A synthetic approach to the delimitation of the Prague Metropolitan Area

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ABSTRACT
The main objective of this paper is to apply a synthetic approach to the delimitation of metropolitan areas, which combines traditional commuting data from the population census with alternative approaches. The presented delimitation, which was originally realized in response to a request from Prague’s planning authority, is based on three methodological pillars: the use of economic and social aspects of metropolization; suburbanization; and daily mobility within the Prague Metropolitan Area. Integrated systems of centers calculated from population census data are complemented with the use of mobile phone data. There was a surprising level of similarity in the spatial patterns gained from the two methods. Zones of residential suburbanization and time spent in the core city provided a complex perspective on the daily urban system within the Prague Metropolitan Area. A synthetic map based on the four methods is provided, accompanied by five analytical maps on a smaller scale.

1. Introduction
The delimitation of metropolitan areas is one of the traditional practical tasks in urban/settlement geography and planning. Frey and Zimmer (2001) offer an overview of different approaches to the delimitation of metropolitan areas in which they distinguish ecological, economic, and social aspects of delimitation. Ecological approaches use basic criteria connected to population size and density. Within the Czech tradition of settlement geography, the so-called areas of maximal population density developed by Jaromír Korčák (1966) serve as an example of this approach. This method was further developed by Martin Hampl (Hampl, Gardavský, & Kühl, 1987). Economic approaches to the delimitation of metropolitan areas employ measures such as the economic structure of the population, commuting patterns, and concentration of jobs. This approach led to the establishment of various definitions of metropolitan areas in the form of metropolitan statistical areas, functional urban areas, or metropolitan labor areas (Hall & Hay, 1980; Johnston, 2009; Kostelecký & Čermák, 2004; Kraft, Halás, & Vancúra, 2014; Sýkora & Muliček, 2009; van den Berg, Drewett, Klaassen, Rossi, & Vijverberg, 1982).

The incorporation of social aspects is relatively rare in comparison with the former two approaches and involves consideration of ‘soft’ characteristics such as urban lifestyle, social climate, residential satisfaction, and social cohesion (Doležalová & Ouředníček, 2006; Špačková, Dvořáková, & Tobrmanová, 2016; Špačková & Ouředníček, 2012). The main objective of the present paper is to apply a synthetic approach to the delimitation of metropolitan areas, which combines traditional commuting data obtained from the population census with alternative approaches and new sources of data connected to more economic and social aspects of metropolization and suburbanization. The delimitation of the Prague Metropolitan Area (PMA) originated from a request from Prague’s planning authority, the Institute for Planning and Development of the Capital City of Prague, for Integrated Territorial Investment (ITI), which is a new tool introduced by the European Structural and Investment Funds. ITI aims to make it easier to manage territorial strategies that require funding from multiple sources and to promote a more ‘place-based’ form of policy making (European Commission, 2014). This is of particular importance in the case of the Prague Metropolitan Area, which is located at the junction of two self-governed administrative regions with different policies, strategies, and planning documents. For example, Prague and the Central Bohemia Region have two separate regional master plans, and the area within the administrative borders of the city of Prague is coordinated independently from the remainder of the metropolitan area. This leads to the main research question in the present paper: Is it...
possible to employ a common tool for metropolitan planning and more specifically to overcome the contemporary polarity of the self-governed administrative division within the Prague Metropolitan Area? A delimitation of the Prague Metropolitan Area can be perceived as one of the first steps towards more coordinated governance of the largest urban center in Czechia.

In the Czech context, the term ‘metropolitan area’ is closely related to the process of metropolization, which can be perceived as a high level of urbanization featuring a profound spatial division of labor and a growing inter-relationship between different parts of the regional settlement system (Musil, 1967, p. 203). The metropolitan area is a functional region that is formed through the socio-spatial division of labor, and functions between different settlements of the region. This functional differentiation developed during the preindustrial, industrial, and post-industrial periods of the settlement system (see Figure 1). The contemporary development of the settlement system and large metropolitan regions features reciprocal (centripetal and centrifugal) relationships, the organic cooperation of settlements, and high spatial concentrations of contacts within the metropolitan region (Hampl et al., 1987; Hampl, 2005). The first pillar of our methodological approach to the delimitation of the Prague Metropolitan Region (Integrated systems of centers) is developed from these ideas.

