🏆 *reviewed paper*

Emergence of suburban employment centres in German metropolitan regions: Impacts on commuter traffic, 1987-2007

Dennis Guth

(Dipl.-Geogr. Dennis Guth, TU Dortmund University, Faculty of Spatial Planning, Department of Transport Planning, August-Schmidt-Str. 10, D-44227 Dortmund, dennis.guth@tu-dortmund.de)

1 ABSTRACT

Over the past decades metropolitan areas became increasingly decentralised. The relocation of workplaces to suburban places has given rise to the emergence of 'new' employment centres, which generally reflect the multicentric nature of an urban landscape. The literature frequently claims that the formation of such centres shortens average commuting distances as people tend to relocate near or even within subcentres. Our results suggest that the majority of people did not come closer to their jobs, as the average journey-to-work distances significantly lengthened over time. Moreover, we can not find decreasing shares of suburb-to-core-city commutes, making us argue that factors other than intrametropolitan jobs-housing-proximities strongly influence where employees reside.

2 INTRODUCTION

During the last couple of decades metropolitan areas have experienced a rapid deconcentration of economic activities to suburban places. A review of empirical studies shows that the emergence of multicentric urban configurations occurred in many metropolitan regions throughout Europe, Asia and the USA. The results indicate that increasingly higher shares of metropolitan employment are concentrated in suburban clusters, nodes or edge cities outside the traditional urban cores (Anas/Arnott/Small 1998). Spatially, these 'new' centres are frequently located in the periphery along or in close vicinity to motorways. Functionally, they mostly do not include all functions of traditional urban centres. They rather may be specialised as office or retail locations (Einig/Guth 2005; Garreau 1991; Giuliano/Small 1991).

One of the recurring topics of this discourse is the interrelation between decentralised employment growth and the development of commuting patterns over time. The impact of subcentring on the journey-to-work has already been addressed in numerous papers (e.g. Alpkokin et al. 2005; Cervero/Wu 1998; Giuliano/Small 1991; Muller 1976; Parolin 2006). However, the evidence is disputed and far from being conclusive:

- Given the existence of a decentralised population within metropolitan regions makes some researchers argue that the suburbanisation of the labour force brings jobs and workers closer together. The spatial convergence of employment and housing locations goes hand in hand with higher shares of intrasuburban commuter flows which are usually associated to be shorter both in terms of times and distances (e.g. Lee/Seo/Webster 2006), thereby leading to more sustainable trip patterns within urban areas (e.g. Crane/Chatman 2003).
- Another strang of papers observed an increase in commuting in terms of distances, durations and/or volumes. These studies have shown that workers living within or close to subcentres do not necessarily have shorter commutes (e.g. Aguilera 2005); partly a reason of a growing number of dual-earner couples who usually fail to both relocate close to their working place (e.g. Cervero 1989). Moreover, some authors argue that restrictive urban land use regulations may prevent people from relocating closer to their workplace (exclusionary zoning hypothesis). As suburban municipalities often do not pursue a coherent policy with regard to jobs and housing aspects, urban spatial structures that minimise commuting may hardly emerge (e.g. Muller 1976).

While recent empirical research on the interrelation of employment suburbanisation and commuter traffic mostly focuses on US (e.g. Yang 2005), French (e.g. Aguilera 2005) and Dutch (e.g. Schwanen et al. 2004) metropolitan regions, there is a striking research gap regarding German literature (exceptions are: Guth et al. 2010; Siedentop 2007). The DFG/SNF-funded research project 'Spatial accessibility and the dynamics of commuting in Germany and Switzerland, 1970-2005' aims to contribute to this topic. The paper presents findings from our research. It examines the following hypotheses with a focus on German metropolitan regions:

- The deconcentration of workplaces to suburbia goes along with a 'decoupling' of the periphery from the traditional urban cores and leads to stronger internal linkages within suburban areas.

- The emergence of suburban employment centres is an outcome of the 'infill' of workplaces in the periphery of metropolitan areas. These centres are – besides the historic urban cores – privileged areas of attraction for commuters and might increase the probability of finding a job near or even within the place of residence. Multicentric urban configurations may therefore generate more travel-efficient commuting trip patterns across metropolitan regions ('co-location' hypothesis).

3 DATA

To examine the hypotheses described above, we use data on commuter flows provided by the Federal Statistical Office (German Census 1987) and the Federal Employment Agency (German Social Security Statistics 2007). The data contain information about in-, out- and internal commuting trips at the spatial scale of municipalities. In both data sets a commuter can be identified by the spatial separation of jobs and housing locations. All persons who do not work and live within the same municipality are considered to be crossmunicipality commuters. There is only in- and out-commuting if an employee crosses at least one municipal boundary on his/her way to work. If no boundary crossing occurs, the person is classified as local (internal) commuter. Both commuting matrices have been validated extensively during our prior work and a weighting factor for daily and periodically (non-daily) commuting activities has been introduced. The share of daily commuting trips by distance (km) has been deducted from the Census 1987. In the following sections we only consider daily commuting activities to avoid the distorting effect of long-distance commuting trips. Furthermore, we only consider employees subject to social insurance contribution due to missing information about self-employed and public servants in the commuter matrix of 2007.

4 DELINEATION OF METROPOLITAN REGIONS

Our study requires the identification of metropolitan areas as a framework for analyses. In the German spatial science literature the assignment of metropolitan boundaries frequently relies on the use of a-priori circular shapes (e.g. 60 km) using GIS-applications to buffer the administrative boundaries of the urban cores (e.g. Siedentop 2007). Several other studies use threshold values of in- and out-commuting intensities for describing the spatial expansion of commuter catchment areas of urban centres[1] (e.g. Herrmann/Schulz 2005). Our approach is similar to the functional definition of commuting regions proposed by the German Federal Office for Building and Regional Planning (BBR 2005). The delineation refers to the year 2007 and works as follows:

- *Identification of metropolitan cores*: First, metropolitan cores have been defined as municipalities having more than 500.000 inhabitants.
- *Identification of second order core cities*: All cities which have above 100.000 inhabitants have been defined as second order core cities. The metropolitan cores and the second order core cities constitute the set of large cities. All other municipalities have been classified as 'potential' suburban municipalities.
- *Identification of large cities' catchment areas*: The out-commuting intensity[2] values of all 'potential' suburban communities to large cities have been calculated using the commuter flow matrix of the year 2007. We checked for different cut-off values ranging from 5% to 10% of all workers within a municipality. The choice of the cut-off point generally determines size and expansion of an urban area (Killer/Axhausen 2009). After a systematic comparison of the different boundaries we finally decided to use the 7,5% threshold value as cut-off level for further analyses.
- *Creation of functional commuting regions*: All communities exceeding the 7,5% threshold value have been classified as suburban municipalities; all other municipalities have been classified as peripheral (non-metropolitan) communities, which had to be excluded from further delineation. In a last step, we finally allocated all suburban municipalities to their respective commuting regions by (i) selecting all commuting flows to large cities and (ii) comparing their values with regard to their out-commuting intensities. After having identified the prevailing flow to a respective large city (highest intensity) we finally were able to define a suburban municipality as being part of a specific commuting region.

