



HAL
open science

Development of new indexes of the 'Generic City' in the Baltic coastal city network

Thomas Gloaguen, Kęstutis Zaleckis, Sébastien Gadal

► To cite this version:

Thomas Gloaguen, Kęstutis Zaleckis, Sébastien Gadal. Development of new indexes of the 'Generic City' in the Baltic coastal city network. XXIX International Seminar on Urban Form ISUF 2022: Urban Redevelopment and Revitalisation. A Multidisciplinary Perspective, Lodz University of Technology Press, pp.365-378, 2023, 978-83-67934-03-9. 10.34658/9788367934039.29 . hal-04692014

HAL Id: hal-04692014

<https://hal.science/hal-04692014>

Submitted on 9 Sep 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial 4.0 International License

Thomas Gloaguen⁽¹⁾, Prof. Dr. Kęstutis Zaleckis⁽²⁾, Prof. Dr. Hab. Sébastien Gadat⁽³⁾

⁽¹⁾ Cultural and Spatial Environment Research Group, Faculty of Civil Engineering and Architecture, Kaunas University of Technology, Lithuania

Aix-Marseille University, CNRS, ESPACE UMR 7300, Nice Sophia-Antipolis University, Avignon University, France

⁽²⁾ Cultural and Spatial Environment Research Group, Faculty of Civil Engineering and Architecture, Kaunas University of Technology, Lithuania

⁽³⁾ Aix-Marseille University, CNRS, ESPACE UMR 7300, Nice Sophia-Antipolis University, Avignon University, France

Department of Ecology and Geography, Institute of Environment, North-Eastern Federal University, Republic of Sakha-Yakutia

10.34658/9788367934039.29

Development of new indexes of the ‘Generic City’ in the Baltic coastal city network

Abstract The concept of ‘Generic City’ is used in space syntax to model the levels of functioning of cities – interactions, flows, impacts of spatial, urban, and territorial structures and organisations. The traditionally associated indexes of ‘Choice’ and ‘Integration’ provide additional possibilities for comparison and classification of urban structures in a context where public policymaking requires more knowledge about cities in terms of connectivity, centrality, accessibility, etc. In this article, we extend the application of the ‘Generic City’ concept, originally designed for cities, to the coastal regions of the Baltic countries – Estonia, Latvia, and Lithuania. New indexes are being experimented to highlight ‘foreground’ and ‘background’ networks and better reflect the local peculiarities of Baltic urban structures, whose evolution is dependent on political and economic factors of the last decades. Their robustness is tested by Spearman and Pearson’s correlations with human activity data. The results show that for a limited radius of 1 km, the ‘Betweenness’ and ‘Length’ indexes perform best in describing the ‘background’ network. For an unlimited radius, the correlations with the ‘Network Quantity Penalized by Distance’ index are robust to validate the ‘foreground’ network model. The results highlight the need to normalise the indexes to compare networks of different sizes.

Keywords Space syntax, Generic City model, Foreground network, Background network, Baltic countries.

Introduction

Studies focusing on urbanisation dynamics have led researchers to question the causes and consequences of this process, particularly when it is uncontrolled. A wide range of negative effects on humans and the environment can be observed: disturbance of ecosystems, land and water pollution, increased vulnerability to natural risks with artificialisation of land, etc. (Paulet 2009). Urban sprawl is also affecting cities in the Baltic States with ‘increasing living standards, land restitution, the desire for home ownership, active real estate market and mortgage policies’ (Cirtautas 2013). Cooperation between different public authorities is highlighted as one of the challenges in developing actions to control urbanisation through urban policies based on principles of centrality or density for example (Cirtautas 2013; Dupuy, Benguigui 2015).

This objective cannot be achieved without the support of spatial analysis models developed since the 1960s, i.e., ‘a theoretical representation formulated in mathematical terms of geographical reality’ (Georges, Verger 2013). The interest of spatial analysis models lies partly in the simulation, attempting ‘to reproduce or better construct reality or to predict a behaviour or an evolution [...] of elements of a spatial system’ (Brunet et al. 1993:334) by simplifying the essential properties of the system (Brunet 2000).

The space syntax as a mathematical graph-based model offers a set of methodologies including statistical indexes comparison with empirical data that describe the social and cultural dimensions of space through the relation between architectural forms and urban functions (Laouar, Manzouz 2017; Hamouda 2018). The space syntax concept of ‘Generic City’ (Hillier 2007) is one of the possible theory matrices for the recognition of the urban structure business centres, peri-urban areas, etc. and to simulate the levels of functioning of cities in terms of interactions, flows, impacts of spatial, urban, and territorial structures and organisations.

The theoretical issue of this paper is to question the relevance of the ‘Generic City’ concept through the development of new indexes and their validation by geospatial data. The experimentation of these indexes

is carried out on the road networks of the coastal regions of the Baltic countries – Lithuania, Latvia, and Estonia. We have extended the application of the ‘Generic City’ concept designed for cities only to a small-scale urban network, which is still rarely invested in space syntax research, except in rare cases such as the UK Integrated Urban Model for example (Space Syntax Limited 2018). The study area is subject to specific urbanisation dynamics related to changes in the political, economic, social, and cultural context since the post-war period (Druzhinin 2019; Gadal, Gloaguen 2021). The space syntax modelling constitutes an application analysis for the detection of the urban fabric and thus contributes to improving the decision-making of public authorities in urban, territorial, and spatial planning (Brunet 2000). In the case of the Baltic Sea Region, this approach can provide new geographical information to complement missing or inaccurate satellite data in the measurement of urbanisation dynamics by remote sensing techniques.

In this paper, we present (1) the ‘Generic City’ concept and its theoretical background, (2) the methodology including the indexes and data used for the analysis and its validation, and (3) the results and their discussions which allow us to conclude on validation or invalidation of the concept applied to the coastal regions of the Baltic States.

