tend to be taken over short distances within a DUS.

General information about the commuting and leisure trips is presented in Appendix 1[1]. Each year, around 9-11 percent and 18-20 percent of the total trips recorded in the database are commuting and leisure trips respectively. The share of commuting trips between DUSs in relation to the total commuting trips increased during the period investigated (from 7 percent to around 9 percent). In contrast, the number of leisure trips between DUSs in relation to the total leisure trips decreased between 1992 and 1995. Although the corresponding share increased from 1995 onwards, it was still lower in 2002 than in 1992. There are also differences between the two trip purposes with respect to distance travelled: for commuting, it increased markedly between 1992 and 1995 and then stabilised, while for leisure purposes it increased from 1992 to 1995 and then declined to about the same level as in 1992. Comparing the two trip purposes, leisure trips were conducted over shorter distances than commuting, particularly after 1995. The urban configuration for leisure flows is therefore likely to be more fragmented than for commuting flows. The differences between the trip purposes confirm that commuting and leisure trips should be analysed separately.

During the period investigated, trips between DUSs are mainly undertaken by private car and leisure trips are more car dependent than commutes (Appendix 1[1]). During the 1990s, car use has dropped, especially for commuting between DUSs. A substantial increase in traffic congestion in peak hours within the Randstad could explain this trend (AVV TRANSPORT RESEARCH CENTRE, 2004a). At the same time, travelling by train is a viable alternative for trips between DUSs, since major train stations are then highly accessible.

Delimitation of DUSs and description of study area

With respect to the delimitation of DUSs, we follow the work by Vliegen (2004) who has identified twenty-two DUSs in the Netherlands. The delineation of DUS was carried out in two steps. First, the centre of each DUS was defined. With a GIS, built-up areas in close proximity (i.e. less than fifty metres apart) were merged together and adjusted to the municipal boundaries if the contiguous built-up areas accounted for more than fifty percent of the total municipal areas and the number of inhabitants. Furthermore, these areas had to have at least 50,000 jobs and 100,000 inhabitants to be qualified as a centre of economic activity. Second, areas under the influence of these economic centres were identified. A non-hierarchical cluster analysis was applied to commuting and migration data to identify mutual interconnectedness between the centre and its surrounding areas (VLIEGEN, 2004). In this study, we have employed the most recent boundaries of DUSs and applied these also to the earlier years to control for the possible outward extension of DUSs over time. We added the DUS of Hilversum, because it has an important role in the northern part of the Randstad (VAN DER LAAN, 1998). There were thus twenty-three DUSs in total.

Regarding our study area, four regions can be identified in the Dutch urban system, namely Randstad Holland, the Intermediate zone, the north and the east region, and the south region (Figure 1). First, the Randstad is the urbanised area in the western part of the Netherlands and comprises four major DUSs; they are densely populated and have economic specialisations particularly in advanced financial and business services (Table 2). More specifically, financial and business services and cultural activities are concentrated in Amsterdam; financial and business services and, to a lesser extent, healthcare in Utrecht; manufacturing, port activities, and logistics in Rotterdam; and governmental functions in The Hague (VAN DER LAAN, 1998; VAN DER WERFF *et al.*, 2005). Another difference between these four major DUSs is that the economic functions in Amsterdam are more internationally oriented than in the other three DUSs (ATZEMA and LAMBOOY, 1999). Based on economic orientation, two sub-regions of DUSs within the Randstad can be identified, namely the North Wing and the South Wing of the Randstad. Amsterdam and Utrecht are the major DUSs in the former, while The Hague and Rotterdam dominate the latter (Figure 1). Previous research has found that the North Wing of the Randstad is more polycentric than its South Wing counterpart (VAN DER LAAN, 1998).

(PLEASE INSERT TABLE 2 ABOUT HERE)

The Intermediate zone constitutes the second region; this consists of two parts. One is the Brabantse Stedenrij, a group of DUSs in the southern part of the Intermediate zone (Figure 1). The short physical distances could have led to the expectation that the interaction between the Brabantse Stedenrij and the Randstad would become more intense over time, as the former may have profited from the decentralisation of economic functions from the Randstad. The other part of the Intermediate zone comprises Zwolle, Apeldoorn, Arnhem, and Nijmegen. The latter two DUSs are closely related and together form the KAN region (Knooppunt Arnhem Nijmegen). In fact, Arnhem is one of the most densely populated DUSs outside the Randstad; Arnhem is economically specialised in financial business and services (Table 2). The third region is a group of DUSs in the south of the Netherlands, including Maastricht, a provincial capital that is specialised in tourism-oriented functions. The fourth region is located in the north and east of the Netherlands; it seems to lag behind other DUSs in an economic sense.

DEVELOPMENTS IN COMMUTING FLOWS

Trends at the national level

Summary statistics for the values of interaction indices are presented in Table 3. When the Netherlands is treated as one urban system, our results are indicative of an incremental development towards a fully polycentric system from 1992 onwards. Note that this development is not uniformly distributed across space, as the spatial variations in the spatial interaction dimensions and indices discussed below make clear.

(PLEASE INSERT TABLE 3 ABOUT HERE)

Regarding the strength dimension, the average dominance index values stabilised over the years concerned, which does not suggest a clear reduction in the differences among nodes in the urban system with respect to their importance (Table 3). Although the average DII_i values are close to one in every year, the medians and standard deviations suggest that there is a substantial variation around the average. This variation indicates that the system is not very close to a fully polycentric state and indicates the importance of considering all summary statistics in an assessment of the state of an urban system. The average strength of interaction per unidirectional link decreased from 1992 and then increased slightly between 1999 and 2002, as the RSI_{ij} values for these four years indicate. The lower values of the mean and standard deviation suggest that the differences among unidirectional links in terms of the strength of the interaction became slightly smaller over the years concerned. To verify this result, we plotted the RSI_{ij} values of all uni-directional links in ascending order and found that the distribution of RSI_{ij} values up to the 90th percentile was flatter from 1992 onwards. This finding suggests that the differences in the intensity of flows become smaller over the years so that development towards a more polycentric system is indicated. As with the dominance index, the differences in strength throughout the system (*EI*) have steadied over time. The *EI* values between 0.68-0.71 suggest that the distribution of the total interaction across links in the system is only moderate. At the node level, the distribution of intensity became on average more even until 1999 and declined slightly afterwards, as the EI_i values suggest. However, the *EI* and EI_i results do not provide clear evidence of a reduction in the hierarchical structure and development towards a fully polycentric system.