The most important urban process contributing to the internal differentiation of metropolitan regions in post-socialist countries is suburbanization (Ouředníček, 2007; Pászto, Brychtová, Tuček, Marek, & Burian, 2015 in this journal). Suburbanization can be defined as the movement of populations and their activities (residential function, jobs, services, administration, etc.) from the core cities to the hinterland. Both the residential and commercial forms of suburbanization are developed around Prague (Sýkora & Ouředníček, 2007), but monitoring residential suburbanization is more useful for the delimitation of a metropolitan region. While locations alongside the main highways and radial patterns are more characteristic of the distribution of commercial functions (logistics, hypermarkets, and offices), residential suburbanization creates concentric patterns of new development. The distinctive features of residential suburbanization are new housing construction and the migration of the population from the core city of the metropolitan area (similarly Halás, Klapka, & Tonev, 2016). Therefore, these two measures – migration from the core city to the hinterland and intensity of housing construction – are used in the present paper for the delimitation of zones of residential suburbanization (Ouředníček, Špacková, & Nováč, 2013), which represents the second pillar of our methodological approach.

There is another form of spatial mobility, in addition to migration, that can be used to identify daily urban systems (Doxiadis, 1970). In accordance with concepts of time-space geography (Hägerstrand, 1982), individual mobility within the metropolitan area for various kinds of activities can structure the social and functional environment of that metropolitan region (Giddens, 1984; Novák & Sýkora, 2007). The Centre for Advanced Spatial Analysis at University College London has developed systematic studies of daily mobilities within cities (Kitchin, 2014; Zhong et al., 2016). Daily routines within the metropolitan area can be traced using data from mobile phone operators on an aggregate level (Ahas, Laineste, Aasa, & Mark, 2007, 2009, 2010; Pospíšilová & Novák, 2016). For example, such data were used for mapping commuting patterns and functional regionalization in Estonia (Novák, Ahas, Aasa, & Silm, 2013 in this journal). In the case of Prague’s hinterland, mobile phone data were employed in a case study of the Dolní Břežany suburb (Novák & Novobilský, 2013). Mapping of daily paths using mobile phone data is, therefore, the third pillar of our methodological approach.

The main map presented here is a cartographic synthesis of these three different pillars used to delimit the Prague Metropolitan Area based on statistical analyses and the combination of results from each pillar. The area consists of 14 administrative units – the Capital City of Prague and 13 adjacent areas of municipalities with extended powers (MEPs) (official units of public administration). Each partial pillar is visualized in one or two smaller scale maps.

### 2. Methods and data

#### 2.1. General approach to the delimitation of the Prague Metropolitan Area

The delimitation of the Prague Metropolitan Area is based on several inter-related requirements. First, we aim to use theoretically and methodically verified concepts and to base the final delimitation on the triangulation of these concepts. At the same time, however, we test the relevance of new data sources used for such purposes.

Second, the delimitation must reflect primarily the socio-economic relations in the regions. The Prague Metropolitan Area should represent the region of intensive daily contacts (thus being smaller than the settlement agglomeration) of a centripetal, centrifugal, or tangential character. Also, the spatial arrangements of both existing and planned structures and networks (mainly connected to transport) should be reflected. While reflecting these requirements, we delimit the Prague Metropolitan Area through a synthesis of four different methods, which combine population census data, annual statistics of migration and housing...
The different methods are used to delimit (i) the integrated system of centers based on commuting patterns (first pillar); (ii) the integrated system of centers based on mobile phone location data (first pillar); (iii) residential suburban zones (second pillar); and (iv) the average time spent in Prague by local populations (third pillar). The essential basic requirement of policymakers and practitioners is to delimit the Prague Metropolitan Area at the level of administrative areas where planning authorities already exist. Therefore, we chose the spatial unit of delimitation to be the administrative districts of MEPs,1 representing areas of decentralized state government (building offices, cadastral offices, planning offices etc.). For very similar reasons, the Prague Metropolitan Area should not exceed the area of the Central Bohemia Region. In addition, integrated functional units in the form of sub-regions, micro-regions, catchment areas, or daily contact areas should be delimited on the borders of the Prague Metropolitan Area to enable local actors to participate actively in the ITI program.

We present a mosaic of six maps. First, there are five smaller scale analytical maps: two showing the integrated system of centers (commuting patterns and mobile phone location data; first pillar)), two for residential suburban zones (second pillar), and one for the average time spent in Prague (third pillar). Second, we provide one synthetic map displaying the final delimitation of Prague Metropolitan Area. We describe the different maps below.