Theoretical background

Space syntax is developed in the early 1980s by Bill Hillier to simulate the social interaction created by the spatial organisation of buildings and cities. Part of conceptualisation in space syntax is based on network theory: cities can be compared to systems composed of sub-systems residential areas, economic activity zones, or cultural places for example connected by networks that create social and physical interactions and condition ‘the way the system functions and evolves’ (Dupuy 1984:21). Pedestrian paths, cycle tracks or roadways are examples of networks that can be modelled in graphs, i.e., ‘segments connected by nodes and expressing a system of relationships’ (Georges, Verger 2013).

The space syntax uses the Mathematic Graph Model to calculate physical properties and simulate the social interactions of networks through a series of indexes. The centrality of a network is one of the most important properties: it is defined by the capacity of an element of the system to locate itself close to other elements of the system and to interfere in the network to capture ‘information, power, prestige or influence’ (Freeman et al. 1991: 141–142). Different indexes measure centrality by considering only the shortest paths closeness centrality or the entire network betweenness centrality, including flow or not, or by calculating the centrality of the link in the network degree centrality (Freeman et al. 1991). These indexes capture the spatial capital of a city: the individuals can take advantage of the resources offered by space material, immaterial, and ideal and access other forms of capital theorised by Bourdieu such as economic, social or cultural capital (Cailly 2007; Marcus 2007). A central location, accessible, with high transit flow, implies a high degree of spatial capital as people access to shops, public services, leisure, etc. most efficiently: the spatial capital gives the ‘possibility to measure the effects of urban form’ (Marcus 2007:9) in terms of land values or rental prices for example (Marcus 2010).

The different types of centralities and by extension, the variation in spatial capital is formalised by Hillier (2007) with the concept of the ‘Generic City’: cities have common spatial and functional characteristics despite their cultural influences. According to this concept, cities have a dual system of ‘foreground’ and ‘background’ networks. The first is characterised by ‘longer lines and nearly straight connections’ that favour economic activities and mobility. The second is characterised by ‘shorter lines with more near right angle connections, and so more localised and with less linear continuity’ that restrict mobility and are specific to a mainly residential functionality. The ‘foreground’ network in essence tends to be similar in all cities while the ‘background’ network is dependent on the cultural context in which it is located (Hillier 2007).

A comparison of these two networks is possible by using the ‘Choice’ and ‘Integration’ indexes in space syntax. The ‘Choice’ index simulates the accessibility for each segment of the network by measuring individually the potential to cross the shortest paths connecting the other segments of the network or radius (Hillier et al. 1987). The ‘Integration’ index simulates the proximity of each segment to other segments in the network or radius, by measuring individually the shortest distances between them (Hillier et al. 1984). These ‘Choice’ and ‘Integration’ indexes are normalised with the ‘Total Depth’ for the former the total topological distance from a segment to other segments in the network or radius and the ‘Node Count’ for the latter the number of segments encountered by each segment in a network or radius. This normalisation is necessary to compare networks of different sizes (Hillier, Hanson 1984; Turner 2004; Hillier et al. 2012). The maximum values of the normalised ‘Choice’ and ‘Integration’ indexes describe the ‘foreground’ network while the average values describe the ‘background’ network.

In research on three Baltic cities and their associated administrative regions Klaipėda (Lithuania), Liepāja (Latvia), and Parnü (Estonia) the results obtained with the two normalised indexes showed limitations in terms of interpretation the results indicated a continuous, low fragmented network for both the ‘foreground’ and ‘background’ networks and in terms of validity (Gloaguen et al. 2022). The indexes proved not to be sensitive enough to model the local peculiarities of Baltic urban structures, which do not differ when comparing European cities with Asian or Arab cities for example. This hypothesis is reinforced by the fact that the Baltic networks

have experienced the superimposition of cultural influences Prussian, Russian, Swedish, Soviet, and post-Soviet which makes modelling more complex (Gadal 2011). For these reasons, it seems obvious to experiment with new indexes which could potentially better consider local context and invalidate or confirm the relevance of the concept of ‘Generic City’ applied in the Baltic cities.

Methodology

Data used and validation

This analysis is based on the road network of the Baltic countries – Estonia, Latvia, and Lithuania – from OpenStreet Map (OSM) data (<https://www.openstreetmap.org>), freely downloadable with the online data tool Overpass Turbo (<https://overpass-turbo.eu>) and already geo-referenced. For each country, a query is formulated to retrieve geospatial data from OSM registered with the key ‘highway’ which corresponds to all motorised, pedestrian, and cycle terrestrial networks. The latter two are excluded from the query to select only the road network. The data is processed on a Geographical Information System (GIS) to prepare the calculations: connectivity errors are repaired, and isolated or duplicated segments are eliminated.

The calculations are performed with the Spatial Design Network Analysis (sDNA) software, which is directly integrated into the GIS and offers a wide variety of index calculations (Cooper, Chiaradia 2020).

Indexes validation requires additional geospatial data. We used 4 types of data that capture human, and more specifically, urban activity. The first data used are amenity density identified on OSM public services, restoration, education services, transport, financial services, health services, leisure facilities, etc. and downloaded as geo-located points (OpenStreet Map 2022). Each segment is assigned a density of amenity within 200 m of it. The second data used is the 200x200 m grid of population density, produced by each national statistical institute (Statistics Lithuania 2020; Statistical Office of Estonia 2021; Central Statistical Bureau of Latvia 2022). The third data used is the nitrogen dioxide (NO₂) density in the troposphere detected by the Sentinel-5 satellite and averaged for the year 2021. NO₂ emissions come from the combustion of fuel by transport, power plants, and non-transportation equipment (European Space Agency, 2018). The latest data used is the level of radiance detected by the VIIRS satellite for the year 2021 which makes it possible to locate the sources of light pollution (Román et al. 2018). For these last three data available in raster format, we created a grid of points with the same resolution as the original data. Each segment was assigned the average of the points located within a 200 m perimeter.

Definition of the study area

In this paper, we focus on the case of the network in the Baltic coastal regions, which implies the first limitation: there are several possible definitions of the coastal zone (Kelmeshev et al., 2017). We chose to consider the coastal zone according to a space syntax index the embeddedness (EMD) (equation 1) based on the ratio of segment density for different radii (Yang & Hillier, 2007; Yang & Hillier, 2012).