For the symmetry dimension, a decline in the hierarchical structure is more readily apparent than for the strength dimension. At the node level, the NSI_i values varied within a smaller range after 1992, as the standard deviations indicate, thereby implying that the differences between nodes decreased slightly. Further examination of the distribution of the NSI_i values reveals that the proportion of nodes with a net surplus remained the same for all years: about 30 percent. This finding suggests that this system can be characterised as a weakly centralised system, where six DUSs attracted more flows than they sent out over the period investigated. At the link level, the average level of link symmetry increased after 1992, although we see a moderate decline from 1999 to 2002. The distribution of LSI_{ij} values shows that the proportion of unidirectional links observed in the system was as high as 50 percent in 1992, but subsequently declined to around 30 percent. The result suggests that the interaction between DUSs became more reciprocal after 1992; however, on average links became less symmetrical again after 1999. This finding does not provide clear evidence of a development towards a fully polycentric system.

Pattern of interaction at the node and link levels

In Figure 3 we present some key results that contribute to further insights based on commuting flows into the development of the urban system (see Appendix 2[1] for the index values for individual DUS).The figure shows all the nodes in the system and a selection of the links between them. In the interests of readability, we have only depicted unidirectional links for which the RSI_{ij} values exceed a threshold of 0.05 percent of the total interaction in the system for a given year. The area of a node is proportional to the value of the dominance index: the larger the value, the more dominant is the node. From Figure 3, four subsystems can be identified within the national system: the Randstad; the south region; and two groups of DUSs in the southern and the northern part of the Intermediate zone, or the Brabantse Stedenrij and the KAN region respectively. Since the Randstad remains the backbone of the national system and the interactions within the Randstad are more intensive than in other regions (Figure 3), we discuss below the changing pattern of interaction within the Randstad during the ten-year period in somewhat greater detail.

(PLEASE INSERT FIGURE 3 ABOUT HERE)

The DII_i values show that the urban system is dominated by the four major DUSs within the Randstad: Amsterdam, The Hague, Rotterdam, and Utrecht (Figure 3). This finding suggests a positive relationship between the concentration of population and number of specialised opportunities (see Table 2). Although not reported here, we have examined whether changes in the number of inhabitants of DUSs and the changes in the importance of DUSs as reflected in the DII_i are positively correlated. This relationship was not statistically significant, however, suggesting that the growth of the population of a DUS does not necessarily imply more intensive interactions with other DUSs. In addition, the number of commutes received by Amsterdam is five times larger than the average received by other nodes in the system and the dominant position of Amsterdam increased slightly throughout the period concerned. Utrecht also became more dominant in the course of time. In 2002, the position of Utrecht was comparable with that of The Hague and Rotterdam; the changes in the degree of dominance of a node result in a sizeable gap between these three DUSs and Amsterdam in terms of the ability to attract workers from distant areas. The stronger positions of Amsterdam and Utrecht can be explained by the fact that these two DUSs are specialised in the financial and business services sector, which has experienced a dramatic growth in the Netherlands in the last decade owing to a change in the economic structure from traditional capital-intensive towards more advanced knowledge-intensive sectors (ATZEMA and LAMBOOY, 1999). Figure 4 shows that the financial and business services sector accounts for a considerable share of the employment in Utrecht and Amsterdam and grew markedly between 1996 and 2002[2]. Note that the results for DUSs outside the Randstad are combined and presented by region to enable us to focus on the DUSs' experience of a noticeable growth of employment in financial and business services. Furthermore, the rise in the share of commuters with a university degree from 21 percent in 1992 to 48 percent in 2002 (Appendix 1[1]) lends credence to our argument that the expansion of commuting between DUSs, and between Amsterdam and Utrecht in particular, tends to be connected to the growth of the services sector as exemplified by the financial and business firms, in which highly-educated workers are overrepresented.

(PLEASE INSERT FIGURE 4 ABOUT HERE)

In contrast, we did not observe a more important role for The Hague or Rotterdam. The dominance of The Hague has even declined. Rotterdam is still specialised in goods-related services; it has the lowest percentage of employment in business and financial services of the four major DUSs (Table 2). Since employees with higher income and education levels are the most likely to commute over long distances (LIMTANAKOOL et al., 2006a), this economic structure tends to attract fewer commutes from other DUSs. On the basis of the RSI_{ij}, we found that the interaction between DUSs in the North Wing became more complex over time than in its South Wing counterpart. As a consequence we see that, within the North Wing, Hilversum, Haarlem, Leiden and Amersfoort attracted more commutes from other DUSs in the years in question. Furthermore, we see an increase in absolute terms in the interaction between the North Wing and the South Wing of the Randstad, but the extent of this increase was much smaller than the growth of the interaction within the North Wing.

Within the Randstad, we can draw a clear distinction between the four major DUSs and the rest in terms of the node symmetry. The Hague and Amsterdam function as major receivers in the system, although the surplus in net interaction gained by these two DUSs decreased in the course of the years concerned. The role of Utrecht as a receiver became more apparent; in 2002, it stood at the same level as Amsterdam and The Hague. Rotterdam was found to be the only major DUS of the four functioning as a sender, although it was rather neutral in terms of net interaction in 2002. Leiden, Haarlem, Amersfoort, and Dordrecht are Randstad DUSs that function as major senders feeding commutes to the major DUSs; their role has remained the same over the years. This finding suggests that the type of employment (that is, highly-skilled) that can attract commutes from other DUSs is more concentrated in the four major DUSs in the Randstad than in the other DUSs (cf. Table 2). Outside the Randstad, Eindhoven is the only DUS functioning as a major receiver from 1995 onwards, presumably because of the concentration of high-tech firms and the technical university there.

With respect to the LSI_{ij}, every link between all four major DUSs within the Randstad became more symmetrical from 1992 onwards. The greatest improvement was found in the links between Amsterdam and Utrecht and between Amsterdam and The Hague. More generally, the average level of link symmetry between DUSs within the Randstad increased from 0.62 in 1992 to 0.79 in 2002. The reduction in the number of unidirectional links observed in the system (that is, $LSI_{ij}=0$) is one explanation of this. These figures are indicative of the increasing reciprocal relationships between nodes within the system.

