5 Transformations of the Network on Public Spaces and its Relations to Spatial Social Content

5.1 Theoretical background of the investigation

City is a versatile and very complex phenomenon which could be described in many ways and from many perspectives: social, cultural, economic, spatial, psychological, ecological, etc. While facing and analyzing such a complicated and constantly changing system, two approaches could be employed – either focus on creation of complicated multilayered models with the aim to describe every possible aspect of urban life in as detailed as possible way or, a search for a relatively simple to elaborate yet capacious in terms of description model. The second approach was chosen during the presented investigation as more preferred in terms of Tomas Kuhn, e.g.: from two equally effective explanations or models, the simplest should be taken as priority. The various concepts could be mentioned as the examples of the second – “simple to understand yet complex to apply” approach, e.g.:

– The idea of secular pilgrimage by Benjamin Walter. It makes a successful attempt to name and explain the nature of attractiveness of a big city life which could be named “magic of a city” if empirically grounded urban patterns of Christopher Alexander are used. According to it, urban spatial environment while bringing together people, activities and buildings, creates countless ways to experience it and re-discover self on the base of accidentally and unpredictably awaken associations and connotations while any element of constantly altering urban environment might be seen as a catalyzer of the above mentioned associations. In this case the simple yet elegant term “secular pilgrimage” could be seen as a city model focused on psyche-environment interaction.

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511 Thomas S. Kuhn: The Structure of Scientific Revolutions, Chicago: University of Chicago Press, 1996, p. 212.
512 Walter Benjamin: The Arcades Project, Harvard: Belknap Press, 2002, p. 1088.
513 Christopher Alexander [etc.], A Pattern Language: Towns, Buildings, Construction, New York: Oxford University Press, 1977, p. 58-62.

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The theory of cultural-historical psychology by M. Cole\textsuperscript{514} introduces the concept of cultural artefact as both material and ideal creation of culture which stores various cultural information. The entire sum of the artefacts of a precise culture could be seen, according to M. Cole, as the form of outer collective consciousness. This statement, if applied to the material form of a city, presents it as a container of a collective psyche of society and allows to look for complex relation between material attributes of the cityscape and its ideal cultural contents.

The concept of the preferred environment while employing such concepts as legibility, coherence, complexity of spatial environment\textsuperscript{515} claims that humans tend to choose specific urban or natural environments over the other places for living if such a possibility exists and call them “preferred environments”. Various researchers describe different indicators of preferability, e.g.: coherence, complexity, legibility, mysteriousness, etc. The most important is to point out, that, according to the theories of environmental psychology, living in non-preferred environment leads to long terms stress and other negative consequences for human health. Such an approach allows using simple measurable features of spatial urban environment for analysis of more complex psychological dimensions of urban space.

Hedonistic land price method approach makes an attempt to relate various measurable qualities of the urban environment (e.g. visible greenery, closeness of a park, etc.) on the base of correlations between land or house market value and qualitative environmental characteristics. As numerous results of investigation demonstrate\textsuperscript{516} there is a firm proof that market values react to various qualitative changes of a close neighbourhood, e.g. presence of greenery, closeness of waterfront or specific function, etc. In general, the hedonistic land price approach demonstrates regularities of dependencies between urban spatial configurations and property market thus creating possibility to look at numerous city components (nature, cultural heritage, etc.) through economic perspective.

All the above mentioned and similar not mentioned approaches to a city investigation and modelling prove the importance of the principle of spatial determinism which means that urban form is both affected by cultural content and shapes a cultural content at the same time. Despite the usefulness of the above discussed models the ideas of Lewis Mumford should be pointed out as the simplest, straight-forward, 

\textsuperscript{514} Michael Cole, \textit{Cultural Psychology: A Once and Future Discipline}, Harvard: The Belknap Press, 2003.
\textsuperscript{515} Robert B. Bechtel, Arza Churchman [editors], \textit{Handbook of Environmental Psychology}, New York: John Willey & Sons, Inc., p. 722.
\textsuperscript{516} Yang Xiao, \textit{Urban Morphology and Housing Market}, Singapore: Tongji University Press and Springer Nature, 2017, p. 11-40.
Theoretical background of the investigation

According to Mumford, there are three essential qualities of city life which distinguish it from the other types of settlements. Those are the following: nightlife, underground city and street culture⁵¹⁷.

“Nightlife” represents the permanent tendency to break out of the life limitations made by the circles of Nature both yearly and daily. “Underground city” could be explained as multilayered structure of a city because of both historical layers and compact structure which requires to construct higher buildings and utilize underground space at least for infrastructural needs. “Street culture” expresses the essence of a cityness – intensification of interactions between people, increase of closeness between activities, direct exchange of information, multiculturality, etc. Numerous examples of the importance of public spaces through the urban history and two way interaction between spatial forms and social – cultural content could be taken as the illustration and prove of the spatial determinism principle, e.g.: street as a space for information exchange and interaction between the private space owners and transit movers in Ancient Rome⁵¹⁸; Roman forum or Greek Agora as the most catalyzing spaces of social, cultural and economic interaction because of its location and specific form; beginning of specialization of public spaces in Renaissance cities as a result of introduction of representative spaces in front of Renaissance palaces as political power centers, etc. On the base of general system theory⁵¹⁹, it could be stated that urban spatial configurations catalyze, direct or organize the exchange of information and goods in specific places of a city. According to the general system theory, the flows of information, materials and energy are seen as the essential processes which assure integrity of a system or city. Contemporary urban planning and urban studies focus on such empirically successfully tested city planning concepts as New Urbanism, Walkable Urbanism, etc., demonstrate importance of street culture catalysation despite augmentation of urban environments.

Thus, the scope of the presented research was formulated as investigation of dependencies between street culture and changes of spatial urban configurations, especially brought to Lithuania by modernistic urbanism during the Soviet period which could be seen as the most significant quantitative and qualitative shift from the perspective of urban history and modernization of Lithuanian cities.

Can be the above mentioned search for interrelation between the urban form be based on simple yet complex and elegant model or concept? The essential criterion

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⁵¹⁷ Mark Gottdiener, Leslie Budd, Key Concepts in Urban Studies, London: Sage Publications, 2005, p. 6-10.
⁵¹⁸ Akkelies van Nes, Indicating street vitality in excavated towns. Spatial configurative analyses applied to Pompeii, in TuDelft Repository, [interactive], 2014, [viewed on 2019-05-06], https://repository.tudelft.nl/islandora/object/uuid%3A072645d0-b6ff-4ffb-b755-c0f4145d5bfd
⁵¹⁹ Ludwig von Bertalanffy, General system Theory: Foundatations, Development, Applications, New York: George Braziller, Inc., 1969, p. 289.
for a selection of the concept would be it is not only qualitative but also quantitative nature. Why it is important? It was mentioned earlier that city is a very complex, open, dynamic system made of many interacting objects, processes, people, etc. The research based just on qualitative approach becomes very sensitive to observers’ intentions, conditions of observations, type of obtained data, etc. Quantitative approach, in such a situation, allows to increase the level of objectivity and might create opportunities not only for understanding based on description but on prediction as well.

On the base of observation of architectural and urban design practices and examples, it becomes quite evident that the precise design solutions make a specific space more or less favourable for specific functions; some spaces could become more mono-functional while others more multi-functional on the base of either conscious or intuitive decision of an architect and depending on the design task. As each architectural object or a space is constructed in advance to its usage, it could be stated that is has certain obvious or more hidden capacity or potential for various predicted and unpredicted functions. Because of a constantly changing users, needs, technologies, cultural values and priorities such a capacity could be seen as an instant feature of any urban space. Let’s call it urban potential. Urban potential could be bigger and smaller e.g. in terms of multi-functionality; user variety, etc. An illustration of differences in urban potential to accept higher variety of functions could be presented as follows: let us imagine a typical medieval town from the 13th century with narrow possession plots, perimetric placement of houses beside a street; allocation of commercial functions on the ground floor, etc. This town was changing through the times in an evolutionary way depending on developing technologies, changing social and political structures but it kept its main genotypic features in terms of Bill Hillier or of patterns in terms of Christopher Alexander and offered suitable spatial structure for high variety of functions and users at the same time. Only the revolutionary changes in a size, transport flows and social segregation caused by the industrialization in the 19th century either shifted city centers from historical spots (e.g. shift of historical center of Vienna with construction of Rigstrasse in the 19th century) or called for some radical renovations as in the case of Hausman’s reconstruction of Paris. Nevertheless, even after some loss of the central position in a city historical downtown in many cases remains an important specialized district just besides a new city center where, because of the high variety of buildings types and public spaces a lot of different functions could be accommodated without significant changes in spatial structure starting from housing and ending with commercial, administrative of cultural establishments. It could be seen as an urban area with high

520 Bill Hillier, Julienne Hanson, *The Social Logic of Space*, Cambridge: Cambridge University Press, 1989, p.12
521 Christopher Alexander [etc.], *A Pattern Language: Towns, Buildings, Construction*, New York: Oxford University Press, 1977, p. 1218.
urban-architectural potential. Single family housing with a uniform in size, regularly places buildings could be seen as an opposite example with low architectural urban potential because it is hard imagining that without significant changes in urban morphological typology it can accommodate something else except housing of a specific social group of city inhabitants.

Intuitively or based on experience and historical examples the possibilities to use urban form in order to generate more social interactions, catalyze shopping experience, reflect cultural scenarios of space usage are known and recognized by the architects, but could the potential of a place be measured?

Essential possibility to evaluate the urban-architectural potential of spatial structures was tested during the preparation of Kaunas Master Plan 2013-2023\(^{522}\). The idea was based on a known usage of fractal analysis of city plan, e.g. analysis of a number of European cities with a focus on different building morphologies\(^{523}\) and the analysis of road networks\(^{524}\). In the first case it was clearly demonstrated the oldest central parts of the investigated cities with the highest density and variety of building types demonstrate the biggest fractal index values\(^{525}\) while functionally monotonous or narrowly specialized areas (e.g. single family housing, modernistic homogenous housing areas, industrial zones) demonstrated the lowest values. In a case of the investigation of road network it was demonstrated that the more complex and dense street network which has higher capabilities to accept more intensive traffic flows and is less sensitive to traffic jams has a higher fractal index values. In the case of Kaunas fractal index was used to identify the functional potential of Kaunas city areas on the base of analysis of street network, buildings, public spaces and greenery. The results of the analysis corresponded quite well to the real situation in terms of multifunctionality, social diversity, intensity of street culture, etc., and demonstrate the biggest potential and the biggest fractal indexes in the oldest parts and zones with the highest variety of morphological types of buildings\(^{526}\).

\(^{522}\) KAUNO MIESTO BENDRASIS PLANAS, ESAMOS BŪKLĖS ANALIZĖ, MIESTO APLINKA, II TOMAS, DALIS-A: MIESTO STRUKTŪRA, p. 27-44, in Kauno miesto bendrasis planas (2013 - 2023 metams), [interactive], 2014, [viewed on 2019-05 06], http://old.kaunoplanas.lt/bendrieji_planai/kauno_miesto_bendrasis_planas_esama_bukle

\(^{523}\) Frankhauser Pierre, “The fractal approach. A new tool for the spatial analysis of urban agglomerations.”, in: New methodological approaches in the social sciences, 1998, p. 205-240

\(^{524}\) Yongmei Lu, Junmei Tang, “Fractal dimension of a transportation network and its relationship with urban growth: a study of the Dallas Fort Worth area”, in: Environment and Planning B: Planning and Design, 2004, volume 31, p. 895-911.

\(^{525}\) Fractal index D has values in a range from 1 to 2. E.g. single line has a value of 1 while cpmplex and dense network of lines – 2.

\(^{526}\) Kęstutis Zaleckis, Jūratė Kamičaitytė-Virbašienė, “Urbanistinių struktūrų potencialo vertinimas: Kauno centros miesto visumos kontekste” in Urbanistika ir architektūra = Town Planning and Architecture, Vilniaus Gedimino technikos universitetas, Lietuvos mokslų akademija, Vilnius, Technika, 2011, T. 35, nr. 4, p. 249-259.
The just described example demonstrates a possibility to use quantitative methods while analyzing spatial-social-economical interactions but the results of investigation have too high resolution in terms of limited possibility to focus on very specific spot in a city and are concentrated on too many aspects of urban form at ones (e.g. building form and density; street network, public spaces; recreational areas) but not on street culture determinants directly.

While formulating our detailed research methodology, there is a need to come back to a general system model applied to a city and elaborate it further. According to Lars Marcus. He states that city is a complex system made of sub-systems of different complexity. The spatial systems as the least complex or simple layer make a firm background for social, economic, cultural interactions which are sometimes hard to model because of very high level of complexity and permanent transformations. The idea of spatial capital was developed by Marcus in order to enable analysis of interactions between the above mentioned sub-systems of a city. Spatial capital is seen as an extension to fundamental value presented by land which could be increased by direct investment into infrastructure, etc., but also by spatial configurations making space more favourable for one or another use. Thus Spatial Capital concerns bot value of market as well as value of everyday use. It could be pointed out the concept of Spatial Capital could be integrated with the widely in social and urban studies used information of Spatial Capital, Economic property value and Cultural capital. In more detailed elaboration of the concept Lars Marcus argues that spatial configuration by creating or destroying co-presence spaces plays a significant role in creation of Social capital. The concept of secular pilgrimage by Walter Benjamin could be used to continue the support argumentation regarding close relations between space and social dimension of city life – specific way of inhabiting a city and streets as public spaces of co-presence acts as a catalyzer of both social and cultural life on

527 Lars Marcus, “The Theoretical Underpinnings of a Theory of Spatial Capital”, in: Conference: The 11th international space syntax symposium, at: Instituto Superior Técnico, Lisbon, Portugal, Volume: Proceedings of the 11th international space syntax symposium, 2017, [viewed on 2019-06-07], https://www.researchgate.net/publication/318679763_The_theoretical_underpinnings_for_a_theory_of.spatial_capital

528 Social capital broadly refers to those factors of effectively functioning social groups that include such things as interpersonal relationship, a shared sense of identity, a shared understanding, shared norms, etc. (Putnam)

529 Cultural capital is the accumulations of knowledge, behaviours, and skills that one can tap into to demonstrate one’s cultural competence, and thus one’s social status (Pierre Bourdieu)

530 Lars Marcus, “The Theoretical Underpinnings of a Theory of Spatial Capital”, in: Conference: The 11th international space syntax symposium, at: Instituto Superior Técnico, Lisbon, Portugal, Volume: Proceedings of the 11th international space syntax symposium, 2017, [viewed on 2019-06-07], https://www.researchgate.net/publication/318679763_The_theoretical_underpinnings_for_a_theory_of.spatial_capital

531 Walter Benjamin: The Arcades Project, Harvard: Belknap Press, 2002, p. 1088.
The theoretical background of the investigation

The base of unexpected associations, connotations, contacts, etc. In terms of spatial configurations, the social-spatial relation could be modelled in terms of distances, specific movement scenarios (e.g. labyrinth like structure as a background for various individual ways to discover a city versus regular structure which catalyzes uniform ways of space usage, etc.), relations between private and public spaces; closeness and openness, etc.

Economic capital by Marcus is related to clustering of certain activities in specific, the most beneficial for them locations, e.g.: the most reachable place is the most suitable for certain commercial activities. This explanation could be expanded by the concept of patterns by Christopher Alexander (as he relates certain patterns to solutions of certain functional problems) and the model of the central places. The model of the central places by Chystraller which states that commercial activities benefit from a close neighbouring to each other. The hedonistic land price model based investigation could be seen as proof of the relation between spatial and economic capital, e.g. closeness of greenery increase housing price, etc. In spatial terms the discussed relation could be described in simple terms of closeness or farness, or while using more complex patterns descriptions.

Lars Marcus mentioned the third sub-system of a city – Ecological capital or ecosystem services. He focusses on a green urban infrastructure mainly, but, if the general system theory is employed we can point out the three essential processes in an anthropo-ecological system: flows of energy, materials and information. All three flows are affected significantly by spatial configurations of the city, e.g. in terms of energy we can speak about adaptation to microclimatic conditions on the base of specific spatial dimensions; in a case of logistics we can speak about shorter or longer, concentrated or deconcentrated traffic flows; in terms of information we can speak about visual perception and cognition of spatial structures, presence of greenery, visibility of cultural heritage, etc. The earlier in this chapter mentioned concept of

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532 Christopher Alexander [etc.], A Pattern Language: Towns, Buildings, Construction, New York: Oxford University Press, 1977, p. X-XII.
533 American Planning Association, Planning and Urban Design Standards, New Jersey: John Wiley & Sons, 2006, p.399-408.
534 Henry Wüstemann, Jens Kolbe, “Estimating the Value of Urban Green Space: A hedonic Pricing Analysis of the Housing Market in Cologne, Germany”, in: SFB 649 Discussion Paper [interactive], 2015-002, 2015, [viewed on 2019-02-10], https://www.researchgate.net/publication/272784713_Estimating_the_Value_of_Urban_Green_Space_A_hedonic_Pricing_Analysis_of_the_Housing_Market_in_Cologne_Germany
535 Lars Marcus, “The Theoretical Underpinnings of a Theory of Spatial Capital”, in: Conference: The 11th international space syntax symposium, at: Instituto Superior Técnico, Lisbon, Portugal, Volume: Proceedings of the 11th international space syntax symposium, 2017, [viewed on 2019-06-07], https://www.researchgate.net/publication/318679763_The_theoretical_underpinnings_for_a_theory_of.spatial.capital
cityscape as a form of collective consciousness by M. Cole supports this interpretation of a city-system with cultural dimension.

In generalization it could be stated that the concept of Spatial capital creates a versatile and firm theoretical background for more detailed investigation of dependencies between spatial urban configurations and its contents (social, economic, cultural) including street culture which is the essential focus of the presented here research. Next step is to choose the precise quantitative model of city space description.

In the beginning, it is worth to remind that the Spatial Capital concept was developed on the background made by Space Syntax theory and presents one of the examples of development of analysis methodology of urban structure into more complex urban theory. Despite this fact the Spatial Capital concept, in my opinion could be treated as an autonomous approach which creates a background for the other spatial determinism oriented city analysis methods, e.g. as earlier in this chapter mentioned fractal analysis. Despite the various possibilities of choice Space Syntax approach was chosen as the most appropriate for the presented investigation. Why Space Syntax and what are the essential statements of this method?

Space Syntax theory was created by Bill Hillier and Julien Hanson in 1980s at UCL. It is stated by Bill Hillier it focusses on the analysis of urban spatial genotype, instead of phenotype. Reference to the idea of Christopher Alexander of two languages of architecture could be seen as analogous concept which helps to explain the initial idea. According to it, pattern of genotype represents the most common, essential features or model of spatial urban structure which could be replicated in more details, different forms and situations without losing them. In this case genotype could be seen as the firm background which despite numerous variations of urban spatial form express the same cultural usage scenarios.

Space Syntax theory could be generalized in the following statements:

– Space is a container and as a such, it is a primary object of investigation. It is undoubtfully true and looks obvious if we consider where all social or cultural processes take place but quite often in architecture or architectural research volume is seen as a primary object of investigation while threatening space either as emptiness or territory. The discussed syntactic approach could be seen as a little similar to and supported by the concepts of space and place by Yi-Fu Tuan. According to it, space is open for transit while place represents location with specific characteristics (e.g. higher degree of closeness) favourable for stay, which creates some sense of belonging, etc. In general, it could be said that

536 Bill Hillier, Julienne Hanson, *The Social Logic of Space*, Cambridge: Cambridge University Press, 1989, p.12

537 Yi-Fu Tuan, *Space and Place the Perspective of Experience*, Minneapolis, London: University of Minessota Press, 2001, p. 67-85.
space-container perspective is essential for presented investigation focused on street culture and allows to look for space-content relations in a direct way.