Equation 1

$$EMD = \log \left(\frac{lnk^x}{lnk^y} \right)$$

Where:

lnk — segment density

x and y — the smaller and the larger radius.

The radii used in the calculation are the average daily journey for reference cities in 2010 (Table 1) (Jacobs Crisioni & Lavalley, 2015) as the smaller radius and the average segment length per country calculated with standard functionalities of ArcGIS as the larger radius.

Table 1. Values used in the radii on the Embeddedness index

Cities	Country	Average distance of daily journey (m)	Average segment length (m)
Klaipėda	Lithuania	4 732	192
Riga	Latvia	5 158	235
Narva	Estonia	7 706	203

Source: unknown.

The choice of these two radii seems particularly appropriate to highlight the main urban areas especially when the study areas are discriminated by the maximum values of the index (Figure 1). This discrimination by maximum values also makes it possible to show very clearly the limit of the coastal zone in Lithuania and Estonia. It can be noted that the coastal zone limits established on low values of the index correspond to natural corridor areas. In Latvia, the particularly concentric structure of the urban network makes this task much more complex (Figure 1).

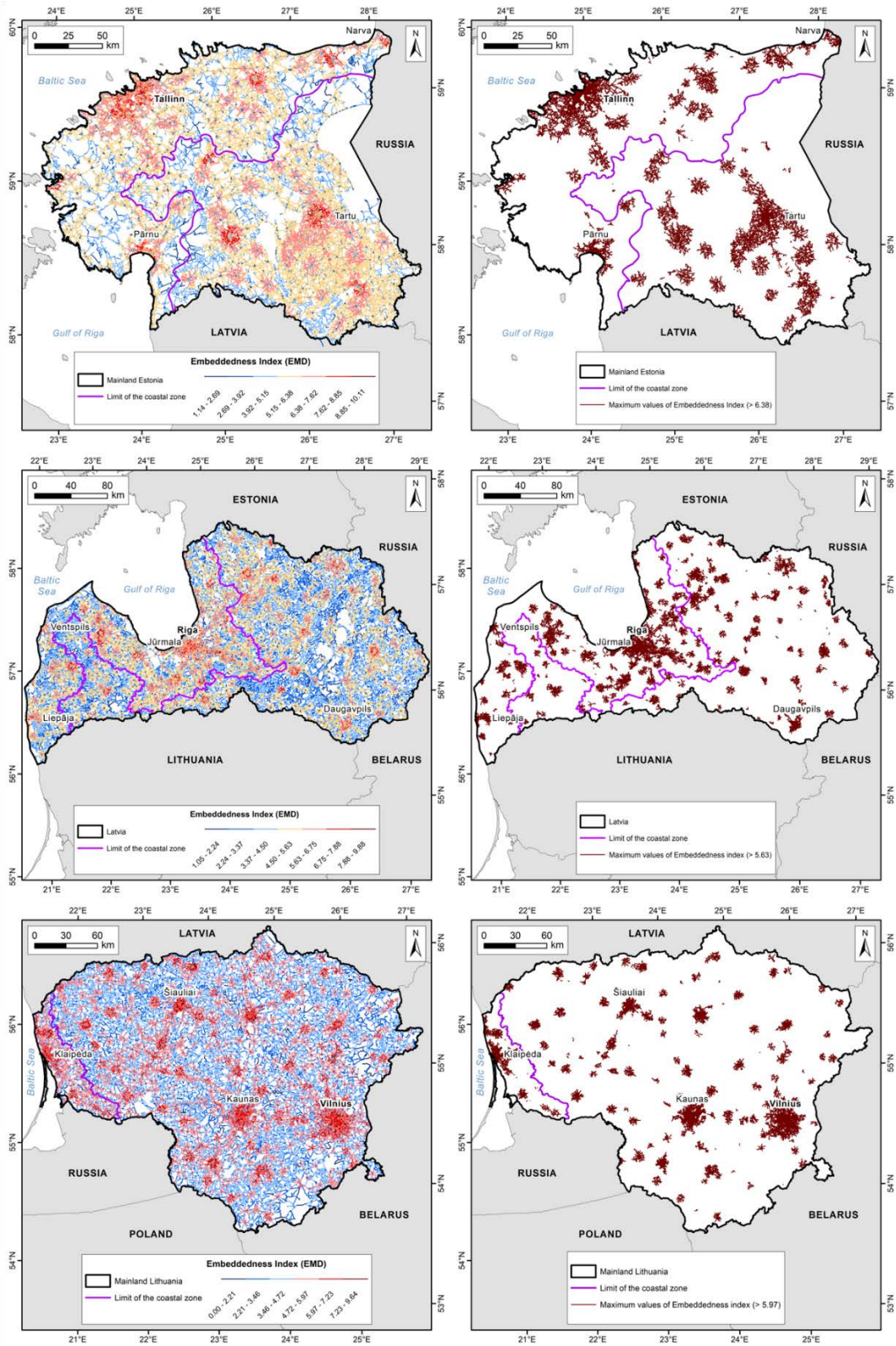




Figure 1. Delineation of the Baltic coastal zone by using the Embeddedness index (left) and discrimination by the maximum values of the index (right)

Source: unknown.