[1] This method has also been carried out for US metropolitan regions (e.g. Berry/Gillard 1977).
[2] The out-commuting intensity is the share of out-commuters among all workers (employed residents) within a specific municipality.

Following this approach, we identified eight metropolitan regions with the core cities of Bremen, Hamburg, Hanover, Frankfurt a.M., Munich, Nuremberg, Rhine-Ruhr (= Cologne, Dortmund, Düsseldorf, Essen) and Stuttgart. Moreover, we identified 15 secondary urban areas. As metropolitan regions generally have enlarged over time (expanding commuter sheds), we decided to take a fixed boundary-delineation, as is often the case in this type of studies (e.g. Aguilera 2005).

Following this approach, we identified eight metropolitan regions with the core cities of Bremen, Hamburg, Hanover, Frankfurt a.M., Munich, Nuremberg, Rhine-Ruhr (= Cologne, Dortmund, Düsseldorf, Essen) and Stuttgart. Moreover, we identified 15 secondary urban areas. As metropolitan regions generally have enlarged over time (expanding commuter sheds), we decided to take a fixed boundary-delineation, as is often the case in this type of studies (e.g. Aguilera 2005).

Table 1 provides some key statistics highlighting structural differences among the metropolitan regions. The spatial expansion of the catchment areas and the location of large cities are shown in figure 1. Because of missing data (1987) with regard to workplaces, workers and commuter flows we were not able to delineate the metropolitan areas of the former German Democratic Republic. In the remainder of this paper, we only consider the municipalities of the West German 'Bundesländer'.

Region	Number of municipalities	Overall area [km²]	WP 1987	WP 2007	ER 1987	ER 2007
Bremen	154	8.977	565.612	605.072	577.350	593.170
Frankfurt a.M.	428	9.244	1.599.571	1.634.727	1.548.888	1.520.332
Hamburg	525	10.677	1.185.710	1.259.426	1.178.400	1.210.022
Hanover	192	8.063	820.442	800.642	813.259	778.614
Munich	379	11.401	1.301.749	1.443.504	1.264.563	1.353.870
Nuremberg	186	6.389	609.920	636.806	594.986	611.804
Rhine-Ruhr	287	19.027	4.255.851	4.129.819	4.227.938	4.063.783
Stuttgart	281	7.133	1.420.016	1.424.284	1.370.246	1.350.223
Other urban areas	1.714	45.106	3.919.750	4.191.808	3.901.571	4.062.801

WP: workplaces; ER: employed residents

Tab. 1: Structural data of the German metropolitan regions (Source: Own computations. Data taken from the German Census 1987 and the German Social Security Statistics 2007)

5 IDENTIFICATION OF SUBURBAN EMPLOYMENT CENTRES

Our study requires the identification of suburban municipalities which have above-average employment stockings. Prior studies have defined suburban centres in several different ways. Some papers use threshold values of employment densities and total employment, considering a subcentre to be a zone or municipality above a given minimum cut-off (e.g. Anderson/Bogart 2001; Giuliano/Small 1991; Giuliano et al. 2005; McDonald 1987). Others suggest more sophisticated approaches to avoid pre-defined (arbitrary) cut-off points. For instance, McMillen (2001) uses non-parametric estimation techniques to identify suburban centres as local peaks in employment density functions. A similar approach has been discussed in Craig/Ng (2001) showing the application of non-parametric specifications for the metropolitan area of Houston (Texas). Other studies refer to the use of spatial autocorrelation techniques to explore regional employment concentrations higher than the mean. The empirical application of such statistics has recently been shown for a selection of four Belgian cities (Riguelle/Thomas/Verhetsel 2007).

This paper follows the approach described in Parolin/Kamara (2003) and Parolin (2006). The methodology has been carried out twice for the metropolitan area of Sydney and works as described subsequently:

- In a first step we need to identify 'potential' subcentres for use in further analyses. A 'potential' subcentre can be defined as (suburban) municipality which has an employment stocking that is significantly higher than the national mean. The identification of above-average employment concentrations is based on the calculation of standardised employment values (z-scores). For each municipality employment data were thus standardised by subtracting the mean of all municipalities from its employment value and dividing the difference by the standard deviation. The body of municipalities which have values higher than 0 were then considered as 'potential' subcentres. In doing so, we identified 1.183 'potential' centres in 1987 and 1.313 in 2007.

- In a second step we confined the set of 'potential' centres by selecting only those municipalities which have a ratio of workplaces to workers (employed residents) greater than 1 resulting in 610 centres in 1987 and 680 in 2007. That means we only considered a municipality to be a subcentre if the respective community exhibits a surplus of in-commuters, indicating a superior attraction for employees. Furthermore, we only included those municipalities which have their location within the boundaries of the metropolitan regions as defined in section 4. After further having reduced the set of subcentres we finally identified 202 subcentres in 1987 and 265 in 2007. All other municipalities within the catchment areas' boundaries (except for the large cities) were assumed to be non-(sub)centres.

