Using Spatial Analysis Approach to Unreveal Scaling of Urban Structures: Prefab Housing Estate in Contrast with Historical Centres

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Abstract

The prefab housing estate is a huge part of urban structures, especially in former countries of Eastern Bloc. There was a mass development these housing estates during the communist and post-communist era in between the 1960s and 1990s. This paper studies street structures within these areas in six eastern-European capitals: Bratislava, Bucharest, Budapest, Prague, Sofia, and Warsaw. Precisely, how such a mass interference to urban structure affected the scaling properties and patterns of streets within these areas. Further, the results are compared to the traditional European urban structures of historical city centres. The evaluation between these two diametrically different areas was done by spatial analysis approaches. The main evaluating criterion was the Ht-index of Natural streets' connectivity. Surprisingly, the prefab housing estate showed to have a slightly higher natural scaling property compared to the traditional European urban structures.

Keywords: Natural streets, Axial lines, Head/tail breaks, Ht-index

1 Introduction

1.1 Background of Study and History

This study is focused on the influence on urban city structures during the communist era in countries of the Eastern Bloc in Europe. Precisely how the mass housing estate constructions have influenced the street patterns and urban structure. In contrast to that stands the city cores and historical centres that were being developed for hundreds of years before. The historical development of European cities was from the time perspective relatively natural and slow process. Back in the days, the development of city structures was usually driven by important places such as markets, churches or places where people were gathering. Therefore, these places used to be in the centre and the city was growing around them.

Probably the most crucial effect on urban development had World War II and the subsequent post-war rise of communism. Where the natural process was violently disrupted. During the communist era, the demands on living capacities were rapidly increased by regime visions. Thus, there was a need for a solution on how to provide housing for hundreds of thousands of people in the shortest time possible. That resulted in mass construction of prefab housing estate (Meuser and Zadorin 2016). The natural urban pattern that was being developed for hundreds of years was suddenly disturbed within a couple of decades. The urban settlement projects were created in between the 1960s and 1990s. For instance, during this period approximately one-third of the population of Czechoslovakia has lived in prefab houses. Nevertheless, nowadays more than one-fourth of the population still lives in such a house (Czech Statistical Office 2011).

Six capitals of six eastern European countries were selected for this study. All of them are former USSR's Eastern Bloc members, namely: Sofia, Bulgaria; Bratislava and Prague, Czechoslovakia (Czech Republic and Slovakia); Budapest, Hungary; Warsaw, Poland; and Bucharest, Romania (*Figure 1*). Regarding their history, the urban development between the 1960s and 1990s is very similar. Thus, the study has a broader perspective in a wider scale.

The selections of study areas had a few conditions. Firstly, the time horizon of the development to follow the period between the 1960s and 1990s. Secondly, the area is a self-standing part of the city. Lastly, the prefab houses had to be the majority in the urban area. The selected prefab urban areas in most case are the biggest of its kind in each city. Thus, they are considered as the most representative units.

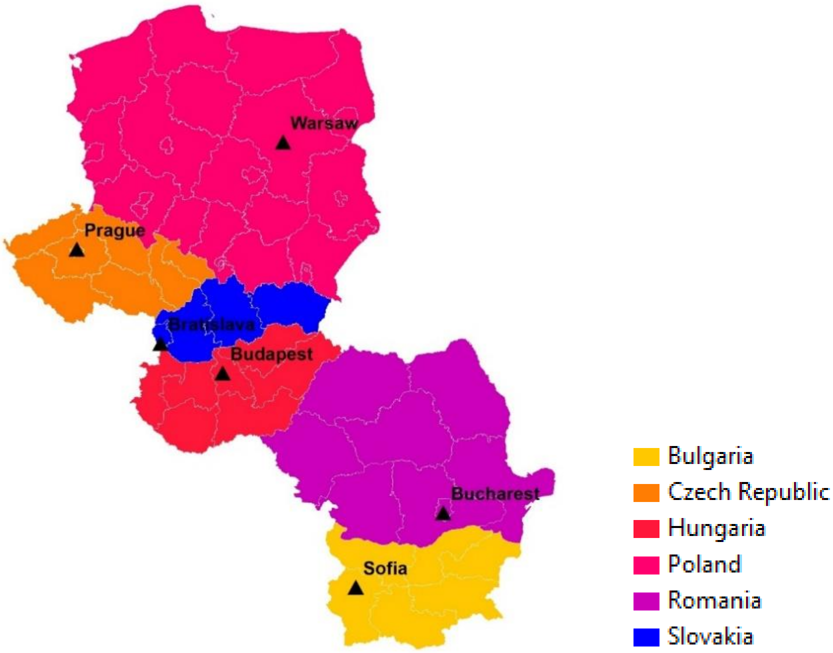


Figure 1: Former countries of Eastern Bloc of Europe

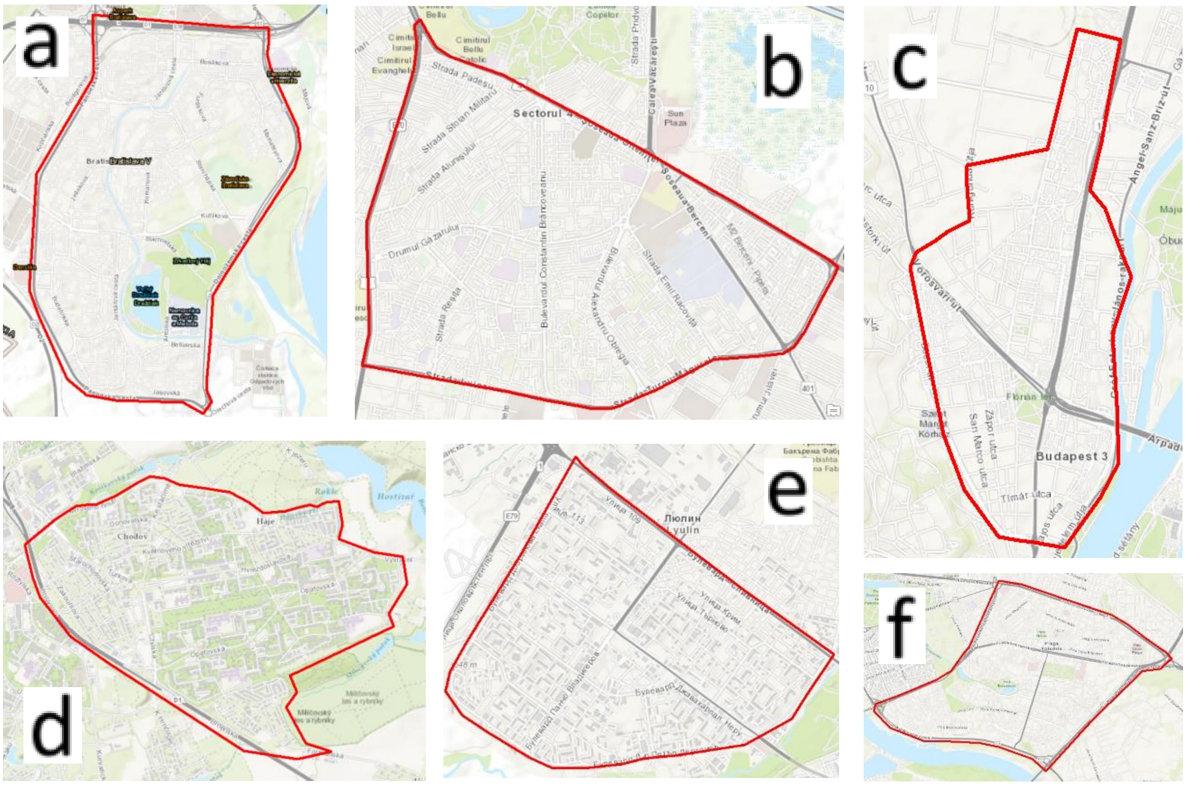


Figure 2: Prefab houses settlements: (a) Bratislava, Slovakia; (b) Bucharest, Romania; (c) Budapest, Hungary; (d) Prague, Czech Republic; (e) Sofia, Bulgaria; (f) Warsaw, Poland.

In contrary to the mass reality development stands the city centres. Which consist of historical buildings and represents the natural developments and the cities identity. From the historical point of view, these cities underwent a relatively similar evolution. The conditions for selecting these areas were based on history and on what is defined as an “old town”. These areas represent central points for each city.