Table 2. Correlation coefficient values for indexes with a limited radius of 1 km

Lithuania		Bt	TPBt	TPD	MED	NQPD	MGL	MCF	Div	Len
Spearman	Amenity	0.50	0.26	0.19	0.22	0.59	0.22	0.12	0.22	0.59
	Population	0.70	0.35	0.20	0.42	0.76	0.42	0.21	0.37	0.85
	Light poll.	0.62	0.30	0.13	0.38	0.69	0.38	0.17	0.38	0.78
	NO ₂	0.03	-0.01	-0.03	0.12	0.00	0.12	0.07	0.07	0.06
Pearson	Amenity	0.36	0.22	0.13	0.18	0.50	0.18	0.09	0.08	0.55
	Population	0.38	0.22	0.11	0.27	0.52	0.27	0.13	0.16	0.66
	Light poll.	0.45	0.26	0.10	0.28	0.64	0.28	0.13	0.18	0.74
	NO ₂	-0.05	-0.06	-0.03	0.07	-0.11	0.07	0.08	0.00	-0.04
Average		0.37	0.19	0.10	0.24	0.45	0.24	0.12	0.18	0.52
<hr/>										
Latvia		Bt	TPBt	TPD	MED	NQPD	MGL	MCF	Div	Len
Spearman	Amenity	0.60	0.32	0.12	0.25	0.68	0.25	0.11	0.28	0.70
	Population	0.75	0.38	0.10	0.43	0.80	0.43	0.22	0.38	0.87
	Light poll.	0.78	0.37	0.07	0.42	0.79	0.42	0.25	0.31	-0.37
	NO ₂	0.10	0.04	-0.02	0.13	0.07	0.13	0.08	0.06	0.03
Pearson	Amenity	0.22	0.20	0.03	0.16	0.01	0.16	0.07	0.00	0.52
	Population	0.30	0.24	0.03	0.31	0.01	0.31	0.16	0.00	0.73
	Light poll.	0.30	0.23	-0.01	0.26	0.01	0.26	0.15	0.00	0.68
	NO ₂	0.06	0.04	-0.03	0.10	0.01	0.10	0.08	0.00	0.08
Average		0.39	0.23	0.04	0.26	0.29	0.26	0.14	0.13	0.41
<hr/>										
Estonia		Bt	TPBt	TPD	MED	NQPD	MGL	MCF	Div	Len
Spearman	Amenity	0.66	0.36	0.16	0.26	0.75	0.26	0.13	0.28	0.74
	Population	0.59	0.31	0.13	0.34	0.65	0.34	0.21	0.24	0.69
	Light poll.	0.80	0.41	0.15	0.40	0.84	0.40	0.25	0.30	0.87
	NO ₂	0.11	0.04	-0.01	0.13	0.10	0.13	0.08	0.07	0.14
Pearson	Amenity	0.26	0.17	0.05	0.17	0.00	0.17	0.10	0.02	0.44
	Population	0.30	0.18	0.05	0.13	0.00	0.13	0.06	0.03	0.45
	Light poll.	0.45	0.31	0.08	0.28	0.01	0.28	0.16	0.07	0.80
	NO ₂	0.04	0.02	-0.02	0.09	0.00	0.09	0.07	0.01	0.06
Average		0.40	0.22	0.07	0.22	0.29	0.22	0.13	0.13	0.52

 Moderate correlation
  Strong correlation
 Level of significance: 0.01

Source: unknown.

Nevertheless, these interpretations remain hypothetical insofar as these indexes propose values of a different nature (ratio, length, etc.). But the main difficulty is related to the comparison of networks of different sizes which requires the normalisation of the indexes as a perspective for our future analyses.

Table 3. Average and maximum index values of the ‘background’ network

		Bt	Len	NQPD
Lithuania	Average	1412	11902	0.42
	Maximum	44162	42190	4
Latvia	Average	2412	13063	0.66
	Maximum	223756	55763	10607
Estonia	Average	2326	13757	0.61
	Maximum	101464	69353	7276



Source: unknown.

If we look at the correlations of the indexes for an unlimited radius which are supposed to reflect the ‘foreground’ network, the results are more contrasted (Table 4).

The best-performing indexes to capture the characteristics of the ‘foreground’ network are respectively the ‘Farness’ index (MED) overall correlation coefficient of -0.33, the ‘Mean Geodesic Length’ index (MGL) overall correlation coefficient of -0.32, the ‘Mean Crow Flight Distance’ index (MCF) overall correlation coefficient of -0.29 and the ‘Network Quantity Penalized by Distance’ index (NQPD) overall correlation coefficient of 0.38. In general, except for Lithuania, a moderate or strong correlation is only found with the Spearman method.

Table 4. Correlation coefficient values for indexes with an unlimited radius

Lithuania		Bt	TPBt	TPD	MED	NQPD	MGL	MCF	Div	Len
Spearman	Amenity	0.05	0.05	0.06	-0.31	0.53	-0.31	-0.24	-0.23	-0.27
	Population	0.03	0.03	0.15	-0.47	0.75	-0.50	-0.40	-0.12	-0.32
	Light poll.	0.03	0.03	0.11	-0.67	0.90	-0.67	-0.62	-0.01	-0.30
	NO ₂	0.02	0.02	0.01	-0.27	0.19	-0.67	-0.62	-0.01	-0.30
Pearson	Amenity	-0.02	-0.02	0.04	-0.18	0.48	-0.18	-0.15	-0.21	-0.13
	Population	-0.04	-0.04	0.07	-0.31	0.55	-0.31	-0.29	-0.11	-0.15
	Light poll.	-0.05	-0.05	0.06	-0.42	0.82	-0.42	-0.39	-0.13	-0.18
	NO ₂	0.02	0.02	0.01	-0.23	-0.02	-0.01	-0.02	0.04	-0.16
Average	0.01	0.01	0.07	-0.36	0.53	-0.33	-0.30	-0.08	-0.17	
Latvia		Bt	TPBt	TPD	MED	NQPD	MGL	MCF	Div	Len
Spearman	Amenity	0.07	0.07	-0.05	-0.45	0.55	-0.45	-0.42	-0.37	-0.34
	Population	0.05	0.05	-0.07	-0.57	0.72	-0.57	-0.55	-0.40	-0.41
	Light poll.	0.05	0.05	-0.04	-0.67	0.80	-0.67	-0.64	-0.42	-0.41
	NO ₂	0.03	0.03	-0.02	-0.31	0.29	-0.31	-0.31	-0.11	0.10
Pearson	Amenity	0.02	0.02	-0.06	-0.14	0.05	-0.14	-0.17	-0.08	-0.14
	Population	0.00	0.00	-0.03	-0.26	0.08	-0.26	-0.29	-0.21	-0.18
	Light poll.	0.02	0.02	-0.07	-0.28	0.09	-0.28	-0.31	-0.22	-0.18
	NO ₂	0.01	0.01	0.01	-0.12	0.02	-0.12	-0.13	-0.07	0.11
Average	0.03	0.03	-0.04	-0.35	0.32	-0.35	-0.35	-0.23	-0.18	
Estonia		Bt	TPBt	TPD	MED	NQPD	MGL	MCF	Div	Len
Spearman	Amenity	0.05	0.05	0.05	-0.41	0.63	-0.41	-0.32	-0.42	-0.39
	Population	0.02	0.02	0.07	-0.32	0.53	-0.53	-0.44	-0.49	-0.44
	Light poll.	0.03	0.03	0.08	-0.53	0.82	-0.53	-0.44	-0.49	-0.44
	NO ₂	0.02	0.02	0.02	-0.27	0.26	-0.27	-0.26	-0.19	0.07
Pearson	Amenity	-0.02	-0.02	0.01	-0.13	0.06	-0.13	-0.11	-0.16	-0.09
	Population	-0.02	-0.02	0.03	-0.10	0.06	-0.10	-0.07	-0.15	-0.10
	Light poll.	-0.03	-0.03	0.02	-0.30	0.12	0.30	-0.24	-0.30	-0.20
	NO ₂	0.02	0.02	0.03	-0.11	0.02	-0.11	-0.09	-0.07	0.11
Average	0.01	0.01	0.04	-0.27	0.31	-0.27	-0.22	-0.27	-0.17	