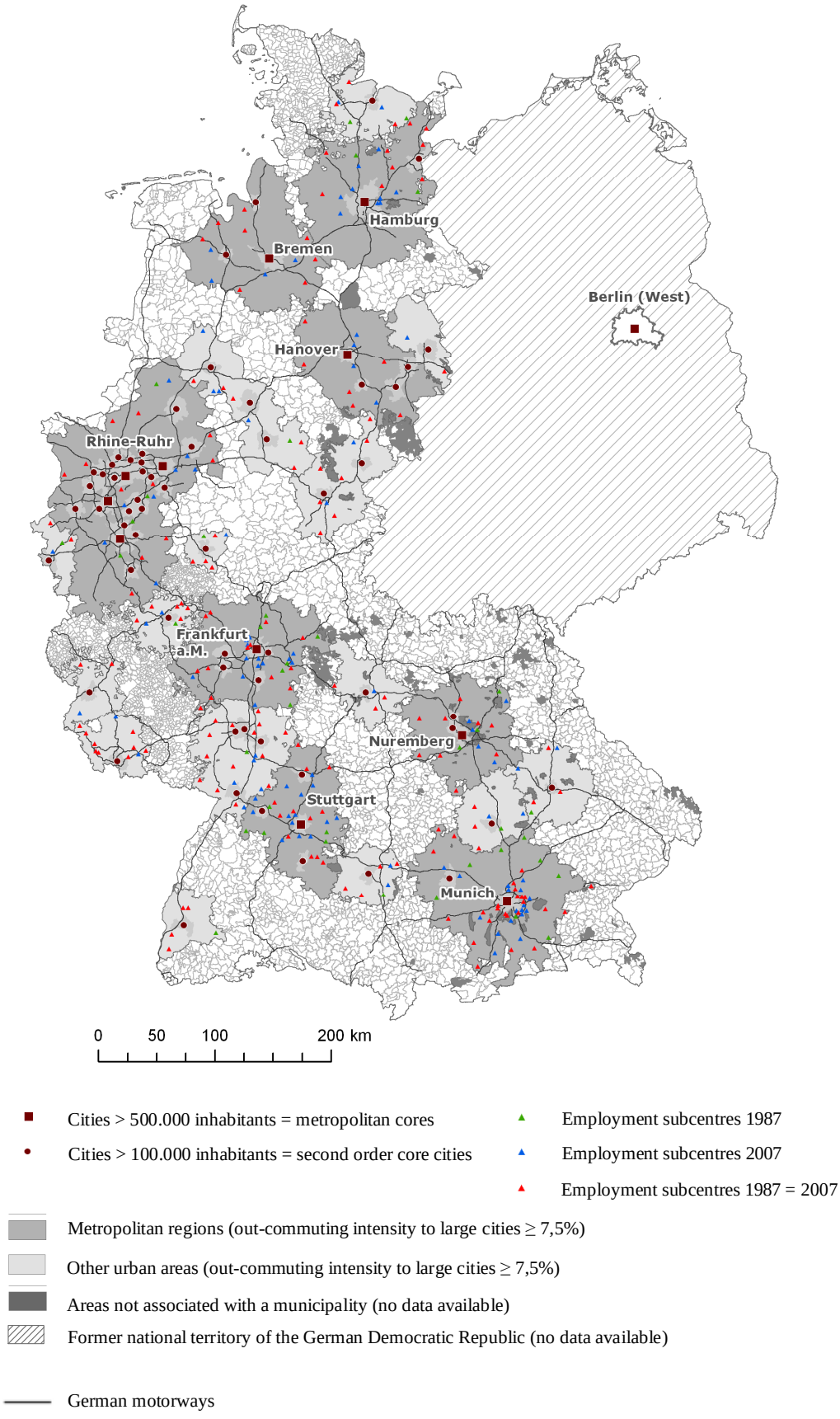

Fig. 1: German metropolitan regions (functional commuting areas) (Source: Own illustration. Data taken from the Federal Agency for Cartography and Geodesy)

Figure 1 shows the location of subcentres within the predefined boundaries of our study regions. Like in many European and US agglomerations, the majority of suburban centres has clearly sprawled along or in

close vicinity to motorways (e.g. Aguilera 2005; Anderson/Bogart 2001; Garreau 1991). Table 2 provides some key statistics with regard to the number of large cities and suburban centres. The table also contains information about the absolute and relative variation in the number of subcentres over time, highlighting a general increase in the number of suburban employment locations across all metropolitan regions. The results further indicate that many centres that have been identified in 1987 still exist 20 years later (1987 = 2007). While some of the 1987 employment subcentres drop out of the table in 2007 and some 2007 centres were below the national mean in 1987, several centres exist both in 1987 and 2007. The 'stability' of clustered employment through recent decades may generally reflect the relevance of strong agglomeration forces over time (Parolin 2006) and might as well support the argument of long-term persistence in metropolitan spatial structures.

Our further analyses proceed by generating statistics on workplaces, workers and commuter flows for the entire set of geographical subdivisions (large cities, non-(sub)centres and subcentres). Some caution is warranted in the cross-interpretation of the results (percentage changes) as some subcentres and non-(sub)centres are not identical in 1987 and 2007. However, the method applied in this paper allows us to check for the 'decoupling' and 'co-location' hypotheses, as we explicitly aim to examine commuting patterns for both 1987 and 2007. Given that subcentres represent the multicentric nature of an urban landscape we (i) expect higher levels of self-sufficiency within suburban municipalities (more internal commuting trips within subcentres and/or increasing shares of suburb-to-suburb commutes) and (ii) a shortening of commutes as firms may favour to move closer to their workforce.

In the following sections we first describe the changing geography of working and housing locations over time. We ask as to whether there is a significantly higher share of workplaces located within suburban municipalities in 2007 (section 6). In a second step we examine whether or not a significant proportion of residents came closer to their jobs, thereby leading to a 'decoupling' of the periphery and to decreasing amounts of commuter traffic over time (section 7).

Region	Number of …							
	… mc	… socc	… lc	… sc				
				1987	2007	1987 = 2007	Δ 1987-2007	
							[abs.]	[%]
Bremen	1	2	3	8	12	8	+4	+50,0%
Frankfurt a.M.	1	4	5	19	26	13	+7	+36,8%
Hamburg	1	1	2	11	18	9	+7	+63,6%
Hanover	1	3	4	6	10	6	+4	+66,7%
Munich	1	1	2	33	42	25	+9	+27,3%
Nuremberg	1	2	3	12	14	9	+2	+16,7%
Rhine-Ruhr	4	22	26	15	19	11	+4	+26,7%
Stuttgart	1	3	4	17	26	12	+9	+52,9%
Other urban areas	(-)	21	21	81	98	70	+17	+21,0%

mc: metropolitan cores: socc: second order core cities; lc: large cities; sc: subcentres

Tab. 2: Number of large cities and employment subcentres in German metropolitan regions, 1987-2007 (Source: Own computations. Data taken from the German Census 1987 and the German Social Security Statistics 2007)

6 CHANGING GEOGRAPHY OF WORKING AND HOUSING LOCATIONS

In this section we describe some major trends of metropolitan evolution since 1987. The focus is on morphological shifts such as the spatial development of employment and housing locations. In doing so, we are able to quantify the degree of spatial deconcentration for both economical and residential activities and can better assess the relevance of centred employment growth in German metropolitan regions. In this chapter we raise two specific questions:

- Is there evidence for employment suburbanisation between 1987 and 2007?
- If so, did jobs tend to cluster in centres or spread out across the urban landscape?

To answer these questions we calculated aggregate workplace statistics for the entire set of German agglomerations (table 3). The results indicate several striking features. First, it becomes clear that suburban municipalities gained importance as locations of employment across all metropolitan regions. The shares of large cities in the regional overall sum of workplaces declined in every single case, whilst the shares of

suburban municipalities increased without any exception. In all agglomerations the growth rates of suburban municipalities exceed the values for the large cities, i.e. a decentralisation of the workforce generally took place throughout German metropolitan areas.