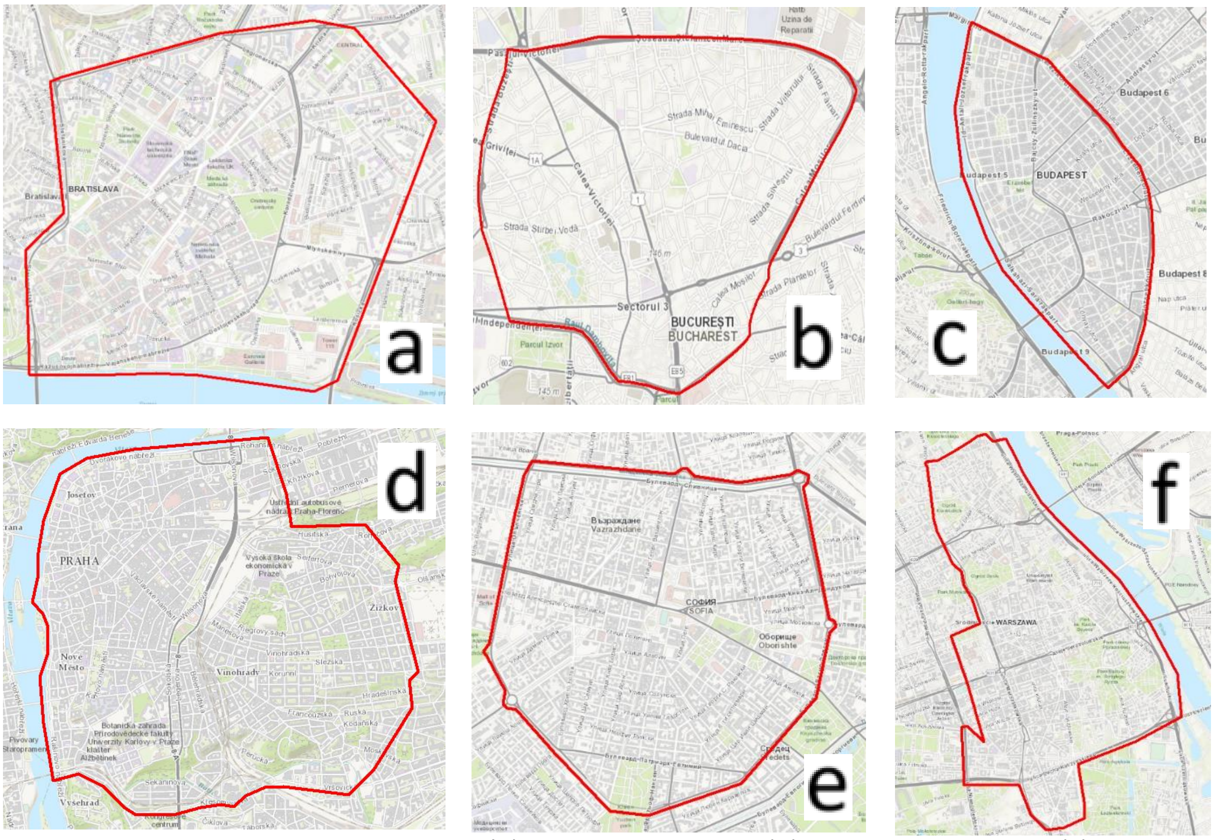


Figure 3: Naturally developed city parts: (a) Bratislava, Slovakia; (b) Bucharest, Romania; (c) Budapest, Hungary; (d) Prague, Czech Republic; (e) Sofia, Bulgaria; (f) Warsaw, Poland.

1.2 Spatial analysis in Geographic Information System

The spatial analysis tool in Geographic Information System (GIS) helps to understand the cities structures and underlying patterns. The analysis of streets in this study is based on the axial lines. The axial lines are defined as the least set of straight lines interconnected along natural streets (Liu and Jiang 2013). These lines are being considered as a walkable or driveable distance of the streets within cities. As mentioned, the axial streets are built on the natural streets. The natural streets are self-organised street elements formed on the Gestalt principle of good continuity. The street elements form the natural streets with their adjacent elements based on the connectivity angle (Jiang et al. 2008). The automatization of these processes is supported by the *Axwoman 6.0* plugin for GIS.

Accordingly, the topological representation in the form of an axial line makes it possible to unravel the underlying patterns. The pattern in manners of axial lines is shown by the hierarchically most active elements. This state can be achieved by scaling the symbology of axial elements based on their connectivity levels. The city streets structure has way less connected elements than well-connected elements (Jiang 2013). According to this theory, the streets are expected to have power-law distribution with a heavy tail. Thus, the symbological hierarchy of axial lines in this study builds upon the head/Tail breaks classification.

2 Theoretical background

2.1 Space syntax, Natural streets, and Axial lines

The psychological approach towards understanding the space thinks in a way, that space is not measurable by any tool or any sense. It is an experience of space itself. Thus, there are no geometric or mathematic relationships. The psychological space is more about space that we can experience with our body, the feelings about our surroundings and its quality, or space with no conditions, no form of the dimension just like an understanding of human awareness (Wellwood 1977). Hence, the psychological space is the essence of mind imagination on an emotional level. The space of each human being is merely unique and relative to current state or circumstances. Regarding planning space, the psychological approach needs to be understood and respected to the broadest possible extent so that everyone could feel comfortable in his or her own spaces. To do so, we need to go a bit further with understanding the space. Unwrap the imagination of space, uncover it and push the boundaries beyond the small unique spaces to a more complex structure with spatial elements.

Space in the city can be defined as freedom of movement using streets, parks, open areas among the whole mass with the dense settlement. In order to understand the city space, deeper thinking is needed. The city is the whole composed of smaller elements, and these elements are interconnected. There would be no city without organised relations of its elements. (Lynch 1960) Described five key elements of the city and how the combination of these elements is creating an image of the city in human minds. Applying Lynch's theory, the city could be described based on human description and perception of surrounding space. The human description is a good way how to understand the space, but it is still not enough for the evaluation of space interconnections or accessibility. This concept is focusing more on the city elements itself rather than the relations among them. For space evaluation, we need to go further in a more scientific way by testing spatial properties according to the city's functions. The city elements can be derived straight from the street network analysis (Hillier and Stronor 2017). The space syntax is a concept of order in space, and it stands for the ability to capture spatial order in city structure by random-based analytical simulations. This concept is resulting in a complex order of restrictions as well as the representation of relations between social life and spatial organising. The theory of spatial syntax is a formal procedure that describes the spatial structure of the city by testing relations between spatial characteristics and observable city functions (Hillier and Hanson 1984).

While decomposing the space, the axial lines are being created. The term axial line stands for the representation of the street segment. One axial line is the longest visibility in the direction of potential movement (Hillier and Hanson 1984). Two-dimensional space represented by an axial line creates the axial map. This map shows us intersections among all axial lines in order to evaluate the space, which is the main goal of this theory, the network is described by morphological parameters and their calculations. The axial line-based space syntax approach has its limitation in fact that the axial lines do not exist in the real world. Hence, the new approach was proposed based on the axial line-based space syntax. The point-based space syntax, rather than axial lines as a main evaluable element uses characteristic points (Jiang and Claramunt 2002). The characteristic points are more reliable as a real-world representation of intersections. This study works with the axial lines that are defined as the least set of straight lines interconnected along natural streets (Liu and Jiang 2012). Where Natural streets that are generated from the smallest street elements and composed into streets with the lowest angle of interconnections.

2.2 Topological Representation

When performing network analysis, we can talk about two approaches – ways of thinking of network representation. On one side geometrical way, on the other side topological way (Jiang and Okabe 2014). Cartography always aimed for real-world representation in the most precise way possible. The more detailed the best, the most geometrically precise the most real. Indeed, it is good at it. We can perfectly display the world in the smallest detail with amazing accuracy. In some cases, it is more than important. On the other hand, the truth is that the real world is sometimes quite chaotic. Here is the question of whether we want to have a precisely displayed "chaos". Would not it be better to put things in order to understand the meaning and structure better? See what is important? Seeing a precise geometric representation of network or city structure does not necessarily mean understanding structure itself. That is where the topological approach takes place. Thanks to topology we can display important elements in a structured order. Furthermore, it is simplifying objects in the sake of gain readability. So that is what is meant by sacrificing geometry. In general, the main difference between geometry and topology is that the geometrical way is displaying the real-world appearance. While the topological way is focusing on relations between elements and their structure.

During the analysis process, the network is gradually distributed into individual elements, and the interconnections between them are explored. The goal is to uncover the network structure. More specifically the aim is to uncover the underlying scaling pattern of the street network. Using software nowadays, the spatial analysis can be applied to various kinds of networks. Applying the topological way of spatial network analysis, we can answer questions regarding the urban connectivity, compare different connectivity and make a statement, or solve issues regarding logistic tasks. So, the more modern topological model, rather than evaluating place based on the geometrical distance uses connectivity between nodes (junctions) and links (streets). The topological model does not deal with geometric properties such as direction, distance, or position. This fact allows us to represent the network in a readable way and it is easier to transmit the information (Jiang and Okabe 2014). Another thing that needs to be uncovered is a scaling pattern regarding network data distribution as a crucial factor when visually representing the whole network.

While creating a topological visual representation, we are abstracting geometrical elements such as shapes, sizes, and directions into a spatial relation such as connectivity or junctions and segments. Within the topological network, we can represent patterns, relations between elements, or morphology. However, what defines a good topology? The visual representation apart of the analytical principals is subject to human perception. Hence the topology should be built up in a way to meet human cognition. As well as fulfil the expectations of the human subconscious of how the elements are related to each other and how they suppose they look like. (Lynch, 1960) Published a book where he claims that based on five key city elements (Paths, Edges, District, Nodes, Landmarks) people can form a mental map of their urban neighbourhood and can sense space thanks to visual sensation, e.g. light, colour, shape and so on. These principles are still applicable when thinking of visual representation of topology. What is more, mental maps can be viewed to some extent as the topology of mind perception.

2.3 Head/tail breaks

The Head/tail breaks classification is a power-law-based method to classify data by setting breakpoints. The conventional approach in modern Geographical Interactive Systems nowadays is to classify data based on data distribution, thus creating breaks based on conventionally known statistics. Such as Quantiles, Natural breaks, Equal intervals, Arithmetic or Geometric progression, Standard deviation, and so on. Head/tail breaks rather than being based on Gaussian thinking is based on Paretian thinking.

Instead of using normal distribution is using Heavy-tailed distribution, data are skewed and may often be evaluated using power laws (Jiang 2013). Head/tail breaks stand for the idea, that in the data there are far more small things (tail) than the large ones (head) concerning 20/80 ratios (Flux 1897). The breaks are computed by dividing means of data until we reach the head, always in one direction, not both sides. The data should be better scaled and more natural looking. This method claims, that beauty of the result is hidden its scale. Empirically verified the distribution of natural street of studied cities in this paper mostly fits a model of 40% as a head and 60 % as a tail. Thus, the visual representation of the cities in this paper underlies this division rule, and it is scaled in such a manner.