 Moderate correlation  Strong correlation Level of significance: 0.01

Source: unknown.

In essence, the ‘foreground’ model is confirmed. As with the local ‘background’ network indexes, greater accessibility of the network (NQPD index) is correlated with higher densities of population, amenities, and light pollution (Table 4). For the other indexes, the correlations are negative: logically, the shorter the distance of segments (MED index) the more intense the light pollution, for example. Similarly, the shorter the average distance between segments of the network (MGL index) and the shorter the distances as the crow flies between segments (MCF index), the greater the light pollution.

With these results, we decided to focus our index validation analysis on the ‘foreground’ network: this creates a continuous network of connections across the whole territory, but people and facilities are concentrated in smaller areas. We, therefore, performed correlations by selecting among the amenity data, those related to mobility. Table 5 shows the correlations made for the same indexes with an unlimited radius, for the density

of car parks and fuel stations. The results confirm the performance of the same indexes as previously identified, i.e., the 'Farness' index (MED), the 'Mean Geodesic Length' index (MGL), the 'Mean Crow Flight Distance' index (MCF), and the 'Network Quantity Penalized by Distance' index (NQPD). Nevertheless, the overall correlation coefficients are less robust on average, respectively, -0.23, -0.23, -0.02, and 0.31. except for Lithuania. The 'Network Quantity Penalized by Distance' index (NQPD) also seems to show a typical Baltic urban structure due to the density and distance of the segments (Figure 3). The index reflects a less polarised and more balanced Lithuanian urban network while those of Estonia and Latvia, whose respective capitals Tallinn and Riga are located in the coastal zone, hegemonically dominate the urban hierarchy (Gadal, 2011, Ubarevičienė, 2018). But these observations will have to be confirmed by using normalised indexes for networks of different sizes.

Conclusions

The concept of 'Generic City' was tested and developed by Space Syntax Modelling to compare and classify urban structures using indexes measuring connectivity, centrality, or accessibility of road networks. One of the interests of this analysis was to use and validate new indexes in the urban context of the Baltic countries – Estonia, Latvia, and Lithuania and more especially the coastal zones, whose evolution is strongly correlated to the political and economic contexts of the last decades.

Traditionally, the 'Choice' and 'Integration' indexes are used to describe the two types of centralities theorised by the 'Generic City' concept, i.e., the 'foreground' and 'background' networks. However, in the case of the Baltic cities, these indexes showed a low fragmentation of both 'background' and 'foreground' networks, indicating their weakness in analysing the urban structures of 'smaller' cultural areas. This observation was confirmed by the low correlation between the indexes and human activity-based data amenity density (Gloaguen et al. 2022). With more validation data population density, light pollution, NO₂ emissions and the experimentation of new indexes based on network geometry, centrality, accessibility, etc., we were able to confirm the validity of the 'Generic City' concept in the context of the Baltic urban networks. The 'Betweenness' and 'Length' indexes proved to be the most robust with positive correlations highlighting local transit routes and local spatial structures such as residential clusters or, economic activity zones. These two indexes are also able to highlight the Soviet united settlement system by comparing the accessibility and length of segments within a limited radius of 1 km, characterising the 'background' network.

The results with unlimited radius showed more contrasting results with robust correlation coefficients only with the Spearman method in general. The calculations presented the 'Network Quantity Penalized by Distance' (NQPD) index as the most relevant of all to characterise the 'foreground' network. Additional validation data, based on mobility-related amenities density of parking and fuel stations confirmed the results obtained with the other validation data, although the strength of the relationship is generally weaker (on average overall -0.02 compared to -0.09). In terms of spatial structure, the NQPD index has highlighted the preponderance of the Latvian and Estonian capitals Riga and Tallinn in the organisation and structuring of national territories, in contrast to the Lithuanian case with a more polycentric network.

Different perspectives for future research are highlighted in our analysis. The first concerns the use of the Radius-Radius method (Hillier, 2007) for indexes describing the 'foreground' network to consider the edge effects existing in the delimitation of coastal regions. The second concerns the use of data such as the density of buildings served by the segments or the type of land use, etc. for the weighted indexes (the 'Two-Phase Betweenness' and the 'Two-Phase Destination' indexes) which could improve their correlation coefficient. Finally, the normalisation of the indexes will be necessary to confirm the hypotheses delivered in this analysis and to compare the indexes with each other and with urban networks of different sizes.