2.2. The integrated system of centers

The methodology used to produce the integrated system of centers (ISC) is derived from the ideas of socio-geographic regionalization, and particularly the theory of Martin Hampl (Hampl, 2005). It is based on an analysis of the mutual commuting relationships within the municipalities of the Central Bohemia Region. The density/concentration of spatial contacts within inner units of metropolitan areas are measured through the combined distances involved in work and school commutes between different pairs of municipalities, measured according to the road distance between units. The data are derived from the results of the last Population Census conducted by the Czech Statistical Office in 2011, where places of residence and places of work are combined with commuting streams of all municipalities. By road distance, we mean the shortest distance by motorway or first or second class roads. This definition of spatial contacts density is significantly conditioned by a unit’s population, the number of jobs it contains, and its school sizes. It is, therefore, appropriate to limit the monitoring to relatively large units. Therefore, Hampl introduced a criterion of complex functional size (CFS) and, based on the results of previous studies (e.g. Hampl, 2005), it set its minimum threshold to 2500. CFS is defined as an average of shares according to two functions: residential (one-third; the number of people living there) and working (two-thirds; the number of jobs) parts (see Hampl, 1999, p. 43). These weights can better describe the...
significance of cities not only as residential but also as job centers. The centers are mainly identified with municipalities, but in some cases, municipalities are merged into agglomerations (e.g. Beroun and Králův Dvůr).

There is a relative continuity in the distribution of the intensity of interactions between pairs of centers in the Central Bohemia Region. However, it is appropriate to distinguish at least three levels of intensity (strong, medium, and weak) and to define a three-tier ISC. In the particular case of the Prague Metropolitan Area, it is possible to distinguish only two distinct zones: the core zone connected by strong ties, and the wider/marginal zone connected primarily by weak ties (see the map Integrated system of centers 2011). The core zone represents a dominant part of the entire PMA and consists of a circle of centers including Beroun, Kladno, Kralupy nad Vltavou, Neratovice, Brandýs nad Labem-Stará Boleslav, Říčany a Černošice. The wider delimitation includes the MEPs of Český Brod, Slaný, Mělník, and Lysá nad Labem. Two MEPs in the southern part of the Central Bohemia region have ties that are too weak to be incorporated in the ISC of the Prague Metropolitan Area.

2.3. The integrated system of centers based on mobile phone location data

The characteristics of mobile phone data allow us to repeat methodically almost the same procedure as in the previous case of the ISC based on census data. However, the different nature of the data should be highlighted. While the population census data cover the entire population, mobile phone spatial data show a representative sample of the population only. Therefore, it is not possible to assume the same thresholds for the density of spatial contacts, and two partial changes are made in the delimitation by mobile phone spatial data. First, we use a different set of spatial units among which the density of spatial contacts is assessed. In addition to centers with a CFS of 2500 and higher, the set is further extended to centers that do not reach this CFS threshold, but which have a population of over 2500. This change makes the ISC delimitation more precise. Second, the thresholds for distinguishing various levels of spatial contact density are set differently, and we use a relativization according to the average value of spatial ties between selected centers. Subsequently, three categories for the intensity of ties based on frequency distribution are defined as weak (300–600), medium (601–1500), and strong (1501 and more).

At this point, the basic three-tier framework of the Prague ISC is created. The presence of any town in the set of spatial units implies the inclusion of that particular MEP in the Prague Metropolitan Area. The maximum value of the intensity in each MEP then determines its classification in the three-tier metropolitan area delimitation. Although it does not meet the defined criteria, the MEP of Český Brod in the eastern part of the metropolitan area is also included in the ISC because of the character of its spatial ties at lower levels (municipalities) and its territorial integrity (see the map Integrated system of centers based on mobile phones location data 2014).

2.4. Residential suburbs

Residential suburbanization is operationalized as migration (the change of permanent residence) of the population from the core cities of metropolitan regions to their hinterlands (see the detailed description of the theoretical framework in Ouředníček et al., 2013). The spatial level of a municipality is chosen as a basic statistical unit to monitor the extent of suburbanization. Although suburban development can also be found within the administrative borders of cities (especially in Prague), we do not take these cases into account when assessing macro-regional patterns of suburbanization. The delimitation of the zone of residential suburbanization is carried out in two consecutive steps.