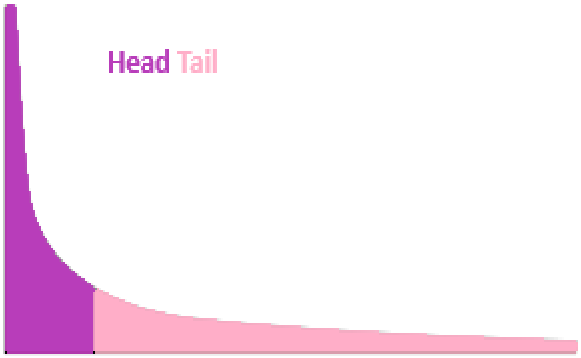


Figure 4: Long tail distribution

The classification can be evaluated based on the Ht-index. This index captures the number of scales in scaling hierarchy from the smallest to the largest ranging. The higher the Ht-index is, the features are more complex, heterogeneous, and natural (Jiang and Yin 2014). The Ht-index in this study is used as an evaluation factor of the complexity of the street structures. What is more, it is a factor that is being considered while comparing the different city structures together.

3 Data and Methodology of Processing

3.1 Data Source

The OpenStreetMap (OSM) is one of the most successful projects with user-generated content within the GI Science field. The founder, Steve Coast was encouraged and inspired by the Wikipedia concept. Wikipedia is probably the most famous platform for sharing knowledge of humankind that is all based on VGI. The OSM was launched in 2004 as a collaborative project whose aim was to create a free map of the world to which everyone can contribute. The data are being collected by Global Positioning Systems (GPS), aerial photography, manual surveys, and so on. Basically, whatever method is accessible to contributors (Bennett 2010). Nowadays the OSM has over five million users, according to the date of this paper. The OSM is supported by non-profit OSM Foundation, but except for this, it is also supported by many partners, companies, and users' pre-paid memberships. The most important about the OSM is that not only the contribution is open, but the data are open and freely available for everyone. Thus, many companies, social networks, services, or even scientist can build upon these data and pay back the effort by development and inventions.

The data of cities for this study were provided by the *Geofabrik* server. It is a member of the OSM Foundation focused on extracting, selecting and processing open source data from the OSMs. The datasets are sorted into regions and subregions in the hierarchy of continents, countries, regions and sometimes even cities. The datasets contain various features such as buildings, traffic, roads, public transportation, services and so on in several data formats. This study is based on the shapefiles of roads, which contains various roads feature types.

3.2 Methodology of Data Processing

Study of the city areas is very important for the credibility of results. Each part of the city has its own borders and components that fulfils its function in the whole. By omitting these parts, the area would not be comprehensive whole anymore. Thus, it might affect the result because everything is related to everything. The history records the development through the time and therefore is important source for each parts' identity. The periods are important to distinguish between the natural development and planned interference. Each part of the city was studied before selecting the extent to get the most representative area. The districts played an important role while setting the boundaries. In most cases, especially for the prefab housing estate area, the city parts are distinguishable from the first sight (*Figure 5*).

The OSM files have a high level of detail. Thus, some of these details needed to be omitted to generate natural streets. Namely, the footpaths through grass fields, trails, stairs, some cycling ways, and sidewalks. These road groups could be deleted by structured query language queries, but there were exceptions where some elements from these groups were an important part of the street network (*Figure 6*). Therefore, the process of data preparation is relatively demanding on time. Nevertheless, it improved the results especially the sidewalks would have caused multiple occurrences of each street.

Figure 5: District boundaries (Bucharest)

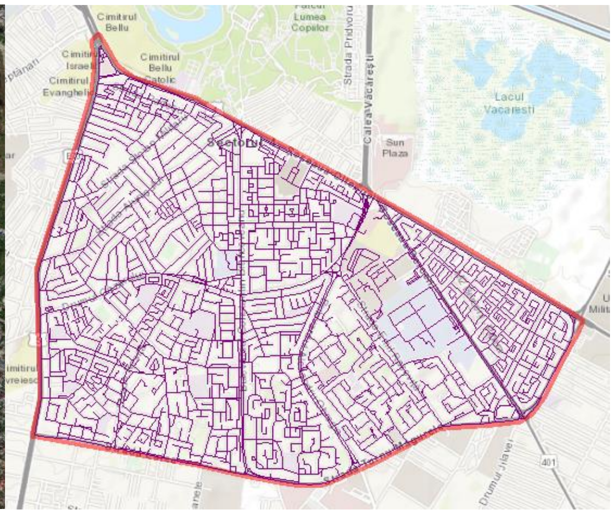


Figure 6: Cropped and selected roads (Bucharest)

The natural streets are being created from the smallest elements (arcs), which are the elements in between two intersections (*Figure 7*). For this reason, the roads were broken into arcs. Before the natural street creation could be started, the isolated lines had to be edited or deleted. After, the arcs were connected again to the natural streets (*Figure 8*). The algorithm is creating the most natural ongoing street while considering the angle threshold of the intersection. More precisely the angle threshold was settled to 45 degrees.

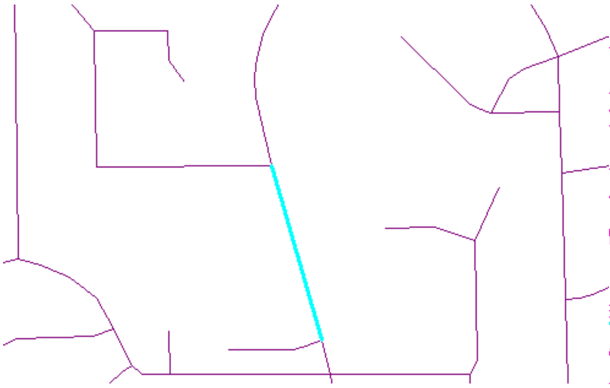


Figure 7: The street arcs (Bucharest)

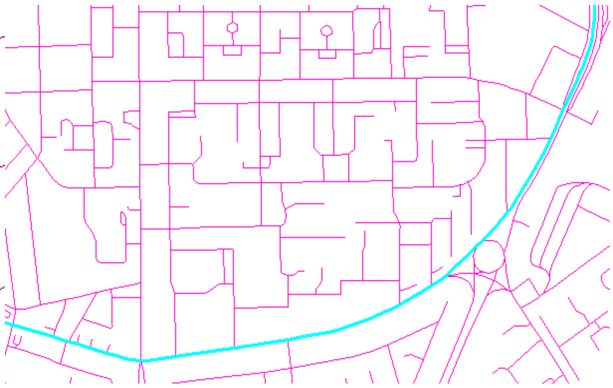


Figure 8: Natural streets (Bucharest)

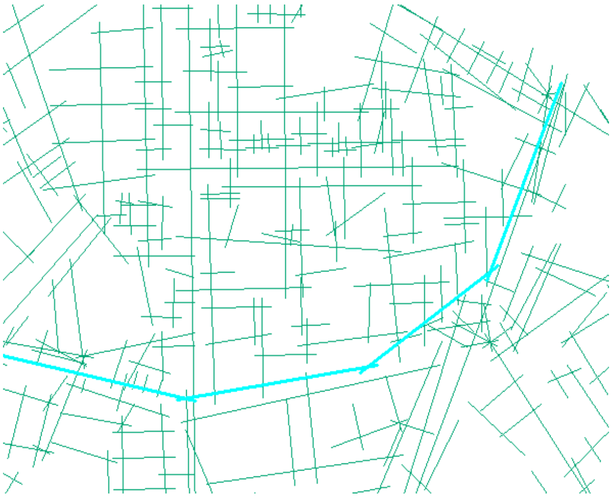


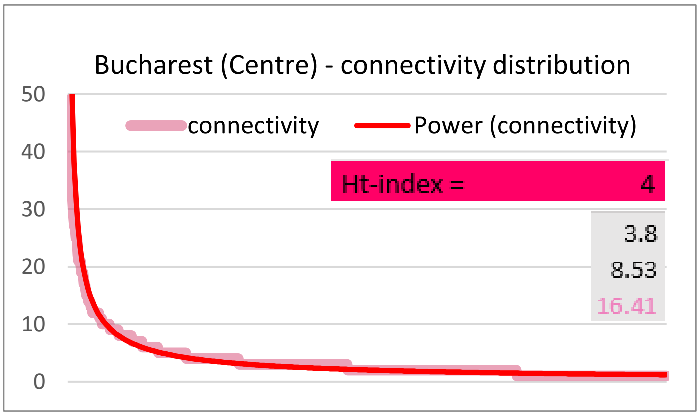
Figure 9: Axial lines (Bucharest)

After the process of creating nature streets was done. The streets were revised again on the isolated lines. Then the axial lines were created from the natural streets. The axial lines are defined by the walkability/drivability, whose parameters were pre-computed by *Axwoman* software. The natural streets were transformed into multiple axial lines (*Figure 9*). Until this point, the technical part of data processing was done. During which the natural streets and axial lines were created. The axial lines do not say anything without classification and attribute of connectivity on which is the classification based.

3.3 Data visualisation and Statistics

The importance and hierarchy in the symbology are based on the number of connections of each axial line or natural street. Axwoman automatically computes this attribute. After the connectivity attribute is computed, the street network can be classified (*Figure 10*). This classification was done automatically by the *Axwoman* based on the Head/tail breaks classification with 40/60 division rule.