A second key finding is that large cities still remain important locations of employment, despite declining shares of total employment. The percentages in the regional overall sum of workplaces (2007) are ranging from 33,5% in Stuttgart (lowest) to 63,6% in Rhine-Ruhr (highest), whilst the shares of jobs within subcentres accounts for 4,9% in Rhine-Ruhr (lowest) and 23,2% in Munich (highest). Comparing our data with the work of Parolin (2006) shows somewhat lower proportions of employment within German subcentres[3] . However, the addition of 63 centres across the entity of metropolitan areas has supposably affected the spatial economies of the study regions. As more and more workplaces tend to cluster within a small number of suburban municipalities, we agree with prior studies, assuming a general rise of multicentric urban growth throughout Europe over time (e.g. Gilli 2009).

		WP 1987				WP 2007				Δ 1987-2007	
		within …				within …				within …	
Region		… lc	… sc	… nc	… sub	… lc	… sc	… nc	… sub	… lc	… sub
Bremen		344.979	59.455	161.178	220.633	334.325	96.191	174.556	270.747	-10.654	+50.114
		61,0%	*10,5%*	*28,5%*	*39,0%*	*55,3%*	*15,9%*	*28,8%*	*44,7%*	-3,1%	+22,7%
	nom	3	8	143	151	3	12	139	151	3	151
Frankfurt a.M.		803.057	128.921	667.593	796.514	763.754	255.715	615.258	870.973	-39.303	+74.459
		50,2%	*8,1%*	*41,7%*	*49,8%*	*46,7%*	*15,6%*	*37,6%*	*53,3%*	-4,9%	+9,3%
	nom	5	19	404	423	5	26	397	423	5	423
Hamburg		788.876	90.868	305.966	396.834	789.828	145.478	324.120	469.598	+952	+72.764
		66,5%	*7,7%*	*25,8%*	*33,5%*	*62,7%*	*11,6%*	*25,7%*	*37,3%*	+0,1%	+18,3%
	nom	2	11	512	523	2	18	505	523	2	523
Hanover		492.652	71.701	256.089	327.790	444.207	98.956	257.479	356.435	-48.445	+28.645
		60,0%	*8,7%*	*31,2%*	*40,0%*	*55,5%*	*12,4%*	*32,2%*	*44,5%*	-9,8%	+8,7%
	nom	4	6	182	188	4	10	178	188	4	188
Munich		779.127	192.123	330.499	522.622	735.879	335.220	372.405	707.625	-43.248	+185.003
		59,9%	*14,8%*	*25,4%*	*40,1%*	*51,0%*	*23,2%*	*25,8%*	*49,0%*	-5,6%	+35,4%
	nom	2	33	344	377	2	42	335	377	2	377
Nuremberg		373.225	111.875	124.820	236.695	362.577	115.767	158.462	274.229	-10.648	+37.534
		61,2%	*18,3%*	*20,5%*	*38,8%*	*56,9%*	*18,2%*	*24,9%*	*43,1%*	-2,9%	+15,9%
	nom	3	12	171	183	3	14	169	183	3	183
Rhine-Ruhr		2.817.037	164.831	1.273.983	1.438.814	2.626.647	200.584	1.302.588	1.503.172	-190.390	+64.358
		66,2%	*3,9%*	*29,9%*	*33,8%*	*63,6%*	*4,9%*	*31,5%*	*36,4%*	-6,8%	+4,5%
	nom	26	15	246	261	26	19	242	261	26	261
Stuttgart		530.976	167.756	721.284	889.040	477.026	233.088	714.170	947.258	-53.950	+58.218
		37,4%	*11,8%*	*50,8%*	*62,6%*	*33,5%*	*16,4%*	*50,1%*	*66,5%*	-10,2%	+6,5%
	nom	4	17	260	277	4	26	251	277	4	277
Other urban areas		1.820.433	658.056	1.441.261	2.099.317	1.830.085	801.793	1.559.930	2.361.723	+9.652	+262.406
		46,4%	*16,8%*	*36,8%*	*53,6%*	*43,7%*	*19,1%*	*37,2%*	*56,3%*	+0,5%	+12,5%
	nom	21	81	1612	1693	21	98	1595	1693	21	1693

WP: workplaces
nom: number of municipalities
lc: large cities; sc: subcentres; nc: non-(sub)centres; sub: suburbia = sc + nc
italics: Share in the regional overall sum of workplaces

Tab. 3: Aggregate workplace statistics, 1987-2007 (Source: Own computations. Data taken from the German Census 1987 and the German Social Security Statistics 2007)

Closer examination further indicates the significance of centred employment within German metropolitan areas. In order to study the spatial (de-)concentration of jobs within urban areas a simple measure of the morphological distribution has been calculated. We use Gini coefficients to investigate the degree of spatial dispersion in metropolitan employment. The index can take values from 0 to 1, and the higher the value, the more concentrated the workforce within each metropolitan region. The Gini coefficient (GC) is calculated as follows (municipalities have to be ranked ascending with regard to their share of employment within the respective region) [4]:

$$GC = 1 - \sum_{i=1}^{n} (u_i - u_{i-1}) \cdot (v_i + v_{i-1})$$

[3] The share of workplaces within identified subcentres accounts for about 38% in the Sydney metropolitan area (Parolin 2006).
[4] In the same way, we calculated Gini coefficients for the distribution of the workers (employed residents).

u_i: accumulated share of municipality i in the overall sum of all municipalities of a region
v_i: accumulated share of a municipality's i employment in the overall sum of all municipalities of a region
n: number of municipalities of a region

Table 4 reveals that all WP-GCs exceed a minimum of 0,75 (2007), indicating that a high proportion of the metropolitan workforce still remains concentrated within a small number of municipalities (see also table 3). Comparing the coefficients for 1987 and 2007 makes clear that the deconcentration of jobs has led to a more equal distribution of employment occasions across metropolitan areas (declining WP-GCs). However, the spatial diffusion of workplaces seems to be rather selective in the sense of that employment tends to cluster within a small number of centres (indicating the unbroken relevance of strong agglomeration forces). In no case there is any scattered (i.e. spatially extensive or sprawl-style) decentralisation pathway as reported for US metropolitan regions (e.g. Burchell et al. 1998). The dynamics in the pattern of employed residents show similar trends. As has been shown for workplaces, the results indicate deconcentration tendencies of residential activities (finding their expression in declining ER-GCs). However, as shown in prior studies, the overall distribution of residents tends to follow a more even distribution across space (e.g. Gilli 2009; Lee 2007; Siedentop et al. 2003). We confirm these prior findings by comparing WP- and ER-GCs for both points in time, showing somewhat lower values of ER-GCs throughout all metropolitan areas.