Outside the Randstad, the DUSs of Geleen/Sittard, Maastricht, and Heerlen form a very stable subsystem in the south, because every DUS is fully connected to the other two and the interaction between them stabilised during the period investigated. The configuration of this subsystem is very close to the ideal type of the fully polycentric system. Nevertheless, this subsystem remains rather isolated, since no strong relationships were found between this subsystem and other DUSs in the national system during the period concerned. With respect to the Intermediate zone, the RSI_{ij} values do not suggest any increase in interaction between Brabantse Stedenrij and the Randstad within the period studied. However, further investigation has suggested that, in absolute terms, the interaction between the Randstad and the Intermediate zone became stronger over the years concerned, but that the strength of the interaction between the DUSs within the Randstad increased at a faster rate. We therefore see fewer connections between the Brabantse Stedenrij and the Randstad from 1995 onwards in Figure 3, which is based on relative numbers. Furthermore, the interaction within the KAN region is rather intense and became stronger over the years concerned. We did not, however, observe any development of a strong interaction between the KAN region and other DUSs in the larger system. Although not reported in the Table, we found an increase in the absolute amount of commutes sent from the KAN region to the North Wing of the Randstad, but the flows in the opposite direction did not increase. This contrast suggests a dependent relationship between the KAN region and the North Wing of the Randstad. The role of the DUSs that have not been discussed is only small; they remain rather isolated, at least according to the current data.

Summary of results

With respect to commute flows, the dominant position of the Randstad is clearly pronounced in the Dutch urban system. Amsterdam is the most dominant and it became more dominant during the period concerned, followed by The Hague, Rotterdam, and Utrecht. In general, the interaction between the DUSs became stronger, more symmetrical, and more evenly distributed in the course of time; but these developments were largely limited to DUSs within regions, suggesting that physical distances play an important part in the urban development process.

The results provide little evidence that, during the period investigated, the Brabantse Stedenrij, the KAN region, and the south region became integrated with the Randstad in relative terms. Taking all the findings into consideration, we can say that there is some evidence for a development towards a fully polycentric system in the Netherlands. However, this process takes place only very slowly, and the pace of the process at the national level is not as fast as at the regional level. This assertion is in line with the finding that urban systems exhibit a degree of persistence and continuity that is difficult to break (BATTY, 1998).

DEVELOPMENTS IN LEISURE FLOWS

Trends at the national level

To gain insight into the development of the urban system on the basis of leisure flows, we examined the distribution of the interaction indices values presented in Table 4. We find that the average DII_i values stabilised over the years concerned. At the link level, the strength of interaction per unidirectional link decreased between 1992 and 1995 and remained about the same thereafter. The EI values show that the total interaction between DUSs was fairly evenly distributed (EI = 0.66) across all links in the system in 1992 before becoming slightly more even and then declining from 1999 to 2002. The same trend was found for the individual nodes; the average value of EI_i increased from 1992 until 1999 and declined slightly thereafter. The results based on the strength dimension do not provide clear evidence of changes in the urban configuration towards a fully polycentric system.

(PLEASE INSERT TABLE 4 ABOUT HERE)

With regard to the symmetry dimension, the standard deviation of the NSI_i values narrowed after 1992, but widened again from 1999 to 2002, so that the data do not provide unambiguous evidence for a development towards a fully polycentric system (Table 4). Further examination revealed that the proportion of nodes with a surplus in net flow and of those with a deficit in net flow remained about the same throughout the period investigated, suggesting that this system can be characterised as a more decentralised system than that for commuting. Perhaps the opportunities and facilities attracting leisure trips over longer distances are more evenly distributed across DUSs than employment opportunities. This would not be surprising, since DUSs can offer a wide range of leisure activities ranging from historical and cultural amenities and entertainment facilities to nature areas such as the coastal and nature parks.

At the link level, the average LSI_{ij} values increased after 1992, but decreased again from 1999 to 2002. The median and the distribution of the LSI_{ij} values suggest that this result was brought about by the large number of unidirectional links in the system. We can assert that the result does not provide strong evidence suggesting a development towards a fully polycentric system on the basis of this index. This assertion is supported by the standard deviation, which shows that the variation in LSI_{ij} values remained the same during the period investigated.

Pattern of interaction at the node and link levels

Figure 5 shows that, as with the commuting system, the leisure system was dominated by the Randstad throughout the period investigated; the interaction between DUSs located within the Randstad was more intensive than elsewhere. The DII_i values show that the dominant nodes (those with DII_i values greater than one) are all located in the Randstad (see Appendix 2[1] for index values for individual DUSs). This dominance might relate to the larger concentration of urban facilities and population in this part of the country. As with commute flows, we do not find statistically significant positive relationships between population change in the DUSs and the changes in the importance of DUSs (DII_i) over the period investigated. Within the Randstad, the role of Amsterdam and Utrecht in attracting leisure trips improved the most: their DII_i values in 2002 were double those of 1992. The important role of Amsterdam and Utrecht as leisure destinations can be explained by the fact that they are historical cities with a unique ambience; they accommodate many cultural activities and also major shopping centres. The economic prosperity of these DUSs may also encourage the growth of urban leisure facilities within them. The way in which groups of museum and historical sites in Amsterdam and Utrecht have marketed themselves jointly could explain the strengthening of the position of these cities as main leisure destinations. Furthermore, their central location in the motorway and train networks makes them even more attractive as leisure destinations. Haarlem and Hilversum also play an important part as major destinations for leisure trips in the system. These two DUSs contain large recreational areas and offer a wide range of outdoor activities (cf. Table 2). The coastal areas in the western part of Haarlem also attract many visitors from other DUSs.

(PLEASE INSERT FIGURE 5 ABOUT HERE)

Figure 5 suggests that the DUSs within the urban system were reasonably well connected in 1992, particularly within the Randstad and between the Randstad and the Intermediate zone. However, considering the relative number of leisure trips, the divisions between regions became sharper during the ten-year period. Further investigation suggests that the strength of interaction between DUSs within the North Wing of the Randstad grew faster than interactions between other DUSs. The DUSs located in different regions were therefore less strongly related to one another in relative terms, as Figure 5 shows. Further analysis has shown that there was also a reduction in the absolute number of trips from the Randstad to the Intermediate zone, suggesting that the Randstad and the Intermediate zone became less firmly connected during the time period investigated. The growing importance of interaction within regions might result from individuals increasingly fulfilling their needs at shorter distances from their home base and becoming more reluctant to travel longer distances for leisure purposes. There are at least two possible explanations for this tendency.

First, people tend to work longer hours (BREEDVELD and VAN DEN BROEK, 2003), reducing the time available for leisure activities, particularly for sports, shopping, and so forth at long distances from home. The increasing shares of highly-educated travellers and full-time workers from 1992 to 2002 (Appendix 1[1]) also support this assertion. Other research using national data has shown that highly-educated individuals and those employed full-time have longer working hours and commute times than other social groups, implying that the former have smaller weekly time budgets for leisure activities (SCHWANEN *et al.*, 2004; VAN DEN BROEK *et al.*, 2004). There may also be an indirect effect; even people working the same number of hours as they did ten years ago may be less willing to engage in leisure activities at a great distance from home if their partner works longer hours; leisure trips over long distances are usually undertaken jointly with other people (LIMTANAKOOL et al., 2006b). Second, the opportunities and facilities for leisure activities available in DUSs may have become more equally distributed over the years. People who used to travel may become able to visit similar facilities and services not too far from where they reside.