Figure 10: Natural streets (left), Axial line (right) symbolised by Head/tail breaks method



The connectivity attribute was then visualised to see the data distribution better (*Figure 11*). The Head/tail breaks were computed using the *HeadTailBreaks* software with the division rule of (40/60). These are fundamentals for visual scaling hierarchy. The software also derived the Ht-index for further evaluations of the scaling properties.

Figure 11: Natural streets - distribution of connectivity and Head/tail breaks properties

4 Results

The results are being presented on the city of Budapest, which was chosen as the most representative. The reasons were indeed simple. Regarding the street structure, Budapest has a typical European-like street structure and has a relatively regular pattern, and relatively diverse pattern of prefab housing estate area (*Figure 12*). While studying the scaling of the streets, the regularity of their pattern plays an important role. The more regular the pattern is, the less scaled is the street structure. According (Jiang and Yin 2014) the structures with higher Ht-index are more likely to be complex, heterogeneous, and natural. The statement, that street structure is more natural, might be misinterpreted. There are two ways. Firstly, natural development, from the historical point of view where cities were being naturally developed in a long-time horizon. Secondly, the natural structure following ubiquitous patterns of nature. Precisely, it is a structure that is well-scaled and complex. This difference is crucial for interpreting the result. Back to the regularity of street patterns, Budapest has a relatively regular pattern of naturally (historically) developed streets. Thus, it is less scaled, and the Ht-index is supposed to be lower due to the regularity. However, the cities studied in this paper are more likely to have a less natural structure, than the prefab housing estate areas. Even though the streets are naturally developed (*Table 3*).

Table 3: Ht-index comparison:

Ht-index coparison							
City	Center		Prefab	**City**	Center		Prefab
Bratislava	5	<	6	**Prague**	3	<	4
Bucharest	4	<	7	**Sofia**	6	=	6
Budapest	4	<	5	**Warsaw**	4	=	4

4.1 Visual Comparison

Both of the city areas have undergone the same process. Thus, the results could be visually compared (*Figure 12*). The regularity of street pattern in the historical area is distinguishable at first sight. The streets are more block-alike, and the lengths of the streets are less diverse than in the other area. The connectivity, which is represented by colour hierarchy, seems to be more balanced and evenly distributed. Also, the whole pattern is so to speak more predictable. In contrast, the prefab housing estate area seems to have different lengths of street elements and the amounts of these elements differ in each hierarchical class (*Figure 13*). Hence it seems more scaled.

Figure 12: Budapest, Natural streets classified by Head/tail breaks method, historical area (left), prefab housing estate area *(right)*

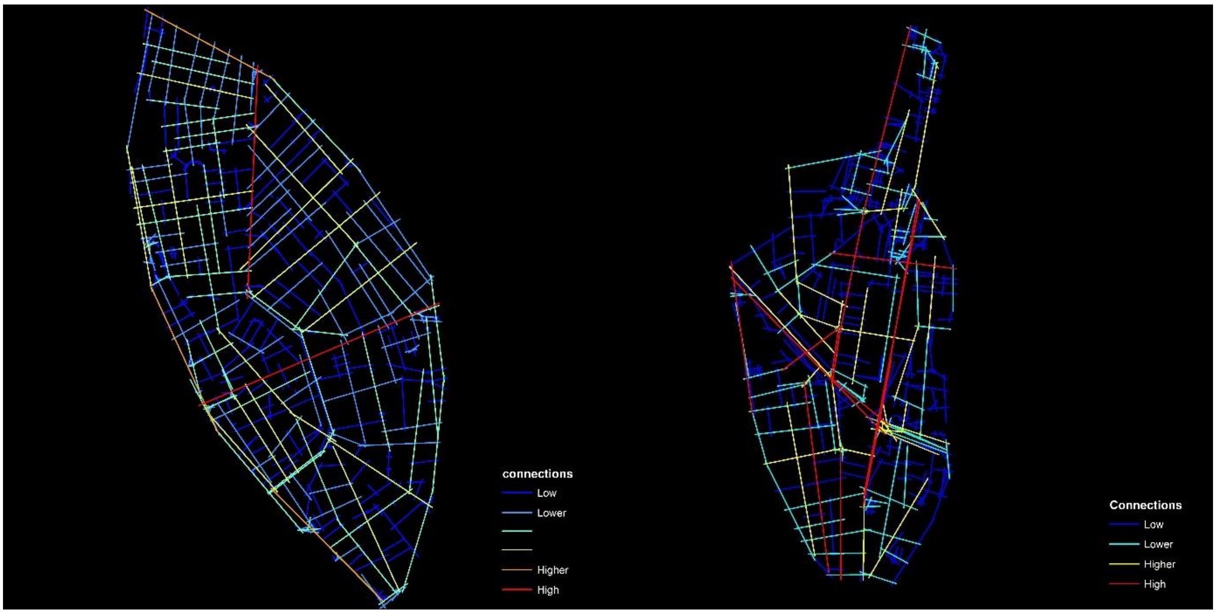
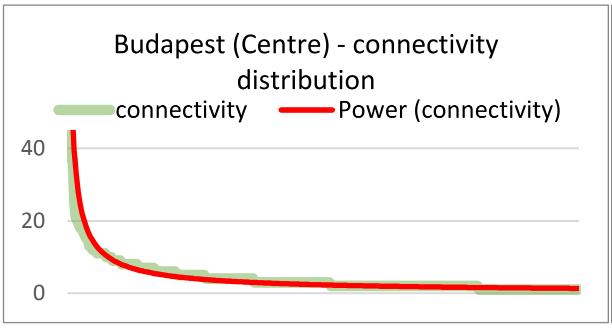


Figure 13: Budapest, Axial lines classified by Head/tail breaks method, historical area (left), prefab housing estate area *(right)*

4.2 Comparison of Distributions and Classifications

To be able to evaluate street based on the Ht-index the distribution of connectivity had to has heavy-tailed distribution and underlie the power law. Thus, the data were tested and visualised with power-law trend line (*Figure 13*). Since the distribution was verified the Ht-index could be used. In (*Table 3*) is shown a comparison between Naturally developed historical parts of the city with the preface estate areas. The comparison trend shows that the preface estate areas are more scaled, thus have a more complex structure.



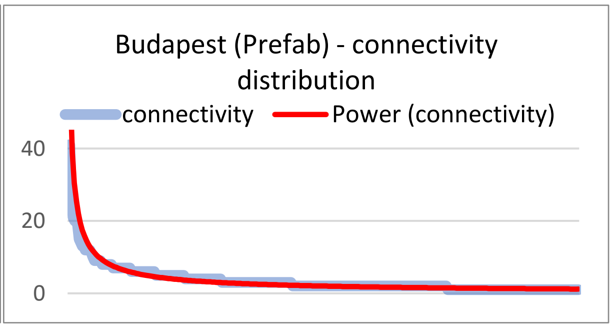


Figure 14: Distribution of the connectivity attributes of the Natural streets with a power-law trend line

Table 1: Head/tail breaks classification

Budapest Centre					
#Data	#head	%head	#tail	%tail	mean
335	90	26%	245	74%	4.33
90	25	27%	65	73%	10.12
25	8	32%	17	68%	18.92
Ht-index =	4				

Table 2: Head/tail breaks classification

Budapest Prefab					
#Data	#head	%head	#tail	%tail	mean
333	100	30%	233	70%	3.64
100	29	28%	71	72%	7.86
29	8	27%	21	73%	14.31
8	3	37%	5	63%	25.62
Ht-index =	5				

5 Conclusion

According to the results of the spatial analysis, the connectivity of natural streets of the prefab housing estate areas in most cases proved to be slightly better-scaled and more complex. Therefore, these areas are better scaled and follow the natural pattern of far more smaller streets, then large ones. This fact does not mean that the naturally developed cities do not have a natural pattern at all, they indeed have. The prefab housing estate street pattern is rather less regular, thus more natural. To sum up, the prefab housing estate areas proved to have at least the same scaling hierarchy, what is more, they might be even better scaled than naturally developed cities (*Table 3*). Which makes them more naturally scaled, more complex, the structure is more living (Jiang B. and Sui 2014). One of the possible explanations is that this might be because the mass prefab estates were planned and developed to be so to speak cities within cities. In most cases, these city parts are self-sufficient in many aspects. These urban projects might not be appreciated from the architectural point of view, but they have a unique value from the urbanistic point of view.

6 Discussion

6.1 Further Steps in Research

As mentioned before the prefab housing estates behave like a city in the city in some cases. Thus, it might be beneficial to examine the structures on how they are clustered and what is their average path length. Then the observation of small-world properties, and the community structure detection can be possible (Watts and Strogatz 1998). Also, the study could be extended using other software suitable for spatial and network analysis such as *Matlab* or *Pajek*.

Another approach that might be beneficial for this study is agent-based modelling. The model is a representation of the agent’s interaction and how they are affecting their environment and the artificial population. The agent in the scenario of a realistic simulation represents an entity with predefined properties. The predefined properties of the agent are affecting its behaviour in the virtual reality simulation (O'Sullivan and Haklay 2000). This modelling method might simulate how people interact on a daily bases in such a structure.

6.2 Look Back

Is worth to mention some short reflections on data processing and the analysis itself. Firstly, the definition of what is street and what is not might differ from person to person. For instance, there is a lot of road attributes and classes such pathways, trail or sidewalks and their use is questionable. In some cases, it might cause that multiplicity of streets. In other cases, it might disrupt connectivity and affect the final scaling properties. Thus, it is necessary to be cautious while omitting some roads or the whole road classes. Secondly, the two-way streets might cause some issues as well. In theory, there are two streets, but they have just one name and are perceived as one street. The consequence is that the number of connections is divided and the hierarchical level of the streets is lower. Finally, the process of generation natural streets and axial lines is very sensitive to input data. Due to lacking error management or input set up of the tools is difficult to detect data defects. Which makes the process less transparent and sometime might happen that the tool process different data layers from the chosen one. Nevertheless, the benefits outweigh the shortcoming after all.