Region	Gini WP			Gini ER		
	1987	2007	Δ [%]	1987	2007	Δ [%]
Bremen	0,881	0,856	-2,8%	0,790	0,746	-5,6%
Frankfurt a.M.	0,868	0,859	-1,0%	0,742	0,711	-4,2%
Hamburg	0,944	0,935	-1,0%	0,870	0,844	-3,0%
Hanover	0,890	0,876	-1,6%	0,778	0,749	-3,7%
Munich	0,872	0,846	-3,0%	0,747	0,704	-5,8%
Nuremberg	0,862	0,843	-2,2%	0,701	0,666	-5,0%
Rhine-Ruhr	0,780	0,758	-2,8%	0,705	0,668	-5,2%
Stuttgart	0,780	0,754	-3,3%	0,620	0,587	-5,3%
Other urban areas	0,866	0,856	-1,2%	0,738	0,715	-3,1%

WP: workplaces; ER: employed residents

Tab. 4: Gini coefficients, 1987-2007 (Source: Own computations. Data taken from the German Census 1987 and the German Social Security Statistics 2007)

7 DYNAMICS OF COMMUTING

The spatio-temporal development of commuter traffic will be analysed in two steps: First, the dynamics of commuting linkages over time will be examined. By comparing the shares of in-, out- and local commuting trips we can assess whether or not a 'decoupling' of the periphery from the traditional urban cores did in fact take place between 1987 and 2007. In a second step we focus on the changes in average distances covered by commuters. In doing so, we are able to test the 'co-location' hypothesis, which claims that the emergence of multicentric urban configurations leads to a shortening of commutes over time.

7.1 Commuting linkages – 'decoupling' of suburbia from large cities?

After having shown the relevance of suburban growth patterns across German metropolitan regions we raise some more specific questions. As the arrival of 'new' jobs within suburban areas generally may have increased the probability for workers to find a job within suburban locations, we (i) could expect decreasing percentages of traditional (long-distance) suburb-to-large-city trips and/or increasing shares of (somewhat shorter) suburb-to-subcentre commutes. Moreover, the emergence of suburban employment centres may (ii) explain higher degrees of self-containment within these municipalities. We thus ask for two questions:

- Do the residents of suburban municipalities orientate towards subcentres?
- Can we observe increasing levels of internal linkages within suburban centres over time?

Table 5 highlights several important findings. One of the most striking features is that the proportion of crossmunicipal commuting trips (in- and out-commuting) has significantly increased across the entire set of metropolitan areas during the past two decades. Compared with the situation in 1987 we can find increasing shares of employees living in a subcentre and working in a large city. Moreover, we can identify higher

shares of people living in a subcentre and working in another subcentre, as well as higher shares of people living in a subcentre and working in a non-(sub)centre and even higher shares of people living in a subcentre and working outside the boundaries of their respective metropolitan area (external commuters). At the same time the proportion of internal commuting trips (people who both live and work in the same subcentre) declined markedly over time, which makes us reject the second question raised above. As for suburban centres, similar dynamics can be found for large cities and non-(sub)centres[5] . Our results thus confirm a trend widely noticed among European transport researchers, that workers expand their activity spaces and do not overwhelmingly tend to live and work within the same municipality[6] (e.g. Aguilera 2005; Bontje 2007; Moser 2007). This makes us assume that the distances covered by commuters may not have declined during recent decades, as claimed by the 'co-location' hypothesis. We provide some deeper insights in the next section.

		Commuters 1987 [%]					Commuters 2007 [%]				
Region		… lc	… sc	… nc	…int	… ext	… lc	… sc	… nc	…int	… ext
Bremen	From lc to …	1,5%	0,4%	5,2%	91,7%	1,2%	3,2%	3,3%	8,8%	82,6%	2,2%
	From sc to …	8,3%	2,1%	8,7%	76,3%	4,7%	22,6%	5,8%	13,1%	50,3%	8,2%
	From nc to …	34,8%	5,5%	14,1%	42,2%	3,4%	39,1%	11,1%	16,9%	27,7%	5,2%
Frankfurt a.M.	From lc to …	7,5%	1,3%	7,5%	83,6%	0,2%	14,1%	6,9%	11,9%	66,0%	1,1%
	From sc to …	22,6%	6,8%	16,8%	51,0%	2,7%	33,8%	11,0%	20,2%	30,9%	4,0%
	From nc to …	33,1%	5,6%	22,8%	36,0%	2,5%	36,3%	12,0%	25,7%	21,9%	4,1%
Hamburg	From lc to …	0,4%	0,7%	4,6%	93,9%	0,4%	0,7%	3,1%	6,7%	88,7%	0,8%
	From sc to …	16,7%	2,7%	10,3%	67,6%	2,7%	35,5%	6,2%	15,1%	39,8%	3,4%
	From nc to …	37,7%	6,9%	18,5%	34,7%	2,3%	41,5%	11,1%	21,5%	22,1%	3,8%
Hanover	From lc to …	3,6%	0,4%	6,4%	88,0%	1,6%	5,9%	3,9%	11,0%	75,3%	3,9%
	From sc to …	12,4%	0,5%	9,5%	74,4%	3,2%	29,5%	3,0%	16,2%	46,4%	4,9%
	From nc to …	39,9%	5,4%	14,3%	37,1%	3,3%	41,4%	9,1%	18,7%	25,8%	5,0%
Munich	From lc to …	0,6%	4,4%	4,9%	89,9%	0,2%	1,2%	13,5%	6,4%	78,1%	0,7%
	From sc to …	28,4%	5,5%	10,5%	52,4%	3,2%	37,4%	15,5%	10,9%	32,6%	3,6%
	From nc to …	39,1%	10,9%	15,0%	31,9%	3,0%	36,6%	17,5%	19,6%	21,1%	5,1%
Nuremberg	From lc to …	11,6%	1,5%	2,5%	84,2%	0,3%	18,9%	4,0%	7,1%	69,0%	1,0%
	From sc to …	22,3%	3,0%	7,0%	65,0%	2,6%	26,9%	4,9%	13,0%	49,0%	6,2%
	From nc to …	41,4%	13,6%	11,4%	29,9%	3,9%	42,3%	14,1%	17,4%	20,5%	5,6%
Rhine-Ruhr	From lc to …	13,8%	0,6%	5,5%	79,9%	0,2%	24,0%	1,5%	10,5%	63,2%	0,8%
	From sc to …	17,4%	0,3%	15,6%	63,2%	3,4%	26,3%	1,2%	23,6%	41,5%	7,3%
	From nc to …	30,1%	2,8%	17,0%	47,6%	2,4%	37,1%	4,1%	22,8%	31,6%	4,5%
Stuttgart	From lc to …	0,8%	3,4%	10,3%	85,1%	0,4%	1,7%	10,4%	18,1%	67,8%	2,1%
	From sc to …	18,2%	3,8%	19,8%	56,2%	2,1%	28,5%	9,0%	26,1%	33,0%	3,4%
	From nc to …	22,4%	7,2%	26,9%	41,8%	1,7%	23,0%	12,3%	33,9%	27,1%	3,7%
Other urban areas	From lc to …	1,8%	2,4%	6,0%	88,4%	1,5%	3,0%	5,7%	12,4%	73,9%	5,0%
	From sc to …	16,0%	5,4%	10,7%	63,0%	4,9%	21,7%	9,1%	16,4%	43,9%	8,9%
	From nc to …	30,2%	10,7%	15,7%	37,7%	5,7%	32,4%	13,5%	19,5%	25,5%	9,1%

