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Unpacking polycentricity at the city-regional scale: Insights from Dusseldorf and Stockholm

Peter Schmitt, Kati Volgmann, Angelika Münter and Mitchell Reardon

Abstract

The normative concept of polycentricity has become a promising tool to pursue spatial policy goals such as spatial equity and justice, sustainable and balanced development, and, more recently territorial cohesion, at various scales across Europe. As earlier research has shown, a number of city-regions use the concept for their planning and development work. In pursuit of polycentric development, they call for a robust terminology, solid analysis and methods. As a result, literature analysing polycentricity at the city- or mega-regional scale has grown significantly and it appears that some consensus has been achieved in regards to the main facets and dimensions. Recognizing that the potentials to comprehend city-regional dynamics by focussing on the extent to which polycentric urban patterns evolve has not yet been fully utilised, this paper intends to contribute to a more comprehensive view on polycentricity at the city-regional scale. In doing so, we study the (potentially) emerging urban patterns of two cases, the Dusseldorf and Stockholm city-regions, employing different theoretical starting points and analytical approaches. With this in mind, we aim to unpack the concept of polycentricity at the city-regional scale and to offer academics, as well as planning professionals and policy-makers, further insights into qualifying, analysing and understanding the complexity of the topic at hand. Likewise, we argue that sound strategies to promote and mobilise different facets of polycentric development should be carefully reflected and related to the theoretical, methodological and even normative starting point of any attempt to comprehending polycentricity.

Keywords: *city-regional dynamics, Dusseldorf, functional relations, polycentricity, Stockholm, urban structure*

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1. Introduction

Fuelled by the discourse on ‘spatial planning for Europe’ (cf. Böhme & Waterhout 2008) and coined through transnational informal policy documents, such as the European Spatial Development Perspective (CEC 1999) as well as the Territorial Agendas from 2007 and 2011 (EU Ministers responsible for Urban Development and Territorial Cohesion 2007; EU Ministers responsible for Spatial Planning and Territorial Development 2011), the normative concept of polycentricity has become a promising means to help to pursue overall spatial policy goals. Notably, these goals include spatial equity and justice, sustainable balanced development, and, more recently territorial cohesion. Since such policy goals, which have been depicted in the aforementioned policy documents at the EU-scale, are easily agreeable and also relevant at smaller scales; it is not surprising that the normative concept of polycentricity has also permeated national and especially regional planning frameworks. Regarding the latter, it seems that a number of city-regions and metropolitan areas across Europe are very keen on using the concept (or at least associated elements of it) for their planning and development work (cf. Meijers 2007, p. 7; Meijers et al. 2012; Schmitt 2013) and inevitably call for robust terminology, solid analysis and evaluation of the pros and cons of a corresponding policy agenda. In resolving this demand, contemporary literature analysing polycentricity at the city- or mega-regional scale has grown significantly (for an overview see van Meeteren et al. 2015) and it appears that some consensus have been achieved in regards to the main facets and dimensions (see section 2).

In this paper, we focus primarily on two of these dimensions, namely the ‘morphological’ and the ‘functional-relational’ to understand spatial processes and dynamics by focusing on the extent to which polycentric urban patterns evolve at the city-regional scale. In doing so, we explore two case studies to analyse polycentric urban patterns on the base of different territorial contexts, dynamics; as well as their respective theoretical, analytical and methodological starting points. With this in mind, we aim to contribute to a more comprehensive view on polycentricity at the city-regional scale, which is often overlooked, rather than focussing solely on one specific element connected to the polycentricity debate at that scale. One example of focusing on one specific element is the recent paper by Decoville & Klein (2014) on the relation of urban hierarchy to the offer of urban amenities or the proposed utilisation of commuting data to better explain the degree of functional polycentricity (cf. Green 2007 and Vasanen 2012). To that end, we have chosen two cases, the Dusseldorf city-region in Germany and the Stockholm city-region in Sweden, to analyse and illustrate emerging polycentric urban patterns through two different theoretical starting points, methods and analytical approaches.

The cases have been selected, because they both have shown indications of becoming more polycentric at the city-regional scale in recent years, which is expected to continue in the near future, in line with contextual socio-economic dynamics. However, they are, as pointed out in section 3 and 4 surrounded and contextualised in rather different larger

regional environments. Hence they seem to be promising examples to simulate and discuss different facets of polycentricity at the city-regional scale. This contribution is expected to enlarge the debate of dimensions or types of such spatial configurations. To that end, their emerging polycentric urban patterns will be discussed and compared through critical investigations of the potentials and limits of comprehending these patterns. In doing so, we aim to enlarge the debate by employing different theoretical starting points and analytical approaches.

By using these two rather different analytical approaches in light of the polycentricity debate we want to address the context sensitivity and path-dependencies of polycentricity and the related processes and dynamics at the city-regional scale, be they rather of functional-relational or morphological character. Hence, the main objective of the paper is to unpack the concept of polycentricity at the city-regional scale and to offer academics, as well as planning professionals and policy-makers, further insight into qualifying, analysing and understanding the complexity of polycentricity at the city-regional scale. Likewise, we assert that sound strategies to promote and mobilise different facets of polycentric development should be carefully reflected and related to the theoretical, methodological and even normative starting point of any attempt to comprehending polycentricity (cf. section 5). This cannot be taken for granted as earlier research has demonstrated (e.g. Schmitt 2013).

2. Key facets and dimensions of polycentricity at the city-regional scale

Polycentricity is far from being a consistently used term. In a narrow, literal sense, the term refers to a spatial unit that consists of more than one centre. However, this leaves the type of centre (e.g. certain business functions, like trade or industry, residence or transport hubs) open to interpretation (Kloosterman & Musterd 2001, p. 623; Schmitt 2013, p. 403). For the urban or city-regional scale Kloosterman and Musterd determine:

Cities as rich, multifaceted and historically contextualised spatial phenomena encompass almost every aspect of social life and this means that polycentricity can, in principle, refer to the spatial clustering of almost any human activity. The diversity in interpretations of polycentricity is, therefore, also a reaction of this inherent complexity. (Kloosterman & Musterd 2001, p. 623)

In this vein, it is not surprising that a number of denotations and conceptualisations exist to capture various elements and characteristics of polycentric urban configurations. Those that are generally addressed in the literature will be briefly discussed below.

Distinguishing generic spatial patterns and scopes

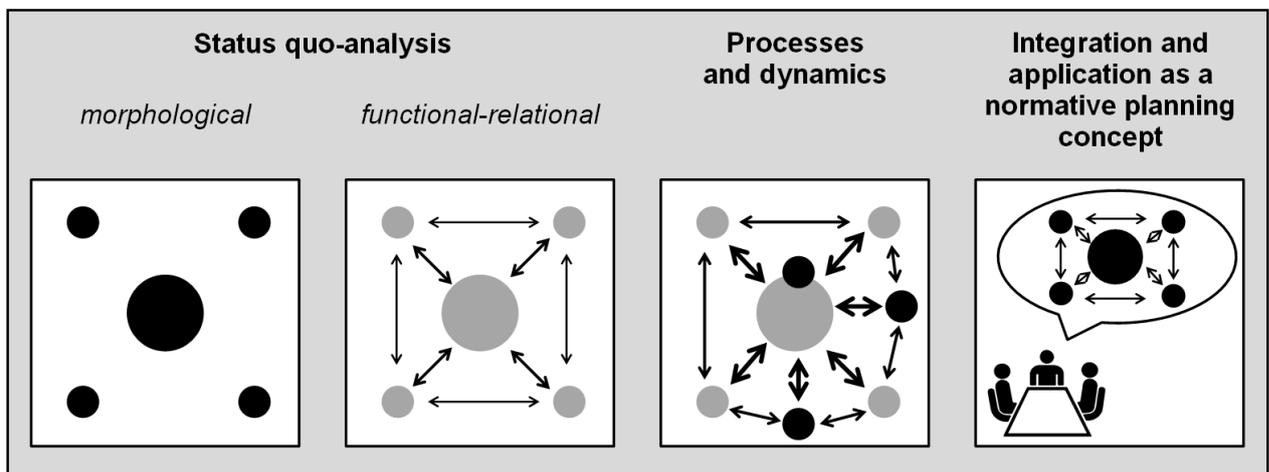
In the established body of literature on the concept, one can clearly identify that beyond polycentricity at the national or even transnational level (which has been intensively discussed in and across Europe since 2000;

see for instance Davoudi 2003; Shaw & Sykes 2004; Meijers et al. 2007; Gløersen et al. 2007, Vandermotten et al. 2008); two perspectives exist in regards to the regional scale. First, polycentricity is being debated on a 'city-regional' scale, which mainly comprises one or more core cities and their direct commuter zones (cf. Adolphson 2009; Decoville & Klein 2014). Second, a 'mega-regional' scale considers polycentric urban configurations as a network of historically independent centres in a larger territory (Hall & Pain 2006; Egermann 2009; Schmitt & Knapp 2006; Modarres 2011; Vasanen 2013). In their early paper on the concept, from 2001, Kloosterman and Musterd distinguish between 'intra-urban' and 'inter-urban' polycentric regions, whereby the former correspond to what we call the city-regional scale and the latter rather to what we call here the mega-regional scale. They argue that 'intra-urban polycentric regions' are polycentric regions that have emerged in the course of post-industrial and post-suburban developments around previously monocentric core cities, while 'inter-urban polycentric regions' evolve due to an increase in the functional interaction between several cities in close proximity (Kloosterman & Musterd 2001). In other words, intra- and inter-urban polycentric regions differ in their evolutionary history and dynamics and most often also in their geographic scope, since the former comprises a rather narrowly defined city-region (e.g. comparable to a labour market region), while the latter describes a larger urban configuration consisting of several distinct cities where, at least potentially, a considerable amount of criss-cross commuting and interaction between the various urban cores can take place.