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Figure References

All figures used in this paper were created by the author.

Appendix

1 Natural Streets
1.1 Bratislava, centre (left), prefab (right)
1.2 Bucharest, centre (left), prefab (right)
1.3 Budapest, centre (left), prefab (right)
1.4 Prague, centre (left), prefab (right)
1.5 Sofia, centre (left), prefab (right)
1.6 Warsaw, centre (left), prefab (right)

2 Axial Lines
2.1 Bucharest, centre (left), prefab (right)
2.2 Budapest, centre (left), prefab (right)
2.3 Warsaw, centre (left), prefab (right)

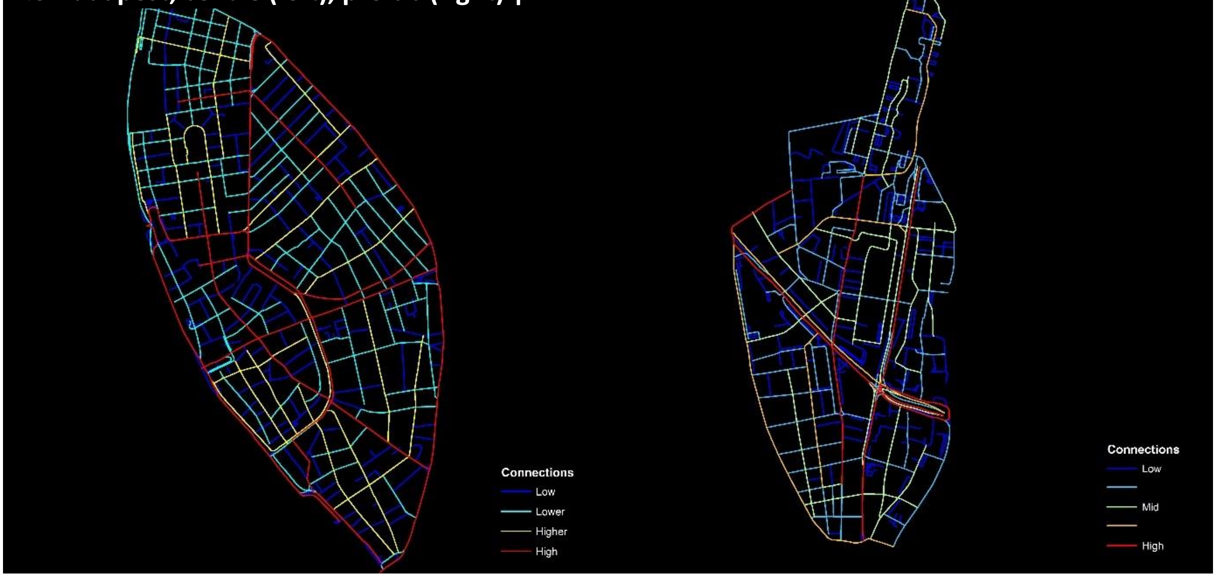
3 Head/tail breaks values
3.1 Bratislava, centre
3.2 Bratislava, prefab
3.3 Bucharest, centre
3.4 Bucharest, prefab
3.5 Budapest, centre
3.6 Budapest, prefab
3.7 Prague, centre
3.8 Prague prefab
3.9 Sofia, centre
3.10 Sofia, prefab
3.11 Warsaw, centre
3.12 Warsaw, prefab

4 Connectivity Distribution
4.1 Bratislava, centre – connectivity distribution
4.2 Bratislava, prefab – connectivity distribution
4.3 Bucharest, centre – connectivity distribution
4.4 Bucharest, prefab – connectivity distribution
4.5 Budapest, centre – connectivity distribution
4.6 Budapest, prefab – connectivity distribution
4.7 Prague, centre – connectivity distribution
4.8 Prague prefab – connectivity distribution
4.9 Sofia, centre – connectivity distribution
4.10 Sofia, prefab – connectivity distribution
4.11 Warsaw, centre – connectivity distribution
4.12 Warsaw, prefab – connectivity distribution

1.1 Bratislava, centre (left), prefab (right) |

1.2 Bucharest, centre (left), prefab (right) |

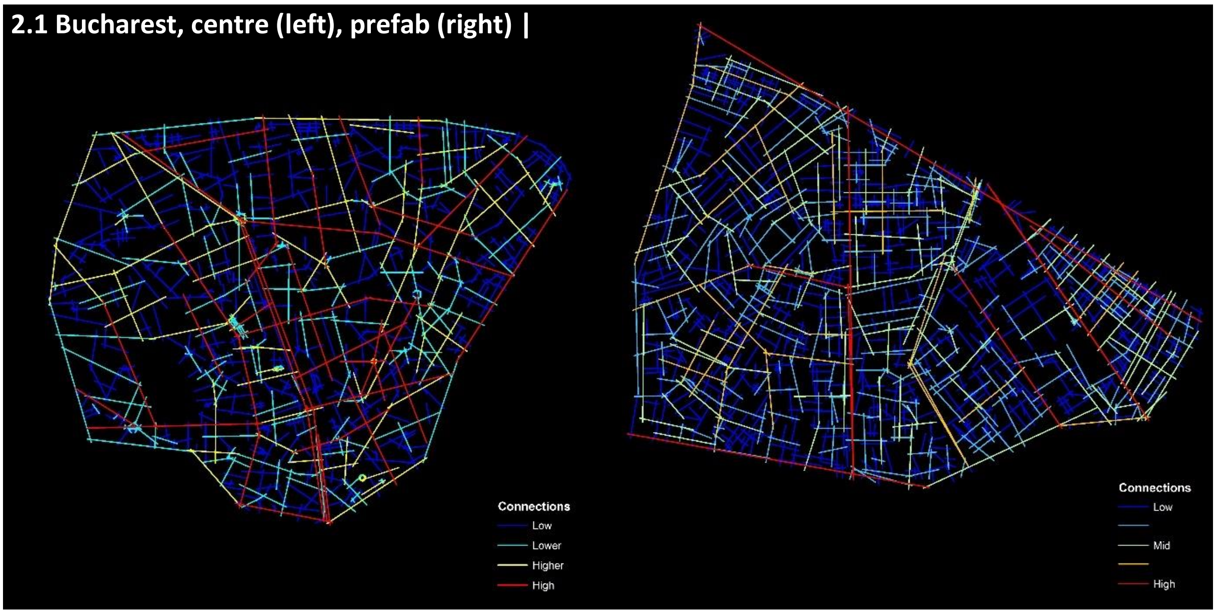
1.3 Budapest, centre (left), prefab (right) |



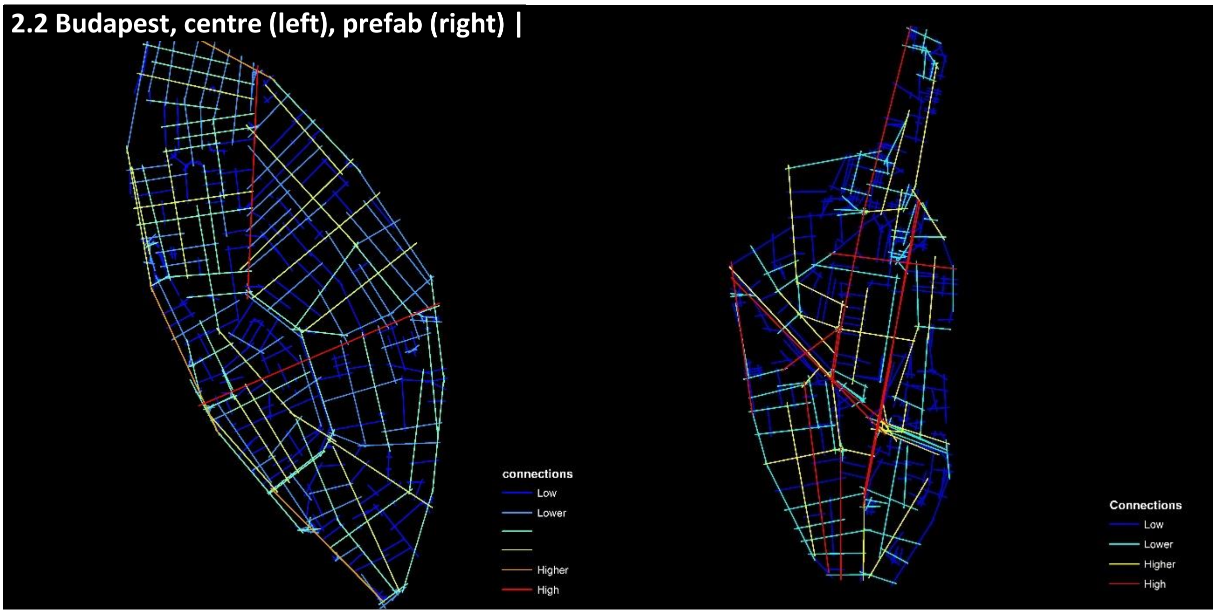
1.6 Warsaw, centre (left), prefab (right) |