Urban spaces make a network – it means even each separate space could be understood only in relation to a rest of a network and any changes in one space could affect a whole network and vice versa. It is important to note that according to this point of view, place in a network is more important than features of space itself what might be not always true (e.g. if we imagine extremely narrow street in the center of a city, it is probable that the main logistic flows or at least part of street culture activities may find another, more suitable neighbouring street), but this statement should be treated in a similar way as the most simple yet effective rule in Agent Based Modelling because Space syntax represents the same group of so called bottom up based models as Agent Based Modelling. This approach allows to investigate city as a whole and to look for influence of new urban areas on historical parts even without the clear changes in later ones.

Movement economy is the third basic principle employed by Space Syntax. It states that people are rational beings and tend to minimize movement distances in a city or move in the shortest way possible. The tendency to minimize movement distances make the most reachable location more attractive for certain activities (e.g. commerce), these activities generate even bigger people flows; these flows attract more activities thus reinforcing the attractiveness of spatial location, etc. Of course it might be not always true that people move in a shortest way if different groups of city users and different interests in a city are considered, but in essence, as it is shown by numerous applied research examples, the concept works quite well. As an example could be mentioned later in the next chapter presented investigation in Kaunas, Vilnius and Klaipeda while looking for dependencies between spatial network configuration and allocation of the officially registered various objects as shops, gas stations, drug-shops, hotels, cinemas, sports clubs, etc. Despite the presented generalized view of a movement in a city this Space syntax principle could be seen in a similar way as previous principle – as the simplest yet effective enough rule for bottom-up modelling purposes. This statement shows the basic way for analysis of an urban network from the point of view of logistic as one of the essential processes in any urban system. It is important to note that the shortest route in space syntax the most often is calculated on the base of accumulated angles of changes of movement direction instead of meters.

The fourth principle: logical symmetry and asymmetry between spaces or network nodes in a city affect co-presence or segregation of people, activities,

538 Alison J. Heppenstall, Andrew T. Crooks, Linda M. See, Michael Batty, Agent-Based Models of Geographical Systems, London: Springer, 2012, p. 95-98.
object. Symmetry by Hillier\textsuperscript{539} is explained as equality of positions for observation and/or movement between two spaces, e.g.: relation between street space and neighbouring house could be named as functionally symmetric if there is a direct connection between the two and visually symmetric if there are windows enabling visual perception both ways from street to interior and from interior to a street. This type of relation is peculiar for majority of streets with intensive street culture and it is very easy to imagine that street surrounded by the blind facades will not catalyze co-presence of people. If applied to street segments a common crossroad makes them symmetric to each other. When any third element appears between two or something changes a balance of connection between two (e.g. one-way transparent window or shooting hole design which is made in a way to give more possibilities for defenders to observe a space outside while staying invisible for outsiders) asymmetry is created and it separates people, activities, and objects.

Of course if we look at the network of street segments in any city we will note that each segment there has just a small number of symmetric segments, because of a limited number of crossroads which one segment can have, and a big number of asymmetric segments. Despite the dominance of the asymmetry in urban network it is important to note that there could be different degrees of asymmetry, e.g. gothic street layout, in essence, is less asymmetric than tree type street plan of a medieval Islamic city because of a bigger number of shorter ways between any pair of street segments in the first one. Thus Space Syntax is primarily interested in calculation of symmetry. While generalizing, it could be said that this concept adds the essential social dimension to city form investigation and could be seen as directly related to street culture.

Where is the mathematics in Space Syntax model? Network there is modelled as a mathematical graph. The first graph model was created by Leonhard Euler in 1736 for the seven bridges of the city of Königsberg in Prussia. Graph is made out of nodes and links or edges. Node can represent any element of a network: it could be space, crossroad, building, human being, employee of any organization, etc. From this point of view Space Syntax approach is not a unique one as mathematical graph is used for transport flow modelling by experts of logistics or multiple centrality assessment tools\textsuperscript{540}. The essential difference between Space Syntax and other urban modelling approaches appear in a process of graph construction. If we focus on a network made

\textsuperscript{539} Bill Hillier, Julienne Hanson, \textit{The Social Logic of Space}, Cambridge: Cambridge University Press, 1989, p.11

\textsuperscript{540} Sergio Porta, Paolo iVito Latora, "Multiple centrality assessment in Parma: A network analysis of paths and open spaces", in: URBAN DESIGN International No.13, 2008, p. 41-50.
by street lines then the logistic modelling and MCA analysis choose crossroads as graph nodes as the main points for logistics in a city. It is called a primary approach. Space syntax marks street axes or segments as nodes thus focusing on spaces essential for street culture. It is called the secondary approach. In 60s graph models were intensively used in social sciences, and various calculation for importance or so called centrality of graph nodes were proposed. Three fundamental examples for further understanding of syntactic concepts should be mentioned

- **Degree centrality** which is calculated as a number of connections a node has, e.g. if a crossroad is marked as a node and it is a meeting point for four streets then its degree centrality is equal to four; if a segment between two crossroads is a node then degree centrality is equal to a number of other segments which share connections to the same two crossroads. In general, it could be considered that an urban space with a higher degree centrality has a higher degree of symmetry if compared to one with a lower centrality index, thus is more favourable for street culture, attract more people and activities. Despite its potential usefulness, degree centrality calculation is just so called local measure as it takes into consideration just links between neighbouring nodes but not a whole network.

- **Closeness or farness centrality** is calculated as a sum of shortest distances from a chosen node to all the other nodes of a network. Distance could be measured in various ways: accumulated angles as in angular segment analysis, number of changes of movement direction or turns in Space syntax axial analysis, meters, time, etc. It will be discussed in more details in a short review of Space syntax evolutions, but the lowest sum of distances means the highest closeness value or the most reachable space from all around a network. In real urban situation it could be related to a city center, most monofunctional and intensively used area, etc. Farness is reciprocal of closeness.

- **Betweenness centrality** tells how often node is chosen as a part of transit route while mowing in a shortest way between pairs of all the other nodes. Mathematically it is equal to a sum of such a hypothetic journeys and should correspond to real traffic flows in a city.

These three and more additional types of centrality are calculated in syntactic models but it is enough to present those three to understand how graph model is used.

As it was mentioned earlier Space Syntax was created in 1980s but since that time the model was constantly improved.

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541 In Space syntax we can find four types of graph: segment and axial graphs made on a base of axial lines representing street courses – axe or segment represent the graph node in this case; visual graph which is made by dividing an analysed space into identical small cells- each cell is a node of a graph; convex graph made of visually as one space perceived spaces, e.g. room squares, etc. – convex space represents graph node in this case.
The initial unique approach of Space Syntax, if speaking about the analysis of street network, lays in the following two distinguishing statements:

- Straight and the longest possible visually perceivable axe in a street is seen as graph node based on the argument that straight, visually perceived axes play a crucial role in orientation inside a city.
- The shortest distance which is important for calculations of various centralities is measured in number of turns or topological steps: one turn – one step. The main argument is that people feel topological distance better than the metric one.

The two most commonly used indicators of Space Syntax axial analysis are integration and choice.

Integration represents a closeness centrality with additional normalization of the values – it enables not only analysis of a precise urban structure but comparison of values between different cities of different sizes. The normalization procedure of integration is made in the following steps:

- Total depth is counted for every single node. It is equal to a sum of the shortest topological distances from this node to the rest of the nodes in a network. In mathematical graph theory, it is called Farness centrality and bigger values show higher probable functional segregation of space and higher degree of asymmetry in Space syntax terms. As it was mentioned earlier, the shortest distances are calculated in topological steps or turns.
- The calculated total depth is compared to the deepest and the shallowest graph with the same number of nodes – it allows to shrink a scale of total depth into interval between zero and one. The new indicator is called Relative Asymmetry.
- Relative Asymmetry still does not allow to compare its values between networks of different sizes. In order to become able to do that Real Relative Asymmetry is calculated. It is based on comparison of Related asymmetry of every node to Relative Asymmetry of a node in the same size graph but with statistically most probable dispersion of symmetry – it is called Diamond graph. Diamond graph could be seen as a graph with one node at a bottom (for this node Real relative asymmetry is calculated and it is called justified graph in Space Syntax), twice more nodes one step away from it; the biggest number of nodes in a middle and again one node on the top.
- Integration is calculated by dividing one by Real Relative Asymmetry values. Thus the bigger numerical values are given for a higher centrality or symmetry which is of primary interest of many analyzed cases.

Betweenness centrality in Space Syntax analysis is called Choice. Choice is calculated as a sum of shortest journeys between all pairs of nodes which choose a calculated node as one of transit spaces on the shortest route between the beginning and the end of journey. Normalization in this case is borrowed from mathematical graph theory: the choice value is divided by a number of pairs in a graph or possible number of hypothetical journeys.
Both described indicators, as well as the others, could be calculated while using various radiiuses, e.g. global when all centrality calculations are conduction within reach n which covers all the network and local radius which covers just part of a networks, e.g. radius 3, 5, 7, etc.

With a time axial Space Syntax analysis demonstrated some weak points: no metric distances which could be important in many situations (e.g. very long straight axe which is identified as one node or a lot of very short axes which make one clearly perceived street but are seen as separate nodes in a graph) were considered; no differences between angles of changes of directions (e.g. Figueiredos argued that angle up to 15 degrees by humans is not recognized as a change of direction of movement\textsuperscript{542}); etc.

Segment analysis was introduced in 2001\textsuperscript{543} and offered a few essential changes:

- Segment graph which as mentioned earlier as a unique space syntax approach. Short reminder: the secondary approach is used where street segments between crossroads are modelled as nodes of a graph.
- Different weights for turns depending on angles while the shortest ways in a network are calculated, e.g. 90 degrees – 1, 180 degrees – 2, etc.
- Possibility to calculate shortest ways in topological steps or meters besides accumulated angle; metric radiiuses besides topological or segment ones in combination with angular analysis.

Angular segment analysis with metric radiiuses is claimed to give the best correlation with various urban phenomena affected by spatial configurations, e.g. allocation of commercial object, movement of people, etc. Segment choice, in this case, is calculated in the same ways as Axial choice. Depending on the way to calculate shortest route it is called angular segment choice, metric segment choice or topological segment choice. Integration in segment analysis is described as a node count squared divided by an earlier described Total Depth just calculated according to segment graph possibilities. Node count is a measure which describes density of networks within certain radius and is equal to a number of graph nodes reachable from calculated node within selected distance or radius, e.g. traditionally old city parts with a high street density and shorter street segments have a higher node count if compared to modernistic districts. The described integration formula in segment analysis represents a specific type of closeness called gravity in graph theory, because it gives a higher value not

\textsuperscript{542} Lucas Figueiredo, Luiz Amorim, “Continuity lines in the axial system”, in: Van Nes (ed), 5th International Space Syntax Symposium, TU Delft, Faculty of Architecture, Section of Urban Renewal and Management, Delft, 2005, p. 161-174.

\textsuperscript{543} Alasdait Turner, “Angular Analysis”. in: Proceedings. 3rd International Space Syntax Symposium, Atlanta, p. 30.1-30.11
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only when sum of distances from calculated node to the others is smaller, but when a bigger number of street segments is closer to it.

One more change introduced in Space Syntax together with segment analysis is related to a way how to map for analysis is prepared. The increasing offer of GIS maps of street central lines offered a tempting possibility to use them in a syntactic analysis. After some tests it was proved that the results of calculations with used street central line maps gives not worse results if comparing to axial maps converted to segment maps. Bin Jiang and his colleagues as well argued that central street lines better represent clues for navigation in a city instead of lines of visual perception.

As in the case of axial analysis a normalization of the values of segment integration and choice is needed if we want to have the possibility to compare different cities directly. Bill Hillier offered a unique way to do that. He proposed unique normalization method of both indicators based on deductive and inductive approaches.

According to him, if we introduce a new measure – total angular choice as a sum of all choice values of all transit nodes in a graph, then a deeper network will produce a bigger value of total choice even with a same number of pairs of nodes between whom the shortest journeys are counted because a deeper structure offers more transit spots for journeys. On the base of this notice, Hillier has proposed to normalize segment choice by dividing Angular Segment choice by Angular Total depth. The final formula looks like this:

\[ NACH = \frac{\log (ACH+1)}{\log (ATD+3)} \]

Here NACH means Normalized angular choice; Logarithms are added in order to shrink a final scale and make differences between close values more significant; One and three are added because of some nuances of graph calculation (e.g. one added to choice helps to avoid zero values in dead end streets which are never chosen as transit nodes) and they just shift a little final scale but do not change it in essence.

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544 Alasdair Turner, “From Axial to Road-Centre Lines: A New Representation for Space Syntax and a New Model of Route Choice for Transport Network Analysis.”, in: Environment and Planning B Planning and Design 34(3), 2007 p.539-555

545 Xintao Liu, Bin Jiang, “Defining and generating axial lines from street center lines for better understanding of urban morphologies”, in: International Journal of Geographical Information Science, 26(8), p. 1521-1532.

546 Bill Hillier, Tao Yang, Alasdair Turner, “Normalising least angle choice in Depthmap and how it opens up new perspectives on the global and local analysis of city space.”, in: The Journal of Space Syntax, ISSN: 2044-7507 Year: 2012a volume: 3 issue: 2, 2012, p. 155-193.

547 Bill Hillier, Tao Yang, Alasdair Turner, “Normalising least angle choice in Depthmap and how it opens up new perspectives on the global and local analysis of city space.”, in: The Journal of Space Syntax, ISSN: 2044-7507 Year: 2012a volume: 3 issue: 2, 2012, p. 155-193.
Normalization proposal for angular segment integration was offered after a notice that in a big number the investigated cities dependency between a number of nodes (node count) and angular total depth could be represented by a function $ATD = M \cdot NC^{1.2}$ where $ATD$ means Angular total depth, $NC$ is a node count in a graph and $M$ is scale coefficient. As both indicators ($ATD$ and $NC$) are essential for identification of not normalized angular integration, the scale coefficient, which does not depend on a size of a graph but represents a genotypic peculiarity of an urban network configuration, was proposed as a background for normalized integration values. The final formula looks like this:

$$NAIN = NC^{1.2}/ATD.$$  

The bigger value means that a precise network offers more symmetrical relations within a shorter distance from the calculated node.

Normalization opened a unique way to compare cities in combination with the concept of a generic city\(^{549}\). According to it, each city is made of two layers of streets – so called foreground and background. Foreground is similar in all cities around the World and is made of long main streets which function as the main logistic network and, quite often, as attractors of city centers. Background is made of shorter, most often housing streets and presents the unique cultural code, genotype or patterns of a city. How these two layers could be described and compared on a base of Normalized angular choice and Normalized angular integration? Hillier offered to look at mean and max values of both indicators: max values of normalized choice show how well a foreground network lines are connected with each other and evenly spread in a network, while normalized integration max values demonstrated a level reachability of foreground from a rest of a network. Higher integration values show better reachability and it allows to expect city center function in a foreground with a higher probability. Higher choice values mean better connected and evenly spread in a city foreground street. Higher mean values of normalized choice show better connectivity between a patchwork of local living streets while higher mean integration values demonstrate better reachability or higher amount of symmetry of local neighbourhood central spaces. Hillier demonstrated and explained this method while using various real urban examples, so let’s repeat his experiment with our own selected examples from various periods and cultures of history of urban planning. Why historical examples? Because in history we can find the most genotypically clear, relatively homogenous
urban structures with well known in principle ways of functioning which allow us to check if the proposed method is working well. For testing purposes the following cities were chosen: old town of Fez, Shibam, Kairouan and Marakesh as examples of mediaeval Islamic cities with specific organic street patterns and strong spatial segregation between public, semi private and private;

Medieval Kaunas (based on 1798 map), Norwich (based on 1830 map) and Berlin as an examples of European urbanism; XVII century Berlin as an example of Renaissance intervention in urban planning; Kaunas from 1863 and Berlin from 1800 as examples of classicism urbanism and Beijing from 1913 as a traditional Chinese city planning with very interesting separation of official public spaces.

Summary of mean and max values of two calculated indicators is presented in table 5.1. while NACH maps are shown in figure 5.1.

|                | Fez | Shibam | Norwich 1830 | Berlin 13th c | Berlin 17th c | Kaunas 1798 | Kaunas 1863 | Kairouan | Marakesh | Beijing 1913 |
|----------------|-----|--------|---------------|---------------|---------------|--------------|--------------|----------|-----------|---------------|
| NACH max       | 1,476 | 1,566  | 1,619 | 1,621 | 1,57 | 1,607 | 1,70 | 1,494 | 1,548 | 1,613 |
| NACH mean      | 0,484 | 0,685  | 0,591 | 0,808 | 0,73 | 0,725 | 0,79 | 0,639 | 0,494 | 0,688 |
| NAIN max       | 0,492 | 1,476  | 1,542 | 1,783 | 1,36 | 1,50 | 1,885 | 2,08 | 1,087 | 1,084 | 1,505 |
| NAIN mean      | 0,345 | 0,979  | 0,99 | 1,27 | 0,94 | 1,05 | 1,317 | 1,34 | 0,811 | 0,698 | 0,965 |

What they can tell us about investigated cities and do it corresponds to a real situation?

Fez, Marrakesh, Kairouan and a little less Shibam demonstrate similar and lower max and mean values of both integration and choice. It means, that comparing to another city we can expect more asymmetric and segregated urban structure here. Is it true? Medieval Islamic cities represent an organic, tree type street structure which helps to segregate public city center from semi-private or even private housing streets as well preventing commercial and public function from spreading all over an urban network as in European cities of the same period. NACH max values fluctuate between 1.476 and 1.566 while mean values change from 0.484 to 0.685 significantly increasing in a smaller town as Shibam and Kairouan thus being significantly lower than in another investigated cities and corresponding to more fragmented spatial structure of both foreground and background. The lower NAIN values (with the exception of Shibam) show in essence the most asymmetric urban system what quite well corresponds to already
mentioned functional and public/private segregation. Shibam, in this case, could be treated as a separate example because of its relatively small territory with limited space for development of organic street layouts and vertical, but vertical instead of horizontal segregation of public/private spaces and functions.

Norwich 1830 plan represents still very little changed medieval structure which because of organic plan and big number of secondary specialized and dead end streets from the first short glance might look more similar to Medieval Islamic cities than to Gothic plan Berlin. Despite a superficial similarity with the first group of investigated cities normalized values show in essence different genotype: NACH max = 1,619, NACH mean = 0,591, NAIN max = 1,543, NAIN mean = 0,99. In essence it says that urban structure is relatively more symmetric and logistically integrated what corresponds to functionally more heterogeneous European city of that period. The 13th century Berlin has the following values: NACH max = 1,619, NACH mean = 0,808, NAIN max = 1,783, NAIN mean = 1,27. From one side, these indicators show the same genotype of foreground as in the case of Norwich, but very regular gothic plan affects much more evenly spread and integrated local traffic flows; from another side, the integration values are higher if compared to Norwich thus reflecting higher reachability at both city layers because of regular plan. The 17th century in Berlin marks construction of Unter den Linden and neighbouring blocks in Renaissance manner, but it was just a local intervention, as in majority of Renaissance urban development thus the indicators are not changed significantly. A slight decrease in values could be explained by segregation of compact city because territorial development away from Medieval part. Medieval Kaunas, according the oldest reliable plan from 1798, demonstrates features of a gothic plan and very similar indicators to Berlin. The classicistic Berlin from 1800 demonstrates increase and light specialization of territory in terms of specialized districts or neighbourhoods (e.g. district with dominant representative buildings) together with Versailles type wide global street network which connects the most important objects and public spaces. This shift into regularity is especially well reflected in increased NAIN values. Kaunas 1863 demonstrates close indicators. Beijing plan within medieval walls demonstrates quite high foreground values what could be expected in regular plan city while mean values are quite low. Of course this fact should be investigated further but preliminary it could be said that it quite well corresponds to a so called Hutong culture when local street life is concentrated not in the main streets which perform more logistic and representative function, but in local and quiet neighbourhood streets.