First, all municipalities with at least 10,000 inhabitants are labeled as possible cores of suburban migration, except large suburban municipalities in the close hinterland of Prague (among which Brandýs nad Labem-Stará Boleslav, Říčany, Čelákovic, and Mílovice exceed this size). Second, we set the criteria for selecting municipalities affected by the suburbanization process. These criteria include: (i) the new development of residential function, defined as the intensity of housing construction (a minimum of 20 dwelling units in the period of 1997–2012), (ii) a high intensity of migration from the core city to the suburb, defined as a minimal share of suburban in-migrants originating in the core city (a minimum of 30% or 40% in the case of two core cities, e.g. Prague and Kladno), and (iii) a high ratio between population sizes of suburb and core city (a minimum of 1:20 or 1:5 in the case of less populated core cities). All data were collected by the Czech Statistical Office; the intensity of housing construction use the number of finished dwellings during the period 1997–2012, migration data cover all registered changes of permanent living during the same period. More details on the delimitation criteria can be found in Ouředníček, Nemeškal, Hampl, Špačková, & Novák, 2014; Špačková, Ouředníček, Novák, & Křivka, 2014).

In total, we delimit three suburban zones based on the different intensity of the suburbanization process in the hinterland of core cities in the Central Bohemia Region, and 376 of these municipalities are located in Prague’s hinterland (see the map Residential suburban zones in the hinterland of Prague 2012). In the next step, we determine the share of suburban municipalities
within the total number of municipalities in terms of MEPs in which at least five Prague suburban municipalities are located. The threshold for the inclusion of an MEP into the Prague Metropolitan Area is defined as 25% (i.e. at least a quarter of municipalities must be Prague suburbs). Supplementary threshold values to capture the intensity of suburbanization in the metropolitan region are set at 40–70% (see the map Structure of residential suburban zones in the hinterland of Prague 2012).

2.5. Average daily time spent in Prague

Mobile phone location data (see description in note 2) also allow us to capture how intensively the Central Bohemian Region inhabitants use the territory of Prague. In general, the intensity of use is defined as the average time which municipal inhabitants spend in different parts of Prague and the Central Bohemian Region. We used the indicator of average time spent in Prague as an alternative way to delimit the metropolitan area. Based on the distribution of indicator values, we define the thresholds to distinguish various degrees of the intensity of use of the territory of Prague. Then a four-tier scale of the choropleth map was prepared, using intervals of 5.1 hours and more, 2.1–5 hours, 1.1–2 hours, and 1 hour and less.

The MEP regions are included in the metropolitan area if they meet the criterion of a minimum share of municipalities in particular categories defined according to the average daily time spent in Prague. The distribution of municipalities according to the average daily time spent in Prague depicts fairly sharp boundaries that allow us to delimit a three-tier metropolitan area. The threshold for the inclusion of an MEP into the Prague Metropolitan Area is defined as at least 60% of municipalities whose inhabitants spend at least 1 hour per day in Prague. Supplementary threshold values to capture the intensity of the daily use of Prague are set at 50% and 90% of municipalities whose inhabitants spend at least 2 hours per day in Prague.

This analysis of mobile phone location data shows somewhat different areas compared to previous delimitations and also includes the MEPs of Benešov, Dobříš or Český Brod; generally, MEPs with small population sizes. Along with the use of residential suburbanization zones, this method rectifies the significant influence of center size, which is inherent in the calculation of the integrated system of centers.

3. Results and discussion: The delimitation of the Prague Metropolitan Area

The final step in the delimitation of the Prague Metropolitan Area is to synthesize the research outcomes of the four partial approaches described above. We used the following criteria for inclusion of a MEP into the Prague Metropolitan Area: (i) the presence of a city integrated into Prague’s integrated system of centers as delimited on the basis of data from the 2011 Census (commuting data) and a strong level of relationship (the thresholds of spatial contact density are set at 90 and 40 respectively), (ii) the presence of a city integrated into Prague’s integrated system of centers as delimited on the basis of mobile phone location data (2014) and a strong level of relationship (the thresholds of relativized spatial contact density are set at 1500, 600, and 300, respectively), (iii) a high proportion of the municipalities within the MEP are included in Prague’s residential suburban zone (the thresholds are set at 50% and 25% respectively), and (iv) a high proportion of municipalities whose inhabitants spend on average at least one (or two) hours per day in Prague (the threshold was set at 40%). The thresholds were set by the authors on the basis of natural breaks within the empirical distribution of values with the aim to clearly differentiate three levels of integration of MEPs into the PMA, which is expressed by two, one, or no asterisks within the individual cells of Table 1.