1.5 Sofia, centre (left), prefab (right) |

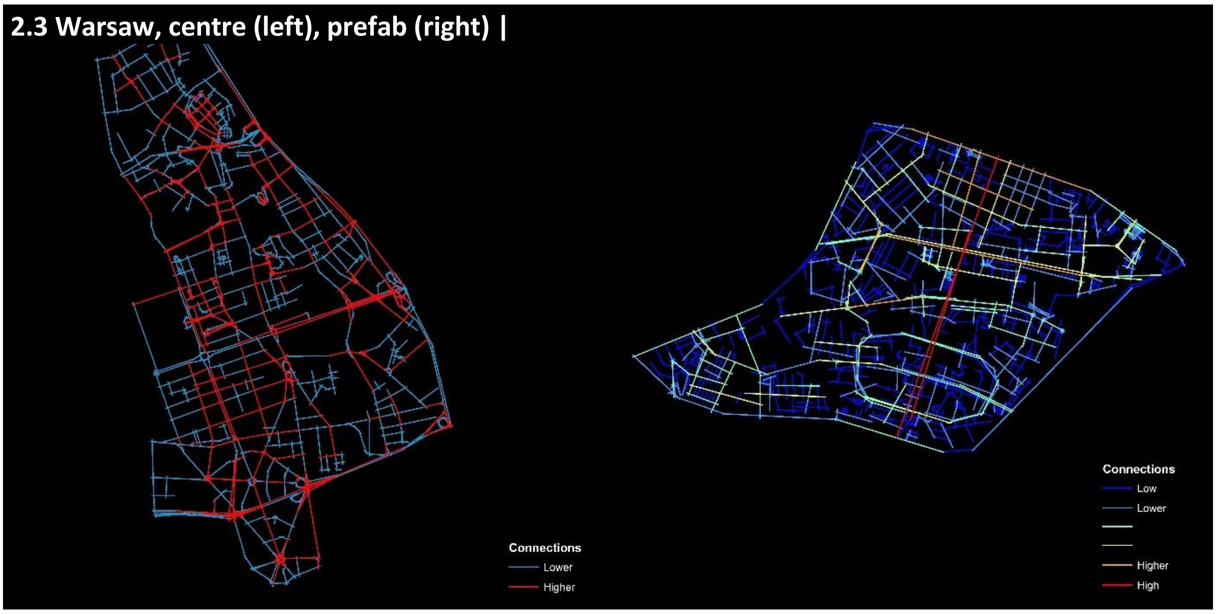
1.6 Warsaw, centre (left), prefab (right) |



2.1 Bucharest, centre (left), prefab (right) |



2.2 Budapest, centre (left), prefab (right) |



2.3 Warsaw, centre (left), prefab (right) |

3.1 Bratislava Center

#Data	#head	%head	#tail	%tail	mean
215	71	33%	144	67%	4.6
71	27	38%	44	62%	8.99
27	11	40%	16	60%	13.74
11	4	36%	7	64%	18.82
Ht-index =	5				

3.2 Bratislava Prefab

#Data	#head	%head	#tail	%tail	mean
1044	312	29%	732	71%	2.71
312	88	28%	224	72%	5.75
88	29	32%	59	68%	11.77
29	10	34%	19	66%	20.62
10	4	40%	6	60%	31.9
Ht-index =	6				

3.3 Bucharest Center

#Data	#head	%head	#tail	%tail	mean
683	195	0.28%	488	0.72%	3.8
195	58	0.29%	137	0.71%	8.53
58	20	0.34%	38	0.66%	16.41
Ht-index =	4				

3.4 Bucharest Prefab

#Data	#head	%head	#tail	%tail	mean
1110	315	28%	795	72%	3.41
315	87	27%	228	73%	7.29
87	29	33%	58	67%	13.33
29	11	37%	18	63%	21.03
11	4	36%	7	64%	27.55
4	1	25%	3	75%	33
Ht-index =	7				

3.5 Budapest Center

#Data	#head	%head	#tail	%tail	mean
335	90	26%	245	74%	4.33
90	25	27%	65	73%	10.12
25	8	32%	17	68%	18.92
Ht-index =	4				

3.6 Budapest Prefab

#Data	#head	%head	#tail	%tail	mean
333	100	30%	233	70%	3.64
100	29	28%	71	72%	7.86
29	8	27%	21	73%	14.31
8	3	37%	5	63%	25.62
Ht-index =	5				

3.7 Prague Center

#Data	#head	%head	#tail	%tail	mean
523	132	25%	391	75%	4.15
132	37	28%	95	72%	10.03
Ht-index =	3				

3.8 Prague Prefab

#Data	#head	%head	#tail	%tail	mean
553	175	31%	378	69%	2.73
175	52	29%	123	71%	5.66
52	18	34%	34	66%	10.35
Ht-index =	4				

3.9 Sofia Center

#Data	#head	%head	#tail	%tail	mean
302	83	27%	219	73%	4.76
83	30	36%	53	64%	11.71
30	10	33%	20	67%	19.7
10	3	30%	7	70%	29.4
3	1	33%	2	67%	38.33
Ht-index =	6				

3.10 Sofia Prefab

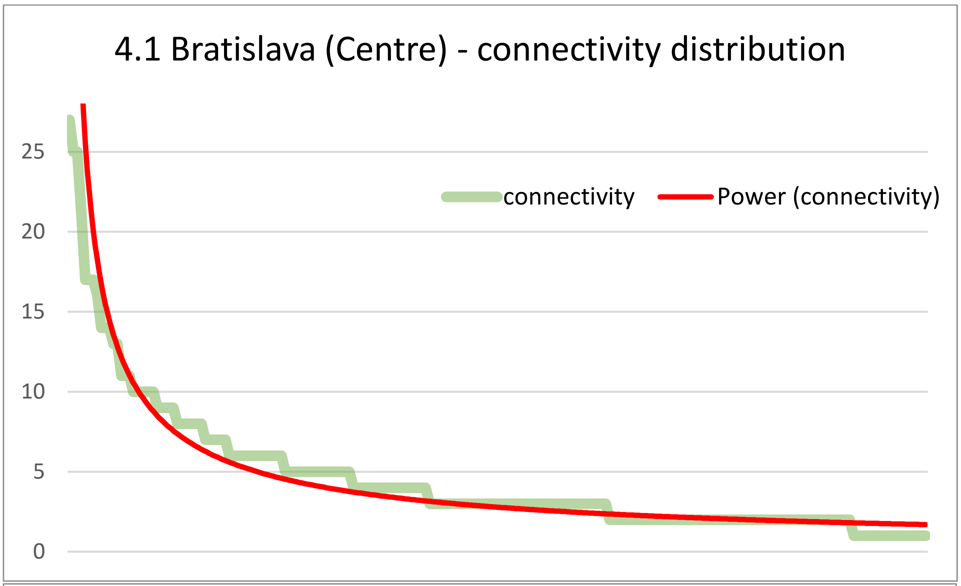
#Data	#head	%head	#tail	%tail	mean
444	108	24%	336	76%	3.12
108	33	30%	75	70%	7.5
33	8	24%	25	76%	13.39
8	3	37%	5	63%	24.25
3	1	33%	2	67%	37.33
Ht-index =	6				

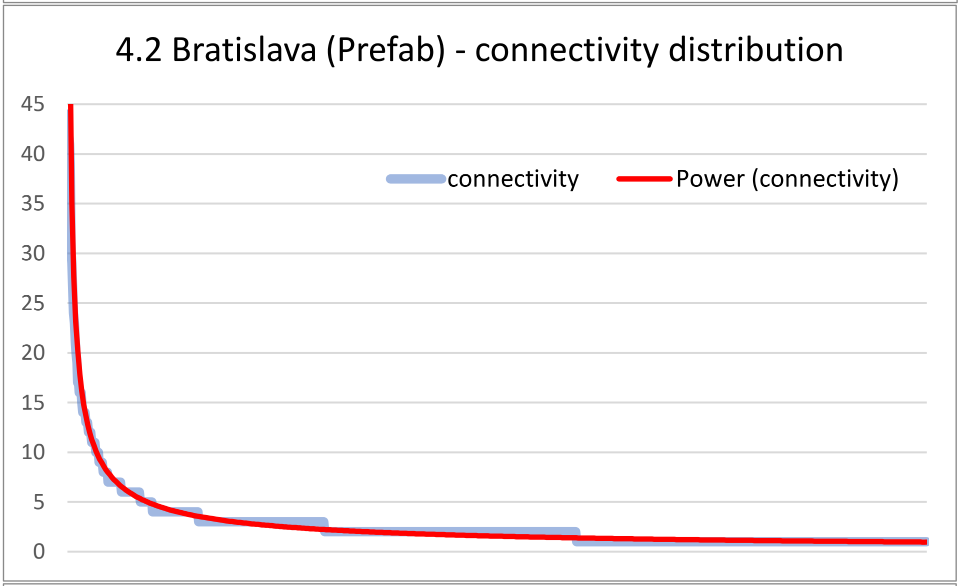
3.11 Warsaw Center

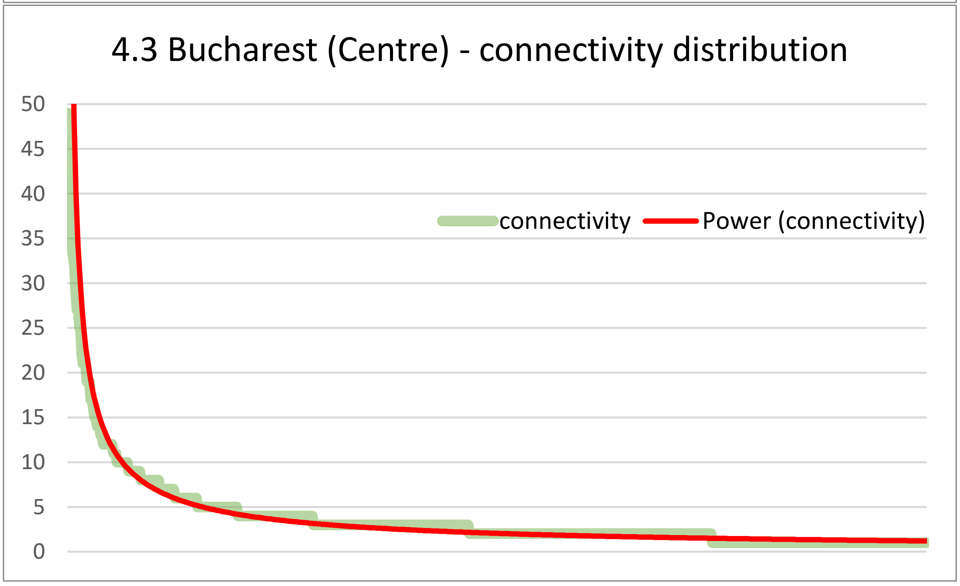
#Data	#head	%head	#tail	%tail	mean
399	92	23%	307	77%	4.16
92	32	34%	60	66%	10.53
32	9	28%	23	72%	18.09
Ht-index =	4				