In particular, with regards to inter-urban polycentric regions Parr (2004, 2008) argues that the ways such urban configurations have evolved historically are multifaceted, but in numerous cases they have offered a locational advantage, leading to an economic boom during a specific economic period (e.g. the Ruhr-Area in Germany and the Upper Silesian region in Poland that benefit from extensive coal deposits during the industrialization). In contrast, what can be termed as 'intra-urban polycentricity' seems to be a phenomena that can be observed in almost all post-industrial metropolitan regions (cf. Hall 1997), since it is characterized by the formation of 'centres' with different functions (residential, various economic activities, etc.) in a comparatively narrow city-regional context. It refers to both the emergence of new centres in the hinterland as well as within the administrative boundaries of the core cities. It can be thus understood as the result of post-industrial and post-suburban restructuring processes and supposedly of strategic planning interventions. The inter- and intra-urban types of polycentricity can obviously evolve within the same 'region' and thus overlap, depending on how the spatial boundaries are defined and what characteristics of polycentricity are taken into account (cf. Parr 2008). In this case the urban patterns of Dusseldorf and Stockholm city-regions are exceptionally complex and have to be interpreted both in light of their traditional inter-urban spatial structures and the emerging post-suburban polycentric patterns at the intra-urban or city-regional scale.

Three dimensions of polycentric urban configurations

In the growing body of literature on polycentric urban configurations, three interrelated key dimensions that are regularly being addressed and which in principal apply to both spatial scopes as briefly discussed above can be extracted (cf. Burger & Meijers 2012; Münster et al. 2015; Green 2007; Kloosterman & Musterd 2001; Lambregts 2009; Meijers 2008; Schmitt 2013; Vasanen 2012). Figure 1 outlines the three main dimensions of polycentricity. The first addresses the analytical dimension of polycentricity as describing a specific spatial structure at a certain point in time. It can be divided into a morphological and a functional dimension. The second dimension considers the dynamics and processes within these structures, while the third focuses on the political-normative aspects, namely the issue of ‘maintaining’ or ‘shaping’ polycentric urban structures, as well as corresponding institutional arrangements (see fig. 1). The first two dimensions will be discussed below and partly further explored within the two empirical examples in section 3, whereas the third one will be only briefly reviewed here.



The morphological dimension

In many city-regions across Europe we can observe a simultaneous extension and re-concentration of urban fabrics, which results in a complex patchwork of new centralities and urban forms (e.g. ESPON & Free University of Brussels – IGEAT 2010; EEA 2010; Hoyler et al. 2008; Maciocco 2008). On the city-regional scale, this becomes evident in post-suburban city-regions, many of which are experiencing employment growth in the areas surrounding central cities. This results in a polycentric restructuring of the centres and the former periphery of the region, with the emergence of new economic cores in the cities as well as in the suburban areas around the traditional inner cities. In the course of these developments, an assimilation of the morphological structures of the city in addition to the former periphery can be observed. While in the past, a sharp phenomenological division between the spatial categories ‘core city’ and ‘hinterland’ could be observed, in recent years these categories are constantly merging, followed by denotations such as the ‘Zwischenstadt’ or ‘Cities without Cities’ as coined by Sieverts (2002).

Figure 1. Dimensions of polycentricity at the city-regional level. Source: Münster et al. 2016 (modified)

In the course of this process of de- and re-concentration within the city-region, an accumulation of functions formerly located solely in the traditional cores, is taking place in more sub-urban locations. Consequently, as Burdack & Hesse (2006, p. 383) note, suburbia matures, because as the more suburban locations physically densify, they become more heterogeneous in social and economic terms and even might form functional labour divisions. In other words, the morphological reorganisation of the urban fabric and the subsequent emergence of new centres can be considered as the backbone of the development of functional-based relations between them.

The functional-relational dimension

Within this dimension, the focus lies on the level and spatial distribution of inter-dependencies between the centres. In this vein, a (city- or mega) region can be characterized as functionally polycentric if multi-directional exchanges between two or more centres occur across and/or through the region (Burger & Meijers 2012, p. 1133, De Goei et al. 2010). The measurement of such functional linkages is frequently based on commuter flows (e.g. Green 2007, Modarres 2011). In addition, other flow data are used as indicators, including shopping routes (e.g. Burger & Meijers 2012), communication and interaction flows within firms (e.g. Hall & Pain 2006; Knapp & Volgmann 2011) or within the organisation of value chains between firms (e.g. Lüthi et al. 2010).

Related to this is the question concerning the extent to which such linkages lead to a division of labour within the city-region at hand, which are ideally characterised by synergies and spill-over effects between the centres and literally jointly borrow size from each other to generate a critical mass for agglomeration advantages in a regional context. Such a division between centres in a polycentric region is for example measured by means of location quotients, which ascertain the specializations of the centres, or correspondence analysis to identify complementarities between the centres (Meijers et al. 2012, p. 36). However, recent research shows the restrictions and directions of exploiting such positive externalities (Burger et al. 2014a).

Processes and dynamics

As touched upon before, today's polycentric urban configurations have very different initial conditions in terms of their spatial structures. Champion (2001, p. 664ff.) identifies three different development paths for emerging polycentric urban configurations:

- *Centrifugal mode*: starting point is a monocentric city, which is continuously growing. To counter agglomeration disadvantages like rising land prices in the inner cities, new centres in the hinterland emerge, which increasingly compete with the core city.
- *Incorporation mode*: starting point is a dominant core city with independent smaller centres in the hinterland. Due to the growth of the core city, these smaller centres are increasingly under its influence.

- *Fusion mode*: starting point is several centres of similar size, with spheres of influence that gradually overlap.

These three paths of polycentric regional development show conceptual overlaps with the two generic spatial patterns and scopes discussed above: the centrifugal and the incorporation modes can be observed particularly on an intra-urban or city-regional scale, while the fusion mode is evident on an inter-urban or mega-regional scale. Nonetheless, these three modes of polycentricity underline the ongoing processes and dynamics within city-regions from morphological and functional dimensions that may stem from demographic factors (population growth and/or suburbanization), a redistribution of economic capacities within the region or from changes in the transport infrastructure for instance (cf. Lambregts 2009, p. 10; Hall & Pain 2006, p. 4). In other words, the emergence (and eventually also the disappearance) of polycentric urban patterns is conceptualised. These patterns will be further explored in the two case studies through two analytical approaches to illustrate dynamics based on a functional-relational as well as on a morphological dimension of polycentricity at the city-regional scale.

Integration and application as a normative planning concept

Across Europe, it appears that the concept of polycentricity has been absorbed by many city- or mega regions (ie. by the respective actors and institutions) and integrated into normative planning and development agendas (cf. Meijers 2007, p. 7; Meijers et al. 2012, Schmitt 2013). With closer inspection, it becomes obvious that the application of polycentricity, through the normative approaches in various city-regions inevitably differs enormously. As argued by Schmitt (2013), some city-regions or better, the respective actors, follow an ‘explicit polycentric agenda’, while others do it rather implicitly. The latter relates to the fact that the concept is being considered as interesting or promising in a number of ways, but has not yet been fully incorporated into respective policy documents. Also he notes that the concept is often understood as a purely strategic one, meaning that it is often related to other planning goals (such as densification, promoting multi-functional urban cores or developing decentralised regional transport networks). Another eye-catching characteristic in this dimension is that one can distinguish between promoting and maintaining polycentricity. The first is about ‘striving to make’ a metropolitan area or city-region ‘more’ polycentric – in a functional and/or morphological sense. The latter is to focus on ‘better utilising’ the current polycentric layout (ibid).

3. Analyzing emerging polycentric urban patterns - two cases

The Dusseldorf city-region: A functional-relational study of polycentricity

The first case study, the city-region of Dusseldorf in Germany (see fig. 2), analyses polycentric urban structures within the functional-relational dimension. The Dusseldorf city-region is a prime example of the complex overlap of polycentric patterns on a city- and a mega-regional scale. Even at the city-regional scale, focusing on the functional relations between Dusseldorf and its hinterland, it can be described as a traditionally multi-core city region consisting of a number of larger and smaller cities. On the larger mega-regional scale, it is part of the polycentric Rhine-Ruhr metropolitan region (Knapp et al. 2006; Münter & Volgmann 2014). In this section, we focus on processes of the city-regional scale, particularly the emergence of new economic cores. This 'city-region' is insofar interesting, since its core city, Dusseldorf, has seen, compared to most of the other cities in the Rhine-Ruhr agglomeration, a positive economic development in the last two to three decades, which resulted in a number of emerging economic cores. In addition, the city of Dusseldorf is among the leading German cities in terms of various economic (e.g. knowledge intensive services) and administrative functions (capital city of the Federal State of North Rhine Westphalia, location of a number of headquarters of larger enterprises) (cf. Volgmann 2013). In this regard, the Dusseldorf city-region and our second case study, the Stockholm city-region, are similar. However, the Dusseldorf city-region as defined for this case study (see fig. 2 and explanations below) also covers the western part of the 'Ruhrgebiet', a highly urbanised region which is still suffering from its steel and coal past. This is expressed by a relatively weak economic performance (e.g. in terms of GDP per head, level of entrepreneurship and (un-)employment rate) as well as by a shrinking population.