By applying these criteria, we can delimit the Prague Metropolitan Area and within this distinguish two types of metropolitan area based on the level of integration of MEPs into the PMA (see the main map Prague Metropolitan Area). The Inner Prague Metropolitan Area (IPMA) includes those administrative districts of MEPs which show a very strong level of integration with Prague in at least three out of four criteria and a strong level of integration in the remaining one. The IPMA is comprised of seven administrative districts of MEPs, which either share administrative boundaries with Prague (Černošice, Brandýs nad Labem-Stará Boleslav, Říčany) or have strong long-term commuting ties to Prague (Kladno, Neratovice, Kralupy nad Vltavou, and Beroun).

The delimitation of the Outer Prague Metropolitan Area (OPMA) consists of administrative districts of MEPs that show a strong level of integration with Prague in at least two criteria. It is interesting to note that the IPMA and the OPMA are distinguishable when commuting patterns are considered (the integrated systems of centers). The OPMA includes six administrative districts of MEPs with different functions in relation to Prague. Northern districts constitute the commuting area (to work and school) and have good transport accessibility to Prague (Slaný and Mělník). They have good economic relations with Prague and other centers in the metropolitan area. On the contrary, southern and eastern districts represent the residential and recreational hinterland of Prague with smaller centers and with potential for the development of suburbanization (Český Brod, Lysá nad Labem, Benešov, and Dobříš). In general, the OPMA is an area of anticipated (and to a large extent also certain) future growth within the Prague Metropolitan Area.
Table 1. The delimitation of Prague Metropolitan Area: a synthetic evaluation.

| Name of MEP          | Integrated system of centers (Census data, 2011): spatial contact density | Integrated system of centers (mobile phone location data, 2014): relative spatial contact density | Residential suburban zone: the share of Prague’s suburbs | Average daily time spent in Prague: the share of municipalities whose inhabitants spend on average at least one (two) hours daily in Prague | Type of metropolitan area |
|----------------------|--------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|--------------------------|
| Černošice            | 204 (Roztoky)**                                                        | 3817**                                                                                         | 93.7**                                                | 100.0 (98.7)**                                                                                                           | Inner metropolitan area |
| Brandýs nad Labem – Stará Boleslav | 132**                                                                | 5613**                                                                                         | 86.2**                                                | 100.0 (98.3)**                                                                                                           | Inner metropolitan area |
| Říčany               | 155**                                                                   | 2832**                                                                                         | 84.6**                                                | 100.0 (96.2)**                                                                                                           | Inner metropolitan area |
| Kladno               | 276**                                                                   | 2507**                                                                                         | 62.5**                                                | 89.6 (33.3)*                                                                                                            | Inner metropolitan area |
| Beroun               | 104**                                                                   | 509**                                                                                          | 45.8**                                                | 97.9 (64.6)**                                                                                                           | Inner metropolitan area |
| Neratovice           | 97**                                                                    | 581*                                                                                           | 50.0**                                                | 100.0 (33.3)**                                                                                                           | Inner metropolitan area |
| Kralupy nad Vitavou  | 90**                                                                    | 606*                                                                                           | 50.0**                                                | 94.4 (50.0)**                                                                                                           | Inner metropolitan area |
| Český Brod           | 31                                                                     | 147                                                                                             | 45.8**                                                | 100.0 (91.7)**                                                                                                           | Outer metropolitan area |
| Lysá nad Labem       | 41* (Milovice)                                                          | 459* (Čelákovice)                                                                               | 33.3* (3 municipalities only)                         | 100.0 (66.7)**                                                                                                           | Outer metropolitan area |
| Slaný                | 51*                                                                     | 594* (Kladno)                                                                                  | 13.5                                                  | 76.9 (7.7)*                                                                                                            | Outer metropolitan area |
| Mělník               | 42*                                                                     | 216                                                                                             | 15.4                                                  | 61.5 (12.8)*                                                                                                           | Outer metropolitan area |
| Benešov              | 36                                                                      | 105                                                                                             | 52.9**                                                | 84.3 (33.3)*                                                                                                           | Outer metropolitan area |
| Dobříš               | 27                                                                      | 131                                                                                             | 29.2*                                                 | 96.0 (56.0)**                                                                                                           | Outer metropolitan area |

Note: The level of integration into Prague: **a very strong level of integration, *a strong level of integration.
Sources: CE Traffic a.s. (2014), Database of migration (1997–2012), Housing construction (1997–2012), and Population and housing census 2011.