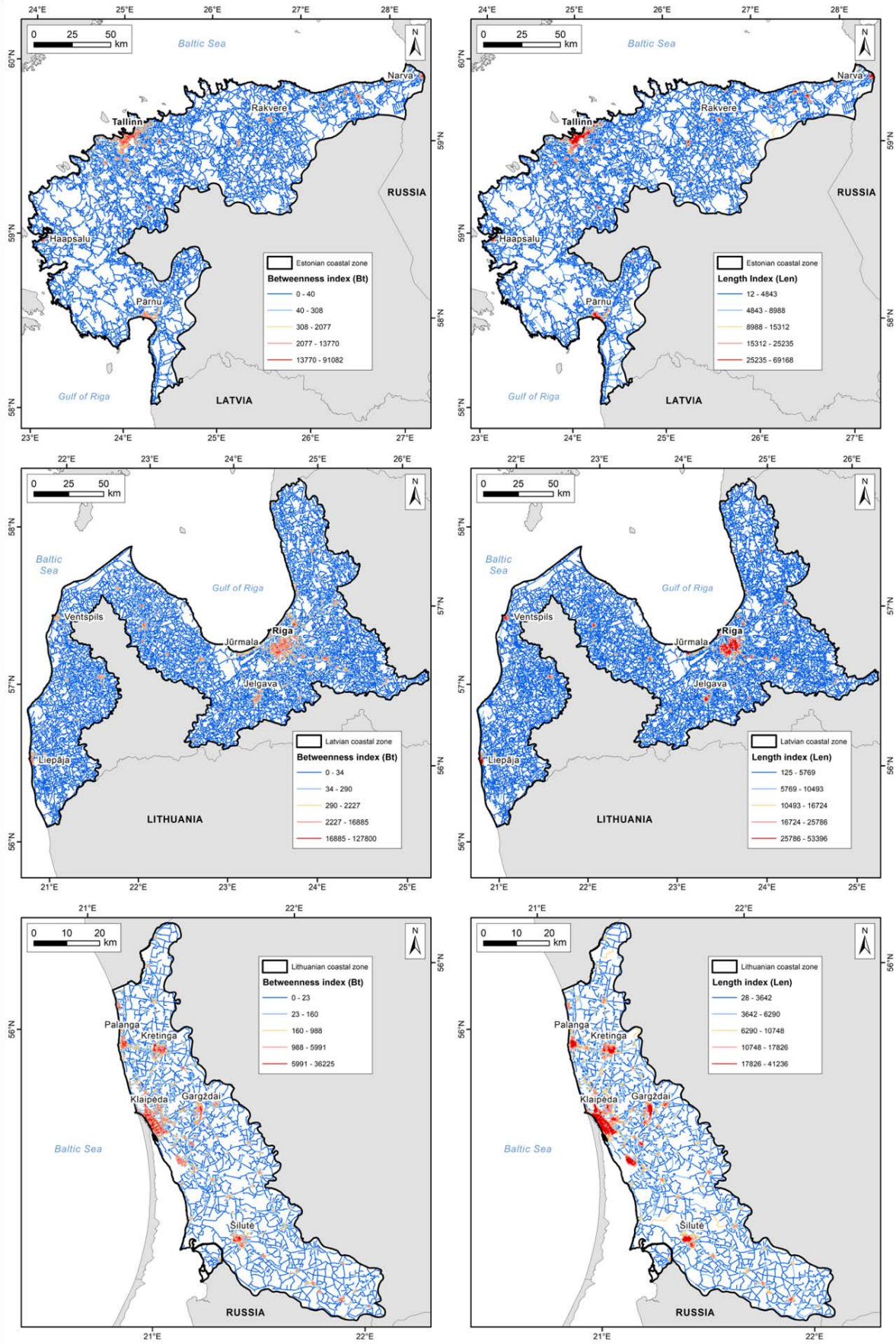


Figure 2. 'Betweenness' (left) and 'Length' (right) index values with a radius limited to 1 km

Source: unknown.