Figure 2 illustrates a functional demarcation of the city-region of Dusseldorf based on commuting flows. Included in the city-region are All municipalities from which more than 5% of their employees commute to the city of Dusseldorf have been integrated. Obviously, by using other thresholds and techniques of defining the spatial boundaries in this particularly part of North Rhine-Westphalia, one can easily demarcate the entire Rhine-Ruhr agglomeration (see Knapp & Schmitt 2003, Knapp et al. 2006, Münter & Volgmann 2014). However, in this paper we are interested in analysing the emerging polycentric urban patterns at a more narrow city-regional scale as represented by the other case of Stockholm as well. The resulting city-region includes 4.36 million inhabitants (2013) and a total of 43 municipalities (see fig. 3). The population of the city-region shrank with 125,000 inhabitants (-2.8%) between 2003 and 2013 due to the low performance of the western part of the Ruhrgebiet. In the same period of time, the population of the core city of Dusseldorf itself increased by 26,200 (4.6%). But the number of employees increased by 67,900 (4.4%) in the entire Dusseldorf city-region and 30.400 (8.8%) in the core city of Dusseldorf.

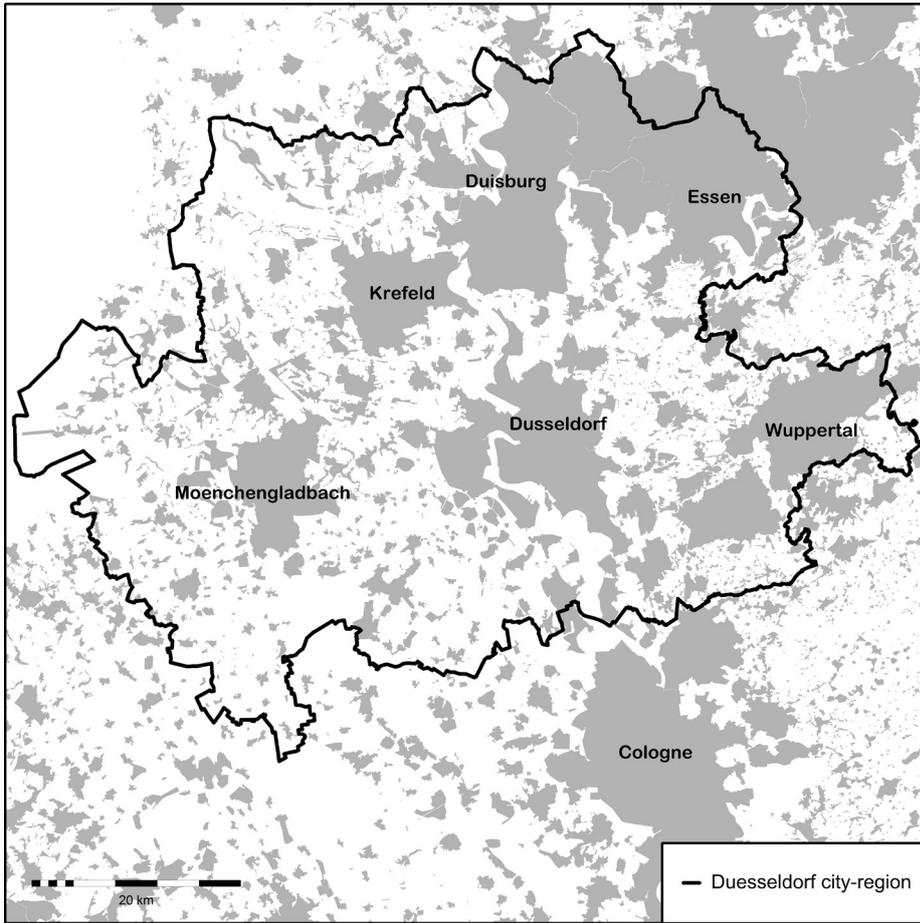


Figure 2. Settlement structure of the Dusseldorf city-region. Data Source: IT.NRW (own illustration)

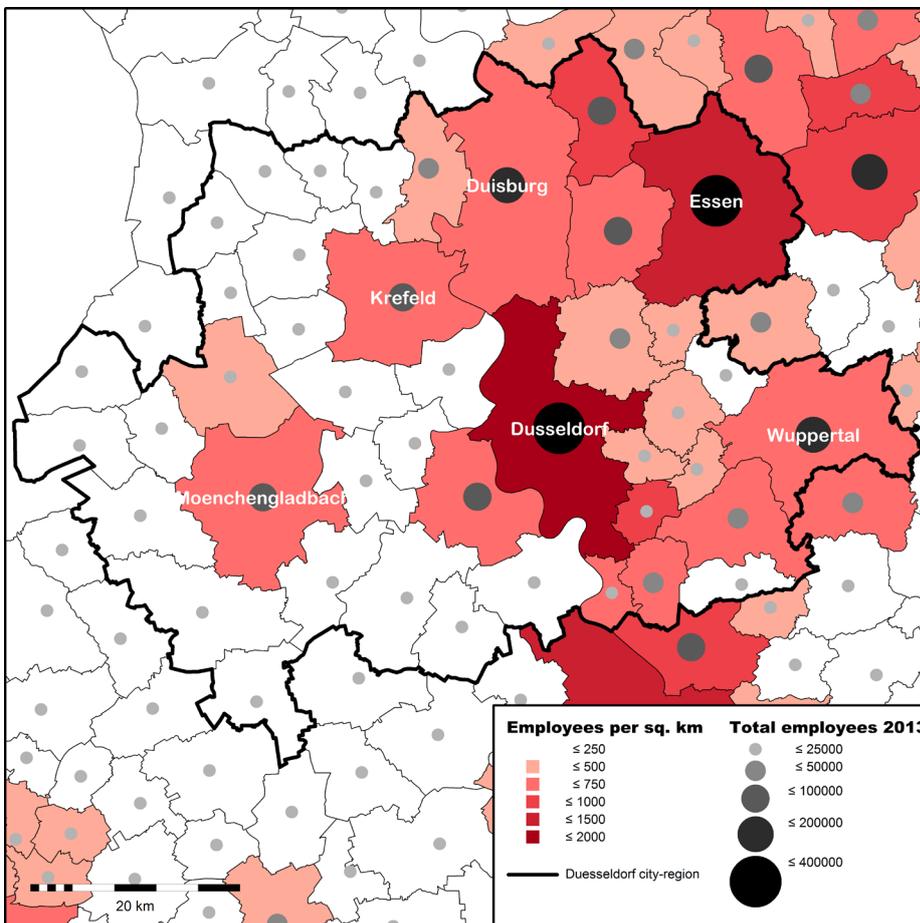


Figure 3. Employment figures of the Dusseldorf city-region. Data Source: IT.NRW (own illustration)

Economic cores in the Dusseldorf city-region

As a first step the economic cores have to be identified to understand the emerging functional-relational pattern of polycentricity within this city-region. In doing so, the business database Hoppenstedt (2007) provides address data of firms in various sorts of commercial activities. With the help of the kernel-density-method, a GIS-supported analysis tool for density/proximity-assessments, the address-data are aggregated to identify economic cores (for more details about the methodology see Knapp & Volgmann 2011; Münter & Volgmann 2014).

In total, 32 cores could be identified in the Dusseldorf city-region (, where 13 are located in traditional inner city locations (e.g. in the cities of Dusseldorf, Mönchengladbach, Krefeld, see fig. 4, dark red coloured areas,) and 19 outside of the inner cities (eleven of them are located inside the administrative borders of the larger core cities and eight within smaller surrounding municipalities, see fig. 4, orange coloured areas). The 19 cores outside the inner city can be called ‘new’ economic cores, since they are all characterised by rather recent economic activities, which have been mainly established in the last 20 years. Only a few are even older, namely from the 1970s, but still comparatively new compared to the inner city locations. For the most part, these activities take place on brownfields (ie. former industrial areas, e.g. the examples of Rath, Derendorf and Oberkassel in Dusseldorf or ‘Am Kaisergarten’ in Oberhausen), but there are also some greenfield developments as the example of the ‘TechnologiePark’ in Essen or the business park in Kaarst illustrate (see fig. 4).