Of the four major DUSs, the NSI_i suggests that Utrecht functions mainly as a receiver, since it has gained a larger surplus of net flow over the years. Despite the finding that the role of Rotterdam fluctuates from year to year, in 2002 it had a major role as a receiver, together with The Hague. Amsterdam is the only major DUS of the four that functions as a sender. The large outgoing flow reflects the large concentration of population in Amsterdam. We find that the Haarlem area is the major destination for travellers residing in Amsterdam, presumably because Haarlem contains the largest recreational area in the North Wing of the Randstad (Spaarnwoude); visitors are offered coastal areas and a wide range of outdoors activities.

Outside the Randstad, we find that the importance of (most) DUSs in the Intermediate zone and the north and the east region declined over the years in question in both relative and absolute terms. The three DUSs in the south of the country interact with one another intensively and constitute a subsystem. We did not, however, observe any strong interaction between regions for the period investigated. Furthermore, we found that symmetrical interaction is largely confined to the links within the region. For every region, the average level of link symmetry within it increased from 1992 and declined from 1999 to 2002.

Summary of results

Our results provide little evidence of any development towards a fully polycentric system between 1992 and 2002 with respect to leisure flows as far as the national level is concerned. Physical distances still play an important part, since intense interaction continues to be confined largely to DUSs in close proximity of each other. As with commuting, there are four subsystems within the national system: the Randstad, the Brabantse Stedenrij, the KAN region, and the southern region. We found that Amsterdam continued to dominate the system, but less markedly so than in the commuting system. The pattern of interaction was also different; the interaction was more concentrated within the region, particularly in the North Wing of the Randstad, and the interaction between regions became less important in relative terms, suggesting that the urban system had become more fragmented. Outside the Randstad, Maastricht, Geleen/Sittard, and Heerlen constituted a stable subsystem during the whole study period, but remained rather isolated from other DUSs. Other DUSs in the north and the east region were also isolated during that time.

CONCLUSIONS AND DISCUSSION

Using the 1992, 1995, 1999, and 2002 Netherlands National Travel Surveys, we examined the developments in the Dutch urban system on the basis of commute and leisure flows between twenty-three DUSs. We took a comparison-in-time perspective and monitored the pattern of interaction via the 3 S-dimensions over a ten-year period: strength, symmetry, and structure.

For commute flows, we saw some development towards a fully polycentric system, but the developments within regions took place at a faster pace than between regions. Although we observed an increase in the level of interaction in absolute terms during the years in question, in a relative sense this development was more apparent for the symmetry than the strength dimension. The Randstad was identified as the most important subsystem; it dominated the national system. The subsystem in the south of the country was found to be fairly stable and its configuration similar to that of the ideal polycentric system. The other subsystems that were identified were the Brabantse Stedenrij and the KAN region. However, the relationship between the subsystems was poorly developed and failed to become stronger in relative terms.

Unlike the commute flows, the results for leisure flows provided little evidence that the urban system had developed towards a fully polycentric system at the national level. In fact, the results suggested that the divisions among regions became sharper. Certain links became stronger and more symmetrical, but these were between DUSs in close proximity of one another. The Randstad also dominated the national system for this trip purpose for the period investigated. The other subsystems are the south region, the Brabantse Stedenrij, and the KAN region. In most of these cases, commute and leisure flows did not produce the same pattern of change; the leisure system was more decentralised and fragmented than the commuting system, which underlines the advisability of analysing leisure trips as a separate category.

Taken together, the results provide some evidence that the configuration of the Dutch urban system has evolved in the direction of a fully polycentric system. The development is more apparent at the regional level, particularly within the Randstad, than at the inter-regional level. We should, however, bear in mind that these findings are based only on flows of people. Different types of flow may produce different patterns of interaction between DUSs.

Three main reasons underlying the limited development towards a fully polycentric system can be put forward. First, our time-scale of a ten-year period in this study is rather short; changes in urban configurations are often incremental and take a very long time span before they can be clearly recognised (BATTY, 1998). Second, the physical distance still plays an important part in determining human corporeal interaction. The distance travelled for the trips analysed, particularly commuting, is inherently coupled to the fact that individuals have to make a return trip to the origin, which is usually their home base. This situation is referred to as *the principle of return* (ELLEGARD and VILHELMSON, 2004). Furthermore, dramatic growth in road congestion and delays in the public transport networks in the last decade (AVV TRANSPORT RESEARCH CENTRE, 2004b) may have discouraged (the growth of) human corporeal interaction over long distances in the Netherlands (see Jarvis (2005) for similar arguments based on an in-depth study of two-earner families in Greater London).

Third, the limited development might have resulted from a change in the travellers' time allocation. In the period investigated, the share and distance travelled of commuting trips between DUSs increased, while the opposite was observed for leisure trips. There seems to be a trade-off between travelling longer distances for employment and shorter distances for leisure activities. The increasing shares of highly educated and full-time employed individuals among leisure travellers support this assertion, as these travellers in particular tend to experience more time pressure and hence spend less time on leisure activities over long spatial distance. This finding requires further verification, however, since the trade-off pattern may be also brought about by the change in the nature of leisure activities pursued (visiting urban amenities which can be found in the vicinity of where they reside rather than travelling further away to the natural areas, for example). The data currently used, however, did not allow for this type of analysis.

Our results, and the potential reasons underlying the limited urban development, suggest some policy implications. First, promoting functional economic specialisation such as financial services or tourism in urban nodes is important to stimulate polycentric development. The specialisation of urban nodes appears to be associated with their ability to attract trips from other areas, as observed in the four major DUSs in the Randstad. Second, good transport connections between distinct areas are necessary but may not be sufficient to encourage the human corporeal interaction over long spatial distances. Following this line of argument, the expectation that 'If, during the next decade, Randstad Holland manages to halve travel time between its large urban centres, the region would function as one coherent economic entity' (REGIO RANDSTAD, 2004, page 21) may appear to be a sanguine view. What ties people to particular places today is not so much insurmountable travel costs or the lack of means of transport, but social and interpersonal relationships (ELLEGÅRD and VILHELMSON, 2004). Better insight is therefore required into the activity patterns of individuals at the micro level to obtain further knowledge of polycentric developments at the macro level. Furthermore, it is also important to gain better understanding of the drivers of the dynamics in urban systems. For this purpose, the results of the current analysis could be extended by, for instance, examining changes in the dominance of urban nodes in relation to changes of some potential explanatory variables, such as the economic prosperity of urban nodes (e.g. GDP per capita) and the socioeconomic characteristics of inhabitants in the DUS (e.g. occupation) over the course of time.