Table 2. Basic statistics for the Prague Metropolitan Area (2016).

| Region                             | Area (km²) | Number of MEPs (municipalities) | Population | Population density (inhabitants/km²) |
|------------------------------------|------------|---------------------------------|------------|--------------------------------------|
| The capital city of Prague (administrative boundaries) | 496.2 | 1 (1)                           | 1,267,449 | 2554                                 |
| Inner Prague metropolitan area     | 2346.9     | 7 (315)                         | 550,857    | 235                                  |
| Outer Prague metropolitan area     | 2140.0     | 6 (199)                         | 209,441    | 98                                   |
| Prague Metropolitan Area           | 4983.1     | 14 (515)                        | 2,027,747  | 407                                  |

Note: MEP – administrative districts of municipalities with extended powers.
Source: Czech Statistical Office (2016).

In total, the Prague Metropolitan Area consists of 14 administrative districts of MEPs and 515 municipalities. More than 2 million inhabitants live there in an area of 5000 km². Although it occupies only 5% of the total area of the Czech Republic, almost 20% of the Czech population is concentrated in the Prague Metropolitan Region. For more detailed information, see Table 2.

4. Conclusions

The synthetic delimitation of the Prague Metropolitan Area includes the capital city of Prague, an inner metropolitan area consisting of seven districts of MEPs, and an outer metropolitan area with six other districts of MEPs. While the inner part of the metropolitan area is strongly integrated into the capital, the outer part represents a potential area of the city for future spatial development and influence. Four different approaches were used to delimit the Prague Metropolitan Area. First, we used the traditional method of defining an integrated system of centers on the basis of data on commuting to work and school from the 2011 Population census. Second, the delimitation was based on three zones of residential suburbanization; i.e. the connectivity of suburbia with the core cities and the intensity of housing construction. Third and fourth, a completely new approach was applied for the first time in the Czech Republic using mobile phone data to show the integrated systems of centers and average time spent in Prague.³

While the results of the two methods based on commuting (either from census data or mobile data) produced very similar spatial patterns, the delimitation of the metropolitan area based on average time spent in Prague showed surprising outcomes in the form of a relatively narrow area in which intensive contact takes place between suburban residents and Prague. This raises the possibility of the establishment of new suburban nodes with relatively autonomous micro-regional centers including education (kindergartens and elementary schools), basic healthcare, local administration, retail, and other services meeting the daily needs of people within the catchment areas around these centers. In the case of residential suburbanization, the results have confirmed the relatively intensive development of the southern part of the metropolitan area with its attractive natural conditions for residential functions, which is also the traditional recreational hinterland of Prague. Although the methods used in the analysis could not cover the recreational function (weekend commuting to cottages), we believe that most concentrations of second homes are included within the delimited area.
Today, there is no accepted definition of metropolitan areas in the Czech Republic, which to a great extent relates to the inability of spatial planning to address problems at the level of metropolitan areas. Regional planning formerly used so-called Large Regional Areas but has now changed to focus on the territories of entire self-governed regions (Territorial Development Policy) or MEPs. Particularly in the case of the division of territory between the two autonomous self-governed regions (Prague vs. Central Bohemia Region), this approach creates problems for both analytical purposes and practical activities (statistical monitoring, coordination of activities of regional activities, regional planning, etc.). This study should thus largely eliminate these problems and, together with alternative methods of defining the metropolitan areas of other large Czech cities (within ITI), also contribute to reviving a discussion of this topic at the boundaries of research and practical applications.

Software
Microsoft Excel 2013 was used for initial data sorting and calculation of variables shown in the map. ESRI ArcGIS 10.3.1 was used for map processing and final visualization.

Notes
1. We can distinguish between a ‘municipality’ and an ‘administrative district’ of MEPs. When using the term MEP, we always mean the whole administrative district. In total, the Central Bohemia Region consists of 26 districts of municipalities with extended powers.
2. We employed T-Mobile data, which cover approximately 40% of the total population within the Central Bohemia Region. Then we used an origin–destination matrix on the level of municipalities. The location of the person during the time interval between 1 am and 5 am was set as place of residence and 10 am to 2 pm as place of work.
3. Recently, the Institute for Planning and Development of the Capital City of Prague produced a web application for Prague and Central Bohemia Region using mobile phone data http://app.iprpraha.cz/apl/app/dynamika-obyvatelstva/.