Just presented mini test investigation, in essence, proves sensitivity of the generic city model to various cultural urban genotypes and, together with further explained detailed methodology will be used as a model for better understanding and comparison of the investigated three cities.
While summarizing this chapter, it could be concluded that in essence Spatial Capital concept creates a good background for investigation of dependencies between urban spatial configuration and social-cultural content of a city, including street culture as one of the essential aspects of city life according to Mumford\textsuperscript{550}. Investigation of the above mentioned space contents could be easily related to such concepts as Social Capital, Economic capital, Cultural capital, etc. Despite the fact that Spatial Capital idea was developed out of Space syntax model, but it remains open to various ways of modelling of spatial urban configuration, yet Space syntax was chosen in the presented research as the most appropriate at the moment because the following reasons:

- View on urban spaces as a complex, constantly interacting network thus reflecting nature of a city as a complex, dynamic system.

\textsuperscript{550} Mark Gottdiener, Leslie Budd, \textit{Key Concepts in Urban Studies}, London: Sage Publications, 2005, p. 6-10.
The essential for Space syntax concept of spatial symmetry as a catalyzer and indicator of co-presence of people, activities and functions which could be analyzed while using mathematical methods. It could be seen as a more detailed tool to evaluate spatial capital as well.

- Possibility to use mathematical graph model for space syntax analysis with the unique secondary approach which focusses on social dimension of a spatial network.
- Even if we will focus on a graph of street segments (angular segment analysis), space syntax offers additional options, e.g. visual graph analysis, convex graph analysis. These models could be used to explore symmetry presence in more details if needed. Such an additional possibility should always be treated as an additional bonus.
- Space syntax offers a high variety of theoretically grounded and empirically tested both normalized and not normalized centrality measures which create a lot of possibilities for spatial configuration analysis and comparison. Integration, choice, closeness and betweenness centralities as described above present just few of these indicators which will be discussed in the next chapter.

5.2 Investigation of historical cities and multi-modal space syntax graph

5.2.1 Space syntax analysis for historical city investigations

In the previous chapter, Space Syntax models were identified as a suitable tool for the present investigation of relations between urban spatial configurations and various forms of street culture. Before proposing or choosing a precise model for our research, the short review of Space Syntax usage in investigation of both transformations and functioning of historical cities should be conducted in order to be able to check the existing methodological approaches.

While mowing from more general to more specific statements usage of space syntax in archaeology could be mentioned as the first case. In his text on “Space Syntax and/in Archaeology” the author presents some basic syntactic indicators such as axial integration and choice together with short introduction of three types of graphs (axial, visual, convex) as suitable for analysis of excavated urban areas if enough information about city plan is available. Finally, Tencer concludes that despite high potential of syntactic models for better understanding and functional interpretation of historical cities Space syntax is still quite much evaluated sceptically.
and used too little\textsuperscript{551}. As examples of good research practice are mentioned Anatolian town forts\textsuperscript{552}, Pompei\textsuperscript{553} Dura Europos, and medieval Hertogenbosch\textsuperscript{554} - some of them will be discussed in more details a little later. Srinurak and Mishima\textsuperscript{555} have successfully supplement GIS investigation methodologies with the syntactic ones. In the conducted investigation of morphology and public space located in historical town Chiang Mai they were analyzing axial integration and connectivity\textsuperscript{556} values as a way to identify the core axes in a town. So called spatial intelligibility, which as proposed by Hillier\textsuperscript{557} as correlation between either connectivity and global integration with radius n or local integration with topological radius 3 and global integration, was employed as an additional model for better understanding of spatial urban structure. The calculated syntactic features were overlapped with data on allocation of various public spaces according to usage (religion, education, government, recreation) and size. Finally, the investigators have concluded dependency between higher syntactic value and higher significance of public spaces with some limitations of the method. Hanna Stöger in 2007 while investigating Roman Ostia used space syntax in order to deepen analysis of excavated structure. She employed few syntactic models: connectivity or degree centrality of axial map, integration of axial map and connectivity of visual graph. The uniqueness of the approach is based on how the axial map was created – it was generated automatically in all not built up are thus

\begin{thebibliography}{99}
\bibitem{Tencer} Tomas Tencer, “Space Syntax and/in Archaeology”, in: DAJ1 Odborná jazyková příprava pro DSP - Academic Writing in Englis [interactive], 2012, [viewed on 2019-03-20], https://is.muni.cz/el/1490/podzim2016/DAJ1/um/Tencer_chapter.pdf
\bibitem{Topcu} Mehmet Topçu, Ayse Sema Kubat, “Morphological Comparison of Two Historical Anatolian Towns”, in: Proceedings, 6th International Space Syntax Symposium, İstanbul, [interactive], 2007 [viewed on 2019 01 20], https://www.researchgate.net/publication/228428046_Morphological_Comparison_of_Two_Historical_Anatolian_Towns
\bibitem{VanNes} Akkelies van Nes, Indicating street vitality in excavated towns. Spatial configurative analyses applied to Pompeii, in TuDelft Repository, [interactive], 2014, [viewed on 2019-05- 06], https://repository.tudelft.nl/islandora/object/uuid%3A072645d0-b6ff-4ffb-b755-c0f4145d5bf6
\bibitem{Craane} Marlous Craane, “The Medieval Urban ‘Movement Economy’ Using Space Syntax in the Study of Medieval Towns as Exemplified by the Town of ‘s-Hertogenbosch, the Netherlands”, in: Proceedings of the 7th International Space Syntax Symposium, Edited by Daniel Koch, Lars Marcus and Jesper Steen, Stockholm, 2009, p. 019:1-019:14.Proceedings
\bibitem{Srinurak} Nattasit Srinurak, Nobuo Mishima, “Study on urban morphology and public space location to identify Character of historic town; Case study of Chiang Mai.”, in: The EAROPH 2015 Region seminar [interactive], 2015, [viewed on 2019-04-05], https://www.academia.edu/20811566/Study_on_urban_morphology_and_public_space_location_to_identify_Character_of_historic_town_Case_study_of_Chiang_Mai
\bibitem{Conn1} Connectivity of a graph node in Space Syntax is called an earlier explained degree centrality as a number of direct connections with neighbouring nodes from a counted node.
\bibitem{Hillier} Bill Hillier, Richard Burdett, John Peponis, Alan Penn, “Creating Life: Or, Does Architecture Determine Anything?” in: Architecture et Comportement/Architecture and Behaviour, 3 (3), 1987, p. 233 – 250.
\end{thebibliography}
including some former private or semi-private spaces as courtyards of insula, into the analysis. She concludes the following: “The spatial case study of Ostia’s insula IV ii has demonstrated that syntactical and visual tools of spatial analysis can add an interesting dimension to the archaeological assessment of a past built environment. Spatial aspects can be detected which would otherwise not be noted by observation only. The real advantage of Space Syntax lies in the fact that the method forces the researcher to understand a building or a group of buildings as a configuration of space.”558. Arnaiz and Urena559 successfully used axial integration calculation over the period from 1950 to 2016 in order to create deeper deductive understanding of changes of spatial configurations in few cities even without overlapping syntactic information with additional data. Mohareb has investigated Arab walled cities – Cairo, Damascus, Alexandria, and Tripoli560. It looks that more advanced Space Syntax segment analysis with metric radiuses and comparison of mean values of choice and integration was applied in order to analyze the potential functioning and morphological structure of close to city wall areas inside the investigated towns. Repetitive spatial-functional patterns along the urban edges, as a “gates to a city” were identified during this research. Sophia Psara from Bartlet school of architecture and her colleagues561 investigated spatial patterns of growth and decline in Detroit from 1776 to the present. Industry, streetcar transportation, and retail activity in the city were mapped through the whole investigated period and overlapped with such syntactic indicators as angular segment integration and choice with various metric radiuses. Remarkable, visually identified correlation between some of the mapped activities/functions and syntactic features were found during this investigation.

558 Hanna Stöger, “Roman Ostia: Space Syntax and the Domestication of Space”, in: Posluschny, A., K. Lambers and I. Herzog (eds.) Layers of Perception, Proceedings of the 35th International Conference on Computer Applications and Quantitative Methods in Archaeology (CAA), Berlin, Germany, April 2–6, 2007 (Kolloquien zur Vor- und Frühgeschichte, Vol. 10). Dr. Rudolf Habelt GmbH, Bonn, p. 322-327.

559 Borja Ruiz-Apilanez, José Urena, “Spatial network analysis based on Space Syntax Methodologies. The evolution of integration in the historic cities of Toledo and Alcalá de Henares”, in: academia.edu [interactive], 2013 [viewed on 2019 01 10], https://www.academia.edu/7562115/Spatial_network_analysis_based_on_Space_Syntax_Methodologies._The_evolution_of_integration_in_the_historic_cities_of_Toledo_and_Alcalá_de_Henares

560 Nabil Mohareb, Robert Kronenburg, “ARAB WALLED CITIES: investigating peripheral patterns in historic Cairo, Damascus, Alexandria, and Tripoli”, in: Proceedings: Eighth International Space Syntax Symposium, Santiago de Chile, 2012, p. 8002:1-8002:16.

561 Sophia Psara, Conrad Kickert, Amanda Pluviano, “Paradigm lost: Industrial and post-industrial Detroit – Ananalysis of the street network and its social and economic dimensions from 1796 to the present”, in: URBAN DESIGN International Vol. 18, 4, 2013, p. 257–281
Benech\textsuperscript{562} has used syntactic calculations as a way for interpretation of geophysical survey map of Hellenistic city Dura-Europos. He presented an interesting attempt to combine two maps with connective calculations: one from axial map and one from visual graph analysis. Even if the technical details are not fully explained, such a combination of two quite different maps might be created while using GIS technologies. In a result the most visible, intelligible, accessible zones in urban network were identified and overlapped with the other data based on geophysical survey maps, e.g. sizes of housing units, allocation of main temples, etc. Space syntax analysis was proved as a valuable addition to traditional geospatial analysis. Kinda Al Sayed\textsuperscript{563} together with his team have investigated the morphological logic of Manhattan and Barcelona. The following syntactic measures were calculated and analyzed in both cities during the period from the 17th century till nowadays: angular segment integration with various radiuses as a tool to identify integration and activity cores; metric mean depth which is counted for each node or segment in the presented case, as total depth or farness centrality, which was explained in the previous chapter, divided the number of accessible nodes. According to Hillier mean metric depth\textsuperscript{564}, which tends to create clusters with similar values, identifies the potential informal neighbourhoods or zones of more intensive zones of spontaneous, informal social contacts and street culture. All together syntactic indicators were used to find similarities between the spatial growth patterns summarized by the bottom up organic growth and the top down planning decisions. The prosed diachronic model created possibility to look for the syntactic features which allow predicting spatial transformations of urban network, e.g. direction of its expansion, etc. Jamie O’Brien and Samm Griffits in 2017 presented the research which aimed in “… in using syntactic descriptions for making detailed diachronic observations of Liverpool’s urban development was to demonstrate how a ‘normative’ method for historical and spatial comparisons could reveal path-dependencies with the capability of underpinning urban images, including boundaries, thresholds, interfaces, gateways and bridges through which community identities are negotiated and controlled.”\textsuperscript{565}. In this case the normalized angular choice and integration values (NAIN and NACH) were used

\textsuperscript{562} Christophe Benech, “The use of “space syntax” for the study of city planning and household from geophysical maps: the case of Dura-Europos (Syria)”, in: Städtisches Wohnen im östlichen Mittelmeerraum 4. Jh. v. Chr.–1. Jh. n. Chr., Vienne, Austria, 2007. p.403-416.

\textsuperscript{563} Kinda Al Sayed, Alasdair Turner, Sean Hanna, “Cities as Emergent Models the Morphological Logic of Manhattan and Barcelona”, in: Proceedings of the 7th International Space Syntax Symposium Edited by Daniel Koch, Lars Marcus and Jesper Steen, Stockholm: KTH, 2009, p. 001:1-001:12.

\textsuperscript{564} Kinda Al Sayed, Space Syntax Methodology, A teaching guide for the MRes/MSc Space Syntax course (version 5), Bartlett School of Architecture, UCL, p. 88.

\textsuperscript{565} Jamie O’Brien, Sam Griffiths, “RELATING URBAN MORPHOLOGIES TO MOVEMENT POTENTIALS OVER TIMEA diachronic study with Space Syntax of Liverpool, UK”, in: Proceedings of the 11th Space Syntax Symposium, Lisbon, 2017, p. 98.1-98.11.
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Together thus allowing to expand or compare the investigation with other cities and various collected historical data about city functioning, e.g. allocation of objects, inhabitants’ activities, movement patterns, etc. Finally, it is claimed, that “… study offered visualization method for making systematical observations of the historical growth of an urban street network that facilitates new forms of engagement with other sources of evidence and approaches to the study of urban history. Furthermore, we believe that it has produced evidence for the existence of normative ‘images’ of urban community formations in the historical street network. Further work using, for example, contemporary demographic data, journalistic accounts and individual testimonies, as well as greater statistical validation, is required to establish the credibility of this hypothesis.”

A little earlier similar approach was used in a collective book edited by Laura Waughan “Suburban Urbanities: Suburbs and the Life of the High Street”. While conducting the investigation of a suburb as a specific and largely ignored by a research structure, the Space Syntax methodology was used as a basic way of thinking and understanding how spatially city grows and develops in interdisciplinary research. Simple angular segment analysis choice and integration values weighted by a segment length which hypothetically corresponds to higher number of houses along a segment were used together with various available social and cultural data and its interpretation (e.g. social inclusion, pedestrian realm, high street diversity, interaction, productivity, etc.) in order to give an in depth complex understanding of suburb as a spatial-social-economic structure on the base of investigation conducted in many cities. A little earlier another article by Griffiths argues that “study of urban form through time space syntax research has opened up a number possibilities for exploring the relationship between urban transformations and social activity.”

In the same article, on the base of Sheffield sample so called spatial histories or histories of spaces are constructed while combining axial

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566 Jamie O’Brien, Sam Griffiths, “RELATING URBAN MORPHOLOGIES TO MOVEMENT POTENTIALS OVER TIME: A diachronic study with Space Syntax of Liverpool, UK”, in: Proceedings of the 11th Space Syntax Symposium, Lisbon, 2017, p. 98.1-98.11.
567 Laura Vaughan, Suburban Urbanities: Suburbs and the Life of the High Street, London, UCL Press, p. 53-74.
568 Sam Griffiths, “THE USE OF SPACE SYNTAX IN HISTORICAL RESEARCH: current practice and future possibilities”, in: Proceedings: Eighth International Space Syntax Symposium, Edited by M. Greene, J. Reyes and A. Castro, Santiago de Chile: PUC, 2012, p.8193:1-8193:26.
integration with various weighting values with the visual graph of so called visual control\textsuperscript{569} are overlapped with land plot usage data.

Research conducted by Akkelei Van Ness on street vitality in Roman Pompeii. While looking for syntactic features of spatial configurations which could be related to street vitality of higher degree of street culture, the researcher combines so called macro and micro tools. Axial integration with a radius \( n \) is used at a macro level, while angular segment choice with a small metric radius is used at a micro level. The research at the micro level is expanded by the originally developed concept of social-spatial control where a number, allocation, topological distance and orientation of entrances to the houses and windows. These are combined into three measurable indicators: intervisibility or possibility to view a street from two sides; constitutedness or continuity of a street as a result of adjacency of building facades and entrances to a street space; depth of public space as a measure of topological distance between public space and entrance to a building. The syntactic data was overlapped with the layers of the other available information as allocation of functions; allocation of sitting benches in front of building facades, etc. Identified correlations between syntactic patterns and the above mentioned data “...contributes to understanding how ancient cities functioned and what the relationship is between spatial layout and socio-economic activities.”\textsuperscript{570} Zaleckis and Laurinaitis in 2016 have presented mini investigation about the spatial changes in Kaunas from 1798 till 1939\textsuperscript{571}. The aim of the investigation was to analyze possible changes in terms of spatial capital while comparing three essentially different periods of Kaunas spatial configurations: medieval city; its expansion with classicistic part and the further development before the Second World War. In order to be able to compare numerical syntactic values of different size segment maps, the normalized angular choice and normalized angular integration were calculated. At the same time the generic city model based on comparison of max and mean values, as described in the previous chapter, was employed. In order to check if deductive interpretations of mutations

\textsuperscript{569} Control in space syntax online glossary is described as following: Control measures what degree of choice each space represent for its immediate neighbours as a space to move to. Each space has a certain number \( k \) of immediate neighbours. Each space therefore gives to each of its immediate neighbours \( 1/k \), and these are then summed for each receiving space to give the control values of that space. Spaces which have a control value greater than 1 will have strong control, those below 1 will be weak control spaces. A typical example is a hospital corridor, which is connected to many one-connected offices. (Hillier, B. & Hanson, J. (1984), The Social Logic of Space, Cambridge University Press: Cambridge. pp.109)

\textsuperscript{570} Akkelies van Nes, Indicating street vitality in excavated towns. Spatial configurative analyses applied to Pompeii, in TuDelft Repository, [interactive], 2014, [viewed on 2019-05-06], https://repository.tudelft.nl/islandora/object/uuid%3A072645d0-b6ff-4ffb-b755-c0f4145d5bfd

\textsuperscript{571} Kestutis Zaleckis, Paulius Tautvydas Laurinaitis, “Planuose užkoduota Kauno evoliucija: 1798–1939”, in: (De)coded History in Architecture, International Interdisciplinary Scientific Conference Vilnius–Dubingiai (Lithuania), 12–14 May 2016, Abstracts, p. 27.
and transformations of spatial structure are leading towards a right direction, the syntactic layer patterns were compared with data on allocation of the most important object such as churches, administrative buildings, markets, river harbour zone, etc.; construction material of houses as bricks versus wood. Few essential conclusions were made:

- Pattern of the high integration values or degree of symmetry matches the allocation of churches, brick buildings and the harbour in Kaunas 1798.
- The change of max and mean values of both NACH if maps of 1798 and 1863 are compared very clearly demonstrate the shift from decentralized logistic network in gothic plan city to more strongly expressed hierarchy of logistic corridors in classicistic plan thus confirming the essence of top-down planning intervention.
- Allocation of the main administrative and representative buildings in Kaunas 1939 remarkable match pattern of the highest values of choice or betweenness centrality, etc.

The presented short review of the usage of Space syntax models in the various investigation of history of urban structures could be continued with a number of other examples, but, for the purpose of the presented investigation it could be seen as complex and symptomatic enough. In essence it becomes obvious from the review that Space Syntax models are successfully used in investigation of historical development from the point of view of spatial determinism in a city. Regarding the precise methodology there exist a high variety of chosen accurate models depending on situation, available data and aim of investigation: axial, segment and convex graphs are employed; bot normalized and not normalized values as calculated; sometimes additional weight is used in a graph in order to make results more precise; Space Syntax results are combined with GIS technologies, etc. Two essential ways of usage of syntactic models could be noted as well – they are used either as a layer while looking for correlations with another available data or as additional interpretative, in a way deductive, explanatory model besides spatial configuration presentations.

### 5.2.2 Multi-modal of urban network and Space syntax

Contemporary cities are multi-modal logistic systems which incorporate various modes of transportation and movement: pedestrians, individual cars, busses, city trains and underground, etc. In order to make syntactic models of urban networks more accurate multi-modality should be considered. Is multi-modality actual for historical investigations of cities? The answers are undoubtedly “yes”, especially if we speak about city development since the 19th century as the starting point for industrialization of cities, development of public transportation, incensement of cities in size, etc. Can we find any Space syntax based research either focused on
contemporary or historical urban investigation with multi-modality aspect addressed and what methodological clues could be used in the presented research?