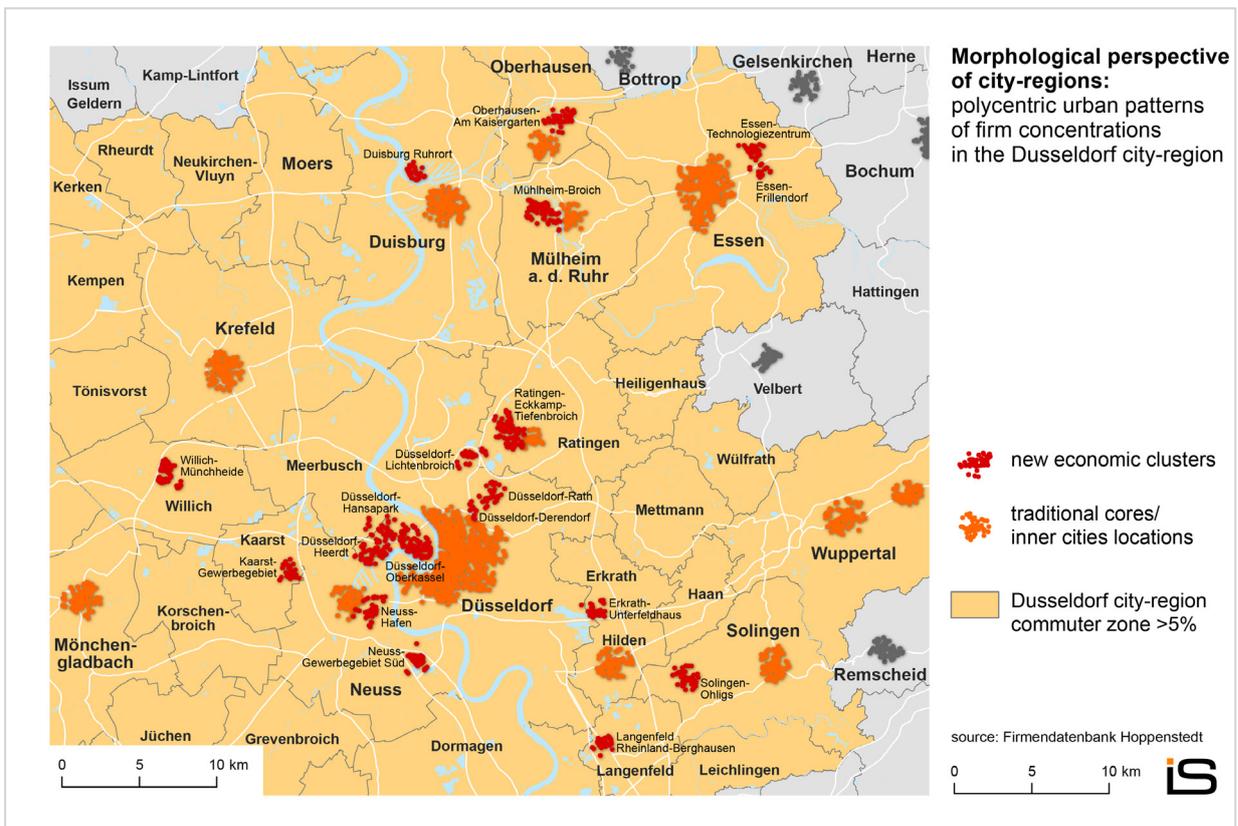


Figure 4. Spatial clustering of firms in the Dusseldorf city-region. Source: Own illustration based on business database by Hoppenstedt

Sectoral specialization and intra-regional division of labour in the Dusseldorf city-region

As Meijers (2005, p. 770) shows, synergies in polycentric metropolitan regions, which enable regions to be more than the sum of their parts, originate from "co-operation (regional organising capacity or frameworks for co-operation and their functioning leading to horizontal synergy) and complementarity (differentiation in the economic roles of cities, in urban facilities, in business and residential milieus coupled with a regional demand leading to vertical synergy)."

The cores in the Dusseldorf city-region differ from each other not only in their spatial scope and size in terms of number of firms and workplaces, but also in their different sector foci. The location quotient (SQ) is a proxy for differentiation in the economic roles of cities. It informs about the extent to which a certain commercial branch is over- or underrepresented in the core at hand (above or below the value 1) compared to the average value of the overall study area, ie. the Dusseldorf city-region (Schätzl 2000, p. 64). (As an indicator for a strong sector specialization, the threshold value 1.2 has been chosen).

Table 1 shows that not only are a large number of economic cores specialized by sector but also that there are indications of a functional division of labour within the city-region. Namely, the cores in the surrounding municipalities as well as those that are inside the main cities (but outside the inner city-locations) seem to complement the functional spectrum represented by the various economic cores of the traditional cores and inner city locations. The latter are more focused on company-related and skill-intensive services, whereas the former two categories are more focused on distributive services such as retail and wholesale trade, transport or energy as well as on manufacturing. In this perspective, one can assume a certain division of labour between the traditional cores (mainly the inner city locations) on the one hand and, what is called here, the new economic cores (at the edge of the main cities or even in the surrounding municipalities) on the other.

Functional-relational perspective: Assessing intra-regional communication potentials

To model intra-regional linkages between the traditional and the new economic cores on the basis of concentrations of firms in the Dusseldorf city-region on a locational level, a modified form of the so-called interlocking network model has been applied.¹ This model was originally developed within the 'Globalization and World City Study Group' (GaWC) (cf. Taylor 2002 and for its application Taylor et al. 2011, p. 424-425) as a proxy for analysing the intensity of flows between cities in the world economy. By studying the presence and importance of intra-firm office locations in cities (service) firms are being considered as key actors in world-city network formation. In our work, the model has been used to capture the relations between the firms in the identified economic cores within the Dusseldorf city-region to analyse their linkages on a

Table 1 (next page). Sectoral specialization (based on the location quotient) in the economic cores of the Dusseldorf city-region. Source: Own illustration based on business database by Hoppenstedt

	Municipality	Energy and manufacturing industry	Trade	Transport and telecommunication	Services, real estate and housing	Credit and insurance industry	Culture, sport and entertainment
Traditional cores/ Inner City Locations	Ratingen	0,88	0,91	0,61	0,90	2,21	0,00
	Dusseldorf	0,71	0,88	0,83	1,26	1,26	1,14
	Neuss	0,86	1,11	0,55	0,85	1,85	0,00
	Hilden	1,68	0,91	1,13	0,55	1,62	0,85
	Oberhausen	0,67	1,25	1,38	0,50	2,75	1,38
	Duisburg	0,69	1,26	0,14	0,83	1,74	1,28
	Essen	0,85	0,81	0,61	1,14	1,18	2,67
	Muelheim an der Ruhr	0,72	1,15	0,00	0,71	2,52	1,27
	Krefeld	1,10	1,06	1,18	0,71	1,84	0,30
	Wuppertal-Barmen	1,46	1,03	0,00	0,67	1,68	0,00
	Wuppertal	0,68	1,27	0,40	0,86	1,52	1,21
	Mönchengladbach	0,70	1,27	1,76	0,72	1,83	0,38
	Solingen	2,03	0,79	2,40	0,43	1,25	1,60
	New Economic Cores inside the main cities	Dusseldorf-Gewerbe im Park + Lichtenbroich	0,89	1,46	2,87	0,85	0,11
Dusseldorf-Rath		1,05	1,12	1,63	0,98	0,57	0,00
Dusseldorf-Derendorf		0,70	0,59	0,94	1,56	0,68	1,12
Dusseldorf-Hansapark		0,81	0,86	1,43	1,29	0,71	0,16
Dusseldorf-Oberkassel		0,63	1,02	0,32	1,36	0,59	0,48
Dusseldorf-Heerdt		1,92	1,13	2,42	0,59	0,07	0,00
Oberhausen Gewerbe- und Technologiepark Am Kaisergarten		1,25	0,85	1,43	1,17	0,09	1,07
Essen-Technologiezentrum		1,69	1,46	0,00	0,59	0,00	0,91
Duisburg-Ruhrort		1,33	0,75	1,29	0,96	1,18	0,97
Essen-Frillendorf		0,87	0,59	2,39	1,54	0,21	0,00
New Economic Cores inside the surrounding municipalities	Muelheim an der Ruhr-Broich	1,67	1,49	0,90	0,45	0,39	0,45
	Ratingen- Eckkamp-Tiefenbroich	1,76	1,02	1,10	0,74	0,46	0,33
	Willich-Münchheide	1,82	1,72	1,50	0,24	0,07	0,00
	Kaarst-Gewerbegebiet	0,90	1,74	2,47	0,56	0,16	1,85
	Neuss-Hafen	1,19	1,36	1,92	0,76	0,28	0,41
	Erkrath- Unterfeldhaus	1,85	1,08	2,30	0,52	0,70	0,00
	Neuss-Erfttal-Derikum	2,00	1,22	0,46	0,53	0,36	0,00
	Langenfeld-Berghausen	2,00	1,25	0,00	0,57	0,00	1,46
	Solingen-Ohligs-Zentrum	1,90	0,98	1,43	0,55	0,99	0,00

city-regional scale. Here we do not follow the original application of this ‘interlocking network model’ as a so-called ‘top-down approach’ that studies the world city network from the perspective of the world’s largest advanced producer service firms (cf. Taylor 2011). Instead we use a ‘bottom-up approach’ that considers key knowledge-intensive firms located within a select number of cities within a regional context. As mentioned above, we are not interested in their inter-linkages to other cities at the national, European or global scale (as other bottom-up studies suggested, cf. Hall and Pain 2006; Lüthi et al., 2010), rather we are interested solely in the ‘assessment of communication potentials’ between different locations (not municipalities) at the intra-regional scale, i.e. within the Dusseldorf city-region.