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References
Ahas, R., Laineste, J., Aasa, A., & Mark, U. (2007). The spatial accuracy of mobile positioning: Some experiences with geographical studies in Estonia. In G. Gartner, W. Cartwright, & M. P. Peterson (Eds.), Location based services and telecartography (pp. 445–460). Berlin: Springer.
Ahas, R., Silm, S., Järv, O., Saluveer, E., & Tiru, M. (2010). Using mobile positioning data to model locations meaningful to users of mobile phones. Journal of Urban Technology, 17, 3–27. doi:10.1080/10630731003597306
Ahas, R., Silm, S., Saluveer, E., & Järv, O. (2009). Modelling home and work locations of populations using passive mobile positioning data. In G. Gartner & K. Rehrl (Eds.), Location based services and telecartography II (pp. 301–315). Berlin: Springer.
CE Traffic a.s. (2014). Mobile phone location data. Prague. Czech Statistical Office. (2016). Database of demographic data for municipalities of the Czech Republic. Prague. Database of migration for the municipalities of the Czech Republic. (1997–2012). Prague: Czech Statistical Office.
Doležalová, G., & Ouředníček, M. (2006). Životní styl obyvatelstva v suburbanizované Praze [Lifestyle of the population in the suburban zone of Prague]. In M. Ouředníček (Ed.), Sociální geografie Pražského městského regionu (pp. 143–159). Praha: Univerzita Karlova v Praze. Přírodovědecká fakulta, katedra sociální geografie a regionálního rozvoje.
Doxiadis, C. (1970). Man’s movement and his settlements. Ekistics, 29(174), 296–321. doi:10.1080/0020737008709391
European Commission. (2014). Integrated territorial investment [Factsheet]. Retrieved from http://ec.europa.eu/regional_policy/sources/docgener/informat/2014/iti_en.pdf
Frey, W. H., & Zimmer, Z. (2001). Defining the city. In R. Paddison (Ed.), Handbook of urban studies (pp. 14–35). London: Sage.
Giddens, A. (1984). The constitution of society: Outline of the theory of structuration. Berkeley: University of California Press.
Halás, M., Klapka, P., & Tonev, P. (2016). The use of migration data to define functional regions: The case of the Czech Republic. Applied Geography, 76, 98–105. doi:10.1016/j.apgeog.2016.09.010
Hall, P., & Hay, D. (1980). Growth centres in the European urban system. London: Heinemann Educational.
Hampf, M. (Ed.). (1999). Geography of societal transformation in the Czech Republic. Prague: Department of Social Geography and Regional Development, Charles University in Prague, Faculty of Science.
Hampf, M. (2005). Geografická organizace společnosti v České republice: transformační procesy a jejich obecný kontext [Geographical organization of society in the Czech Republic: Transformation processes and their general context]. Praha: Univerzita Karlova v Praze, Přírodovědecká fakulta, katedra sociální geografie a regionálního rozvoje.
Hampf, M., Gardavský, V., & Kühl, K. (1987). Regionální struktura a vývoj systému osídlení ČSR [Regional structure and settlement system development in the CSR]. Praha: Universita Karlova.
Hägerstrand, T. (1982). Diorama, path and project. Tijdschrift voor economische en sociale geografie, 73(6), 323–339. doi:10.1111/t.1467-9663.1982.tb01647.x
Housing construction database in municipalities of the Czech Republic. (1997–2012). Prague: Czech Statistical Office.

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Johnston, R. (2009). Metropolitan area. In D. Gregory, R. Johnston, G. Pratt, M. J. Watts, & S. Whatmore (Eds.), The dictionary of human geography (5th ed.) (p. 459). Chichester: Wiley-Blackwell.

Kitchin, R. (2014). The real-time city? Big data and smart urbanism. Geojournal, 79, 1–14. doi:10.1007/s10708-013-9516-8

Korcáč, J. (1966). Vymezení oblasti maximálního zalidnění [Definition of maximum population density areas]. Acta Universitatis Carolinae – Geographica, 1, 65–72.

Kostelecký, T., & Čermák, D. (2004). Metropolitan areas in the Czech Republic – definitions, basic characteristics, patterns of suburbanisation and their impact on political behaviour. Sociological studies 04/03. Praha: Institute of Sociology, Academy of Sciences of the Czech Republic.

Kraft, S., Halás, M., & Vančura, M. (2014). The delimitation of urban hinterlands based on transport flows: A case study of regional capitals in the Czech Republic. Moravian Geographical Reports, 22(1), 24–32. doi:10.2478/mgr-2014-0003

Musil, J. (1967). Sociologie soudobého města [Sociology of the contemporary city]. Praha: Svoboda.