The modelling of the London underground network could be presented as the first serious multi-modality modelling attempt while using Space Syntax models as the authors claim “Because no published precedent for analyzing underground systems was found in published space syntax literature, two approaches were tested (created)”\(^572\). There, two underground network models were created and analyzed against entry/exit movement in tube stations in the mentioned article. The first model considered only underground network of tube lines and stations while using axial space syntax map: connection between two stations was drawn as straight axe on the base of premise that journey from one station to another is equal to one topological step in a graph and underground distance is perceived in number of stations but not in metric distances; change of metro lines was models as three topological steps. Because the position of the station above the ground was considered important as well, so the ground level street network was modelled. Underground stations were assigned local integration values from axial map as indicators of accessibility. The results of the modelling demonstrated that “both the topological configuration of the underground and the spatial accessibility of the above ground station surrounding are related to the number of passengers boarding and alighting at each station. Underground configuration appears to have a particularly important influence (r\(^2\) = 0.54) and underlines the power of the network effect on underground general movement.”\(^573\).

Schwanger argues that “The importance of public transport networks for contemporary city-regions is beyond question ... and recent Space Syntax research has shown the need to include them into a fully configurational urban simulation model” while focusing on modelling of the railroad network in South East England\(^574\). The author argues his choice by saying that railways make an influence on urban morphology; rail travels play a significant role in everyday movement of inhabitants and rails might increase competitiveness of city-region in general in terms of attraction of investment. Despite the fact that only the rail network with stations is modelled in the described research, it presents very interesting and possibly useful combination.

\(^572\) Alain Chiaradia, Edouard Moreau, Noah Raford, “Configurational Exploration of Public Transport Movement Networks: a Case Study, The London Underground”, in: 5th Sapce Syntax Symposium, Delft, [interactive], 2005, [viewed on 2019-06-03], http://spacesyntax.tudelft.nl/media/Long%20papers%201/alainchiaradia.pdf

\(^573\) Alain Chiaradia, Edouard Moreau, Noah Raford, “Configurational Exploration of Public Transport Movement Networks: a Case Study, The London Underground”, in: 5th Sapce Syntax Symposium, Delft, [interactive], 2005, [viewed on 2019-06-03], http://spacesyntax.tudelft.nl/media/Long%20papers%201/alainchiaradia.pdf

\(^574\) Christian Schwander, “NETWORK ANALYSIS APPLIED: the railway network in South East England”, in: Proceedings, 6th International Space Syntax Symposium, Istanbul, 2007, p. 076:01-076:18.
of different graphs: topological graph typical to Space syntax investigation when one step (in this case change of station); so called flow network which weight graph links by train journeys frequency and time network, which considers journey time and train speed between the stations. Three types of centralities (degree, closeness and betweenness) calculated in the three above mentioned networks was compared with the data on train station usage as number of people using it over certain period of time and journey route change. It is worth to note that the flow network weighted by a number of train journeys gave the best correlation (0.727) with degree centrality.

Chiaradia and his colleagues continued the investigation of the London underground network and published article “Towards a Multi-Modal Space Syntax Analysis. A case study of the London street and underground network”\(^{575}\). In this research the double-layered graph and single layered angular segment graph models were tested against entrances/exits to the stations. Measuring of distance in accumulated angles and in time was tested while combining journeys for 10000 and 25000 meters. The best correlation (0.504) was observed while combining 10000-meter angular shortest distance on streets and 25000-meter angular shortest distance on tube. Such a result could be seen as a quantitative argument for further investigation in syntactic multi-modality approaches. Even if the precise methodology is not fully describing it could be made a premise that GIS technologies were used to merge syntactic calculations in two layered graph.

Gill as well investigated possibilities to integrate public transport models into axial syntactic maps\(^{576}\). Approach was in essence similar yet more simple as in the previously discussed investigation. Street network was modelled as an axial graph instead of segment angular graph as in the previous case. The results were integrated with a topological graph of underground network while modelling entrance to the underground as one additional axial line. Depthmap feature “link graph nodes” was used to perform the merging procedure. In three test areas from five, the pedestrian movement data demonstrated better correlations with global integration.

Investigation by Zhang, Chiaradia and Zhuang in Shanghai\(^{577}\). The researches started from the statement that spatial accessibility in a city makes an influence on travel and land use patterns. The objective of the research was to identify the spatial configuration and composition details of multimodal networks using micro-macro

\(^{575}\) Stephen Law, Alain Chiaradia, Christian Schwander, “TOWARDS A MULTI-MODAL SPACE SYNTAX ANALYSIS. A case study of the London street and underground network”, in: Proceedings Eighth International Space Syntax Symposium, Santiago de Chile: PUC, 2012, p. 8021:1-8021:20.

\(^{576}\) Jorge Gil, “Integrating Public Transport Networks in the Axial Model”, in: Proceedings Eighth International Space Syntax Symposium, Santiago de Chile: PUC, 2012, p. 8103:1-8103:21.

\(^{577}\) Lingzhu Zhang, Alain Chiaradia, Yu Zhuang, “Configurational Accessibility Study of Road and Metro Network in Shanghai”, in: Recent Developments in Chinese Urban Planning, Selected Papers from the 8th International Association for China Planning Conference, Guangzhou, China, June 21 - 22, 2014, p. 219-245.
relative accessibility. In order to complete this task, the following calculations were conducted:

- Street network angular accessibility described by betweenness centrality at micro, midi, and macro spatial scales for the street networks (radius 600 m, 2,000 m, 5,000). The three radii correspond to walking, cycling for a short distance, bike and bus ride journey, and both short and long car trips.
- Urban block size
- Metro lines network topological accessibility as a closeness centrality.

In a results it was concluded the following: “...we found that most of the metro stations, bus stops and commercial land use are co-located on the part of the road network with the highest level of micro to macro accessibility, indicating a coupling multiplier effect between metro stations, commercial land use and multi-level multi network structural flow derived from accessibility analysis. Moreover, block size is revealed as an important variable.”

Despite the relatively small number of examples of multi-modality addressed in Space Syntax based research and no single model or approach agreed on, the promising results of the discussed cases, allow to think about multi-modality as one of the perspective ways of further Space Syntax development. It looks especially actual for a contemporary city, but might be worth consideration while conducting historical investigation as well. It is especially true if the crucial points of urban revolution from the point of view of rapid technological changes in transportation are focused on. Having it in mind, the ambition to use a multi-modal syntactic analysis for the investigation of transformations of Vilnius, Kaunas and Klaipeda was formulated.

5.2.3 Detalization of Space Syntax models for investigation of Vilnius, Kaunas and Klaipeda

The final proposal for methodology for investigation of dependencies between transformations of urban spaces and street culture in three Lithuanian cities from period just before the World War 2 to nowadays with the aim to see the influence of Soviet modernistic urbanism was constructed on the base of the conducted and earlier presented theoretical background, review of the precise cases of investigation, available data and the aims of investigation. The basic methodological approach was based on the following cornerstones:

578 Lingzhu Zhang, Alain Chiaradia, Yu Zhuang, “Configurational Accessibility Study of Road and Metro Network in Shanghai”, in: Recent Developments in Chinese Urban Planning, Selected Papers from the 8th International Association for China Planning Conference, Guangzhou, China, June 21 - 22, 2014, p. 219-245.
Investigation of historical cities and multi-modal space syntax graph

Space Syntax segment analysis, based on secondary graph approach which is focused on social dimensions of space, was chosen as the most advanced way to model city street and other public spaces network.

A bigger number of not normalized syntactic values was used for investigation of correlations between syntactic features and the results of content analysis of usage of public spaces in order to avoid limitations of the results by initial pre-selection of indicators which might be worked in another investigation. But it could be not the best choice for the present one.

Normalized angular segment choice and integrations were used for comparison of the three investigated cities in order to evaluate similarities and differences between the essential spatial genotypic transformations and mutations.

It was decided to address the aspect of multi-modality in urban networks because it is especially actual for the investigated period in Lithuania as it marks the boom in single car usage and rapid development of public transport. E.g. the first public transport lines appeared in Kaunas in 1892–1929 in the form of horse tram (konke), but just before the World War 2 there were more than 10 bus lines in a city; at the end of the Soviet period city had developed network of buses and trolleybuses which was expanded by increasing number of lines and adding so called mini-taxis after regained independence in 1990. The types of movement in a city were addressed: pedestrian, individual car and public transport. Each of them has a different speed, different optimal radiuses and at least partially separated parts of public space network.

As in some of the reviewed research examples, it was decided to compare multi-modal approach with more or less traditional space syntax model. In this case, the second one was presented by angular segment analysis with various metric radiuses.

Because modernistic urbanism introduced a strict separation of car and pedestrian traffic, it was decided to create a segment graph for analysis not only from full-fledged streets, but also from paths or other public spaces available only for usage by pedestrians and cyclist thus making the analyzed network of public spaces more accurate. A full-fledged street and pedestrian route will be modelled differently in multi-modal and segment angular graphs.

Both models, as it was mentioned above, were based on the statement that we have three types of mowers in a city: pedestrians, public transport users and individual car drivers. The three types of journeys have different optimal distance and speeds. The pedestrian mean speed was made equal to 5 km/h; individual car speed in a city was chosen as 50 km/h based on existing restrictions while before the World War 2 it was

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579 Here street is called a full fledged if, on the base of one or another form of spatial organization, it could be used both pedestrians and cars or public transport.
made equal to 40 km/h based on the premise that people were driving slower. The bus speed was chosen as a little lower if comparing to the individual car speed because of regular stops and it was set as 40 km/h for the Soviet period and contemporary time while 30 km/h was chosen for the earlier period. 1 km or 12-20 minutes’ walk was chosen as mean pedestrian distance; 5 km as distance travel with public transport included according to statistical data on main Lithuanian cities. It is important to note that 5 km is quite close to the mean depth from the most globally integrated line in the graphs of three cities since the Soviet period. Because this correspondence and the smaller size of cities before the World War 2, the public transport mean distance or journey radius was decreased to 4 km in pre-war maps. Car journeys were modelled with the longest possible radius – n.

The first model was made on the base of generalization that people use the maximum speed possible in a city depending on available possibilities. Thus three scenarios were described accordingly:

- People are just walking in a city. All syntactic values or graph centralities are calculated while using radius 1 km.
- People are mowing by a walking speed in pedestrian paths, courtyards and similar spaces and then changing to the car speed when street is reached. All syntactic values, in this case, are calculated with a radius n.
- People are walking till the nearest street with a public transport line and then taking a bus. All syntactic values are calculated for radiiuses of 4 and 5 km for these journeys.

Different speed of movement, according to the attributes of segments and the city map, is modelled as a ratio between segment length and speed. This ratio is used in a graph for calculation of the shortest travel distance instead of accumulated angle of changes of movement directions in angular segment analysis – it is called a custom segment graph. The above described modelling was performed while using GIS technologies and the Spatial Design Network Analyst (sDNA) for ArcGIS. This approach allowed to combine streets and pedestrian paths in one graph in a city of the modernistic period; to reflect pedestrian stairs and river ferry connections which existed before construction of some bridges before the World War 2 as important connections; inclusion of pedestrian streets in a city center as Laisves avenue during the Soviet period in Kaunas, etc.

Correction to the list of three scenarios was made for the investigated period before 1939 – the scenario of car movement was abandoned because of the small number of car users in Kaunas and very probably the other two investigated cities. According to the available statistical data, there were 108196 inhabitants in Kaunas in

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Pranciskus Juskevicius, Vidualdas Valeika, *Lietuvos miestyų sistemos raida*, Vilnius, 2007, p.61
1937 and only 705 individual cars including taxis. All three scenarios were analyzed in 1987 and 2016. Various syntactic features were calculated for custom segment graph within earlier identified radiiuses, and correlations with the content analysis results described in the previous chapters were checked. The counted centralities are described together with the results of investigation in the next chapter. The synergies between the indicators with the strongest correlations were calculated as multiplication of mathematical values in order to get the second chance to combine different movement scenarios and types of movement in one index and to try to find even stronger correlations if possible.

The second model, as it was mentioned earlier, was based on angular segment analysis and reflected three movement scenarios in an indirect way – just by different radius as 1km, 4-5km and radius n. In this case, there was no possibility to reflect differences between purely pedestrian routes and full streets, but such simplification was accepted because of two reasons:

- To check if the first model gives more correct results when compared with the data of Content Analysis.
- Because it was noted in the constructed graphs of three investigated cities, that pedestrian routes, especially in modernistic housing blocks, have essentially bigger angular depth or higher degree of asymmetry caused by more curved lines if compared to the main streets, there the prediction was made that the main streets will have a higher centrality values at a higher radius despite not reflected differences between them and pedestrian routes.

As in the case of application of the first model, correlations between numerous centrality calculations and the results of content analysis results were checked in order to select the best indicators for calculations of synergies and secondary correlation check. In this case the Depthmap software was used.

The additional model comparison and check were conducted because of two reasons:

- Validate the Syntactic approach in the three investigated cities with an independently collected open data which is not related to the results of the content analysis.
- To generate visually recognizable patterns of the most intensive street culture allocations in Klaipeda and Vilnius. This aim appeared because the content analysis was conducted in all three cities, but creation of GIS database was made for Kaunas only because of limited time resources.

581 *Kauno miesto statistikos metraštis 1938*, Kaunas, 1939, p. 56.
Initially, the diachronic development of spatial genotypes of three cities was checked while using the Generic city model\(^{582}\) based on comparison of both mean and max values of the normalized angular choice (NACH) and normalized angular integration (NAIN)\(^{583}\). This comparison aimed at identification if spatial transformations of Klaipeda, Vilnius and Kaunas were essentially similar and if the spatial genotypes of the cities are of the same spatial-social type. As the content analysis results demonstrated very similar results in the three cases, then such a spatial similarity would allow expecting similar spatial patterns of street culture activities.

In the next step, the syntactic model was correlated with available open GIS data on allocations of the most important building in all three cities: shops, shopping malls, gas stations, cultural and administrative objects, schools and universities, sports clubs and other leisure objects. The data was made freely available through online GIS tools of ArcMap software by Hnit-Baltic. In more details the results of this investigation will be presented in the next chapter, but it could be said in advance that quite significant correlations were found between some syntactic indicators and allocation of the mentioned above objects thus confirming validity of the graph model itself.

The third step was based on the Artificial Intelligence (AI) usage for recognition of the relations between spatial patterns, described by the syntactic indicators, and either functional or social content of public spaces. Initially, the Neural Network via plug-in in Matlab was taught to understand relations between the centrality values of street segments and allocation of the main objects. It was conducted on the base of the 15 percent of Kaunas territory selected by the program itself. The next step – prediction of allocation of the analysed objects in the rest of Kaunas and correlation check between the predicted and real data. As the experiment was successful then the same Neural Network was asked to make the same prediction for Vilnius and Klaipeda without any additional learning in these cities – the correlations between predicted allocations and real situation in all three cases were bigger than between the selected centrality index and allocation of the objects. After that, the Neural Network of the same configuration was taught to recognize and predict spatial allocation patterns of the most important for the conducted investigation content analysis results in Kaunas. Correlations between the predictions and the earlier collected and into GIS database entered data were checked again. Finally, AI made prediction of allocation

\(^{582}\) Bill Hillier, “The Genetic Code for Cities: Is It Simpler than We Think？”, in: Juval Portugali, Han Meyer, Egbert Stolk, Ekim Tan (Editors), Complexity Theories of Cities Have Come of Age, An Overview with Implications to Urban Planning and Design, New York, Springer, 2012. p. 129-152.

\(^{583}\) Bill Hillier, Tao Yang, Alasdair Turner, “Normalising least angle choice in Depthmap and how it opens up new perspectives on the global and local analysis of city space”, in: The Journal of Space Syntax ISSN: 2044-7507 Year: 2012 volume: 3 issue: 2 Online Publication Date: 28 December 2012, p. 155-193.
of the street culture allocation in Klaipeda and Vilnius which was used for diachronic view on the most important transformation of spatial-social patterns.

The above described methodology summarizes the essential aspects of the application of Space Syntax models in the presented research. It is based on both examples of already conducted researches and original proposals. The precise indicators, their meaning, correlation values, comparison of genotypes and spatial allocation patterns of street culture in the three cities will be described in details in the next chapter.

### 5.3 The results of modelling

The centrality calculations for the first syntactic model were conducted with the Spatial Design Network Analyst tool (sDNA) for ArcGIS and correspondingly, in order to avoid possible misunderstanding if the terms would be changed, the names of calculated centralities offered by sDNA were used. Explanations of each indicator, as well as its corresponding Space Syntax analogues, are presented in the following text of this chapter. The difference in terms has appeared because sDNA is using traditionally used names from graph theory while Space Syntax offers its own terms. As it was mentioned earlier, the various centrality values were checked for correlations with the results of content analysis which was made earlier and represented both typologies of users and activities in public spaces. Because of the big amount of data obtained during the content analysis and in order to get meaningful numerical values all the data on both users and activities in public spaces were combined into the most numerous following seven relatively conditional groups according to the data used:

- All activities performed by all type of users;
- Adults performing physical activities and sports;
- Adults performing social activities;
- Adults performing recreational activities
- Children performing physical activities and sports;
- Teenagers performing physical activities and sports;
- Teenagers performing social activities.

Logical premise was made that the allocation of the investigated activities depend not only on spatial locations, which was identified while using photographs, but also on density of inhabitants, e.g.: two similar photos with family walk in a street were found; one represents a densely inhabited area, the other one – industrial suburb with very low number of housing; it would be logical to think that in the first case collected picture represents an event which might be in reality met quite often in the precise area while the second picture could be treated as more exceptional event.

According to this premise, two datasets of content analysis were used:
original one with numeric values represented as multiplications of sums of both user types and activities; one type of users or one type of activity equals one;
- weighted one where the above calculated numerical values were multiplied by a density of inhabitants.

The density of inhabitants for Kaunas 2016 map was taken from the official web page of the Lithuanian statistical department where census 2011 results are presented\(^{584}\). For the map 1987, in essence, the same data was used with some small corrections, e.g. in 1987 not yet constructed modernistic areas were corrected. In 1939 the probable inhabitant density was reconstructed for groups of urban blocks according to a number of plots, dominant type of houses (e.g. single family, multi-flat, etc.), dominant social group (e.g. workers, the intelligentsia, etc.), number of family members and the size of block.

Pearson’s correlation was counted between the centralities and calculated data on public space usage. Correlation between 0,50 and 1,00 was counted as strong; 0,30-0,49 as medium and 0,00-0,29 as weak\(^{585}\).

It is important to remind that because of the small number of cars in 1939 in Kaunas, only two scenarios (walking and walking and taking a bus) were analysed for this period.

The first from calculated centralities is called **Mean Custom Distance in Radius (MCD)**. It is an equivalent of Mean Depth in Space syntax and for a precise street segment is counted as a sum of the shortest distances from it to the rest of the nodes within a specified radius in a network, and divided by the number of nodes minus one thus eliminating the node for which calculation is performed. It should be reminded that in this case distance is counted in journey time. The bigger numerical values of MCD show higher degree of asymmetry of a segment thus probably corresponding to more specialization, segregation, mono-functionality, etc. The correlations between the activities of street culture in both weighted and unweighted version and MCD area presented in table 5.2.