The aforementioned business database Hoppenstedt provides the necessary information. Thereby all firms within these identified economic cores with two or more locations inside the Dusseldorf city-region have been examined regarding their relative importance inside the firm’s office network. The underlying assumption is that the higher the rank of the office at hand within the firm’s hierarchy, the higher the exchange of information, knowledge, directives, capital etc. with other offices within the firm’s office network (for more details on the application of this model, see Knapp & Volgmann, 2011). A comparatively high connectivity value thus expresses that the economic core at hand has a (relatively) high communication potential in regards to other economic cores within the Dusseldorf city-region. These ‘linkages’ are captured through the physical office location and the functional importance of an office location at hand within the firm’s internal network.

The resulting pattern of linkages illustrated in figure 5 indicates the degree of polycentric interconnectedness on a city-regional scale, which is based on strategic location decisions made by the respective responsible persons of the firm(s) under consideration. Nonetheless, as noted previously, despite of some critical voices (e.g. as argued within studies on the Dutch Randstad; cf. Lambregts 2009; Burger et al. 2014b) the applied methodology has to be viewed as a ‘proxy for the assessment of communication potentials’ between firms and, in this sense, also between economic cores (see also Derudder and Parnreiter 2014 and their response to some of the critics in this respect). The most intensive linkages can be identified between the cores inside the administrative city of Dusseldorf, e.g. between Dusseldorf-Hansapark and Dusseldorf-Oberkassel (228 relations, standardized to 1.00) or, although with a large gap to the latter, between Dusseldorf-Hansapark and Dusseldorf-Heerdt (76 relations). Additional relatively strong tangential-intra-regional linkages (red line) can be recognised between the traditional economic cores of the surrounding municipalities such as between Krefeld, Mönchengladbach and Neuss or Duisburg and Essen. What is noteworthy are the many inter-municipal ‘medium intensive’ linkages (orange line) between the new economic cores. However, at closer inspection, we see that in most cases these new economic cores have two or three linkages of medium intensiveness but seldom more. An exception seems to be the new cores but also the traditional core of Dusseldorf. Looking

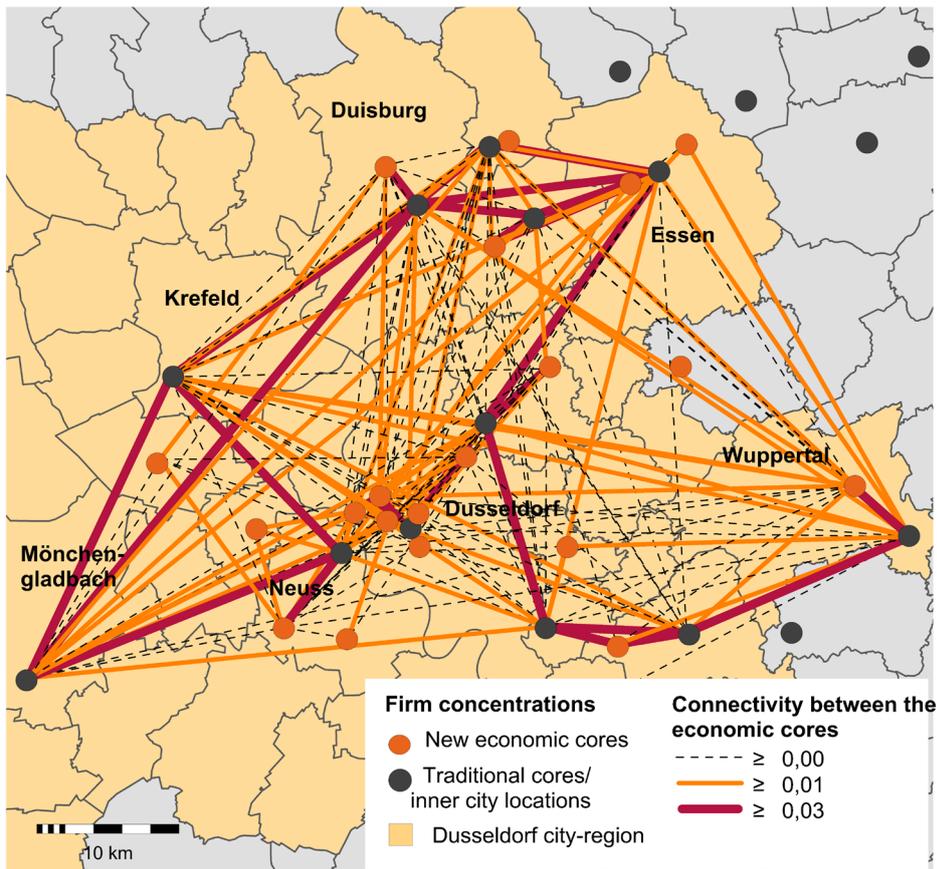


Figure 5. Intra-regional functional relations between the economic cores of the Düsseldorf city-region. Source: own illustration based on Firmendatenbank Hoppenstedt

at linkages between traditional and new economic cores, the emerging pattern is rather fuzzy. Nonetheless, the relative central function of Düsseldorf becomes clear as well as the fact that the more intensive intra-regional linkages occur mainly between the traditional cores of the main cities.

Although there is a widespread exchange between the new cores, these cannot be considered separately from the traditional core areas as they seem to form a division of labour with them. However, applying this method, it becomes clear that the city centres are no longer the exclusive magnets for employment; rather together with the new economic cores, they form a functional intra-urban polycentric pattern.

The Stockholm city-region: a scenario-based morphological study of polycentricity

The second case study focuses on Sweden’s capital city-region, which has been selected because of the explicit normative approach of becoming more polycentric at the city-regional scale in recent years (cf. Schmitt 2013; Schmitt et al. 2013). Though, the core city, Stockholm, historically has been the clear leading city in terms of its size and functional dominance compared to a handful of smaller centres at the edge of Stockholm’s municipal boundaries or further outside in the neighbouring municipalities. Over the centuries, Stockholm’s urban fabric has spread outwards from the Old Town, at a ridge between the lake Mälaren and the Baltic Sea, and due to its hilly topography, with a number of water

bodies in-between, it has literally jumped outwards over to the ‘next island’ and/or next municipality (cf. Schmitt et al. 2013).

In recent years, the normative concept of polycentricity has been heavily debated in the Stockholm city-region as an overarching response to a number of related challenges. The most prominent challenge to cope with is the, at in a European comparison, immense population growth. Between 1990 and 2002, Stockholm County grew by 13% (200,000 people in total, compared to 4 percent in the whole country. This growth is expected to continue, with 2.914 million residents expected by 2045, an increase of 800,000 people from 2014 (TMR & SCB 2012)

The indicative strategic regional plan from 2010 suggests polycentric development by aiming to develop eight so-called ‘regional urban cores’ (regionala stadskärnor) at a distance of fifteen to forty kilometres from the inner city of Stockholm. Such ‘regional urban cores’ shall serve as ‘territorial anchors’ to concentrate land developments as well as to accommodate distinct urban functions. To that end, investments in the transport system, increased density and energy efficient settlements (e.g. creating competitive milieus, more diversified work places, higher education and health care facilities) shall be promoted to develop a robust polycentric structure (Office of Regional Planning and Urban Transportation 2009; Office of Regional Planning, 2010).

Assessing future potentials for ‘more’ morphological polycentricity

The rationale for using a scenarios as a method to assess future potentials for ‘more’ morphological polycentricity (and based on this eventually even ‘more’ functional polycentricity) is based on the assumption that existing urban forms tend to be stable, even in phases of accelerated growth. As argued by Schremmer et al. (2011a, p. 112) “the spatial grid, the main transportation infrastructures and the way residential and economic functions are being localized and formed can be transformed only in decades”. Also, the scenario method can provide realistic of the space for action for policy makers and planners until the year 2050 by generating a ‘base’ scenario that reflects prevailing trends and the current local and regional policy and planning agenda and one scenario that is geared to improve the city-regions resource efficiency (a so-called ‘SUME’ scenario²). To that end, four principles have been applied, which correspond exactly with the above-sketched aims of the strategic regional plan in regards to making Stockholm more polycentric: a) spatially focused densification; b) high-density development only with high quality Public Transport access; c) functional mix in urban quarters; and finally d) combine urban and building (object)reconstruction.