Novák, J., Ahas, R., Aasa, A., & Silm, S. (2013). Application of mobile phone location data in mapping of commuting patterns and functional regionalisation: A pilot study of Estonia. Journal of Maps, 9(1), 10–15. doi:10.1080/17445674.2012.762331

Novák, J., & Novobilský, J. (2013). Inovativní přístup k zachycení přítomného obyvatelstva: data mobilních operátorů [Innovative approaches to catch the actual population: Data from mobile operators]. Urbanismus a územní rozvoj, 3, 14–18. Retrieved from http://www.uur.cz/images/5-publikaci-cinnost-a-knihovna/casopis/2013/2013-03-04_inovativni.pdf

Novák, J., & Sýkora, L. (2007). A city in motion: Time–space activity and mobility patterns of suburban inhabitants and structuration of spatial organisation in the Prague metropolitan area. Geografiska Annaler B: Human Geography, 89(2), 147–168. doi:10.1111/j.1468-0467.2007.00245.x

Ouředníček, M. (2007). Differential suburban development in the Prague urban region. Geografiska Annaler B: Human Geography, 89(2), 111–126. doi:10.1111/j.1468-0467.2007.00243.x

Ouředníček, M., Špačková, P., & Novák, J. (2014). Vymezení funkčního území Prážské metropolitní oblasti pro potřeby uplatnění Integovraných teritoriálních investic [Delimitation of functional area of Prague Metropolitan Area for integrated territorial investments purposes] (Research report). Retrieved from http://www.atlasobyvatelstva.cz/sites/default/files/_UPLOAD/vymezenipmo_komplet_01062014.pdf

Ouředníček, M., Špačková, P., & Novák, J. (2013). Metodické problémy výzkumu a vymezení zón rezidenční suburbanizace v České republice [Methodological problems of research and delimitation of residential suburbanization zones in the Czech Republic]. In M. Ouředníček, P. Špačková, & J. Novák (Eds.), Sub Urbis: krajina, sídla a lidé (pp. 309–332). Praha: Academia.

Pászto, V., Brychtová, A., Tuček, P., Marek, L., & Burian, J. (2015). Using a fuzzy inference system to delimit rural and urban municipalities in the Czech Republic in 2010. Journal of Maps, 11(2), 231–239. doi:10.1080/17445647.2014.944942

Population and housing census. (2011). Prague: Czech Statistical Office.

Pospíšilová, L., & Novák, J. (2016). Mobile phone location data: New challenges for geodemographic research. Demografie, 58(4), 320–337.

Sýkora, L., & Mulíček, O. (2009). The micro-regional nature of functional urban areas (FUAs): lessons from the analysis of the Czech urban and regional system. Urban Research & Practice, 2(3), 287–307. doi:10.1080/1753506903319228

Sýkora, L., & Ouředníček, M. (2007). Sprawling post-communist metropolis: commercial and residential suburbanisation in Prague and Brno, the Czech Republic. In E. Razin, M. Dijst, & C. Vázquez (Eds.), Employment deconcentration in European metropolitan areas: Market forces versus planning regulations (pp. 209–233). Dordrecht: Springer.

Špačková, P., Dvořáková, N., & Tobarmanová, M. (2016). Residential satisfaction and intention to move: The case of Prague’s new suburbsites. Geografiska Annaler: Series B, Human Geography, 98(4), 331–348. doi:10.1111/geob.12108

Špačková, P., & Ouředníček, M. (2012). Spinning the Web: New social contacts of Prague’s suburbsites. Cities, 29 (5), 341–349. doi:10.1016/j.cities.2011.09.002

Špačková, P., Ouředníček, M., Novák, J., & Křivka, M. (2014). Zóny rezidenční suburbanizace 2013 [Residential suburbanization zones 2013] [Map]. Retrieved from http://www.atlasobyvatelstva.cz/cs/suburbanizace

van den Berg, L., Drewett, R., Klaassen, L. H., Rossi, A., & Vijverberg, C. H. T. (1982). A study of growth and decline: Volume 1 of urban Europe. Oxford: Pergamon Press.

Zhong, C., Batty, M., Manley, E., Wang, J., Wang, Z., Chen, F., & Schmitt, G. (2016). Variability in regularity: Mining temporal mobility patterns in London, Singapore and Beijing using smart-card data. PLoS ONE, 11(2), e0149222. doi:10.1371/journal.pone.0149222