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\(^{584}\) Oficialiosios statistikos portalas, GIS duomenys, [interactive], 2011, [viewed on 2019 06 20] https://osp.stat.gov.lt/gis-duomenys

\(^{585}\) Statistics Solutions, Pearson’s Correlation Coefficient [interactive], [viewed on 2019 01 03] https://www.statisticssolutions.com/pearsons-correlation-coefficient/
The results of modelling

Table 5.2. Correlations between MCD and activities/users in public spaces. The most important correlations are in bold.

| MCD                  | Activities/users weighted | Activities/users not weighted |
|----------------------|---------------------------|-------------------------------|
| Kaunas87 radius 5000 | -.352** all all w         | -.166” all all               |
|                      | -.349** adult sport w     | -.113” adult sport           |
|                      | -.338” adult soc w        | -.258** adult soc            |
|                      | -.330” adult rec w        | -.184” adult rec             |
|                      | -.347” child sport w      | .049” child sport            |
|                      | -.347” teen sport w       | .048” teen sport             |
|                      | -.338” teen soc w         | -.204” teen soc              |
| Kaunas87 radius n    | -.272** all all w         | -.107” all all               |
|                      | -.273” adult sport w      | -.052” adult sport           |
|                      | -.249” adult soc w        | -.162” adult soc             |
|                      | -.263” adult rec w        | -.130” adult rec             |
|                      | -.277” child sport w      | .056” child sport            |
|                      | -.277” teen sport w       | .072” teen sport             |
|                      | -.255” teen soc w         | -.142” teen soc              |
| Kaunas87 radius 1000 | .168” all all w           | .059” all all                |
|                      | .173” adult sport w       | .058” adult sport            |
|                      | .154” adult soc w         | .073” adult soc              |
|                      | .171” adult rec w         | .099” adult rec              |
|                      | .167” child sport w       | -.015” child sport           |
|                      | .166” teen sport w        | -.017” teen sport            |
|                      | .151” teen soc w          | .045” teen soc               |
| Kaunas39 radius 1000 | .052** all all w          | .024” all all                |
|                      | .041” adult sport w       | .015 adult sport             |
|                      | .059” adult soc w         | .095” adult soc              |
|                      | .082” adult rec w         | .069” adult rec              |
|                      | .020 child sport w        | -.114” child sport           |
|                      | -.002 teen sport w        | -.052” teen sport            |
|                      | .013 teen soc w           | .059” teen soc               |
| Kaunas39 radius 4000 | -.360** all all w         | -.148” all all               |
|                      | -.372” adult sport w      | -.084” adult sport           |
|                      | -.322” adult soc w        | -.250** adult soc            |
|                      | -.386” adult rec w        | -.123” adult rec             |
|                      | -.355” child sport w      | .072” child sport            |
|                      | -.322” teen sport w       | .016 teen sport              |
|                      | -.170” teen soc w         | -.139” teen soc              |
| Kaunas2016 radius 1000 | .134” adult sport w      | .098” adult sport          |
|                      | .151” adult soc w         | .116” adult soc              |
|                      | .165” adult rec w         | .134” adult rec              |
|                      | .126” child sport w       | .086” child sport            |
|                      | .132” teen sport w        | .095” teen sport             |
|                      | .147” teen soci w         | .112” teen soc               |
|                      | .030” all all w           | .028” all all                |
The most important results could be pointed out as following:

- A -0.250 correlation was found between MCD 4000 and social not weighted activities of adults in Kaunas 1939;
- A -0.360 correlation was found between MCD 4000 and weighted all activities of all users in Kaunas 1939;
- A -0.258 correlation was found between MCD 5000 and social not weighted activities of adults in Kaunas 1987;
- A -0.352 correlation was found between MCD 5000 and weighted all activities of all users in Kaunas 1987;
- A -0.414 correlation was found between MCD 5000 and not weighted adult social activities in Kaunas 2016
- A -0.410 correlation was found between MCD n and not weighted adult social activities in Kaunas 2016
- A -0.372 correlation was found between MCD 5000 and weighted adult social activities in Kaunas 2016
- A -0.361 correlation was found between MCD n and weighted adult recreational activities in Kaunas 2016

In general, the found correlation is just medium, but it is enough to demonstrate that the dependency between spatial configuration and street culture exists and is worth further investigation. The interesting tendency could be noted by increased importance of car user’s scenario in Kaunas 2016 and stronger correlation between public usage scenario and space usage in 1939. The interesting aspect is very weak or practically no correlations between local symmetries or MCD 1000 and street activities.

| MCD          | Activities/users weighted         | Activities/users not weighted |
|--------------|-----------------------------------|-------------------------------|
| Kaunas2016 radius 5000 | -0.337** adult sport w            | -0.341** adult sport          |
|              | **373** adult soc w               | -0.414** adult soc            |
|              | -0.364** adult rec w              | -0.335** adult rec            |
|              | -0.327** child sport w            | -0.302** child sport          |
|              | -0.336** teen sport w             | -0.315** teen sport           |
|              | -0.370** teen soc w               | -0.395** teen soc             |
|              | **076** all all w                 | -0.081** all all              |
| Kaunas2016 radius n  | -0.313** adult sport w            | -0.328** adult sport          |
|              | -0.356** adult soc w              | **040** adult soc             |
|              | **362** adult rec w               | -0.348** adult rec            |
|              | -0.303** child sport w            | -0.294** child sport          |
|              | -0.312** teen sport w             | -0.308** teen sport           |
|              | **353** teen soc w                | -0.392** teen soc             |
|              | **096** all all w                 | -0.103** all all              |

** Correlation is significant at the 0.01 level (2-tailed).
The second calculated centrality is called **Network Quantity Penalized by Distance in Radius** (NQPD). It is a kind of closeness or sometimes called gravity in graph models, which reflects not only mean distance from the node to the rest of the network but also the number of close street segments. In other words, NQPD of the precise node is bigger if its mean distance to the other nodes within radius is smaller and the density of nodes close to the calculated one is bigger. Sometimes, if suitable data is available, segments could be weighted (e.g. by length if it is considered that the longer street has more buildings and thus is more important then the shorter one; number of inhabitants; density of inhabitants; number of shops, etc.). In Space Syntax angular segment analysis integration could be named as the closest analogue of this indicator. The following formula is used for the calculation:

\[ \text{NQPD}(x) = \frac{\sum (W(y) \cdot P(y))}{D(x,y)} \]

Here \( W(y) \) is weight of a segment – in this research initial idea was to use the density of inhabitants as the weight here, but initial calculations did not demonstrate significantly better results if compared with calculations with unweighted graph and it would be a mistake to use the same indicators for weighting of both graph and the results of content analysis, so in used formula the weight is equal to one. \( P(y) \) – so called proportion or a part of the node which falls into the radius, e.g. it is equal to one if all segment is within calculated radius and smaller if just a part of segment meets the same condition. \( D \) is a distance between \( x \) (the node for which calculation is done) and \( y \) (the node which is within calculated radius and is used in calculation). \( \text{nqodn} \) and \( \text{nqpdd} \) are degrees which might be used in order to reflect bigger importance of either node number or distance for NQPD. The found correlations are presented in table 5.3.

| NQPD               | Activities/users weighted | Activities/users not weighted |
|--------------------|---------------------------|------------------------------|
| Kaunas87 radius 5000 | .562** all all w          | .325** all all               |
|                    | .553**** adult sport w    | .259** adult sport           |
|                    | .552** adult soc w        | .416** adult soc             |
|                    | .544** adult rec w        | .355** adult rec             |
|                    | .528** child sport w      | .047** child sport           |
|                    | .529** teen sport w       | .048** teen sport            |
|                    | .535** teen soc w         | .341** teen soc              |

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586 Spatial Design Network Analysis (sDNA), *Manual in Spatial design network analysis sDNA*, [interactive], [accessed on 2019 05 06], https://www.cardiff.ac.uk/sdna/wp-content/downloads/documentation/manual/sDNA_manual_v4_0_2/
| NQPD          | Activities/users weighted | Activities/users not weighted |
|--------------|---------------------------|------------------------------|
| Kaunas87 radius n | .434“all all w          | .290“all all               |
|               | .459“adult sport w       | .285“adult sport           |
|               | .416“adult soc w         | .346“adult soc             |
|               | **.460**“adult rec w     | **.367**“adult rec         |
|               | .413“child sport w       | .071“child sport           |
|               | .413“teen sport w        | .072“teen sport            |
|               | .377“teen soc w          | .244“teen soc              |
| Kaunas87 radius 1000 | **.609**“all all w     | .421“all all               |
|               | .606“adult sport w       | .352“adult sport           |
|               | .598“adult soc w         | **.494**“adult soc         |
|               | .574“adult rec w         | .404“adult rec             |
|               | .589“child sport w       | .176“child sport           |
|               | .590“teen sport w        | .177“teen sport            |
|               | .585“teen soc w          | .441“teen soc              |
| Kaunas39 radius 1000 | .002 all all w     | .025‘all all               |
|               | -.011 adult sport w      | .004 adult sport           |
|               | .009 adult soc w         | .031“adult soc             |
|               | .007 adult rec w         | .007 adult rec             |
|               | -.011 child sport w      | .002 child sport           |
|               | -.007 teen sport w       | .025‘teen sport            |
|               | .002 teen soc w          | .059“teen soc              |
| Kaunas39 radius 4000 | .028“ all all w     | .036“all all               |
|               | .012 adult sport w       | .009 adult sport           |
|               | .037“ adult soc w        | .055“ adult soc            |
|               | .035“ adult rec w        | .016 adult rec             |
|               | .006 child sport w       | -.009 child sport          |
|               | .007 teen sport w        | .018 teen sport            |
|               | .015 teen soc w          | .068“teen soc              |
| Kaunas2016 radius 1000 | **.560** adult sport w | **.418** adult sport      |
|               | **.609**“ adult soc w    | **.503**“adult soc         |
|               | **.605**“ adult rec w    | **.432**“ adult rec        |
|               | **.549**“ vai sport w    | **.382**“ vai sport        |
|               | **.562**“ teen sport w   | **.400**“ teen sport       |
|               | **.607**“ teen soc w     | **.486**“ teen soc         |
|               | **.193**“ all w          | **.186**“ all w            |
| Kaunas2016 radius 5000 | **.455** adult sport w | **.346**“ adult sport      |
|               | **.455**“ adult soc w    | **.458**“ adult soc        |
|               | **.506**“ adult rec w    | **.374**“ adult rec        |
|               | **.431**“ child sport w  | **.290**“ child sport      |
|               | **.453**“ teen sport w   | **.322**“ teen sport       |
|               | **.516**“ teen soc w     | **.437**“ teen soc         |
|               | **.135**“ all w          | **.138**“ all w            |
The results of modelling

| NQPD          | Activities/users weighted | Activities/users not weighted |
|---------------|---------------------------|-------------------------------|
| Kaunas2016 radius n | 0.306** adult sport w     | 0.283** adult sport           |
|               | 0.374** adult soc w       | 0.404** adult soc             |
|               | 0.394** adult rec w       | 0.358** adult rec             |
|               | 0.288** child sport w     | 0.237** child sport           |
|               | 0.303** teen sport w      | 0.261** teen sport            |
|               | 0.368** teen soc w        | 0.381** teen soc              |
|               | 0.128** all all w         | 0.130** all all               |

** Correlation is significant at the 0.01 level (2-tailed).

The most important results of calculations:
- Between NQPD with radius 1000 in Kaunas 87 and adults not weighted social activities (+0.494) and all weighted activities of all users (+0.609);
- Between NQPD with radius 5000 in Kaunas 87 and adults not weighted social activities (+0.416) and all weighted activities of all users (+0.562);
- Between NQPD with radius n in Kaunas 87 and adult weighted recreational activities (+0.460);
- Between NQPD with radius 1000 in Kaunas 2016 and adults not weighted social activities (+0.503) and the weighted ones (+0.609);
- Between NQPD with radius 5000 in Kaunas 2016 and adults not weighted social activities (+0.458) and weighted social activities of teens (+0.516).

Few interesting aspects related to NQPD correlations could be mentioned here:
- In essence, stronger correlations if compared to MCD were found – in some cases even strong ones in both weighted and not weighted activities.
- It is interesting that no correlations were found in Kaunas 1939 while MCD demonstrated even moderate ones with all activities of all users. It could be related to the even structure of public spaces in Kaunas in this period and densifications of the pedestrian networks in modernistic urbanism because of separation of car and pedestrian flows. This explanation could be supported by the found strongest correlations between users/activities and NQPD at the lowest radiuses in 1897 and 2016. For the final conclusion, it will be important to see similar correlations in angular segment analysis later as way to find the shortest distance might affect the results.
- It might be worth to pay attention that there are some stronger moderate correlations between NQPD and recreational activities of car users (radius n) in 1987 – it might reflect some of the roles of car usage in the Soviet period.
- In general, some shift from more global to local structure as more important for street activities might be noted in 2016 and 1987.
The third was calculated **betweenness centrality** (BtC) or choice according to Space Syntax terminology. Mathematical value of BtC for a segment x is calculated as a sum of the all shortest journeys between all y segments which choose x as a transit spot. As it was mentioned earlier – in this case, the shortest journey routes are calculated as journey time. The results of calculations are presented in table 5.4.

**Table 5.4. Correlations between BtC and activities/users**

| BtC            | Activities/users weighted | Activities/users not weighted |
|----------------|---------------------------|-------------------------------|
| **Kaunas87 radius 5000** |                           |                               |
| .139” all all w | .120” all all             |                               |
| .129” adult sport w | .099” adult sport        |                               |
| .155” adult soc w | .145” adult soc           |                               |
| .147” adult rec w | .132” adult rec           |                               |
| .105” child sport w | .038” child sport         |                               |
| .105” teen sport w | .038” teen sport          |                               |
| .129” teen soc w | .111” teen soc            |                               |
| **Kaunas87 radius n** |                           |                               |
| .015” all all w | .047” all all             |                               |
| .020” adult sport w | .055” adult sport        |                               |
| .018” adult soc w | .038” adult soc           |                               |
| .029” adult rec w | .063” adult rec           |                               |
| .005 child sport w | .038” child sport         |                               |
| .005 teen sport w | .039” teen sport          |                               |
| .004 teen soc w | .025” teen soc            |                               |
| **Kaunas87 radius 1000** |                           |                               |
| .365” all all w | .296” all all             |                               |
| .370” adult sport w | .263” adult sport        |                               |
| **.372** adult soc w | **.344** adult soc       |                               |
| .366” adult rec w | .299” adult rec           |                               |
| .336” child sport w | .140” child sport         |                               |
| .336” teen sport w | .140” teen sport          |                               |
| .332” teen soc w | .278” teen soc            |                               |
| **Kaunas39 radius 1000** |                           |                               |
| .194” all all w | .104” all all             |                               |
| .239” adult sport w | .120” adult sport        |                               |
| .148” adult soc w | .109” adult soc           |                               |
| .214” adult rec w | .082” adult rec           |                               |
| .216” child sport w | .014” child sport         |                               |
| **.262** teen sport w | **.181** teen sport       |                               |
| .153” teen soc w |                               |                               |
| **Kaunas39 radius 4000** |                           |                               |
| .100” all all w | .018 all all              |                               |
| .064” adult sport w | -.033” adult sport       |                               |
| .107” adult soc w | .074” adult soc           |                               |
| .105” adult rec w | .009 adult rec            |                               |
| .020 child sport w | -.113” child sport        |                               |
| .056” teen sport w | -.034” teen sport         |                               |
| .141” teen soc w | .106” teen soc            |                               |
The results of modelling

| BtC        | Activities/users weighted | Activities/users not weighted |
|------------|---------------------------|------------------------------|
| Kaunas2016 radius 1000 | 0.300** adult sport w, 0.356** adult soc w, 0.285** adult rec w, 0.300** teen sport w, 0.353** teen soc w, 0.165** all all w | 0.231** adult sport, 0.314** adult soc, 0.263** adult rec, 0.200** teen sport, 0.220** teen sport, 0.301** teen soc, 0.157** all all |
| Kaunas2016 radius 5000 | 0.050** adult sport w, 0.122** adult soc w, 0.075** adult rec w, 0.014** teen sport w, 0.113** teen soc w, 0.025** all all w | 0.050**adult sport, 0.101**adult soc, 0.081**adult rec, 0.027**teen sport, 0.049**teen soc, 0.026**all all |
| Kaunas2016 radius n | -0.013** adult sport w, 0.027** adult soc w, 0.011** adult rec w, -0.030** teen sport w, -0.014** teen soc w, 0.025** teen soc w, 0.014** all all w | 0.045** adult sport, 0.112** adult soc, 0.060** adult rec, 0.015** teen sport, 0.039** teen soc, 0.106** teen soc, 0.010** all all |

The most important medium and weak correlations:
- Between BtC with radius 1000 in Kaunas 87 and adults not weighted social activities (+0.344) and all weighted activities of all users (+0.372);
- Between BtC with radius 1000 in Kaunas 39 and teen not weighted social activities (+0.181) and teen sport weighted activities (+0.262);
- Between BtC with radius 1000 in Kaunas 2016 and adult not weighted social activities (+0.314) and adult social weighted activities (+0.356)

The results of BtC analysis show that only the local or pedestrian movement gives more significant weak and moderate correlations with activities of street culture in all periods. These results look very logic in the context of such contemporary urban theories which focus on street culture activations as New Urbanism, Walkable Urbanism, etc.

The fourth calculated indicator is **two phase betweenness** (TPB). It is calculated by the following formula:

587 American Planning Association, *Planning and Urban Design Standards*, New Jersey, John Wiley & Sons, Inc., 2006, p.90, 409-446.
588 Jeff Speck, *Walkable City: How Downtown Can Save America, One Step at a Time*, New York, North Point Press, 2012, p.302.
TPB = \sum_{y \in N} \sum_{z \in R_y} OD(y,z,x) W(z) P(z) / \text{total weight}(y)\[^{589}\]

Where OD is a number of the shortest journeys between all y and z nodes, when x, for which calculation is done, lays between them. Y marks the beginning of a journey and z – its end. Every node in the graph within calculated radius becomes y and z. W(z) – weight of z. P(z) – proportion of z which fall within calculated radius. Total weight (y) – sum of weights of all journey starting segments. Ry – radius. Sum yN - sum of all y within the system with number of node N. Sum Ry - the set of polylines in the network radius from link x. The simple betweenness or BtC just shows the possible number of hypothetical shortest journeys in a graph while TPB could be seen as a kind of gravity betweenness as it shows how the journeys which use x as an interim point and are reaching z, are important in relation to the weight of starting segments. In the conducted modelling all weights were equal to one, so TPB could be considered as a kind of normalization of betweenness centrality. The results are shown in table 5.5.