NOTE

1. http://researchgroup.geo.uu.nl/45/content/appendix1-3_limtanakool_070207.pdf

2. Although LISA data from before 1996 are also available, they cannot be compared readily to those from 1996 onwards because of changes in the data collection methods implemented in that year.

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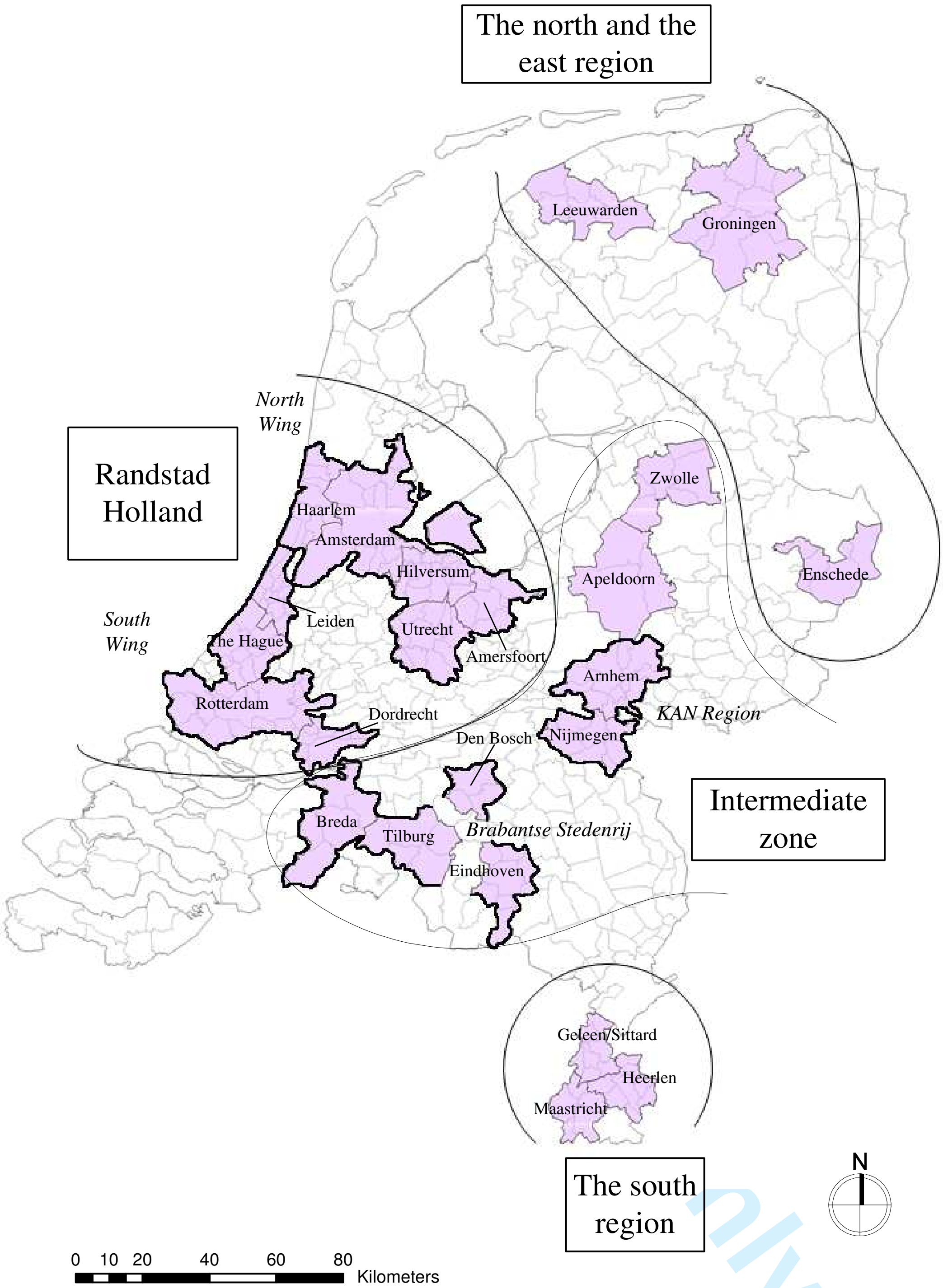