Figure 6 outlines the two urban development scenarios for the Stockholm city-region: BASE and SUME. They have been elaborated based on the Urban Morphological Zone (UMZ), which comprises those urban areas that are identified from land cover classes contributing to the urban tissue and function.⁴ These land-cover classes have been related to statistical data and available projections for population, jobs, the building stock (especially housing type and building age) and the approximated total floor space per capita and workplace. For the further

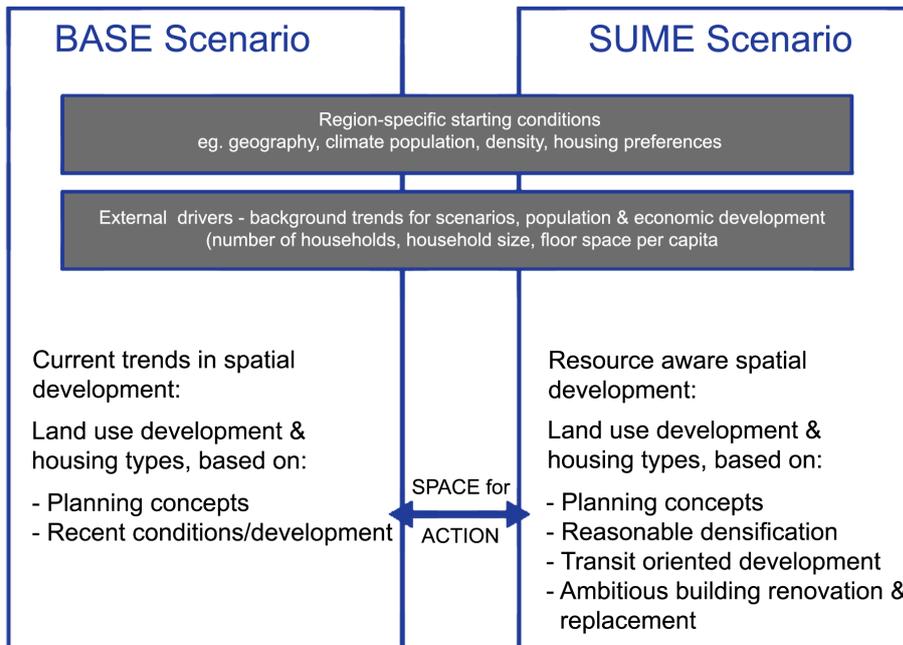


Figure 6. Overall structure of the BASE versus the SUME scenario³. Source: Schremmer et al., 2011b, p. A11, amended

preparation of the two scenarios, the Stockholm UMZ has been divided into 786 cells (census tracts) - ranging from a minimum population of 0 to a maximum of 9,464. For the pure calculation process, the following steps (1 and 2a to 2d) have been undertaken as illustrated in figure 7.⁵ The resulting Stockholm UMZ illustrates a rather narrow city-regional geographic scope compared to the Dusseldorf case (cf. fig. 9 and 10). Compared to the BASE scenario, the SUME scenario has a clear focus on harnessing the potentials for densification in all areas within the UMZ, with a particular emphasis on those areas proximate to high-speed public transportation infrastructure. The ‘allocation’ of population and jobs has been guided by applying different specific density thresholds for the identified prevailing housing types (i.e. ‘single family homes’, ‘mixed area’ and ‘multi-storey’, which are higher in the SUME compared to the BASE scenario (cf. Schremmer et al. 2011c, p. B61 and B62). Further, in

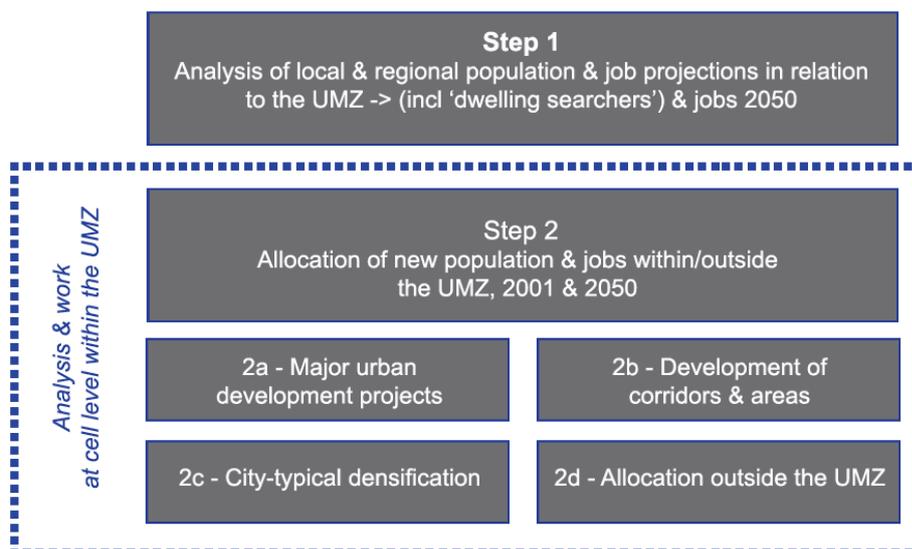


Figure 7. Working steps for calculating the two scenarios Source: Schremmer et al. 2011b, p. A26, amended

Type of input data	2001	2050 BASE & SUME	Change (in %)
Population	1 280 450	1 848 000	+ 567 550 (44,3%)
Jobs	763 629	1 102 102	+ 338 473 (44.3%)
'Dwelling seekers' (leaving existing housing stock)		160 056	
Total population to be allocated		727 606	
Total jobs to be allocated		338 473	
Approximated floor space per capita (m2)	40	45	
Approximated floor space per workplace (m²)⁶		22.5%	

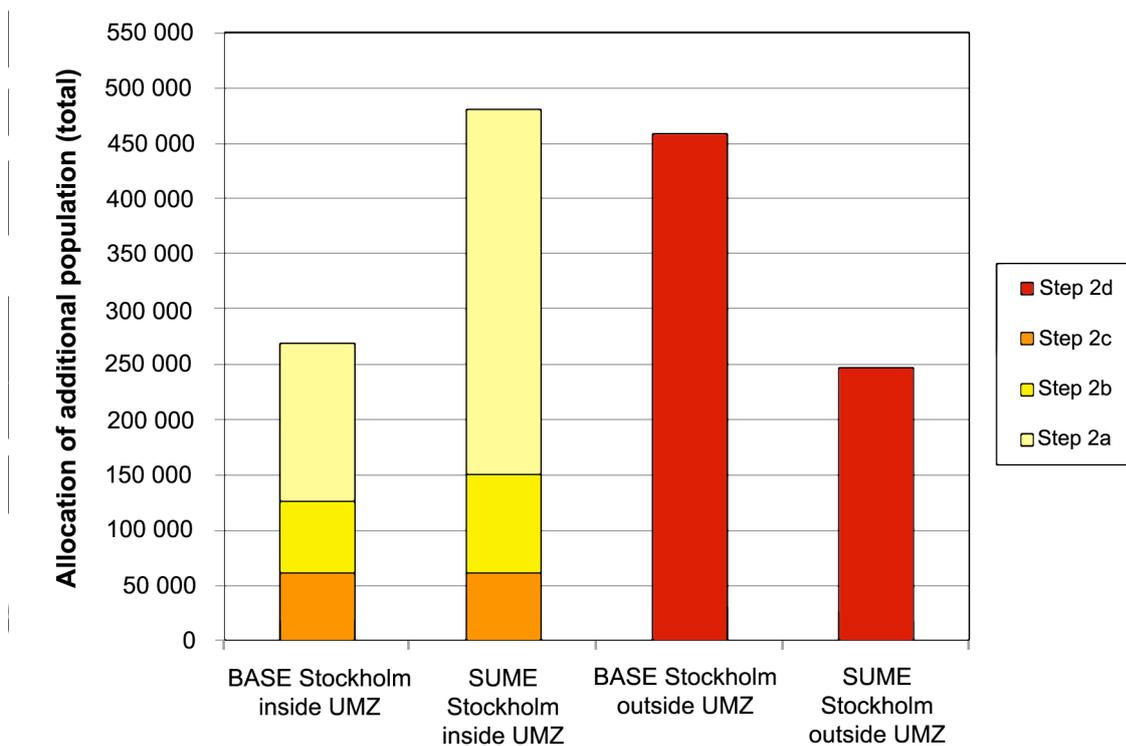
Table 2. Basic input data to the two urban scenarios for the Stockholm city-region
Source: Schremmer et al. 2011c, p. B57, amended

the SUME scenario, all census tracts with access to a high-level public transport station (within a 3.5 km catchment of the city centre or within a 1 km catchment of a rail-based public transit line) have been 'upgraded' by one housing type.

Assessing Stockholm's future potential for 'more' morphological polycentricity

Consequently, as figure 8 illustrates, there is a noteworthy difference between the population that is allocated to the Stockholm UMZ in the BASE and SUME scenarios. As mentioned, there is no difference between the population (or jobs) allocated in the 2a projects as they are based on projects already in the planning stage, but within STEP 2b additional 24,200 people have been distributed within the UMZ in the SUME scenario (compared to the BASE one), which is due to the higher threshold densities that are assumed in this scenario. However, the main distinction between the two scenarios lies in the number of people that are distributed within the Stockholm UMZ in STEP 2c (cf. fig. 8). The SUME scenario, based on a higher density threshold and a densification of cells in proximity to public transportation, allocates additional 187,902 people compared to the BASE scenario in STEP 2c. Based on Stockholm's population forecast for 2050, it can be further noted, that the area of the Stockholm UMZ will grow by 46.7% in the BASE scenario compared to only 19.6% in the SUME scenario.