Table 5.5. Correlations between TPB and activities/users

| TPB              | Activities/users weighted       | Activities/users not weighted |
|------------------|---------------------------------|-------------------------------|
| Kaunas87 radius 5000 | .105** all all w                | .111** all all               |
|                  | .096** adult sport w            | .094** adult sport           |
|                  | .120” adult soc w              | .125” adult soc             |
|                  | .111” adult rec w              | .113” adult rec             |
|                  | .076“ child sport w            | .053” child sport           |
|                  | .076“ teen sport w             | .053” teen sport            |
|                  | .096“ teen soc w               | .102” teen soc              |
| Kaunas87 radius n | .011” all all w                | .048” all all               |
|                  | .016” adult sport w            | .055” adult sport           |
|                  | .014” adult soc w              | .036” adult soc             |
|                  | .025” adult rec w              | .061” adult rec             |
|                  | .003 child sport w             | .043” child sport           |
|                  | .003 teen sport w              | .043” teen sport            |
|                  | .000 teen soc w                | .026” teen soc              |
| Kaunas87 radius 1000 | .234” all all w                | .230” all all               |
|                  | **241 adult sport w            | .212” adult sport           |
|                  | .233” adult soc w              | **244 adult soc             |
|                  | .240” adult rec w              | .233” adult rec             |
|                  | .222” child sport w            | .141” child sport           |
|                  | .222” teen sport w             | .141” teen sport            |
|                  | .206” teen soc w               | .203” teen soc              |

[^589]: Spatial Design Network Analysis (sDNA), Manual in Spatial design network analysis sDNA, [interactive], [accessed on 2019 05 06], https://www.cardiff.ac.uk/sdna/wp-content/downloads/documentation/manual/sDNA_manual_v4_0_2/
| TPB                  | Activities/users weighted | Activities/users not weighted |
|----------------------|---------------------------|------------------------------|
| **Kaunas39 radius 1000** |                           |                              |
|                      | .101** all all w          | .060** all all               |
|                      | .121** adult sport w      | .062** adult sport           |
|                      | .077** adult soc w        | .055** adult soc             |
|                      | .121** adult rec w        | .049** adult rec             |
|                      | .110** child sport w      | .014 child sport             |
|                      | .133** teen sport w       | .075** teen sport            |
|                      | .079** teen soc w         | .089** teen soc              |
| **Kaunas39 radius 4000** |                           |                              |
|                      | .100** all all w          | -.004 all all                |
|                      | .064** adult sport w      | -.048** adult sport          |
|                      | .107** adult soc w        | .044** adult soc             |
|                      | .105** adult rec w        | -.010 adult rec              |
|                      | .020 child sport w        | -.106** child soc            |
|                      | .056** teen sport w       | -.039** teen sport           |
|                      | .141** teen soc w         | .079** teen soc              |
| **Kaunas2016 radius 1000** |                           |                              |
|                      | .164** adult sport w      | .165** adult sport           |
|                      | **205** adult soc w       | **230** adult soc            |
|                      | .204** adult rec w        | .181** adult rec             |
|                      | .153** child sport w      | .142** child sport           |
|                      | .164** teen sport w       | .156** teen sport            |
|                      | .203** teen soc w         | .221** teen soc              |
|                      | .094** all all w          | .092** all all               |
| **Kaunas2016 radius 5000** |                           |                              |
|                      | .021** adult sport w      | .046** adult sport           |
|                      | .070** adult soc w        | .118** adult soc             |
|                      | .048** adult rec w        | .065** adult rec             |
|                      | .000 child i sport w      | .013** child sport           |
|                      | .020** teen sport w       | .039** teen sport            |
|                      | .066** teen soc w         | .109** teen soc              |
|                      | .014** all all w          | .013** all all               |
| **Kaunas2016 radius n** |                           |                              |
|                      | .021** adult sport w      | .045** adult sport           |
|                      | .070** adult soc w        | .112** adult soc             |
|                      | .048** adult rec w        | .060** adult rec             |
|                      | .000 child sport w        | .015** child sport           |
|                      | .020** teen sport w       | .039** teen sport            |
|                      | .066** teen soc w         | .106** teen soc              |
|                      | .014** all all w          | .010* all all                |
The following correlations could be noted as the most important in TPB analysis:

- Between TPB with radius 1000 in Kaunas 87 and adult not weighted social activities (+0.244) and weighted adult sports activities (+0.241);
- Between TPB with radius 1000 in Kaunas 2016 and adult not weighted social activities (+0.230) and the same weighted indicator (+0.205);

In general, TPB confirms the tendencies demonstrated by BtC – the local movement gives slightly stronger correlations with street culture in 1987 and 2016. As it was mentioned, it might be related to separation and specialization of movement routes in modernistic urbanism. Another preliminary guess might be related to the possible fact that car oriented modernistic urbanization created a lot of alternative competing movement routes thus weakening dependency between various transits in a city. This explanation could be checked just with a bigger number of cities investigated, including both modernistic and non-modernistic ones. The indicator of the degree of competition or existence of a big number of alternative routes of relatively similar length might be lower ration between BtC max and mean values.

The fifth calculates centrality is called **two phase destination** (TPD). It is calculated according to the following formula:

$$TPB = \sum_{y \in N} \sum_{x \in R_y} W(x)P(x) / \text{total weight}(y)$$

$W(x) =$ weight of $x$ as transit segment for which calculation is conducted. $P(x) =$ proportion of $x$ that fall within radius $R$. Total weight(y) is a sum of the weights of all starting segments $fo all journeys$. Sum $y \in N$ is a sum of all $y$ within the system with number of node $N$. Sum $x \in R_y$ is a set of segments in the network within radius $R$. The essential difference if compare with TPB is that TPD reflects weight of the calculated transit space in comparison to the weight or number, if weight is equal to one as in our case, of the starting points of all journeys while TPB shows the ratios of the weight of the destinations of the journeys in relation to the total weight of the starting points of all travels. To make it more simple to understand a simple example could be presented: the bigger TPB will be if a segment $x$ lays on the shortest route to a bigger number and weightier destinations (e.g. longer, more densely populates or simply more numerous if weight is equal to one as in our case); the bigger TPD will be if a segment $x$ has a bigger weight by itself or more journeys starting from $y$ go through $x$. Thus TPD reflects the importance of transit point in the movement while TPB focuses on importance of destination. The found correlations are presented in table 5.6.

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590 Spatial Design Network Analysis (sDNA), *Manual in Spatial design network analysis sDNA*, [interactive], [accessed on 2019 05 06], https://www.cardiff.ac.uk/sdna/wp-content/downloads/documentation/manual/sDNA_manual_v4_0_2/
### Table 5.6. Correlations between TPD and activities/users

| TPD                          | Activities/users weighted                      | Activities/users not weighted                   |
|-------------------------------|------------------------------------------------|------------------------------------------------|
| Kaunas87 radius 5000          | .285** all all w                               | .228** all all                                  |
|                               | .292** adult sport w                           | .214** adult sport                              |
|                               | .264** adult soc w                             | .213** adult soc                                |
|                               | .280** adult rec w                             | .233** adult rec                                |
|                               | .291** child sport w                           | .163** child sport                              |
|                               | .291** teen sport w                            | .163** teen sport                               |
|                               | .260** teen soc w                              | .200**teen soc                                  |
| Kaunas87 radius n             | .196** all all w                               | .178** all all w                                |
|                               | .201** adult sport w                           | .166** adult sport                              |
|                               | .184** adult soc w                             | .178** adult soc                                |
|                               | .189** adult rec w                             | .177** adult rec                                |
|                               | .202** child sport w                           | .119** child sport                              |
|                               | .202** teen sport w                            | .119** teen sport                               |
|                               | .180** teen soc w                              | .160**teen soc                                  |
| Kaunas87 radius 1000          | .248** all all w                               | .229** all all                                  |
|                               | .249** adult sport w                           | .209**adult sport                               |
|                               | .236** adult soc w                             | .226** adult soc                                |
|                               | .235** adult rec w                             | .214**adult rec                                 |
|                               | .251** child sport w                           | .167** child sport                              |
|                               | .251** teen sport w                            | .168** teen sport                               |
|                               | .231** teen soc w                              | .215**teen soc                                  |
| Kaunas39 radius 1000          | .037** all all w                               | .043** all all                                  |
|                               | .064** adult sport w                           | .060**adult sport                               |
|                               | .028** adult soc w                             | .022* adult soc                                 |
|                               | .022* adult rec w                              | -.006 adult rec                                 |
|                               | .051** child sport w                           | .054**child sport                               |
|                               | .082** teen sport w                            | .126** teen sport                               |
|                               | .036**teen soc w                               | .063**teen soc                                  |
| Kaunas39 radius 4000          | .272** all all w                               | .086** all all                                  |
|                               | .271** adult sport w                           | .034**adult sport                               |
|                               | .297** adult soc w                             | .216**adult soc                                 |
|                               | .270** adult rec w                             | .029**adult rec                                 |
|                               | .218** child sport w                           | -.085** child sport                             |
|                               | .179** teen sport w                            | -.049** teen sport                              |
|                               | .070** teen soc w                              | .019 teen soc                                   |
| Kaunas2016 radius 1000        | .132** adult sport w                           | .156** adult sport                              |
|                               | .159** adult soc w                             | .197** adult soc                                |
|                               | .166** adult rec w                             | .197**adult rec                                 |
|                               | .131** child sport w                           | .148** child sport                              |
|                               | .134** teen sport w                            | .153** teen sport                               |
|                               | .160** teen soc w                              | .194**teen soc                                  |
|                               | .046** all all w                               | .021** all all                                  |
The following correlations could be noted as the most important in TPB analysis:

- Between TPD with radius 5000 in Kaunas 87 and all not weighted activities of all users (+0.228) and weighted adult sports activities (+0.292);
- Between TPD with radius 1000 in Kaunas 87 and all not weighted activities of all users (+0.229) and weighted adult sports activities (+0.242), all activities of all users (+0.248), child and teen sports activities (+0.251);
- Between TPD with radius 4000 in Kaunas 39 and not weighted adult soc activities (+0.216) and weighted adult recreational activities (+0.297);
- Between TPD with radius 5000 in Kaunas 2016 and not weighted adult soc activities (+0.348) and weighted adult recreational activities (+0.335).

It should be pointed out that the public transport network is the most important for TPD in all three periods – it might mean that relatively more times chosen transit street segments in relation to the number of journeys more correlate to various street culture activities. As public transport concentrates those choices, then the result shows effectiveness of public transport network and, having in mind a smaller number of available data for the period before the World War 2, especially in 1939. At the moment it is hard to explain relatively higher correlations in TPB and TPD context for radius 1000 in Kaunas 1987.

The sixths and the last centrality which was analyzed in the first network model is called **length in radius** (Len). It is exactly the same as metric reach in Space syntax. According to John Peponis, metric reach or Len is directly related to more active
The results of modelling unplanned social contact in public spaces or street culture. Mathematically Len is calculated as a length of streets reachable within a specified radius from segment x, for which calculation is made. Investigation in Space Syntax demonstrates that similar values of metric reach tend to cluster together thus catalyzing appearance of informal neighbourhood spaces. Because with the radius n Len will identical for a whole network so it is calculated just with smaller radiiuses. Calculated correlations are presented in table 5.7.

Table 5.7. Correlations between Len and activities/users

| Len                 | Activities/users weighted | Activities/users not weighted |
|---------------------|---------------------------|-------------------------------|
| Kaunas87 radius 5000| .548** all all w          | 288** all all                 |
|                     | .548” adult sport w       | .235” adult sport            |
|                     | .521” adult soc w         | .362” adult soc              |
|                     | .537” adult rec w         | .338” adult rec              |
|                     | .530” child sport w       | .028” child sport            |
|                     | .530” teen sport w        | .028” teen sport             |
|                     | .517” teen soc w          | .296” teen soc               |
| Kaunas87 radius 1000| .667** all all w          | .430” all all                |
|                     | .656” adult sport w       | .356” adult sport            |
|                     | .648” adult soc w         | .492** adult soc             |
|                     | .623” adult rec w         | .411” adult rec              |
|                     | .651” child sport w       | .187” child sport            |
|                     | .651” teen sport w        | .188” teen sport             |
|                     | .647” teen soc w          | .454” teen soc               |
| Kaunas39 radius 1000| .365” all all w           | .192” all all                |
|                     | .407” adult sport w       | .180” adult sport            |
|                     | .306” adult soc w         | .270** adult soc             |
|                     | .416** adult rec w        | .169” adult rec              |
|                     | .377” child sport w       | -.037” child sport           |
|                     | .385” teen sport w        | .108” teen sport             |
|                     | .209” teen soc w          | .267” teen soc               |

591 John Peponis, Sonit Bafna, Zongyu Zhang, “The Connectivity of Streets: Reach and Directional Distance”, in: Environment and Planning B: Urban Analytics and City Science Environment and Planning B: Planning and Design, Volume: 35 issue: 5, 2008, p.881-901.

592 Kinda Al Sayed, Space Syntax Methodology, Bartlett School of Architecture, UCL, 2018, p.88-89.
The following correlations could be noted as the most important in TPB analysis:
- Between Len with radius 5000 in Kaunas 87 and all not weighted activities of all users (+0.288) and the same weighted activities (+0.548);
- Between Len with radius 1000 in Kaunas 87 and adult soc activities (+0.492) and all weighted activities of all users (+0.667);
- Between Len with radius 1000 in Kaunas 39 and adult soc activities (+0.270) and weighted recreational activities of adults (+0.416);
- Between Len with radius 1000 in Kaunas 39 and adult soc activities (+0.343) and weighted recreational activities of adults (+0.408);
- Between Len with radius 1000 in Kaunas 2016 and adult soc activities (+0.529) and the same weighted activities (+0.655);
- Between Len with radius 5000 in Kaunas 2016 and adult soc activities (+0.457) and the same weighted activities (+0.500).

While analyzing Len correlations, it could be stated the following:
- Len gives the strongest correlations from all centralities in the first model. It allows to say preliminarily that street culture depends more on clustered network of spaces which act as catalyzers of opportunities but not on hierarchically, in terms of reachability or transit, important areas of a network.
In Kaunas 2016 and 2019 Len with a pedestrian radius gives the best correlation with a street culture while in 1939 the public transport might play a more significant role here thus making a street and public spaces network more integrated continues and hierarchical. As well it might demonstrate the process of horizontal fragmentation of modernistic city as a whole in terms of street culture.

The **final step in the first syntactic model analysis** presents an attempt to combine the above presented centralities in order to get better correlations with the content analysis results. The combination approach was based on either multiplication or division of the numerical values of calculated centralities while combining local (radius 1000) and global (radiuses 5000, 4000, n), just local or just global syntactic values. The aim was to find the combination of the indicators which gives a better correlation if compared to single centralities and the results of content analysis. One idea was in addition to multiplication raise the multiplied numbers by a degree thus reflecting real percentage of city inhabitants using a precise transportation mode but only the Eurostat very general data on Lithuania was available which stated how many people every day use individual car, public transport and walk or bike. Because of the lack of more precise data and initial tests which gave no better results than unweighted multiplication this idea was put to aside.

In the investigated case of Kaunas, the new correlations have to exceed the following numbers:
- 0.341 for not weighted activities and 0.381 for weighted ones in Kaunas 39;
- Accordingly, 0.494 and 0.667 for Kaunas 87;
- 0.529 and 0.655 for Kaunas 2016.

The best results were reviewed while using the following different formulas for different periods:
- Len 1000*Len4000 / MCD4000 for both weighted and unweighted activities/users in Kaunas 39
- Len 1000*Len5000 / MCD5000 for weighted and Len1000 / MCD1000 for unweighted data on Kaunas 87;
- Len1000 / MCD1000 for both weighted and unweighted data in Kaunas 2016.

The results of calculations with some additional data are presented in table 5.8.
Transformations of the Network on Public Spaces and its Relations to Spatial Social Content

Table 5.8. The best found correlations between combined syntactic indicators and the usage of public spaces. The combined index which was the most appropriate for one period was as well checked in the two other periods in order to check its transformation over time. The best found correlations are in bold. The strongest correlations (marked by bolt) were found with social activities of adults with some exceptions. In the case of exception, it is additionally marked in the table.

| Formula | 1939 weighted | 1939 not weighted | 1987 weighted | 1987 not weighted | 2016 weighted | 2016 not weighted |
|---------|---------------|------------------|---------------|------------------|---------------|------------------|
| Len 1000*Len4000 / MCD4000 (for 1939) | 0.477 | 0.366 | 0.700 (all activities by all users) | 0.458 | 0.600 | 0.482 |
| Len 1000*Len5000 / MCD5000 (for 1987 and 2016) | 0.440 Adult soc | 0.262 | 0.685 (all) | 0.500 | 0.654 | 0.544 |
| Len1000 /MCD1000 | 0.318 adult soc | | | | |
| Max correlation values with a single centrality which has to be exceeded | 0.381 | 0.341 | 0.667 | 0.494 | 0.655 | 0.529 |
| R squared between combined value and the best correlating indicator | 0.227 | 0.134 | 0.458 | 0.250 | 0.428 | 0.285 |

While looking at the summarizing table, few important preliminary conclusions could be given:

- In essence, the approach works quite well with the exception of weighted data in Kaunas 2016. Various combinations of indicators were tested but no stronger correlations were found.
- While looking diachronically it could be noted that each period has its own best combined index thus demonstrating the change of dependencies between spatial configurations and street culture. In general, modernistic urban transformations could be related to fragmentations of urban body in terms of activities in public spaces and lost role of multi-modality for it. It could be clearly seen if the formulas of 1939 and 2016 are compared: the first one combines both local and global indicators, while the second one – just local. The situation of 1987 could be seen as an interim stage as correlations, based on different formulas, exceed required values. More hierarchically integrated spatial-social structure of Kaunas 1939 could be explained by more center oriented public transport network in this period and more developed, less concentrated on one are, more alternatives giving bus and trolleybus network in 1987 and 2016.
The results of modelling

- Stronger correlations in 1987 and 2019 if compared to 1939 are noted. It could be explained in two ways: a smaller amount of data in 1939 or shift from dominance of obligatory functions to optional ones as it was found and described in chapter 3. According to Gehl\(^{593}\) obligatory activities in public spaces are unavoidable everywhere (e.g. going to a shop) and thus, could be treated as less dependable on spatial configurations. Optional activities as recreational walking, sitting in a street café, etc. could be seen as more dependent on spatial urban configurations.

- Because correlations do not show direct dependency between two variables, then the regression coefficient R squared was calculated in order to check if street culture intensity could be predicted on the base of combined syntactic features. If the weighted data is used, then the results varied from 0.227 in 1939 to 0.458 in 1987 and 0.428 in 2016. These values are moderate, but enough to additionally confirm relations between spatial urban features and social-cultural content of spaces. From another perspective it would even be not realistic to expect very high R squared just on base of spatial features because even if thought very important they make just one layer in a complex urban system.

- The formulas itself confirm premise by John Peponis, that higher metric reach or Len, in this case, corresponds to zones of higher social interactions in street network\(^{594}\) – this indicator is present in all formulas. Quite interesting as absence of choice in the effective calculations. It might mean that the investigated street networks are dense and homogenous enough to present a big number of the alternative shortest routes. If it is true it will be checked later when the generic city model of three cities will be analyzed.

The final maps with the centralities which gave the best correlations are presented in figures 5.2, 5.3, 5.4.

Kaunas map 1939 (Fig. 5.2.) demonstrates homogenous and integrated more active zones of street culture. They cover historical city center, the main streets, part of the main park and some local centers in Zemieji Sanciai, Aleksotas and Vilijampole. All three places are known as nodes of activities: local market; river port with yacht club; specific historical Jewish neighbourhood.

Both maps of Kaunas 1987 (Fig.5.3, 5.4.), if compared to situation 1939 demonstrate more fragmented pattern without clear center and much focused on functionally segregated modernistic housing areas – in terms of geographical city patterns it could be named as a shift from concentric to multi-nuclei model. The same tendency is seen in Kaunas 2016 (Fig. 5.5.)

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\(^{593}\) Jan Gehl, Cities for People, London: Island Press, 2010.

\(^{594}\) John Peponis, Sonit Bafna, Zongyu Zhang, “The Connectivity of Streets: Reach and Directional Distance”, in: Environment and Planning B: Urban Analytics and City Science Environment and Planning B: Planning and Design, Volume: 35 issue: 5, 2008, p.881-901.
Fig. 5. 2. Kaunas1939: Len 1000*Len4000/MCD4000. Red colour shows the biggest numerical values.

Fig. 5. 3. Kaunas1987: Len 1000 / MCD1000. Red colour shows the biggest numerical values.
Now the results of the analysis of the first syntactic model, which was based on time-distance calculations and was directly focused on multi-modality of movement in a city, will be compared with more traditional for Space Syntax Angular Segment analysis or so called the second syntactic model of the presented research. Multi-modality on movement in it is reflected indirectly through the optimal movement radiuses. Model construction while using both pedestrian and car routes are based on the premise that differences in two types of logistic public spaces will be reflected, while calculating the shortest angular routes, because of the essentially higher angular depth of pedestrian paths.

Fig. 5.4. Kaunas1987: Len 1000 Len5000 MCD5000. Red colour shows the biggest numerical values.
The following indicators were calculated for further analysis:

- Metric reach with is equal to Len and was explained earlier. This indicator in the first model demonstrated the best correlations with higher diversity of activities and number of users.