lc: large cities; sc: subcentres; nc: non-(sub)centres; int: internal commuting trips (= local commuters); ext: external commutes (= workplace destination not within same metropolitan region)

Tab. 5: Dynamics of commuting linkages, 1987-2007 (Source: Own computations. Data taken from the German Census 1987 and the German Social Security Statistics 2007)

As already has been pointed out for French metropolitan areas (Aguilera 2005), table 5 also shows that the majority of people living in a subcentre work outside their places of residence, giving us some more indication to reject the questions raised above. It further becomes apparent that the main out-commuter flows are still directed towards the higher level cities in the urban hierarchy (large cities). This is true for both categories of suburban municipalities; i.e. subcentres and non-(sub)centres. Comparing 1987 with 2007 indicates that the situation was even more distinct in 2007 than 20 years before. We thus find increasing rather than decreasing shares of traditional suburb-to-large-city commuting trips over time.

[5] There is only one exception in the case of Munich: The share of employees living in non-(sub)centres and working in large cities declined from 1987 to 2007.

[6] More generally we can speak of intensifying commuting patterns over time as already have been observed by Bontje (2007) for the region of Amsterdam. His main findings are a constantly high level of in-commuters into Amsterdam and a steady increase in reverse commuters with jobs in the newly developed suburban employment centres. This pattern, which he describes as 'exchange commuting', clearly suggests a qualitative mismatch between job supply and job demand.

At the same time as large cities became more attractive as destinations for suburban employees, the peripheral type of suburb-to-suburb trips gained importance, too. We thus agree with Killer/Axhausen (2009) who suggest that commuting linkages are becoming more and more complex over time. We further support the argument of Moser (2007) claiming that the commuters' destination choice became increasingly arbitrary through recent decades. All these findings make us reject the 'decoupling' hypothesis. Neither, can we identify more or less self-reliant 'villages' in the urban fringes nor can we find declining linkages between the traditional cores and suburban municipalities as reported for several US agglomerations (Lee/Seo/Webster 2006). However, we find evidence for a marked increase in disperse commuting patterns, which one may interpret as a general outcome of the infill of 'new' job opportunities within suburban locations ('urbanisation of suburbia'). In the following section we study as to whether these trends led to more sustainable short distance trip patterns over time.

7.2 Commuting distances – shortening of the journey-to-work?

In this chapter the distances covered by commuters will be analysed. Information about the real distances travelled by crossmunicipal commuters are missing in the data sets. As often is the case in this type of studies we hence calculated straight line distances between the centroids of the working and housing municipalities (e.g. Siedentop 2007). The distances covered by local commuters are estimated as well. A complete description of this approach can be found in Guth et al. (2010).

Table 6 shows the average distances covered by in- and out-commuters both for 1987 and 2007. We additionally calculated the mean distances for the sum of all commutes, i.e. in- and out-commuting trips including internal commutes. This chapter particularly aims at testing the 'co-location' hypothesis. As firms may have relocated where employees reside or, vice versa, as people might have relocated closer to their workplaces, we could expect somewhat shorter commutes within metropolitan areas. Again, we raise some specific questions:

- Can we observe significantly lower in-commuting distances to suburban employment centres over time?
- Did the emergence of suburban centres lead to shorter trips in the study regions?

We start by comparing average in-commuting distances of large cities with those of subcentres and non-(sub)centres. There has already been a broad discussion on whether or not working in central cities is associated with above the mean distances. Our findings clearly suggest that in-commuters of traditional urban cores have longer work trips than people working in subcentres or non-(sub)centres. This is true both for 1987 and 2007, and for the entire set of metropolitan areas. Our results are consistent with Cervero/Wu (1998) and the recent work of Siedentop (2007) for a selection of five German metropolitan regions. Moreover, we confirm that commuting trips to employment subcentres are somewhat longer than commutes to jobs within noncentred employment locations. This again is true for both points in time; but not for the region of Hanover[7].

To finally answer the questions raised above we need to analyse the shifts in commutes over time. Table 6 indicates that journey-to-work trips lengthened among all types of municipalities from 1987 to 2007. To return to 'co-location': As more and more people live and work within suburban places, we expected to find somewhat shorter commutes on average. But people obviously do not live closer to their jobs than 20 years before. On the contrary there is an increasing spatial separation of homes and workplaces in all municipality classes[8]; moreover, the regions' total average distances increased significantly over time. Some caution is needed as the tc-values are highly dependent on the share of internal commuters, who cover distinctly lower distances than in- or out-commuters on average. As shown in section 7.1 the share of local-commuters declined markedly over time, providing some explanation why the average distances rose as vast as shown in table 6. However, our results are in line with prior studies from Germany and abroad (e.g. Aguilera 2005;

[7] Referring to Giuliano/Small (1991) we can provide a possible explanation: As large cities and subcentres generally have high concentrations of jobs, they do not only draw workers from their adjacent municipalities but from a wider geographical space. Hence, a significant proportion of people working in a major centre requires longer average commutes and, thus, contributes to the existence of large-scale commuter sheds.

[8] Parolin (2006) visually determines the spatial spread of trips to suburban centres using GIS-flowmap applications. His results show a general increase in trip lengths and an expansion of overlapping commuting areas since 1981. His findings make him argue that the idea of self-containing suburban municipalities is *"indeed a long way off as a planning goal"* (Parolin 2006, p. 11)

Cervero/Wu 1998; Guth et al. 2010; Parolin 2006; Siedentop 2007). All the findings presented here lend weight to the argument that the 'co-location' hypothesis does not hold for German metropolitan regions and makes us come to the conclusion that the emergence of multicentric urban configurations has not given rise to shorter commutes on average.