Figure 1 Twenty-three DUSs in the Netherlands

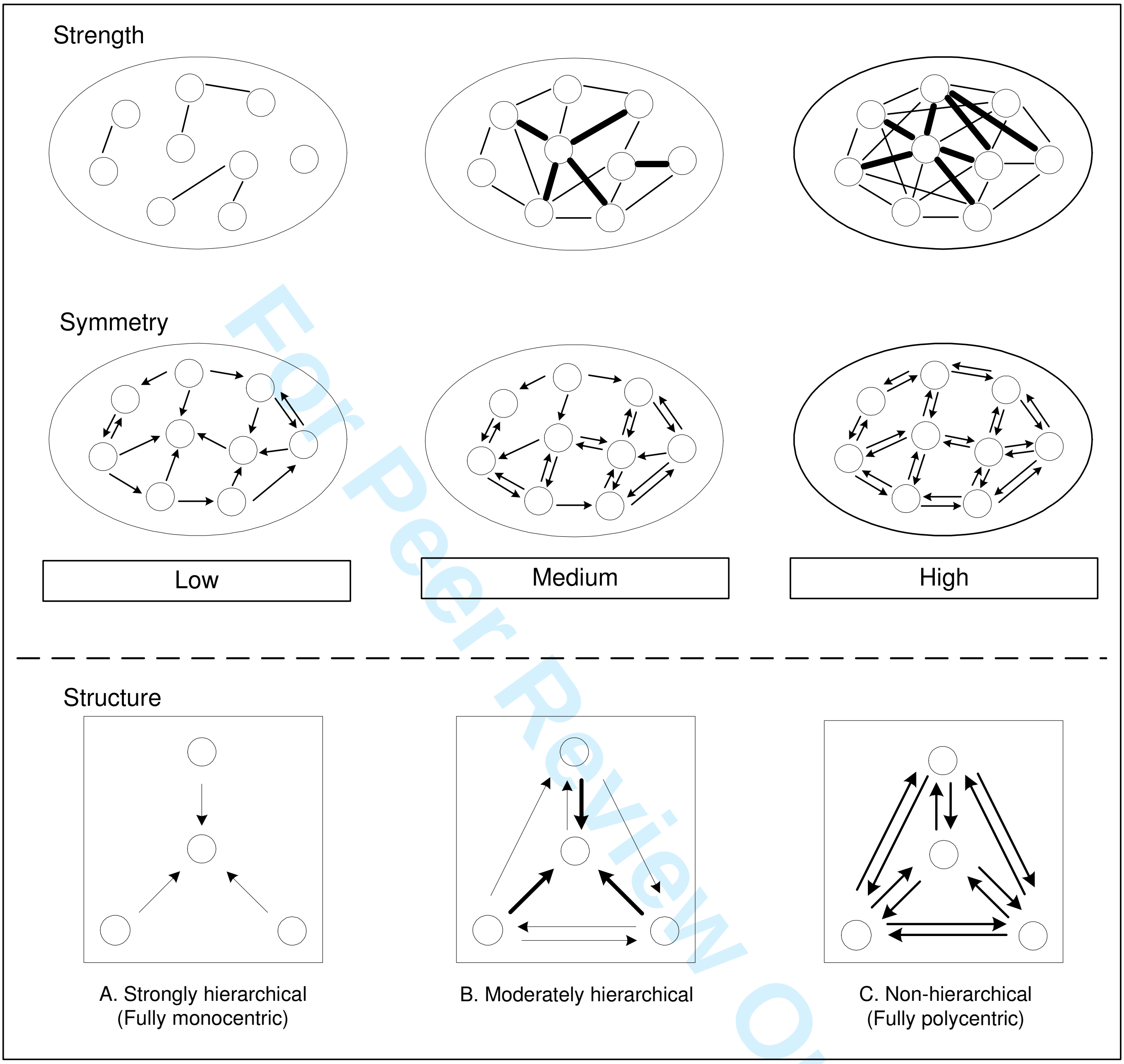


Figure 2 Three dimensions of spatial interaction

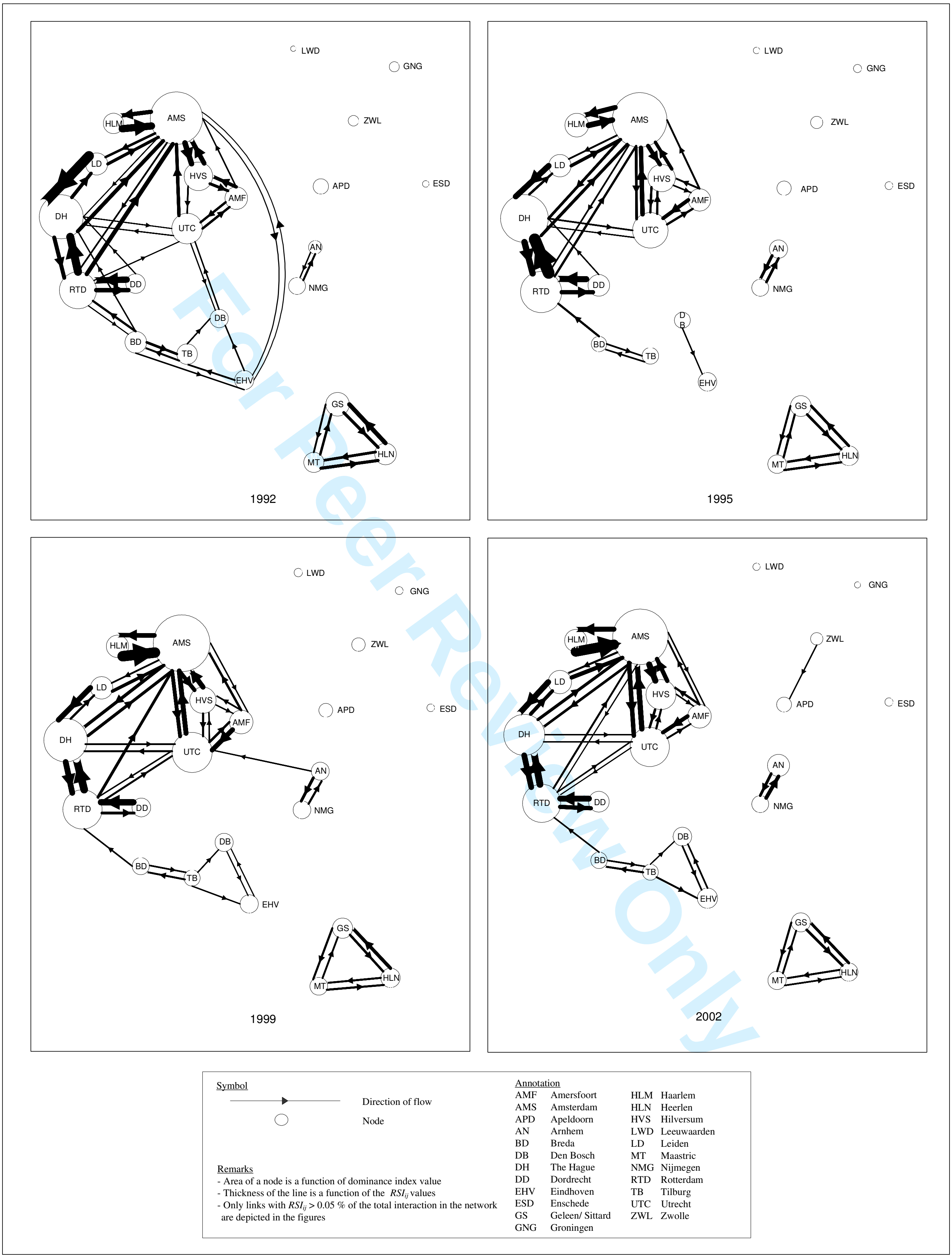
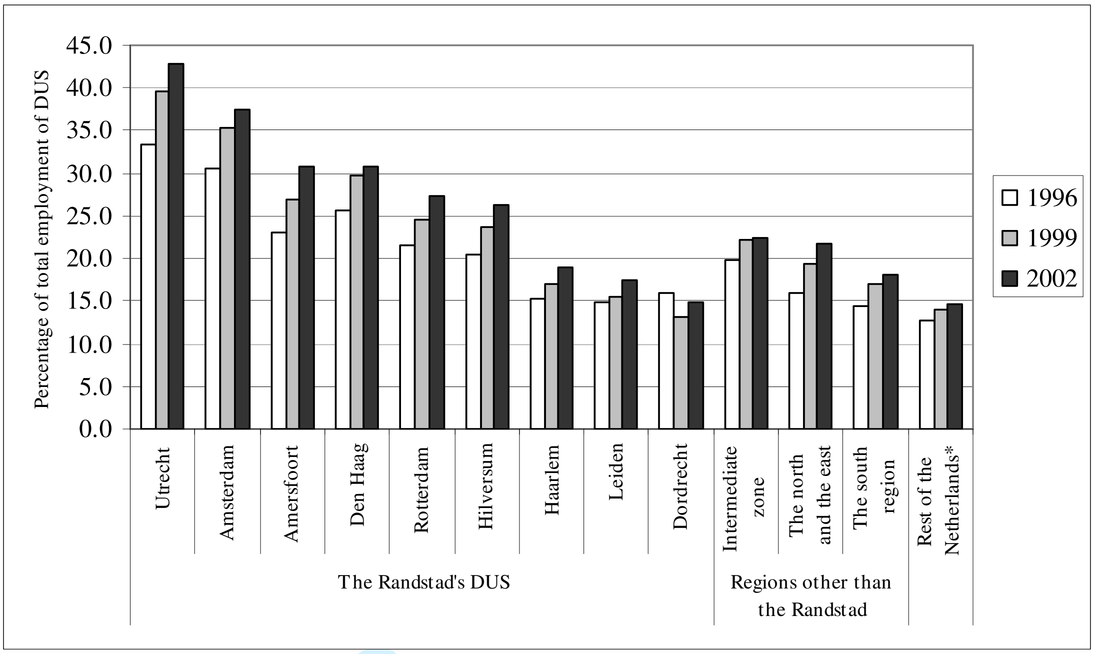