The key findings from the BASE and SUME scenarios are illustrated by showing the change in densities implied by the BASE (see fig. 9) and SUME (see fig. 10) scenario between 2001 and 2050. The two maps highlight the densification of many cells (census tracts) surrounding the inner city, with a particular emphasis on the area immediately west of the central core, the inner city of Stockholm and the substantial development just to the northeast of the city centre. Most notably, high growth rates in both the BASE and SUME scenarios are projected along the transport corridor toward the regional urban core of Haninge. Ad-

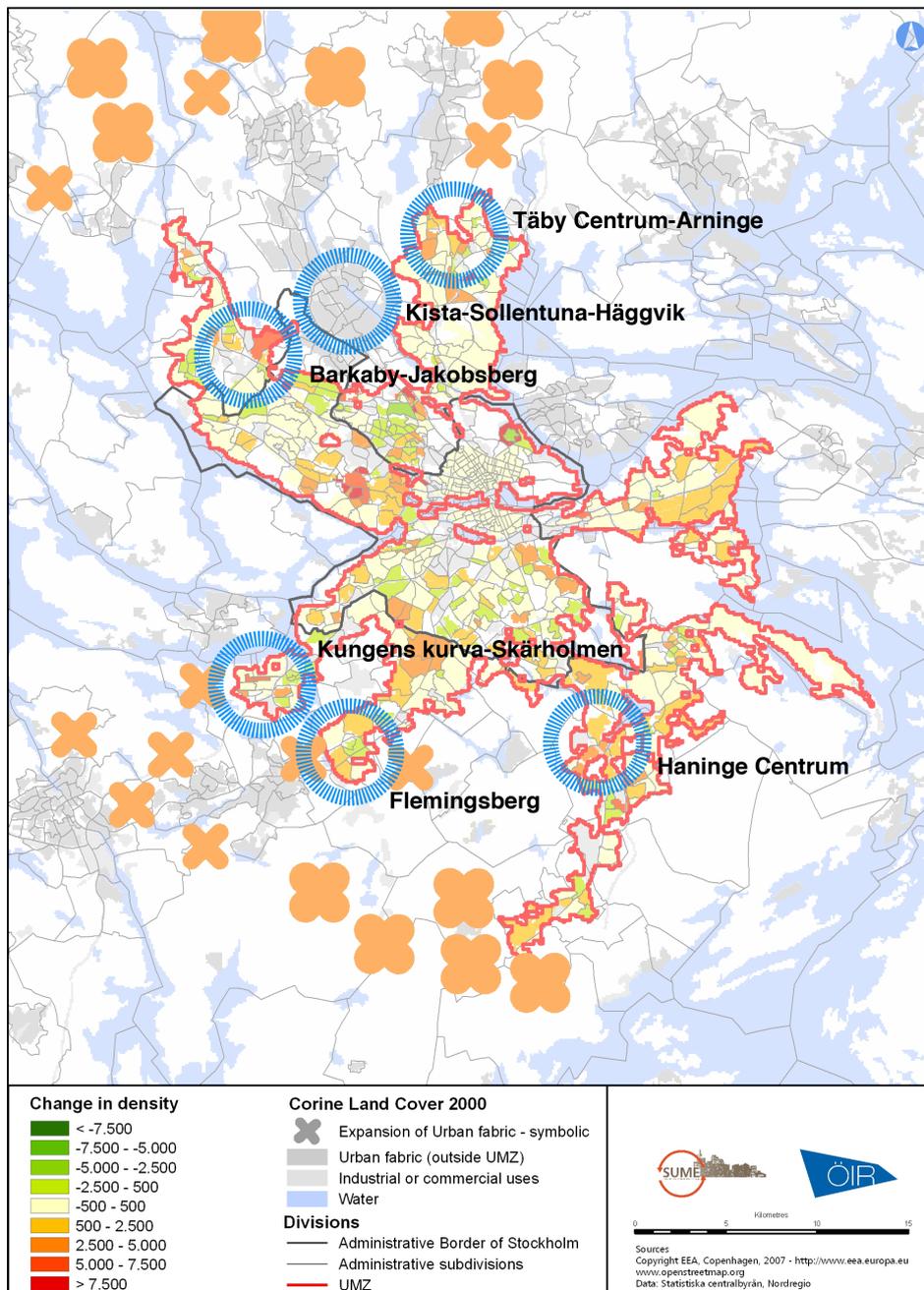


ditionally, the designated regional urban cores of Täby, Flemingsberg, Kungens Kurva- Skärholmen and Barkaby-Jakobsberg also show significant growth potentials in terms of the allocation of population and jobs. Further, both scenarios also indicate the limited potential in the inner city to absorb additional population, which is caused by three factors: the relatively high current density, the preservation of sites of historic interests and the projected increase of floor space per capita by 12.5% (see table 2). Particularly in the SUME scenario, we can recognise potentials for further densification along some transport corridors (e.g. on a northwest trajectory moving from the inner city or towards (and including) the designated regional urban cores of Haninge, Flemingsberg and Täby, see fig. 10).

The analysis of growth potentials in the Stockholm urban form demonstrates that efforts to accommodate Stockholm's growth in terms of population and workplaces will need to largely focus on surrounding areas outside the inner city of Stockholm that currently have lower densities. If the current regional plan is fully implemented, according to the BASE scenario, Stockholm's urban fabric will still expand by 155 km². However, if policies that promote even further densification in strategic areas are adopted, as assumed in the SUME scenario, this expansion would be reduced to 65km². Further, the persistence of current planning trends (here the BASE scenario) would result in about 167,000 additional residents within the current UMZ in 2050, while a denser development strategy, as anticipated in the SUME scenario, would lead to about 379,000 new residents within the Stockholm UMZ.

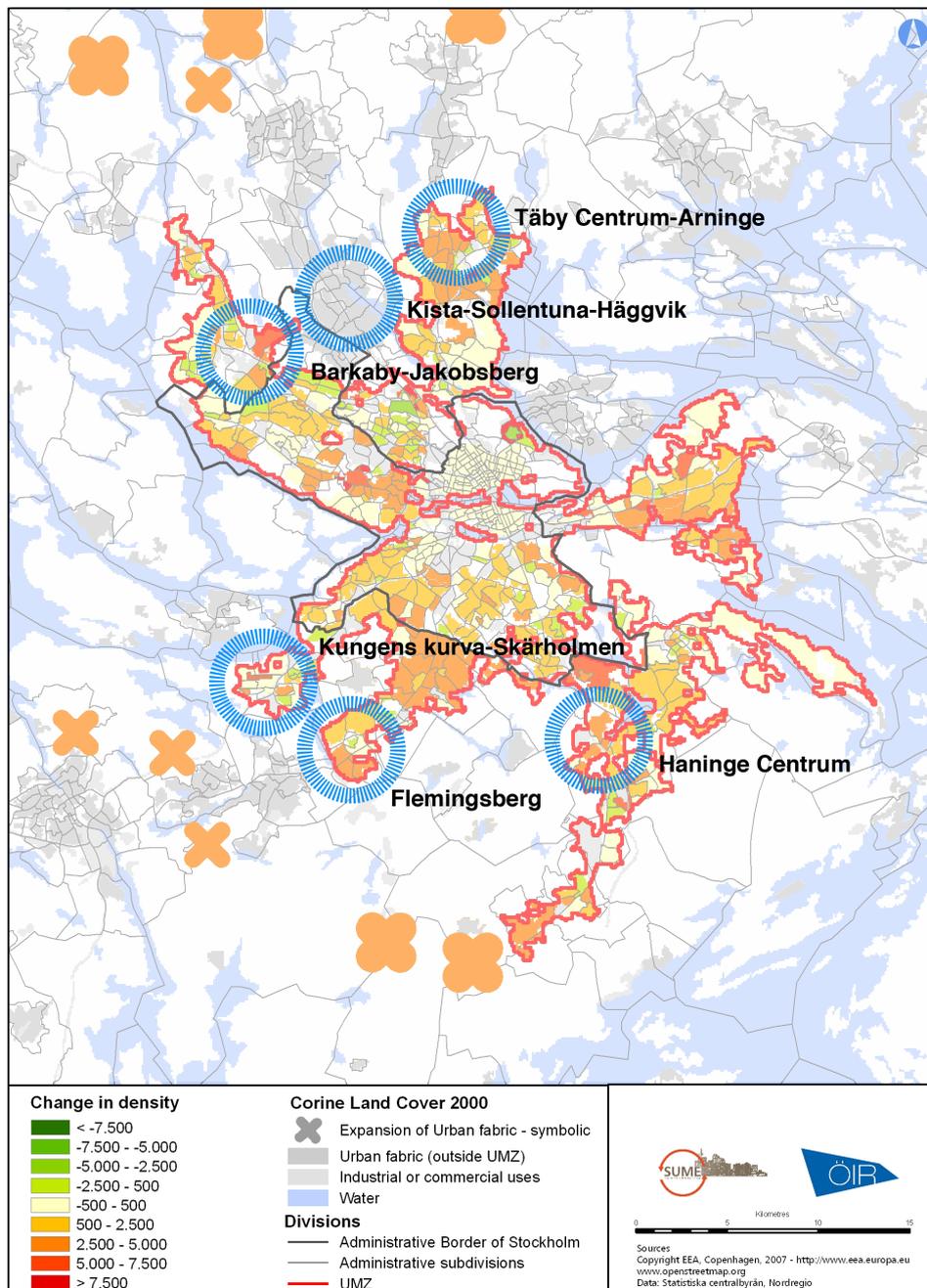
The comparison of the two scenarios also makes it clear that the potentials for morphological polycentricity in the Stockholm city-region

Figure 8. Allocation of additional population (in total). Source: Schremmer et al. 2011c, p. B63, amended



can only be utilised if the two general principles of the SUME scenario are implemented, namely ‘higher density thresholds for the prevailing housing types’ as well as ‘further densification of cells in relation to public transportation’. Only then can a polycentric morphological structure be visible in 2050 that is characterised by higher densities in the ‘regional urban cores’ compared to their surrounding areas. These cores could become the backbone for also carving out a much stronger degree of functional-relational polycentricity at the city-regional scale as it is now.