		Average distances 1987 [km]			Average distances 2007 [km]		
		ic*	oc*	tc*	ic*	oc*	tc*
Region							
Bremen	lc	22,4	32,8	11,3	24,6	30,5	14,6
	sc	14,1	24,4	10,0	17,1	20,7	13,9
	nc	13,3	16,6	11,6	15,4	17,9	14,5
	total	18,5	19,0	9,9	20,4	20,2	13,2
Frankfurt a.M.	lc	20,4	16,0	12,3	23,4	19,5	16,4
	sc	11,0	16,4	10,0	14,5	15,6	13,1
	nc	10,8	14,1	10,2	13,4	16,5	13,8
	total	15,7	14,4	9,5	18,3	16,9	13,5
Hamburg	lc	27,0	26,4	13,0	29,5	27,8	15,3
	sc	13,9	23,7	11,0	16,6	20,9	14,7
	nc	12,1	17,8	12,9	14,6	19,9	16,5
	total	20,3	19,1	11,0	22,3	21,2	13,7
Hanover	lc	21,6	20,6	12,0	22,4	23,4	14,5
	sc	11,5	23,8	9,6	15,4	19,3	13,2
	nc	13,4	15,9	11,5	15,8	17,5	14,4
	total	18,3	16,8	10,2	19,3	18,8	13,0
Munich	lc	25,8	18,1	12,2	28,5	20,9	15,2
	sc	12,5	18,6	11,0	16,2	17,2	14,4
	nc	10,8	16,9	12,3	12,9	18,7	15,4
	total	18,9	17,3	10,1	20,4	18,8	13,2
Nuremberg	lc	19,4	14,0	10,8	20,6	16,4	13,7
	sc	12,6	17,5	9,5	14,6	18,8	12,6
	nc	9,4	14,9	11,3	11,7	15,8	13,3
	total	16,3	15,1	9,1	17,3	16,3	11,9
Rhine-Ruhr	lc	18,9	17,6	9,5	22,1	21,3	13,7
	sc	12,3	15,0	9,0	15,2	17,3	12,9
	nc	12,2	15,0	9,8	15,2	17,6	13,8
	total	16,3	15,9	8,4	19,3	19,0	12,4
Stuttgart	lc	17,8	14,4	10,6	20,5	17,4	13,9
	sc	10,2	11,5	7,8	12,5	12,2	10,7
	nc	10,1	11,6	8,2	11,7	13,1	10,8
	total	12,9	11,8	7,8	14,6	13,5	10,9
Other urban areas	lc	16,0	18,7	10,1	18,9	22,4	13,7
	sc	10,9	14,9	8,6	13,5	16,2	11,8
	nc	10,0	12,7	9,2	12,2	14,4	11,9
	total	13,0	13,4	8,4	15,4	15,6	11,9

** ANOVA (F-Test): p < 0,05*
lc: large cities; sc: subcentres; nc: non-(sub)centres; total: region total
ic: in-commuting, oc: out-commuting; tc: total-commuting
(= in-, out- and local commuting)

Table 6: Dynamics of average commuting distances (one way), 1987-2007 (Source: Own computations. Data taken from the German Census 1987 and the German Social Security Statistics 2007)

8 SUMMARY AND OUTLOOK

This study has examined the role of suburban employment growth on the evolution of metropolitan commuting patterns over the past two decades. The paper focused on three specific topics: First, the identification of major employment subcentres across German metropolitan areas. Second, the question of whether or not the deconcentration of workplaces goes along with a 'decoupling' of the periphery from traditional urban centres and, third, the validity of the 'co-location' hypothesis for German agglomerations.

The interrelations between decentralised employment growth and the journey-to-work have already been addressed in numerous papers (especially USA, France, Netherlands). However, the evidence is disputed and far from being conclusive. Our empirical findings suggest that the decentralisation of employment has not led to a 'decoupling' of suburban municipalities from their respective urban cores. Neither found we higher numbers of self-reliant subcentres in the periphery of agglomerations, nor were we able to detect a decline of commuting linkages between cores and suburban centres over time. Moreover, our results suggest that the decentralisation of the workforce did not favour to bring more people closer to their jobs, as the average journey-to-work distances lengthened over time. All these findings made us reject the 'co-location' hypothesis[9]. We agree with Parolin (2006) and come to the conclusion "that factors other than proximity to

[9] As we focused on the investigation of average commuting distances exclusively, we have to amend that the empirical verification of the 'co-location' hypothesis frequently bases on the examination of commuting times, too. E.g. Gordon/Richardson/Jun (1991)

workplace have influenced and will continue to influence where workers reside. It is of paramount importance for metropolitan and transport planners to better understand what these other factors are likely to be if we are to move towards achieving sustainability" (Parolin 2006, p. 14).

The results presented in this paper shed a first glance on the dynamics of commuter traffic in German metropolitan regions since 1987. In order to broaden the empirical basis and to allow more general conclusions, additional analyses on the correlation between spatial development of employment, jobs-housing-proximity and commuter traffic will be necessary. Future work will extend on other urban regions and on an additional point in time (Census 1970). Moreover, it is intended to use road network distances instead of straight line distances to estimate the distances covered by commuters more precisely.

ACKNOWLEDGEMENT

We would like to thank the German Research Foundation (DFG) and the Swiss National Science Foundation (SNF) for funding this work as part of the project 'Spatial accessibility and the dynamics of commuting in Germany and Switzerland, 1970-2005'. This project is jointly carried out at the Department of Transport Planning at TU Dortmund University and the Institute for Transport Planning and Systems at ETH Zurich.

9 REFERENCES

Aguilera, A. (2005): Growth in commuting distances in French polycentric metropolitan areas: Paris, Lyon and Marseille. In: Urban Studies, Vol. 42, Issue 9, pp. 1537-1547.

Alpkokin, P; Black, J.; Gercek, H.; Hayashi, Y. (2005): Polycentric employment growth and impacts on urban commuting patterns: Case study of Istanbul. In: Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, pp. 3835-3850.

Anas, A.; Arnott, R.; Small, K. A. (1998): Urban spatial structure. In Journal of Economic Literature, Vol. 36, Issue 3, pp. 1426-1464.

Anderson, N. B.; Bogart, W. T. (2001): The structure of sprawl: Identifying and characterizing employment centers in polycentric metropolitan areas. In: American Journal of Economics and Sociology, Vol. 60, Issue 1, pp. 147-169.

BBR – Bundesamt für Bauwesen und Raumordnung (2005): Raumordnungsbericht 2005, Bonn.