Figure 3 Commuting flows between DUSs in the Netherlands, 1992-2002



* Areas outside the twenty-three DUSs

Figure 4 Growth of employment in financial and business services: 1996-2002

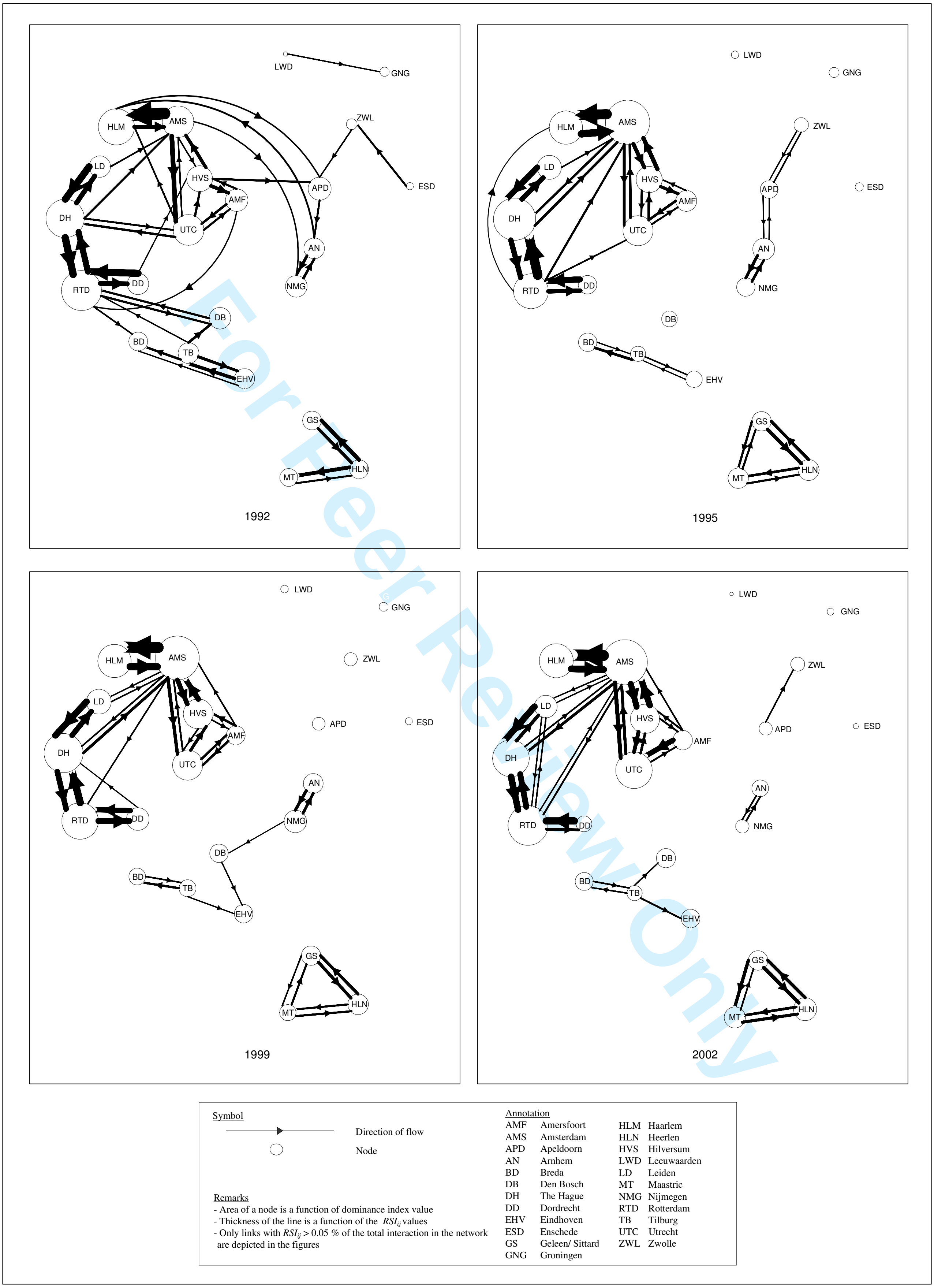


Figure 5 Leisure flows between DUSs in the Netherlands, 1992-2002

Table 1 Spatial interaction indices: Description, formula and their relations with dimensions of spatial interaction