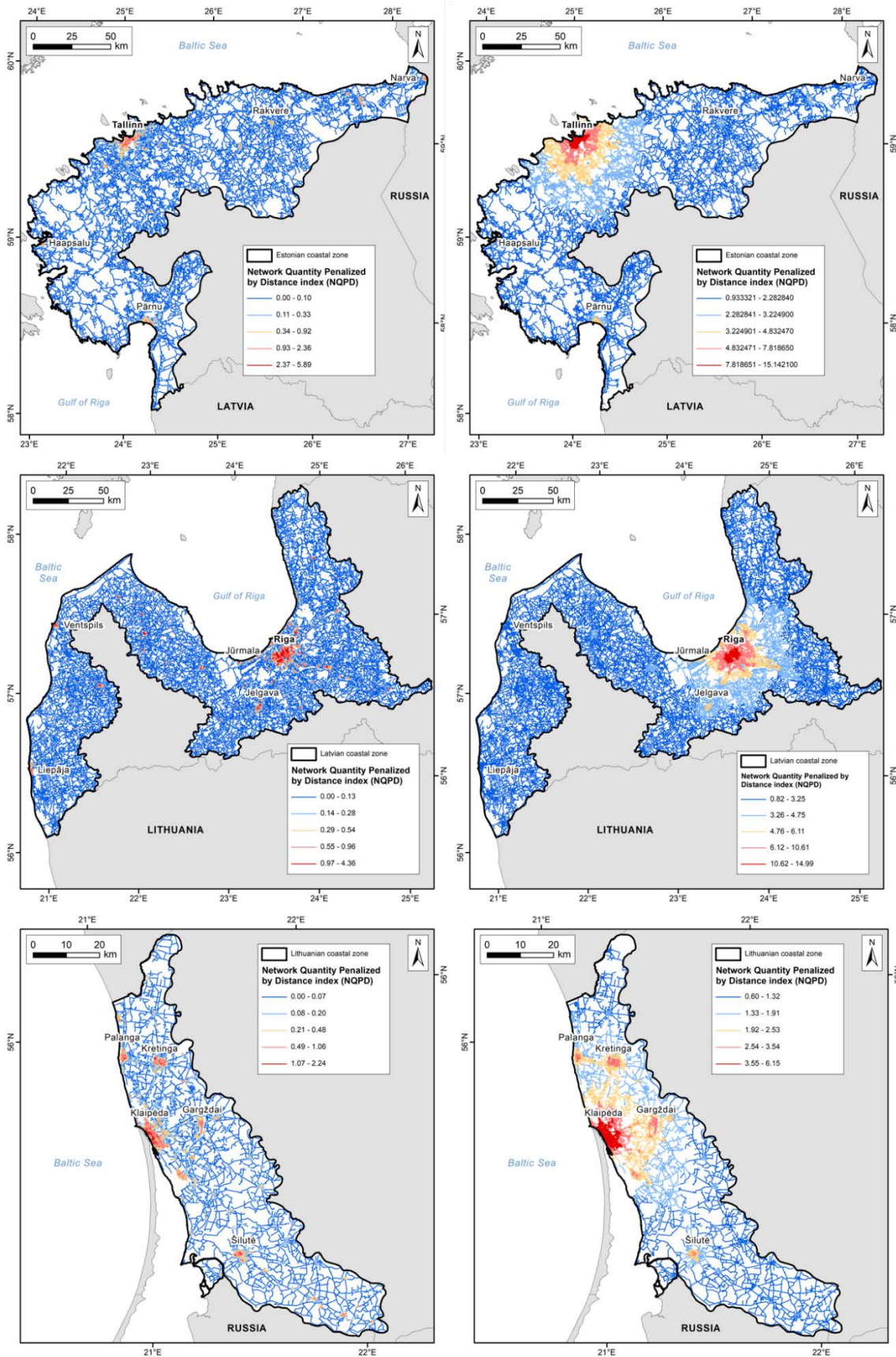




Figure 3. 'Network Quantity Penalized by Distance' index values with a 1 km radius limit (left) and an unlimited radius (right)

Source: unknown.

Table 5. Correlation coefficient values for mobility-related amenity data for indexes with an unlimited radius

Lithuania		Bt	TPBt	TPD	MED	NQPD	MGL	MCF	Div	Len
Spearman	Parking	0.05	0.05	0.05	-0.30	0.48	-0.30	-0.24	-0.20	-0.24
	Fuel statio.	0.07	0.07	0.00	-0.23	0.29	-0.23	-0.20	-0.10	-0.11
	Combined	0.06	0.06	0.04	-0.32	0.51	-0.32	-0.25	-0.21	-0.25
Pearson	Parking	-0.02	-0.02	0.04	-0.19	0.48	-0.19	-0.16	-0.17	-0.13
	Fuel statio.	-0.04	-0.04	0.00	-0.15	0.32	-0.15	-0.14	-0.09	-0.06
	Combined	-0.01	-0.01	0.04	-0.20	0.51	-0.20	-0.09	-0.18	-0.13
Average		0.02	0.02	0.03	-0.23	0.43	-0.23	-0.18	-0.16	-0.15
<hr/>										
Latvia		Bt	TPBt	TPD	MED	NQPD	MGL	MCF	Div	Len
Spearman	Parking	0.05	0.05	-0.01	-0.17	0.21	-0.17	-0.16	-0.17	-0.10
	Fuel statio.	0.06	0.06	-0.04	-0.41	0.51	-0.41	-0.39	-0.34	-0.30
	Combined	0.06	0.06	-0.04	-0.41	0.52	-0.41	-0.39	-0.35	-0.30
Pearson	Parking	0.04	0.04	-0.01	-0.09	0.03	-0.09	-0.10	-0.09	-0.07
	Fuel statio.	0.02	0.02	-0.04	-0.18	0.06	-0.18	-0.21	-0.12	-0.16
	Combined	0.02	0.02	-0.04	-0.18	0.06	-0.18	-0.21	-0.13	-0.16
Average		0.04	0.04	-0.03	-0.24	0.23	-0.24	-0.20	-0.18	0.23
<hr/>										
Estonia		Bt	TPBt	TPD	MED	NQPD	MGL	MCF	Div	Len
Spearman	Parking	0.07	0.07	0.00	-0.19	0.27	-0.19			-0.16
	Fuel statio.	0.04	0.04	0.03	-0.34	0.54	-0.34			-0.35
	Combined	0.05	0.05	0.03	-0.35	0.55	-0.35			-0.35
Pearson	Parking	0.05	0.05	0.00	-0.09	0.04	-0.09	-0.07	-0.12	-0.09
	Fuel statio.	-0.02	-0.02	0.03	-0.12	0.08	-0.12	-0.07	-0.21	-0.15
	Combined	-0.02	-0.02	0.03	-0.12	0.08	-0.12	-0.08	-0.22	-0.16
Average		0.03	0.03	0.02	-0.20	0.26	-0.20	-0.08	-0.18	-0.21

 Moderate correlation
  Strong correlation
 Level of significance: 0.01

Source: unknown.

Acknowledgments

This research was funded by the CNES TOSCA AIMCEE (Apport de l'imagerie satellitaire Multi-capteurs pour répondre aux Enjeux Environnementaux et sociétaux des socio-systèmes urbains). This research work is carried out within the UMR ESPACE of Aix-Marseille University (AMU), and the Research Group on Cultural and Spatial Environment of the Kaunas University of Technology (KTU).

References

- Brunet R., (2000), *Des modèles en géographie? Sens d'une recherche*, 'Bulletin de la Société de Géographie de Liège', no. 2, pp. 21–30.
- Brunet R., Ferras R., Théry H., (1993), *Les mots de la géographie dictionnaire critique*, GIP Reclus.
- Cailly L., (2007), *Capital spatial, stratégie résidentielles et processus d'individualisation*, 'Annales de la géographie', no. 2, pp. 169–187.
- Central Statistical Bureau of Latvia, (2022), *Number of population: detailed spatial data incl. grid, 1989–2022*, online <https://stat.gov.lv/en/statistics-themes/population/population-number/maps/k52-number-population-detailed-spatial-data> (access: 18.07.2022).
- Cirtautas M., (2013), *Urban sprawl of major cities in the Baltic States*, 'Architecture and Urban planning', no. 7: pp. 72–79.
- Cooper C., (2021), *Spatial Design Network Analysis sDNA version 4.1 Manuel*, online <http://www.cardiff.ac.uk/~sdna/software/documentation> (access: 18.07.2022).
- Cooper C.H., Chiaradia A.J., (2020), *sDNA: 3-d spatial network analysis for GIS, CAD, Command Line & Python*, 'SoftwareX', vol. 12.
- Druzhinin A., Gontar N., Mikailov A., (2019), *Population dynamics in the Coastal Urban Settlements of the Baltic Sea Region*. 'Journal of Settlements and Spatial Planning', vol. 10, no. 1, pp. 61–70.
- Dupuy G., (1984), *Villes, systèmes et réseaux. Le rôle historique des techniques urbaines*, Les annales de la recherche urbaine, 23 (1): 231–241.