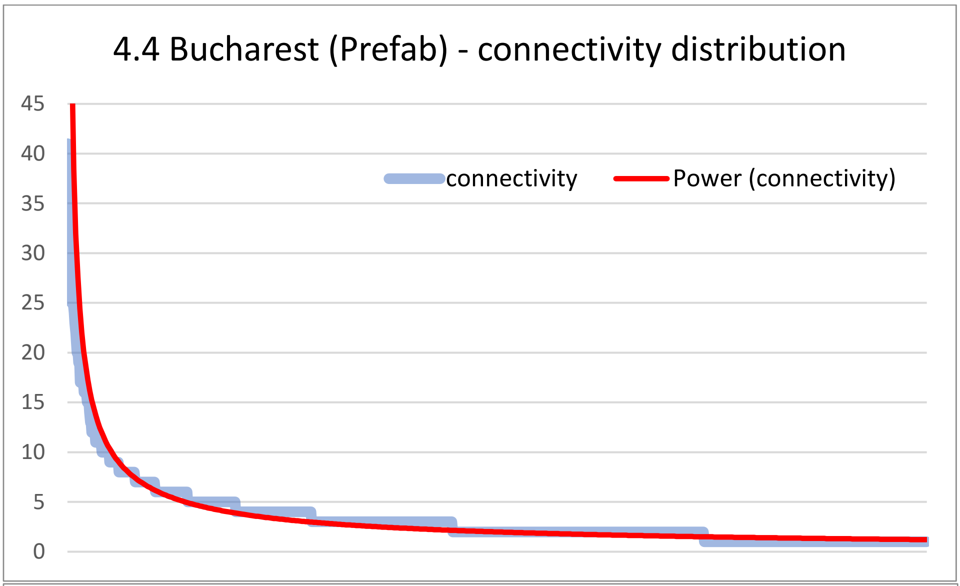
3.12 Warsaw Prefab

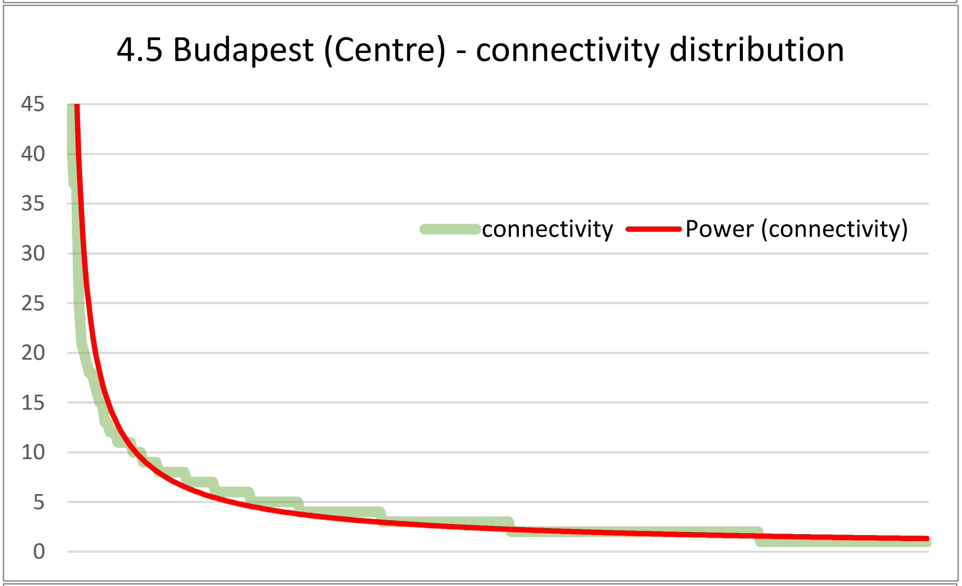
#Data	#head	%head	#tail	%tail	mean
771	173	22%	598	78%	3.01
173	50	28%	123	72%	7.44
50	17	34%	33	66%	13.46
Ht-index =	4				