	Relative Strength (RSI_{ij})	Dominance (DII_i)	Entropy (EI and EI_i)	Node Symmetry (NSI_i)	Link Symmetry Index (LSI_{ij})
Equation	$RSL_{ij} = \frac{T_{ij}}{\sum_{i=1}^{I}\sum_{j=1}^{J} T_{ij}}$	$DII_i = \frac{I_i}{\left(\sum_{j=1}^{J} I_j \middle/ J\right)}$	$EI = -\sum_{i=1}^{L} \frac{(Z_l)Ln(Z_l)}{Ln(L)}$ $EI_i = -\sum_{j=1}^{J} \frac{(x_l)Ln(x_l)}{Ln(J-1)}$ for z,x = 0 holds that (z,x)Ln(z,x) = 0	$NSI_{ij} = \frac{\sum I_i - \sum O_i}{\sum I_i + \sum O_i}$	$LSI_{ij} = -\left(\frac{(f_{ij})Ln(f_{ij}) + (f_{ji})Ln(f_{ji})}{Ln(2)}\right)$
Min/ Max value	$0 \leq RSI_{ij} \leq 1$	$0 \leq DII_i < \infty$	$0 \leq EI$ and $EI_i \leq 1$	$-1 \leq NSI_i \leq 1$	$0 \leq LSI_{ij} \leq 1$
Relations between dimension of spatial interaction and indices					
Strength	-	0: a node does not involve in the network →∞: a node dominating the network as every interaction in the network is associated with this node	0: flow is concentrated on only one link 1: flow is evenly distributed across all links in the network/ or all links attached to a given node	-	-
Symmetry	-	-	-	-1: a node is asymmetrical by having a maximum deficit of net flow 0: a node is fully symmetrical in terms of its net flow 1: a node is asymmetrical by having a maximum surplus of net flow	0: a link is fully asymmetrical. An interaction only exists in one direction 1: a link is fully symmetrical. There is two-way interaction and the flows in each direction are equally large
Structure	A RSI_{ij} value of 1 for one link and RSI_{ij} values of 0 for all the other links, means that all interaction is concentrated on one link in the network. A network does not have a hierarchical structure when every link in the network has equal value of RSI_{ij}	A network does not have a hierarchical structure when every node in the network is associated with equally large flows or every node has a DII_i value of 1	A network does not have a hierarchical structure when every link in the network is equally strong. This corresponds to the situation in which the system has a EI value of 1 and every node has a EI_i value of 1.	A network does not have a hierarchical structure when every node in the network has $NSI_{ij} = 0$	A network does not have a hierarchical structure when every link has $LSI_{ij} = 1$

Denotation

l	*Link in the network (l=1,2,3,…,L)*
Z_l	*Proportion of journeys on link l in relation to the total number of journeys in the network*
I_i,I_j	*The number of inward journeys to node i and j*
T_{ij}	*The number of journeys from node i to j*
O_i	*The number of outward journeys from node i*
f_{ij}	*The proportion of journeys on the link from node i to node j in relation to the total number of journeys between node i and j*
f_{ji}	*The proportion of journeys on the link from node j to node i in relation to the total number of journeys between node i and j*
X_l	*The proportion of flow on link l in relation to the total flow on links connected to node i*
i, j	$i = 1, 2, 3, \ldots, I; j = 1, 2, 3, \ldots, J; \text{for } i \neq j$

Table2 Total population and composition of employment for individual DUSs in 2002 (shares in percentages of total employment per DUS)

	Total population in 2001 (1000s)	Financial and business services	Cultural and recreational activities	Governmental functions	Health care	Logistics and port activities	Manufacturing
DUSs within the Randstad							
Amsterdam	1394	27.3	5.4	5.2	11.3	12.1	5.7
The Hague	755	23.5	6.1	15.9	13.4	6.7	4.4
Rotterdam	1224	21.5	3.9	4.8	13.4	10.7	8.0
Utrecht	542	30.0	4.7	4.9	14.6	5.7	4.7
Amersfoort	257	23.6	4.2	5.0	12.0	5.1	8.9
Dordrecht	240	13.0	3.6	5.1	13.2	6.9	11.0
Haarlem	369	15.9	5.4	5.5	16.9	4.5	13.6
Hilversum	253	20.8	11.9	3.4	15.4	3.6	9.9
Leiden	329	14.9	3.5	5.4	20.0	3.4	9.8
DUSs outside the Randstad							
Apeldoorn	211	19.3	4.6	10.6	15.1	4.0	10.3
Arnhem	345	21.7	4.7	8.4	15.6	5.8	7.3
Breda	300	15.9	3.9	7.0	14.4	5.4	13.2
Den Bosch	184	21.4	3.6	7.5	13.0	5.5	7.1
Eindhoven	386	23.4	3.3	2.8	10.9	5.5	16.1
Enschede	305	14.6	3.6	5.2	14.6	4.9	15.8
Geleen/Sittard	155	13.4	3.1	3.1	12.2	6.2	18.5
Groningen	335	19.8	3.9	7.7	17.9	5.0	7.1
Heerlen	267	15.6	4.5	7.8	16.5	4.5	11.4
Leeuwarden	156	19.7	4.8	10.8	16.8	4.5	8.4
Maastricht	186	16.3	4.4	5.8	16.5	8.2	10.9
Nijmegen	271	13.2	4.2	4.7	22.2	5.1	11.6
Tilburg	283	12.6	4.1	6.1	15.5	7.1	14.2
Zwolle	199	14.8	3.4	6.4	16.1	9.4	8.0
Total population in NL	15827	-	-	-	-	-	-
Percentage of employment in NL*	-	18.1	4.4	5.9	13.8	6.8	11.0

*Share in percentage of total employment in the Netherlands as a whole, not only in the DUSs

Own calculation based on LISA and CBS data obtained from Milieu en Natuur Planbureau

Table 3 Means, medians, and standard deviations of interaction indices for commute flows

	Commute			
	1992	1995	1999	2002
RSI_i				
Mean	0.007	0.004	0.003	0.004
Median	0.004	0.001	0.001	0.001
Standard deviation	0.010	0.008	0.007	0.008
DII_i				
Mean	1.05	1.06	1.06	1.05
Median	0.74	0.58	0.57	0.61
Standard deviation	1.13	1.26	1.27	1.19
EI_i				
Mean	0.43	0.52	0.54	0.48
Median	0.44	0.55	0.59	0.49
Standard deviation	0.17	0.16	0.14	0.16
EI	0.68	0.69	0.71	0.69
NSI_i				
Mean	-0.04	-0.06	-0.07	-0.06
Median	-0.10	-0.06	-0.08	-0.06
Standard deviation	0.26	0.15	0.18	0.17
LSI_i				
Mean	0.44	0.59	0.61	0.54
Median	0.00	0.88	0.88	0.78
Standard deviation	0.46	0.45	0.44	0.45

Table 4 Means, medians, and standard deviations of interaction indices for leisure flows

	Leisure			
	1992	1995	1999	2002
RSI_i				
Mean	0.010	0.004	0.004	0.005
Median	0.005	0.001	0.001	0.002
Standard deviation	0.011	0.008	0.008	0.009
DII_i				
Mean	1.03	1.03	1.03	1.04
Median	0.84	0.70	0.69	0.68
Standard deviation	0.79	0.94	0.91	1.01
EI_i				
Mean	0.34	0.53	0.54	0.46
Median	0.41	0.54	0.54	0.49
Standard deviation	0.18	0.15	0.16	0.15
EI	0.66	0.70	0.70	0.68
NSI_i				
Mean	0.02	-0.02	-0.02	-0.04
Median	0.00	-0.01	0.00	0.06
Standard deviation	0.37	0.15	0.13	0.26
LSI_i				
Mean	0.38	0.54	0.51	0.41
Median	0.00	0.78	0.80	0.00
Standard deviation	0.45	0.45	0.46	0.45