- Dupuy G., Benguigui L.G., (2015), *Sciences urbaines: interdisciplinarités passive, naïve, transitive, offensive*, 'Métropoles', vol. 16.
- European Space Agency, (2018), *ESA Sentinel-5P TROPOMI L3 products*, online https://developers.google.com/earth-engine/datasets/catalog/COPERNICUS_S5P_OFFL_L3_NO2 (access: 18.07.2022).
- Freeman L.C., Borgatti S.P., White D.R., (1991), *Centrality in valued graphs: A measure of betweenness based on network flow*, 'Social networks', vol. 13, no. 2, pp. 141–154.
- Georges P., Verger F., (2006), *Dictionnaire de la géographie*, Presses universitaires de France.
- Gadal S., (2011), *Habilitation Diriger des Recherches – Volume 1: Métropolisations, territoires émergents et systèmes géographiques d'information et de modélisation territoriale*, Université Paris Diderot Paris 7.
- Gadal S., Gloaguen T., (2021), *Environmental issues in the coastal regions of the south-eastern Baltic Sea: A sensitive natural environment in the face of increasing anthropic pressures*, 'Baltica', vol. 34, no.2, pp. 203–215.
- Gloaguen T., Zaleckis K., Gadal S., (2022), *Investigation of the use of the 'Generic City' concept and its indexes in the analysis of urban and territorial structures in the Baltic States*, IGU Urban Geography Commission Annual Conference. Paris, France.
- Hamouda A., (2018), *Syntaxe spatiale comme un outil d'analyse de l'espace architectural*, 'International Journal of Innovative Technical and Applied Sciences', vol. 2, no. 1, pp. 22–30.
- Hillier B., (2007), *Space Is the Machine: A Configurational Theory of Architecture*, Space Syntax.
- Hillier B., (2010), *The Need for A Spatial Ontology for Societies*, The Space Syntax Workshop at the European Archaeological Association Conference. The Hague, Netherlands.
- Hillier B., Burdett R., Peoponis J., Penn A., (1987), *Creating Life: Or, Does Architecture Determine Anything?* 'Architecture et Comportement/Architecture and Behaviour', vol. 3, no. 3, pp. 233–250.
- Hillier B., Hanson J., (1984), *The Social Logic of Space*, Cambridge University Press, pp. 108–109.
- Hillier B., Yang T., Turner A., (2012), *Advancing depthmap to advance our understanding of cities* [in:] M. Greene, J. Reyes, A. Castro (eds.) *8th International Space Syntax Symposium*, Pontificia Universidad Católica de Chile, Santiago, Chile.
- Jacobs Crisioni C., Lavallo C., (2015), *UDP – Average travel distance, 2010 and 2050 (JRC LUISA Reference Scenario 2016)*, online <http://data.europa.eu/89h/jrc-luisa-udp-distance-reference-2016> (access: 18.07.2022).
- Klemeshev A.P., Korneevets V.S., Palmowski T., Studzieniecki T., Fedorov G.M., (2017), *Approaches to the definition of the Baltic Sea Region*, 'Baltic Region', vol. 9, no. 4, pp. 4–20.
- Laouar D., Manzouz S., (2017), *La carte axiale, un outil d'analyse de l'accessibilité spatiale: cas de la ville d'Annaba*, 'Synthèse: Revue des Sciences et de la Technologie', vol. 35: pp. 111–123.
- Marcus L., (2007), *Spatial capital and how to measure it: an outline of an analytical theory of the social performativity of urban form*, Sixth international space syntax symposium, pp. 5–11.
- Marcus L., (2010), *Spatial capital*, 'The Journal of Space Syntax', vol. 1, no. 1, pp. 30–40.
- Moreno C., (2019), *The 15 minutes-city: for a new chrono-urbanism!*, online <https://www.moreno-web.net/the-15-minutes-city-for-a-new-chrono-urbanism-pr-carlos-moreno/> (access: 18.07.2022).
- OpenStreet Map, (2022), online <https://www.openstreetmap.org> (access: 18.07.2022).
- Paulet J.P., (2009), *Géographie urbaine*, Armand Colin.
- Román M.O., Wang Z., Sun Q., Kalb V., Miller S.D., Molthan A., Schultz L., Bell J., Stokes E.C., Pandey B., Seto K.C. et al., (2018), *NASA's Black Marble Nighttime Lights Product Suite*, 'Remote Sensing of Environment', vol. 210, pp. 113–143.
- Space Syntax Limited, (2018), *Space Syntax OpenMapping*, online <https://spacesyntax-openmapping.netlify.app> (access: 18.07.2022).
- Statistics Lithuania, (2020), *2020 m. bandomojo gyventojų surašymo geoerdviniai duomenys 1x1 km gardelėse*, online https://open-data-ls-osp-sdg.hub.arcgis.com/datasets/29c13ced1ebb4b59bfb9d9e638f94839_0/about (access: 18.07.2022).
- Statistical Office of Estonia, (2021), *Population by sex, age group and place of residence*, online <https://estat.stat.ee-/StatistikaKaart/VKR#> (access: 18.07.2022).
- Turner A., (2004), *DepthMap4: A Researcher's Handbook*, Bartlett School of Graduate Studies, ULC, p. 29.
- Ubarevičienė R., (2018), *City systems in the Baltic states: the Soviet legacy and current paths of change*, 'Europa Regional', vol. 25, no. 2, pp. 15–29.