Berry, B. J. L.; Gillard, Q. (1977): The changing shape of metropolitan America. Commuting patterns, urban fields, and decentralization processes, 1960-1970, Cambridge (Massachusetts).

Bontje, M. (2007): Deconcentration and commuter traffic: Trends and policies in the Netherlands. In: Informationen zur Raumentwicklung, Vol. 2/3, pp. 141-148.

Burchell, R. W. et al. (1998): The costs of sprawl – revisited. TCRP-Report. Washington D.C.

Cervero, R. (1989): Jobs-housing balancing and regional mobility. In: Journal of the American Planning Association, Vol. 55, Issue 2, pp. 136-150.

Cervero, R.; Wu, K.-L. (1998): Sub-centring and commuting: Evidence from San Francisco Bay area, 1980-1990. In: Urban Studies, Vol. 35, Issue 7, pp. 1059-1076.

Craig, S. G.; Ng, P. T. (2001): Using quantile smoothing splines to identify employment subcenters in a multicentric urban area. In: Journal of Urban Economics, Vol. 49, Issue 1, pp. 100-120.

Crane, R.; Chatman, D. G. (2003): As jobs sprawl, whither the commute? In: Access, Vol. 23, pp. 14-19.

Einig, K.; Guth, D. (2005): Neue Beschäftigtenzentren in deutschen Stadtregionen. Lage, Spezialisierung, Erreichbarkeit. In: Raumforschung und Raumordnung, Vol. 63, Issue 6, pp. 444-458.

Garreau, J. (1991): Edge City: Life on the new frontier. New York: Doubleday.

Gilli, F. (2009): Sprawl or reagglomeration? The dynamics of employment deconcentration and industrial transformation in Greater Paris. In: Urban Studies, Vol. 46, Issue 7, pp. 1385-1420.

Giuliano, G.; Small, K. A. (1991): Subcenters in the Los Angeles region. In: Regional Science and Urban Economics, Vol. 21, Issue 2, pp. 163-182.

Giuliano, G.; Redfearn, C.; Agarwal, A.; Li, C.; Zhuang, D. (2005): Not all sprawl: Evolution of employment concentrations in Los Angeles, 1980-2000. In: Proceedings of the ERSA Conference, Amsterdam, Netherlands.

Gordon, P.; Richardson, H. W.; Jun, M.-J. (1991): The commuting paradox. Evidence from the top twenty. In: Journal of the American Planning Association, Vol. 57, Issue 4, pp. 416-420.

Guth, D.; Holz-Rau, C.; Maciolek, M.; Scheiner, J. (2010): Beschäftigungssuburbanisierung, Siedlungsstruktur und Berufspendelverkehr – Ergebnisse für deutsche Agglomerationsräume 1999-2007. In: Raumforschung und Raumordnung (forthcoming).

Herrmann, H.; Schulz, A.-C. (2005): Räumliches Muster der Berufspendlerverflechtung im Raum Schleswig-Holstein, Beiträge aus dem Institut für Regionalforschung der Universität Kiel, Vol. 40, Kiel.

Killer, V.; Axhausen, K. W. (2009): The spatial and temporal change of commuting regions, Arbeitsberichte Verkehrs- und Raumplanung, Vol. 583, Institute for Transport Planning and Systems, ETH Zurich.

studied trends in US agglomerations between 1980 and 1985 and found a significant decrease in mean commuting times, despite considerable metropolitan urbanisation processes during the same period. The finding that the traffic increase associated with these urbanisation processes did not involve increasing commuting time burdens is interpreted as a 'commuting paradox'. They explain their results by a shift from radial commute trips, which are likely to take place on congested roads, towards more peripheral flows within suburbia. We currently prepare road travel time matrices for use in further analyses. These data allow us to examine the question whether or not the suburbanisation of workplaces has given rise to constant or even lower intrametropolitan commuting times during past decades.

Lee, S.; Seo, J. G.; Webster, C. (2006): The decentralising metropolis: Economic diversity and commuting in US suburbs. In: Urban Studies, Vol. 43, Issue 13, pp. 2525-2549.
Lee, B. (2007): 'Edge' or 'edgeless' cities? Urban spatial structures in U.S. metropolitan areas, 1980 to 2000. In: Journal of Regional Science, Vol. 47, Issue 3, pp. 479-515.
McDonald, J. F. (1987): The identification of urban employment subcenters. In: Journal of Urban Economics, Vol. 21, Issue 2, pp. 242-258.
McMillen, D. P. (2001): Nonparametric employment subcenter identification. In: Journal of Urban Economics, Vol. 50, Issue 3, pp. 448-473.
Moser, P. (2007): Pendelstrukturen im Großraum Zürich: Entwicklungen und Perspektiven. In: Informationen zur Raumentwicklung Vol. 2/3, pp. 131-139.
Muller, P. O. (1976): Intrametropolitan employment deconcentration and its impacts on commuting distances. In: Southeastern Geographer, Vol. 16, Issue 1, pp. 26-34.
Parolin, B. P.; Kamara, S. (2003): Spatial patterns and functions of employment centers in metropolitan Sydney, 1981-1996. In: Proceedings of State of Australian Cities National Conference, Parramatta, Australia.
Parolin, B. P. (2006): Employment centres and the journey to work in Sydney: 1981-2001. In: Proceedings of State of Australian Cities 2nd National Conference, Brisbane and Melbourne, Australia.
Riguelle, F.; Thomas, I.; Verhetsel, A. (2007): Measuring urban polycentrism: a European case study and its implications. In: Journal of Economic Geography, Vol. 7, Issue 2, pp. 193-215.
Schwanen, T.; Dieleman, F. M.; Dijst, M. (2004): The impact of metropolitan structure on commute behavior in the Netherlands: A multilevel approach. In: Growth and Change, Vol. 35, Issue 3, pp. 304-333.
Siedentop, S.; Kausch, S.; Einig, K.; Gössel, J. (2003): Siedlungsstrukturelle Veränderungen im Umland der Agglomerationsräume. In: Bundesamt für Bauwesen und Raumordnung – BBR (ed.): Forschungen, Vol. 114, Bonn.
Siedentop, S. (2007): Auswirkungen der Beschäftigungssuburbanisierung auf den Berufsverkehr. Führt die Suburbanisierung der Arbeitsplätze zu weniger Verkehr? In: Informationen zur Raumentwicklung, Vol. 2/3, pp. 105-124.
Yang, J. (2005): Commuting impacts of spatial decentralization: A comparison of Atlanta and Boston. In: Journal of Regional Analysis and Policy, Vol. 35, Issue 1, pp. 69-78.