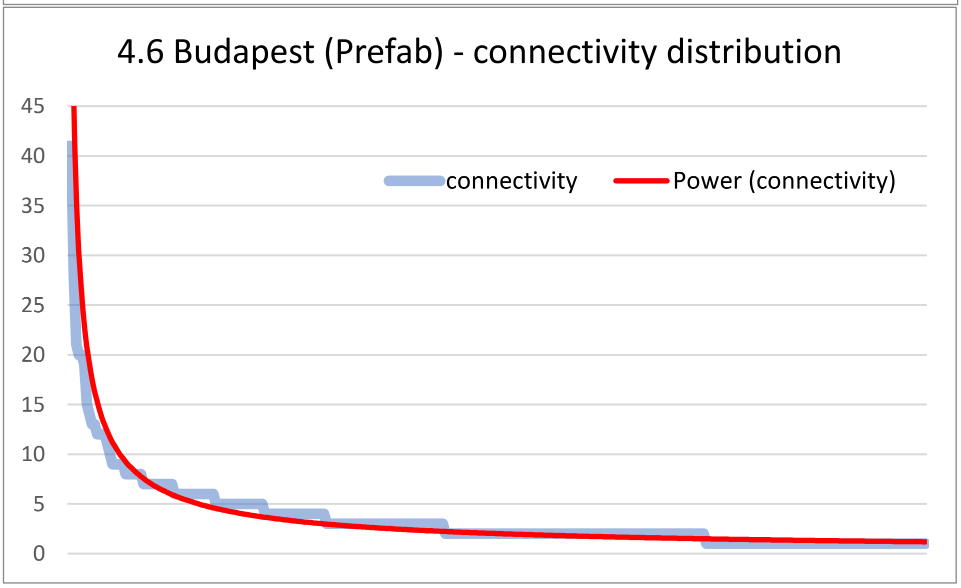

4.1 Bratislava (Centre) - connectivity distribution
25
20
15
10
5
0
connectivity
Power (connectivity)

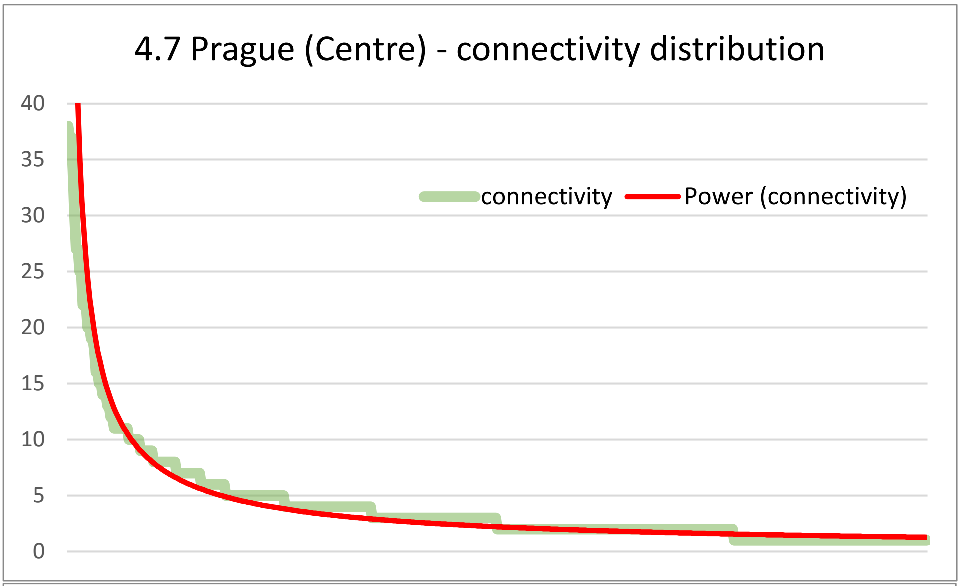

4.2 Bratislava (Prefab) - connectivity distribution
45
40
35
30
25
20
15
10
5
0
connectivity
Power (connectivity)

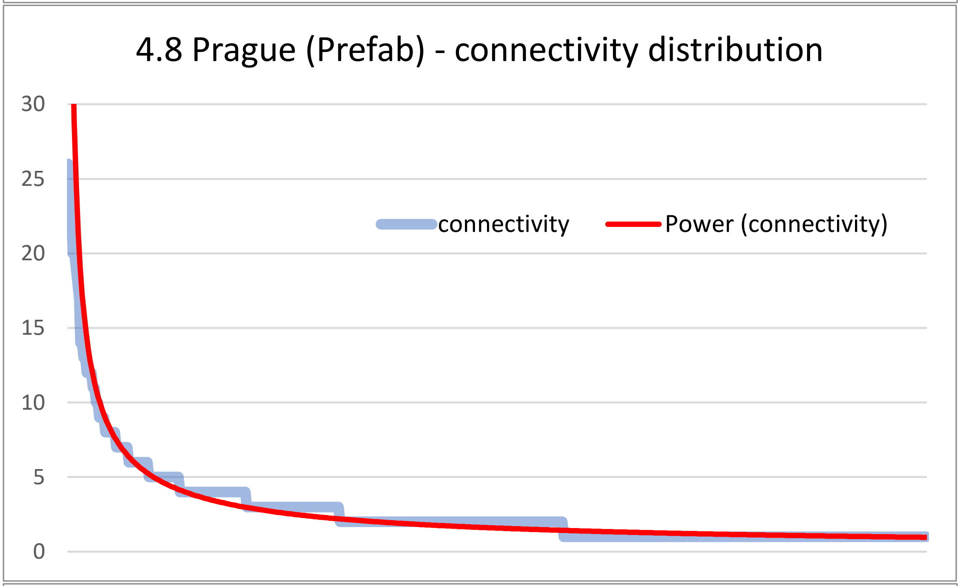

4.3 Bucharest (Centre) - connectivity distribution
50
45
40
35
30
25
20
15
10
5
0
connectivity
Power (connectivity)

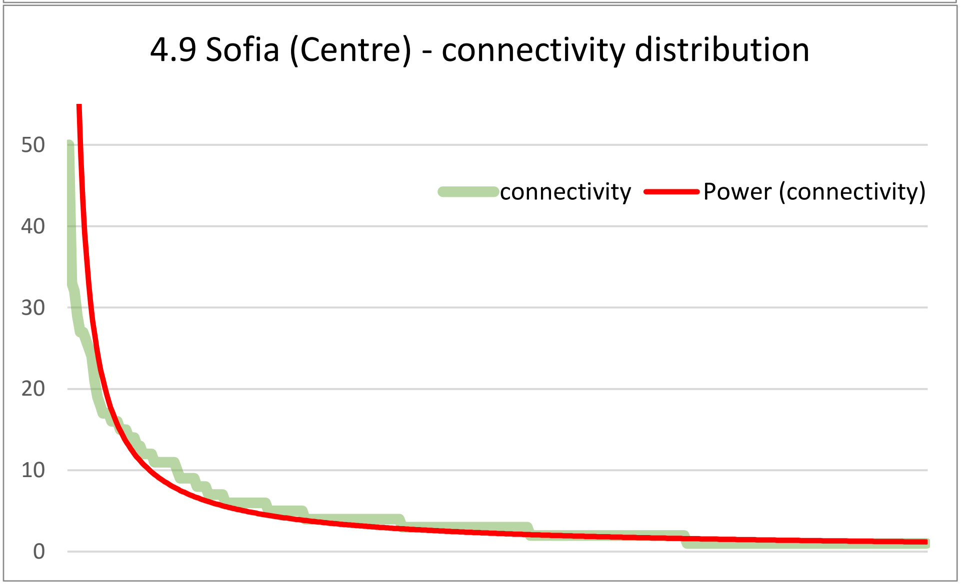

4.4 Bucharest (Prefab) - connectivity distribution
45
40
35
30
25
20
15
10
5
0
connectivity
Power (connectivity)

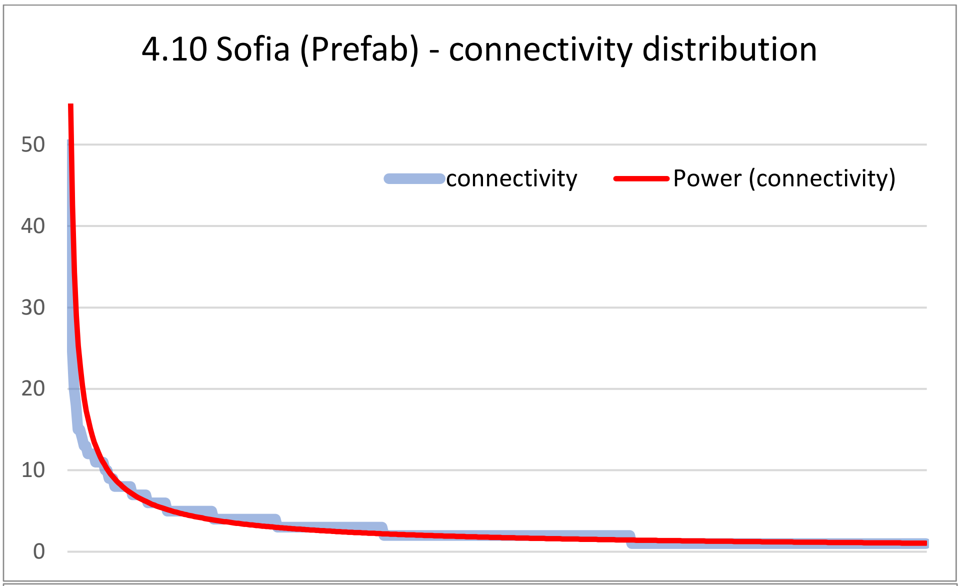

4.5 Budapest (Centre) - connectivity distribution
45
40
35
30
25
20
15
10
5
0
connectivity
Power (connectivity)

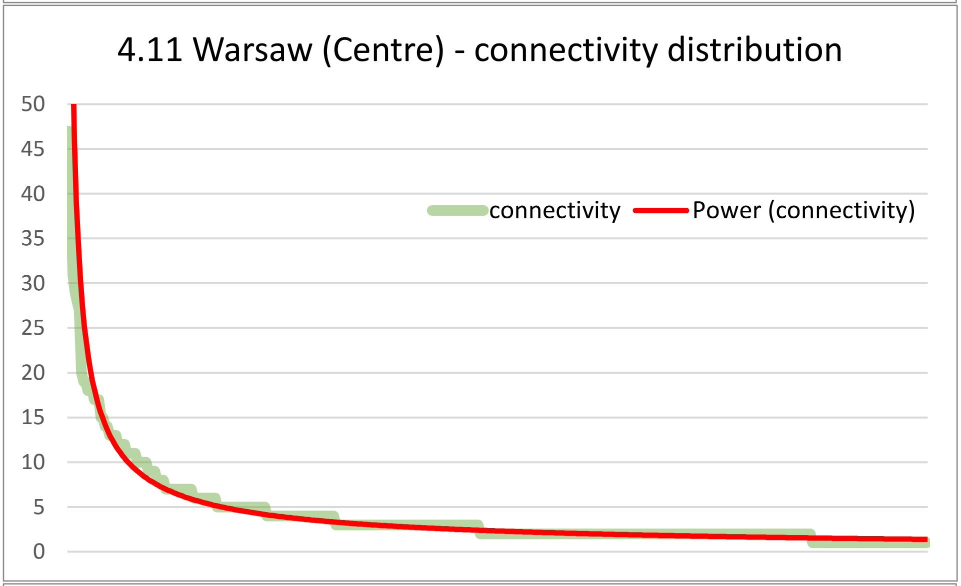

4.6 Budapest (Prefab) - connectivity distribution
45
40
35
30
25
20
15
10
5
0
connectivity
Power (connectivity)

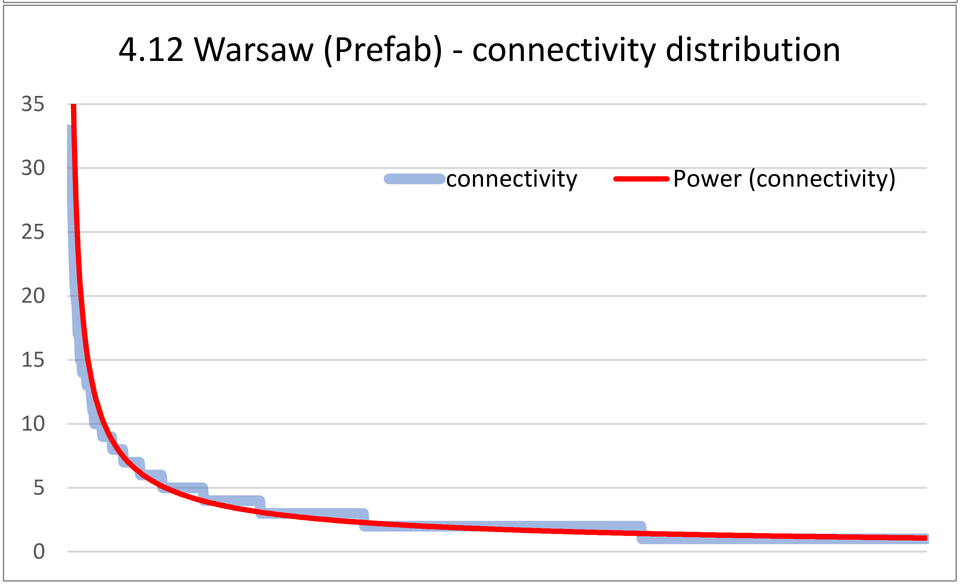

4.7 Prague (Centre) - connectivity distribution
40
35
30
25
20
15
10
5
0
connectivity
Power (connectivity)


4.8 Prague (Prefab) - connectivity distribution
30
25
20
15
10
5
0
connectivity
Power (connectivity)


4.9 Sofia (Centre) - connectivity distribution
50
40
30
20
10
0
connectivity
Power (connectivity)


4.10 Sofia (Prefab) - connectivity distribution
50
40
30
20
10
0
connectivity
Power (connectivity)


4.11 Warsaw (Centre) - connectivity distribution
50
45
40
35
30
25
20
15
10
5
0
connectivity
Power (connectivity)


4.12 Warsaw (Prefab) - connectivity distribution
35
30
25
20
15
10
5
0
connectivity
Power (connectivity)