- Angular segment choice (ACH) which is calculated for segment x in a similar way as metric choice – as a sum of all the shortest journeys from all y to all z which go through x. The essential difference – the shortest route is found on the base of the smallest accumulated angle of changes of movement direction. In Space syntax calculations choice of dead end streets is always equal to zero as the x could not be equal to y or z – it means Ach is not calculated for the starting or endpoint of a journey.
Angular integration which identifies zones with a highest degree of symmetry in a network of public spaces with all the generated consequences as higher diversity of users and uses, density of objects, etc. Angular segment integration is calculated according to the following formula:

\[ AI = \frac{n}{AMD} = \frac{n}{(ATD / n)} = \frac{n^2}{ATD} \]

Here \( n \) marks a node or segment count within identified radius; AMD means angular mean depth counted as a sum of the shortest distances (Angular total depth or ATD) from \( x \) to all other nodes divided by the number of those nodes or \( n-1 \).

Embeddedness is calculated by the following formula:

\[ Ebd = \ln \left( \frac{n_k}{n_m} \right) \text{ when } k > m. \]

\( N \) represents the node count in a graph, \( k \) and \( m \) – two different radiuses. By Space Syntax online training platform this indicator is described as “Embeddedness measures the degree to which a space is spatially embedded into the contexts with increasing radius. It is defined as the rate of change in node count, based on either axial or segment representations. It seeks to investigate how the spatial structure of a city is organized at different scales, varying from connecting one street with its immediately surrounding streets to aggregating all the streets into a well-structured city as a whole.”

The same radiuses were used as during the analysis of the first models: 1000, 4000/5000 and \( n \).

The correlations between the calculated centralities and both weighted and not weighted activities/users are presented in tables 5.9, 5.10, 5.11.

The strongest correlations were found between \( A_in4000 \) and weighted adult social and recreational activities (0.415 and 0.421); between \( A_in4000 \) and adult not weighted social activities (0.363); between \( A_in1000 \) and weighted teen sports (0.463); between \( M_R1000 \) and weighted adult sports activities (0.423). Good correlations could be noted between various activities and \( A_in \) thus reflecting relatively small size of the city.

In general, they confirm importance of \( A_in \) 4000, \( A_in \) 1000 and \( M_R \) 1000 as the indicators which are the most either directly or indirectly related to social/cultural content of public spaces. It confirms the results of the first model received during analysis of Kaunas 1939.

As the strongest correlations in 1987 could be mentioned the following: \( M_R1000 \) and all weighted activities by all users (0.661) and not weighted activities by adults (0.501); \( A_in1000 \) and both weighted and not weighted adult social activities (0.547 and 0.512). These results, in essence, confirm the shift to stronger relation between street culture and local syntactic indicators in modernistic Kaunas as identified in the first model.

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595 Tao Yang, Bill Hillier, “The fuzzy boundary: the spatial definition of urban areas”, in: The Proceedings of 6th International Space Syntax Symposium, 2007, p.091:08-091:16;
### Table 5.9. Correlations between syntactic indicators and users/activities in Kaunas 1939

| Indicator | Activities/users weighted | Activities/users not weighted |
|-----------|---------------------------|-------------------------------|
| ACh 1000  |                           |                               |
| ACh1000   | .194** all all w          | .102** all all                |
|           | .231** adult sport w      | .107** adult sport            |
|           | .152** adult soc w        | .118** adult soc              |
|           | .218** adult rec w        | .089** adult rec              |
|           | .207** child sport w      | -.003 child sport             |
|           | .244** teen sport w       | .101** teen sport             |
|           | .149** teen soc w         | .175** teen soc               |
| ACh4000   | .104** all all w          | .019 all all                  |
|           | .086** adult sport w      | -.014 adult sport             |
|           | .122** adult soc w        | .092** adult soc              |
|           | .105** adult rec w        | .004 adult rec                |
|           | .038** child sport w      | -.099** child sport           |
|           | .067** teen sport w       | -.024** teen sport            |
|           | .099** teen soc w         | .084** teen soc               |
| Ach n     | .036** all all w          | -.055** all all               |
|           | .013 adult sport w        | -.082** adult sport           |
|           | .069** adult soc w        | .019 adult soc                |
|           | .028** adult rec w        | -.056** adult rec             |
|           | -.022** child sport w     | -.129** child sport           |
|           | -.011 teen sport w        | -.081** teen sport            |
|           | .029** teen soc w         | .006 teen soc                 |
| Ebd       | -.144** all all w         | -.046** all all               |
|           | -.205** adult sport w     | -.066** adult sport           |
|           | -.058** adult soc w       | -.015 adult soc               |
|           | -.164** adult rec w       | -.047** adult rec             |
|           | -.249** child sport w     | -.017 child sport             |
|           | -.274** teen sport w      | -.131** teen sport            |
|           | -.104** teen soc w        | -.166** teen soc              |
| AIn 1000  | .391** all all w          | .198** all all                |
|           | .443** adult sport w      | .188** adult sport            |
|           | .325** adult soc w        | .264** adult soc              |
|           | .427** adult rec w        | .138** adult rec              |
|           | .410** child sport w      | -.007 child sport             |
|           | **463** teen sport w      | .180** teen sport             |
|           | .269** teen soc w         | .319** teen soc               |
### Table 5.10. Correlations between syntactic indicators and users/activities in Kaunas 1987

| Indicator | Activities/users weighted | Activities/users not weighted |
|-----------|---------------------------|-------------------------------|
| **AIn 4000** | .384** all all w | .184** all all |
|           | .369** adult sport w | .118** adult sport |
|           | **.415** adult soc w | **.363** adult soc |
|           | **.421** adult rec w | .147** adult rec |
|           | .266** child sport w | -.130** child sport |
|           | .249** teen sport w | -.042** teen sport |
|           | **.175** teen soc w | **.146** teen soc |
| **AIn n** | .355** all all w | .144** all all |
|           | .318** adult sport w | .048** adult sport |
|           | .390** adult soc w | .310** adult soc |
|           | .368** adult rec w | .082** adult rec |
|           | .250** child sport w | -.105** child sport |
|           | **.207** teen sport w | **.075** teen sport |
|           | **.126** teen soc w | **.058** teen soc |
| **MR 1000** | **.377** all all w | **.198** all all |
|           | **.423** adult sport w | **.186** adult sport |
|           | .314** adult soc w | .273** adult soc |
|           | **.426** adult rec w | **.168** adult rec |
|           | .396** child sport w | -.029** child sport |
|           | .405** teen sport w | .121** teen sport |
|           | **.216** teen soc w | **.278** teen soc |
| Indicator | Activities/users weighted | Activities/users not weighted |
|-----------|---------------------------|-------------------------------|
| Aln n     |                           |                               |
|           | .361** all all w          | .278** all all               |
|           | .353** adult sport w      | .208** adult sport           |
|           | .364** adult soc w        | .351** adult soc             |
|           | .354** adult rec w        | .268** adult rec             |
|           | .333** child sport w      | .075** child sport           |
|           | .334** teen sport w       | .076** teen sport            |
|           | .337** teen soc w         | .302** teen soc              |
| Aln 5000  |                           |                               |
|           | .527** all all w          | .337** all all               |
|           | .528** adult sport w      | .278** adult sport           |
|           | .506** adult soc w        | .408** adult soc             |
|           | .522** adult rec w        | .374** adult rec             |
|           | .507** child sport w      | .079** child sport           |
|           | .507** teen sport w       | .079** teen sport            |
|           | .489** teen soc w         | .337** teen soc              |
| Aln1000   |                           |                               |
|           | .539** all all w          | .432 all all                 |
|           | .546** adult sport w      | .379** adult sport           |
|           | **547** adult soc w       | **512** adult soc            |
|           | .531** adult rec w        | .431** adult rec             |
|           | .503** child sport w      | .184** child sport           |
|           | .504** teen sport w       | .184** teen sport            |
|           | .501** teen soc w         | .425** teen soc              |
| Ebd       |                           |                               |
|           | -.242** all all w         | -.219** all all              |
|           | -.235** adult sport w     | -.193** adult sport          |
|           | -.239** adult soc w       | -.195** adult soc            |
|           | -.214** adult rec w       | -.167** adult rec            |
|           | -.240** child sport w     | -.204** child sport          |
|           | -.240** teen sport w      | -.204** teen sport           |
|           | -.240** teen soc w        | -.219** teen soc             |
| ACh5000   |                           |                               |
|           | .140** all all w          | .172** all all               |
|           | .134** adult sport w      | .140** adult sport           |
|           | .157** adult soc w        | .196** adult soc             |
|           | .161** adult rec w        | .193** adult rec             |
|           | .102** child sport w      | .069** child sport           |
|           | .101** teen sport w       | .069** teen sport            |
|           | .120** teen soc w         | .153** teen soc              |
| Ach n     |                           |                               |
|           | .041** all all w          | .114** all all               |
|           | .022** adult sport w      | .070** adult sport           |
|           | .064** adult soc w        | .131** adult soc             |
|           | .051** adult rec w        | .103** adult rec             |
|           | .006 child sport w        | .056** child sport           |
|           | .005 teen sport w         | .056** teen sport            |
|           | .040** teen soc w         | .120** teen soc              |
The results of modelling

Table 5.11. Correlations between syntactic indicators and users/activities in Kaunas 2016

| Indicators | Activities/users weighted | Activities/users not weighted |
|------------|---------------------------|-------------------------------|
| Ach n      | -0.007 adult sport w      | 0.045** adult sport           |
|            | 0.014** adult soc w        | 0.081** adult soc             |
|            | -0.024** adult rec w       | 0.009* adult rec              |
|            | -0.034** child sport w     | 0.007 child sport             |
|            | -0.007 teen sport w        | 0.042** teen sport            |
|            | 0.014** teen soc w         | 0.080** teen soc              |
|            | 0.018** all all w          | 0.014** all all               |
| Ach 5000   | 0.064** adult sport w      | 0.077** adult sport           |
|            | 0.116** adult soc w        | 0.152** adult soc             |
|            | 0.103** adult rec w        | 0.103** adult rec             |
|            | 0.042** child sport w      | 0.039** child sport           |
|            | 0.064** teen sport w       | 0.072** teen sport            |
|            | 0.115** teen soc w         | 0.147** teen soc              |
|            | 0.077** all all w          | 0.066** all all               |
| Ach 1000   | 0.193** adult sport w      | 0.359** adult sport           |
|            | 0.256** adult soc w        | 0.443** adult soc             |
|            | 0.261** adult rec w        | 0.416** adult rec             |
|            | 0.179** child sport w      | 0.323** child sport           |
|            | 0.192** teen sport w       | 0.340** teen sport            |
|            | 0.252** teen soc w         | 0.425** teen soc              |
|            | 0.168** all all w          | 0.156** all all               |
| Ebd        | -0.300** adult sport w     | -0.137** adult sport          |
|            | -0.327** adult soc w       | -0.189** adult soc            |
|            | -0.321** adult rec w       | -0.142** adult rec            |
|            | -0.295** child sport w     | -0.117** child sport          |
|            | -0.301** teen sport w      | -0.125** teen sport           |
|            | -0.326** teen soc w        | -0.177** teen soc             |
|            | -0.090** all all w         | -0.074** all all              |
| Aln1000    | 0.466** adult sport w      | 0.363** adult sport           |
|            | 0.543** adult soc w        | 0.492** adult soc             |
|            | 0.542** adult rec w        | 0.403** adult rec             |
|            | 0.650** child sport w      | 0.319** child sport           |
|            | 0.466** teen sport w       | 0.341** teen sport            |
|            | 0.538** teen soc w         | 0.469** teen soc              |
|            | 0.211** all all w          | 0.189** all all               |
| Indicators | Activities/users weighted                | Activities/users not weighted       |
|-----------|----------------------------------------|-------------------------------------|
| AIn5000   | **462** adult sport w                  | **357** adult sport                 |
|           | **520** adult soc w                    | **459** adult soc                   |
|           | **534** adult rec w                    | **398** adult rec                   |
|           | **443** child sport w                  | **311** child sport                 |
|           | **461** teen sport w                   | **336** teen sport                  |
|           | **517** teen soc w                     | **441** teen soc                    |
|           | **137** all all w                      | **134** all all                     |
| AIn n     | **174** adult sport w                  | **152** adult sport                 |
|           | **227** adult soc w                    | **250** adult soc                   |
|           | **205** adult rec w                    | **133** adult rec                   |
|           | **155** child sport w                  | **119** child sport                 |
|           | **174** teen sport w                   | **143** teen sport                  |
|           | **226** teen soc w                     | **241** teen soc                    |
|           | **074** all all w                      | **062** all all                     |
| MR1000    | **602** adult sport w                  | **434** adult sport                 |
|           | **656** adult soc w                    | **527** adult soc                   |
|           | **650** adult rec w                    | **439** adult rec                   |
|           | **592** child sport w                  | **396** child sport                 |
|           | **604** teen sport w                   | **413** teen sport                  |
|           | **654** teen soc w                     | **508** teen soc                    |
|           | **167** all all w                      | **158** all all                     |

In Kaunas 2016 the strongest correlations were found between Ain1000 and both weighted and not weighted adult social activities (0.543 and 0.492); between Ain5000 and weighted adult recreational activities (0.534) and not weighted adult social activities (0.459); between MR1000 and both weighted and not weighted adult social activities (0.656 and 0.527). These results confirm the tendency identified in 1897 while using angular segment analysis and 1987/2016 results of the first model: in all cases, the importance of local syntactic features is increasing while global decreasing thus confirming the conclusion about fragmentations of social/spatial body of a city. It could be noted that this effect is noted in both new modernistic and old historical parts of the city.

The search for a combined syntactic features was made in a similar way as in the first model – various combinations of a single centralities were tested against the data of content analysis. The analogues variants of combinations of single syntactic indicators were tested as in the case of the first model. The following could be mentioned: MR1000 * In 1000; MR1000 * In 5000; MR1000 * Ch 1000; MR1000 * In5000 * In n; MR1000 * In1000 * In5000 * In n; MR1000/Ebd; In1000*MR1000*In; In5000 * MR1000 *In n; MR1000/ Ebd; etc. The results of the final stage of this modelling are presented in table 5.12.

Table 5.12. The best found correlations between combined syntactic indicators and the usage of public spaces. The combined index which was ground as the most
The results of modelling appropriate for one period was as well checked in the two other periods in order to check its transformation over time. The best found correlations are in bold. The strongest correlations were found with social activities of adults with some exceptions. In the case of exception, it is additionally marked in the table.

| Formula | 1939 weighted | 1939 not weighted | 1987 weighted | 1987 not weighted | 2016 weighted | 2016 not weighted |
|---------|---------------|------------------|---------------|------------------|---------------|------------------|
| ln4000*MRI000*ln (for 1939) | 0.453 | 0.376 | 0.602 | 0.487 | 0.584 | 0.480 |
| ln5000*MRI000*ln (for 1987 and 2016) | 0.391 (Adult rec) | 0.322 (teen soc) | 0.602 | 0.530 | 0.581 | 0.492 |
| ln1000*MRI000 | 0.424 (adult rec) | 0.297 | 0.585 | 0.525 | 0.552 | 0.472 |
| ln1000*MRI000*ln | 0.358 (adult sport) | 0.278 (teen sport) | 0.649 (all all) | 0.505 | 0.658 | 0.544 |

Max correlation values with a single centrality which has to be exceeded

R squared between combined value and the best correlating indicator

0.426 | 0.363 | 0.661 | 0.512 | 0.656 | 0.527A

The result demonstrates that in the second model, the aim to exceed maximal correlations of single syntactic indicators was reached successfully. The results confirm the findings of the first models: increased significance of local spatial features; global impact at a scale of a whole city of modernistic changes; shift from more globally integrated in 1939 to more segregated in 1987 and 2016 city; etc. Do visually expressed patterns demonstrate the same results? They are presented in the figures 5.6., 5.7., 5.8.

While looking at the figures 5.6., 5.7., 5.8 the same patterns as in pictures 5.3., 5.4., 5.5 are recognized. They demonstrate the same diachronic evolution: from concentric patterns of street culture allocation to multi-nuclei model.

In general, it could be clearly stated that both models, even if based on a little graph models demonstrate very similar results and diachronic tendencies. How it could be transferred to Vilnius and Klaipeda?
Fig. 5.6. Kaunas1939: In4000*MR1000*ln. Red colour shows the biggest numerical values.
Fig. 5.7. Kaunas1987: ln1000*MR1000. Red colour shows the biggest numerical values.
5.4 Additional check of a syntactic models

There was no possibility to make GIS allocation of the data of the Content Analysis in Vilnius and Klaipeda as it was made for Kaunas in the presented research. In order to model a transformation of spatial/social street culture patterns in both cities and compare it with Kaunas. The modelling was based on the principles of logical analogy between the three investigated cities. Similarity of the received content analysis results in the three cities in terms of typologies and diachronic transformations; similarities of spatial genotype and its transformations; and similarities in dependencies between spatial configurations and allocation of various functional objects which were not directly investigated in this presented research. The pattern modelling procedure was made in the following steps:
- Comparison of spatial genotypes of the three cities based on usage of normalized angular choice and normalized angular integration.
- Additional test of relations between syntactic models and urban content in all three cities while using additional, independently from the project obtained data.
- Test of the ability to predict allocation of various important objects in three cities based on above mentioned additional data while using AI technologies.
- Test of the AI predictions on allocation of patterns of street culture in Kaunas and prediction for Vilnius and Klaipeda.

**Comparison of the spatial genotypes** is based on the earlier mentioned generic city model and comparison of NAIN and NACH indicators. The essence of the model was described in chapter 5.1. Short reminder: each city is made of foreground and background street networks; foreground represents a city center and is made of the main streets; its features in comparison to another city are described by max NAIN and NACH values; background is made out of shorter housing streets; its features in comparison with another city are described by mean NAIN and NACH values; NACH allows to speak about connectivity of urban network; NAIN describes reachability. In order to have a wider background for comparison the historical data from Chapter 5.2 on the investigated normalized syntactic indicators of the 11 historical cities (table 5.1.) will be used as well. Normalized mean and max values of Kaunas, Klaipeda and Vilnius in 1939, 1987 and 2016 are presented in table 5.13a. It is important to point out that for those calculations a simplified graph of street network was used in order make it easier comparable to the historical cities; it means only the full-fledged streets that can combine both cars and pedestrians were modelled.

**Table 5.13a.** NACH and NAIN values of Kaunas, Vilnius and Klaipeda

|          | NACH max | NACH mean | NAIN max | NAIN mean |
|----------|-----------|-----------|-----------|-----------|
| Kaunas 39          | 1.541     | 0.565     | 0.911     | 0.588     |
| Kaunas 1987        | 1.566     | 0.753     | 1.219     | 0.764     |
| Kaunas 2016        | 1.544     | 0.741     | 1.281     | 0.816     |
| Vilnius 39         | 1.501     | 0.767     | 0.979     | 0.664     |
| Vilnius 90         | 1.508     | 0.768     | 1.040     | 0.668     |
| Vilnius 2016       | 1.514     | 0.777     | 1.100     | 0.713     |
| Klaipeda 39        | 1.602     | 0.898     | 1.369     | 0.827     |
| Klaipeda 90        | 1.570     | 0.783     | 1.418     | 0.865     |
| Klaipeda 2016      | 1.565     | 0.774     | 1.379     | 0.831     |

Diachronically all three cities represent similar dynamics:
- In all three periods three cities have relatively similar NACH max values which fluctuate around mean value of 1.546 with Kaunas being the closest to it, Klaipeda a little exceeding it and Vilnius presenting a little lower values. Differences could be explained by peculiarities of spatial configurations: Klaipeda is the smallest and most
compact while Vilnius represents an organic star shape structure with presence of the islands of urban sprawl. It is important to note that modernistic urbanization and later evolution till 2016 weakens differences between all three cities.