Figure 9. Change of aggregated population and workplace density: 2001 compared to 2050 (BASE Scenario). Source: Schremmer et al. 2011c, p. B68, amended



4. Key lessons from the two case studies

In this paper we have illustrated two ways to comprehend city-regional dynamics through an analysis of emerging polycentric urban patterns. In the example of the Dusseldorf city-region, a study of the functional-relational dimension has been applied to analyse the ‘current’ degree of ‘functional’ polycentricity with a specific focus on the role of economic cores that are located outside the inner cities and that have been established in the last twenty years. In the case of the Stockholm city-region, the focus has been on assessing the ‘future’ potential degree of polycentricity within a ‘morphological’ dimension.

The examples are also rather different due to their wider territorial and evolutionary context. The Dusseldorf city-region is embed-

Figure 10. Change of aggregated population and workplace density: 2001 compared to 2050 (SUME Scenario). Source: Schremmer et al. 2011c, p. B69, amended

ded within the wider Rhine-Ruhr urban agglomeration, which could be characterised according to what Champion (2001 664-665) identifies as a 'fusion mode' of a polycentric city-region (cf. also the discussion by Schmitt & Knapp 2006). The Stockholm city-region is surrounded by a comparatively modest urbanised hinterland, but is in a process to either follow the centrifugal mode or the incorporation mode according to Champion's typology (ibid.). The latter might be the case if the urban fabric will develop as it is forecasted in the BASE scenario, the former could become reality if a land-use policy would be followed that is closely based on those criteria that have underpinned the SUME-scenario.

Both case studies show various sorts of spatial dynamics which have been carved out by using established tools and methods in urban and regional studies; 1) namely symmetrical kernel function, location quotient, intra-firm linkages based on the GaWC-interlocking network model, and 2) analysis of planning policy and statistics, scenario-based land-use models. However, these tools and methods have been modified in view of the questions at hand.

The empirical findings for the Dusseldorf city-region show the emergence of new economic cores (see fig. 4 and 5 as well as table 1) in particular in the last twenty years that indicate a functional intra-urban polycentric pattern based on the communication potentials of the various firms. A picture of polycentric interconnectedness at the city-regional scale is emerging. However, this does not wipe away the historically established urban hierarchy and level of functional and morphological polycentricity. Rather, another layer of urban cores have been added in the last 20 years or so, which, in this sense, increases the overall level of functional intra-urban polycentricity in the Dusseldorf city-region.

The scenario-based study on Stockholm's potentials for more polycentricity has revealed that it might be even more difficult to carve out such structures against the background of the forecasted extreme growth dynamics (in terms of population and workplaces) as well as under consideration of the current planning agenda. Indeed, the strategy for promoting polycentricity has been reinforced in the recent regional development plan (Office of Regional Planning, 2010) as an important factor for combating urban sprawl that would counteract the development of a more distinctive polycentric urban configuration. But as our analysis shows, a much stronger focus must be put on integrating the designated regional urban cores into a transit-oriented development strategy at the city-regional scale that is characterised by dense and mixed used areas, if urban sprawl is sought to be prevented.

However, interviews with municipal planners in 2010 verified that the designation served as a catalyst for developing denser, more intensively used centres, only for some municipalities. For other municipalities, there was little interest in promoting urban qualities such as higher densities or a greater mix of uses in such designated cores. For these municipalities, the designation was more of an honour than the foundation for a new regional urban core. Ensuring that stakeholders are aware of their opportunities and responsibilities in becoming such regional urban cores is key to fostering an urban form that is more conducive

to public transit and densification. Beyond this, several planners from smaller municipalities noted concern about competition between designated regional urban cores in the regional development plan and areas that the City of Stockholm intended to develop on its territory in terms of densification and functional mix.

Having said this, it shall be also noted that both studies highlight rather ‘potentials’ (here in a sense of ‘communication potentials’ or ‘potentials for future land-use changes’) for becoming ‘more’ polycentric, be it in regarding the functional-relational or rather morphological dimension and not necessarily a status-quo analysis. The future will show to what extent these potentials are further utilised or confronted with more monocentric driving forces. This underlines the importance of analysing processes and dynamics (see fig. 1), which seems to be critical in doing research on polycentricity.

5. Conclusions

The two case studies as well as the different dimensions (functional-relational and morphological) that underpin them illustrate some facets of polycentricity at the city-regional scale. In doing so, we have demonstrated that although some consensus has been established in the literature about the key facets and dimensions of polycentricity (see section 2), at closer inspection, there are a number of variations in terms of the internal dynamics, the territorial contexts and path-dependencies of (becoming) polycentric urban regions. If one would have added more cases and eventually more facets to view polycentricity, these variations might have come even more obvious. Hence we argue that, academics as well as planning professionals and policy-makers need to be aware of these different spatial dynamics at the city-regional scale, be it functional-relational or rather morphological. This awareness offers the benefit of being able to construe and characterise the current or future state of polycentricity of a particular city-region as well as to identify options for planning and policy. In other words, sound strategies to promote and mobilise various facets of polycentric development should be carefully reflected and related to the specific territorial context at hand as well as the theoretical, methodological and even normative starting point of any attempt of comprehending polycentricity.

Nonetheless, our two rather differently designed case studies illustrate opportunities for understanding city-regional dynamics through analysing of emerging polycentric pattern (ie. the integration of various facets and dimensions of polycentricity and the application of different methods), as well as several of the main restrictions. The latter relates particularly to issues such as data availability (e.g. in regards to functional linkages, forecasts, or the geographical scale of information) or the explanatory power of generated data (e.g. using attribute data to anticipate relations between places).

In conclusion caution must be taken regarding how polycentricity at the city-regional scale is viewed and understood, what aspects are in focus, what restrictions in terms of methodology and data availability are unavoidable and, most importantly, what expectations are linked to

it by policy- and decision makers. Such investigations need to be carefully anchored in the multi-faceted debate on polycentricity within city-regions, due to the various dimensions, underlying theoretical starting points as well as different methodological potentials and limitations. A particular focus should be laid on the processes and dynamics, ie. understanding polycentricity as an evolutionary process that reveals different insights into the various dimensions and facets which should be construed separately (as suggested here by the two different case studies). In other words, one dimension or facet can tend towards 'more' polycentricity, whereas the other one towards 'less' polycentricity. Hence future research should engage more with exposing and comparing these facets and dimensions. Only in this way the analysis of 'more or less' polycentric city-regions is expected to give useful insights into urban and regional development dynamics and can support modifying corresponding normative reflexes with regards to spatial planning concepts and related policies.

Endnotes

¹As the new economic poles were identified on a sub-municipal locational level, commuter data which are the most common proxy of functional linkages within polycentric regions (see for example De Goei et al., 2010 or Green 2007) cannot be applied here for comparison, since they are only available on the municipal level.

²SUME stands for 'Sustainable Urban Metabolism for Europe' and is the name of an international research project that has been funded within the 7th Framework Research Programme of the European Union in which two of the authors of this paper have been involved in.

³Within the SUME-project, similar urban development scenarios have been applied for in total seven city-regions: Vienna, Munich, Oporto, Athens, Newcastle, Marseille and Stockholm (cf. Schremmer et al. 2011a, b and c).

⁴These UMZs have been provided by the European Environmental Agency (EEA). To that end, CORINE land-cover classes considered as 'urban' (which comprises the following 'core' classes: 'Continuous urban fabric', 'Discontinuous urban fabric', 'Industrial or commercial units', and 'Green urban areas') have been merged to UMZs, if their individual grid cells are located less than 200m apart as recommended in a UN Habitat definition of urbanization

⁵The original methodology has covered two additional steps (3 and 4), which should not be considered here as they are not of further importance for the purpose of this paper (see Schremmer et al. 2011b). The urban scenario for the Stockholm city-region has been conducted in 2010, but to be able to calculate reasonable projections for those data that were not available for the year 2050, the year 2001 has been taken as a starting point. The data gathering for the identification of major urban development projects (step 2a) was provided by studying city planning documents as well as the previously mentioned regional plan from 2010. That said, in both scenarios (BASE and SUME) the application of the concept of polycentricity has been fully integrated, since the designated regional urban cores have been prioritized for steps 2b, 2c and 2d (see fig. 7).

⁶The space used per workplace within the urban fabric is defined as being approximately half of the residential use of floor space per capita. Hence, the input value of total 'on site-density' is calculated as density of population and half of jobs within the urban fabric $[(\text{population} + \text{jobs}) / 2] / \text{km}^2$ urban fabric (see Schremmer et al. 2011b). These approximated values can be considered as fairly moderate in order to avoid overestimating the need for further densification.

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