- In the case of NACH mean the differences are biggest in 1939 with Kaunas demonstrating the most segregated logistic background network because of numerous natural boundaries in the form of rivers and river valley slopes. Meanwhile the smallest and the most compact city Klaipeda demonstrates high mean values and the most connected background network. In 1987 and 2016 NACH mean indicators again approach closer to each other and fluctuate between 0.741 and 0.783 thus demonstrating the similar tendencies of transformations.

- NAIN max values which speak about reachability or symmetry degree of a foreground differ a little more – from 1.418 to 0.911. It could be explained by in essence different geographical configuration and sizes of the three cities: Vilnius, being more organic in terms of city plan, in relation to Kaunas and Klaipeda reflects similar situation as medieval Norwich if compared to either Berlin or Kaunas.

- NAIN mean values reflect similar differences as NAIN max, and could be explained by the same differences between more regular and more organic city plans.

If we look at the four-angled star representation, proposed by Hillier596 for easier understanding of the applied model and comparison (Fig. 5.9.), it is relatively clear that in general, generic city patterns presented here could be described as better connected (Higher NACH values) but with variations in terms of reachability or symmetry (NAIN values). As well the significant similarities of the patterns while moving from 1939 to 2016 could be noted. If compared to the short analysis presented in the table 5.1., it could be said that Kaunas, Klaipeda and Vilnius, especially in 1987-2016 fit into one genotypic category of cities with two sub-types in terms of reachability. Is it enough to conclude that the presented spatial genotypes have a similar effect on social-cultural content? The answer could be positive if we see a city as a dynamic complex system which moves to similar or different aims from various starting positions and in different ways, which could be easier described and understood in diachronic models, but the final answer depends on sensitivity of the content to peculiarities of spatial configuration as well. The next test of the relations between spatial peculiarities of street network presented by a simple syntactic model and city content will help to make situation more clear.

596 Bill Hillier, Tao Yang, Alasdair Turner, “Normalising least angle choice in Depthmap and how it opens up new perspectives on the global and local analysis of city space”, in: The Journal of Space Syntax ISSN: 2044-7507 Year: 2012 volume: 3 issue: 2 Online Publication Date: 28 December 2012, p. 155-193.
Fig. 5.9. Four star models of three investigated cities in three periods representing NACH and NAIN values.
In order to check if syntactic models in the investigated cities correlate with another data which was collected independently from the presented investigation but still, at least indirectly is either affected or affects a street culture, the additional modelling was made.

For that purpose, the online GIS data created by HNIT-BALTIC company on allocation of various enterprises in a whole Lithuania was used together with the same model as in the case of comparison of normalized angular syntactic values. The contemporary information about the following enterprises was available: shopping malls and other shops, pharmacy shops, restaurants and cafes, object of logistic infrastructure (e.g. stations), recreational objects (e.g. night clubs, pubs, sport clubs, etc.), hospitals and other medicine establishments, schools and universities, hotels, banks including bankomats, post offices, police offices and embassies. Kaunas 2016 segment map with marked enterprises is presented in Fig. 5.10.

![Fig. 5.10. Kaunas2016: allocation of enterprises. Presence of at least one object close to a segment is marked by red, absence – by green.](image-url)
Initially, angular segment analysis of the graph of street network was performed in Kaunas 2016 and compared against allocation of enterprises. The following options to represent enterprises were chosen: all objects, all objects without educational objects because of possible specific logic of placement of those (e.g. place for kinder garden might be not suitable for a shop); gas stations as a specific, transit oriented objects. In addition, correlations with density of inhabitants were checked. The found correlations are presented in table 5.13b.

|                     | ACh 1000 | ACh 5000 | ACh n | AIN 1000 | AIN 5000 | AIN n | Ebd | Density of inhabitants |
|---------------------|----------|----------|-------|----------|----------|-------|-----|-----------------------|
| Gass stations       | .141**   | .188**   | .090**| .203**   | .241**   | .172**| .019** | .219**                |
| All without schools | .340**   | .300**   | .109**| .445**   | .429**   | .259**| -.051** | .454**                |
| All                 | .369**   | .300**   | .100**| .488**   | .467**   | .263**| -.064** | .522**                |
| Density of inhabitants | .428** | .265**   | .042**| .549**   | .541**   | .237**| -.065** | 1                     |

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The strongest correlations were found between placement of all marked objects and angular segment integration with radius 1000 (Fig. 5.11.); the same integration and density of inhabitants; density of inhabitants and allocations of the objects. It is important to note that the correlations between integration and placement of the objects are the weakest from the three mentioned above. The received results are very important for the conducted investigation because of few aspects. First of all, the found moderate correlation between Ain 1000 and dislocation of important functionally objects in Kaunas supports the general approach of the investigation described in this book. Second – the higher correlations with syntactic features of local radiuses in 2016 indirectly confirm the results received while analyzing spatial patterns of street culture as shows the possible way to improve accuracy of the investigation in the future. Third: strong correlations between density of inhabitants and both local syntactic features and locations of the enterprises prove that the idea to use density as a weight for the results of content analysis is quite logical.

The Ain 1000, even if it might give not the strongest correlations with a similar data in Klaipeda and Vilnius was chosen as an indicator for the experiment with an artificial intelligence. The MatLab Neural Network plugin was used for that purpose.
Neuron network default configuration of two-layer feed forward with sigmoid hidden neurons and linear output neurons was used because of its ability to fit multi-dimensional mapping problems quite well. Ain 1000 was used as an impute data, on which target data, allocation of enterprises, were predicted after in Kaunas, Vilnius and Klaipeda. The Neural Network learned to predict target data while using 15 percent of Kaunas territory and then predicted placement of the modelled objects for the rest of it. Correlations between segments with predicted existence of the objects and real data were 0.498, correlation between predicted objects and Ain 1000 was 0.979. The map of the prediction is presented in Fig. 5.12. Results could be seen as satisfactory for the need of conducted research, especially having in mind that just a single syntactic indicator was used instead of few weighted indicators which can increase precision of prediction.

Fig. 5.11. Kaunas2016: Ain 1000. Red colours mark the biggest numerical values.
Additional check of a syntactic models

Fig. 5.12. Kaunas2016: predicted locations of enterprises. On the left shown in multi-numerous scale (red colour shows the higher probability of existence of the predicted objects), on the rate – transformed to scale 0-1 (1 shows existence of objects and is marked in red).

Prediction procedure was repeated with Klaipeda and Vilnius. The same neural network which was taught on Kaunas, was used in both cases. Initial calculation of correlations as in case of Kaunas are presented in table 5.14.

Table 5.14. Pearson correlations between Space Syntax indicators and allocation of enterprises in Klaipeda. The strongest correlations are marked in bold.

|        | Ach 1000 | Ach 5000 | Ach n | AIN 1000 | AIN 5000 | AIN n | Ebd |
|--------|----------|----------|-------|----------|----------|-------|-----|
| All    | .479**   | .330**   | .122**| .649**   | .678**   | .394**| -.179** |

**. Correlation is significant at the 0.01 level (2-tailed)
Fig. 5.13. Klaipeda2016: Ain 1000. Red colours mark the biggest numerical values.
Fig. 5.14. Klaipeda2016: allocation of enterprises. Presence of at least one object close to a segment is marked by red, absence – by green.
Fig. 5.15. Klaipeda 2016: predicted locations of enterprises.
The results of the calculation, in essence, show the same tendency as in Kaunas with even stronger correlations and AIN 500 identified as a little more important than AIN 1000. It, as well as relatively big correlations with Ach 1000, in comparison to Kaunas, might be explained by the linear structure of a city, when two or three parallel streets which accumulate. Despite a little shift in the correlations, which corresponds quite well to the differences in generic city model, AIN1000 will be used for prediction. If the results will be good enough, it means that similarity of spatial-social genotypes of two cities allows at least approximately predict allocation of street culture patterns too. Pictures 5.13 presents Klaipeda AIN 1000. When compared visually with picture 5.15, it could be seen that the biggest concentration of enterprises overlaps with the highest values of AIN1000.

The prediction is shown in Fig. 5.15. The correlation with the real data is equal to 0.631. It is a little weaker if compared to the syntactic indicator (AIN 1000) but still looks good. In addition, the Neural Network of the same configuration was trained on Klaipeda and correlations with prediction based on AIN 1000 and AIN 5000 were checked. In the first case the results were practically identical, while in the second correlations with the existing objects reached 0.658.

Thus the Klaipeda case and its analysis demonstrate that if usage of the unique for each city indicators might give better results, but, because of the genotypic closeness the same indicator gives quite good results.

The results of the analysis of Vilnius are presented in table 5.15.

**Table 5.15.** Pearson correlations between Space Syntax indicators and allocation of enterprises in Vilnius. The strongest correlations are marked in bold.

|                  | Ach 1000 | Ach 5000 | Ach n | AIN 1000 | AIN 5000 | AIN n | Ebd |
|------------------|----------|----------|-------|----------|----------|-------|-----|
| All enterprises  | .449**   | .307**   | .185**| .558**   | .623**   | .523**| .013** |

**. Correlation is significant at the 0.01 level (2-tailed)

In Vilnius, as in both previous cases, AIN 1000 and AIN 5000 give the best results. What is interesting in comparison to Kaunas, that both Vilnius and Klaipeda demonstrate significantly stronger correlations with local choice. It could be explained by differences of street networks in three cities: Klaipeda, as it was mentioned, could be seen as a variant of a linear city; Vilnius represents more organic, center oriented city which might concentrate significant traffic flows on some centered routes; Kaunas, meanwhile, demonstrates relatively regular street network with a little isolated center because of natural boundaries in the form of rivers and river walleye slopes thus, possibly creating a bigger number of alternative shortest routes.

Allocation of all enterprises and AIN1000 in Vilnius are shown in figures 5.16., 5.17.
Fig. 5.16. Vilnius 2016: allocation of enterprises. Presence of at least one object close to a segment is marked by red, absence – by green.
Correlation between prediction and real data is 0.566 and, as in the case of Kaunas, is stronger than between AIN1000 and real data. The predicted map is how in figure 5.18. Additionally, an attempt to teach Neural Network on AIN5000 in Kaunas and make prediction in Vilnius was made, but the results were just slightly better if compared already presented modelling.

So, in generalization, it could be concluded that test with Neural Network usage and analysis of additional data proved few important things for the finalizations of the research described in this chapter:

- Despite the differences in spatial configurations of Kaunas, Vilnius and Klaipeda, all three cities belong to the same genotypic group.
The above mentioned fact allows to use the logical principle of analogy and to project the same patterns of localization of the main functional objects in all three cities despite different phenotypical configurations of the networks of public spaces in them.

All three cities in 2016 demonstrate the same shift from more global to more local patterns of allocation of the central objects as was indicated in the investigation of the results of content analysis in Kaunas.

The additional modelling check with neural networks confirms the positive potential of usage of inhabitant density weighting for increased precession of the modelling.

Some additional insights into further development of the research in the future (e.g. additional weighting; combination of street culture with data on allocation of the main functional object, etc.) were generated.

Fig. 5.18. Vilnius 2016: predicted locations of enterprises.
5.5 Identification of patterns of street culture allocation to Vilnius and Klaipeda

For the prediction of patterns of both bigger variety and activities and users in public spaces in Vilnius and Klaipeda, the procedure which was tested while predicting allocation of the most important functional objects in Kaunas, Vilnius and Klaipeda, was used. First of all, the results of Neural Network modelling of pattern allocation were tested in Kaunas again. For the situation of 1939 the combined indicator from the first model, which was based on time-distance calculations was chosen as it gives slightly stronger Pearson's correlation if compared to the second or angular segment model. The chosen indicator is calculated by the formula \( \text{len1000*Len4000} / \text{MCD4000} \), which correlates with the weighted adult social activities by 0.477 versus 0.453 of the similar indicator in the second model. R squared correspondingly is 0.277 versus 0.205 which makes quite significant difference. The same neural network configuration as earlier was used. Fig. 5.19. represents two maps: the input indicator and the target data – weighted adult social activities placed on segment map.

![Fig. 5.19. Kaunas 1939: len1000*Len4000 / MCD4000 on the left and weighted adult soc activities on the right. Red colour marks the bigger numerical values.](image)

The picture 5.20. represents results of the prediction or weighted adult social activities mapped by the artificial intelligence. Person correlation between the data of content analysis and prediction is equal to 0.429. It is a little weaker if compared to correlation between combined input indicator and original data (0.477) but could be considered as acceptable having in mind the little amount of data about street culture in 1939 and base of modelling made just out of spatial configuration data. In essence, both predicted pattern, original patterns of syntactic indicator and the patterns of the results of content analysis of pictures could be named as a combination of concentric
and sectoral patterns. The first is presented by clearly dominating center surrounded by the rings of less intensive colours. The second one could be seen in prolonged extensions of the center of higher values of activities to the north and south from the downtown.

While using Kanas 39 syntactic combined indicator data as an input, the same Neural Network made prediction for Klaipeda and Vilnius in 1939. Both patterns (predicted and syntactic) are shown in the figures 5.21., 5.22.

In both cases, concentric patterns with features of the sectoral models could be seen. In case of Vilnius, the second pattern is presented by the expansion of the most active zones along contemporary Kalvariju street, to Zverynas area and along Savanoriu prospect. In Klaipeda the sectoral features are demonstrated by the Old Town itself and logical expansion in parallel direction to the Baltic coastline. If syntactic calculated and predicted patterns are compared, the second ones in both cases demonstrate strange phenomenon – some streets in the cores of the adult social activities are predicted as spaces used by relatively small number of users for little activities. It is not changing the whole patterns, but looks like a small mistake. How it could be explained? If we look into the content analysis results with social adult activities merged with segment map in Kaunas (Fig. 5.23.), the lower intensity in some high streets could be noted, e.g. in Juozapaviciaus prospect’s part which was surrounded by barracks or similar objects less generative in terms of street culture; in Kestucio and Donelaicio streets which are parallel to the main street in New Town – Laisves aleja which at this time already was the main space for various social, cultural and commercial activities. It would be logical to guess that Laisves avenue because of its attractiveness absorbed users and activities form the neighboring spaces. This phenomenon could help to understand some strange points in the predicted maps of Vilnius and Klaipeda.

For the modelling of the year 1987 combined syntactic indicator Len 1000 / MCD1000 was chosen as it gives one of the strongest correlations with a higher diversity of activities and users, demonstrates the higher R squared values and reflects the general shift of increased significance of more local syntactic features if compared to 1939. The comparison of the allocation of the highest values of the combined syntactic index and the content analysis results is presented in the Fig.5.23. The prediction could be seen in Fig. 5.24. In this case the strong correlations between content analysis data on adult social activities and the predicted areas were found. It is equal 0.687. In all three maps the pattern of “red colours” could be described as multi-nuclei because of irregular configurations, allocation of more intensive areas and variations of intensity of colours.

The results of neural network modelling for Vilnius and Klaipeda in 1987 could be seen in the figures 5.25.,5.26.

In both cities, the same multi-nuclei patterns of the most intensive zones could be observed. The anomalies of inactive main streets in terms of street culture in the predictions are visible but they do not disturb the clearness of patterns.
While modelling Kaunas in 2016 MR1000/ Ebd was chosen as an input data because of the best Pearson’s correlation and the biggest R squared value. Both MR1000/ Ebd and content analysis maps are presented in figure 5.27. The strong correlations were found between the content analysis data and predicted locations: 0.677 with weighted and 0.522 with not weighted adult social activities.

Map with the prediction is presented in figure 5.28.

Vilnius (Fig. 5.29.), Klaipeda (Fig. 5.30.) and Kaunas both syntactic and predicted maps clearly demonstrate the same multi-nuclei patterns as in 1987. Together with data on correlations, it says that the essential transformations of three cities, which happen during the Soviet period, affect functioning of the cities in terms of street culture up to day.

Fig. 5.20. Kaunas 1939: predicted allocation of adult social activities. Red colour means a bigger variety of both users and activities.
Fig. 5.21. Klaipeda 1939: len1000*Len4000 / MCD4000 on the left and predicted adult soc activities on the right. Red colour marks the bigger numerical values.
Fig. 5.22. Vilnius 1939: len1000*Len4000 / MCD4000 on the left and predicted adult social activities on the right. Red colour marks the bigger numerical values.
Fig. 5.23: Kaunas 1987: len1000 / W1000 on the left and weighted adult social activities on the right. Red colour marks the bigger numerical values.
Fig. 5.24. Kaunas 1987: predicted allocation of adult social activities. Red colour means a bigger variety of both users and activities.
Fig. 5.26. Vilnius 1987: len1000 / MCD1000 on the left and weighted adult social activities on the right. Red colour marks the bigger numerical values.
Fig. 5.26. Klaipeda 1987: len1000 / MCD1000 on the left and weighted adult soc activities on the right. Red colour marks the bigger numerical values.
Fig. 5.27. Kaunas 1987: MR1000 - Ebd on the left and weighted adult social activities on the right. Red colour marks the bigger numerical values.
Fig. 5.28. Kaunas 2016: predicted allocation of adult social activities. Red colour means a bigger variety of both users and activities.
Fig. 5.29. Vilnius 2016: MR1000/ Ebd on the left and weighted adult social activities on the right. Red colour marks the bigger numerical values.
Identification of patterns of street culture allocation to Vilnius and Klaipeda

Fig. 5.30. Klaipeda 2016: MR1000/ Ebd on the left and weighted adult social activities on the right. Red colour marks the bigger numerical values.
In chapter 5.3, when theoretical background of the investigation was presented, the concept of the spatial capital as one of the layers of a city as a complex system was presented. The Space Syntax was chosen as the most suitable and the most developed in terms of mathematical apparatus theoretical tool for the modelling of spatial capital yet the concept of pattern language by Alexander was mentioned as an analogous approach which might be seen as an older and wider theoretical framework for Space syntax theory. Concept of the pattern as a graphically expressed model which defines functional properties of architectural or urban structure grounds the analysis of the spatial configurations as a way to look into various functional aspects of a building or a city. Why the pattern concept might be needed when we have the space syntax theory? Each similar research as presented in this book initially specializes on a specific question, tools and methods, thus deepening knowledge of the subject. It could be called an analytical stage of the investigation, but, when certain amount of scientific knowledge is reached, there always appears a need for generalization which lowers a resolution of presented data making it easier for understanding and allows connections with other sets of data generated in another investigation – it could be called a synthesis stage. The pattern concept could be seen as more generalized tool to connect space syntax models to more general understanding of city functioning. Having the above said in mind, the pattern term was used in order to describe allocation of concentrations of street culture in Kaunas, Vilnius and Klaipedra earlier in this chapter. The terms concentric and multi-nuclei patterns were mentioned while short descriptions of them were presented. In this case patterns were analyzed as generalized models of spatial allocation of both syntactic indicators related to more intensive street culture and allocation of street culture itself thus double checking the conclusions about what patterns are seen. While having in mind that city is made of multilayered capitals (spatial, social, economic, ecological, etc.) it would be logical to assume the spatial patterns could be generated on various data accordingly and, in such a way generated patterns, not necessarily coincide. Similarities or difference between various patterns which make a city, might help better understand its functioning and its transformations. Thus, in order to get more knowledge out of identified earlier patterns and their transformations the attempt to combine it with some additional data was made. In precise case it is the available data on density of inhabitants in Lithuanian cities\footnote{Officialiosios statistikos portalas, GIS duomenys [interactive], 2011, [viewed on 2019 03 10], https://osp.stat.gov.lt/gis-duomenys} and allocation of commercial enterprises\footnote{Officialiosios statistikos portalas, GIS duomenys [interactive], 2015, [viewed on 2019 03 10], https://osp.stat.gov.lt/gis-duomenys}. Before going to describe the results of this additional analysis it is worth to remind three basic geographical patterns of a city in more details. This review is
based on the article by Matt Burdett\textsuperscript{599}. The first one is the concentric zone model or patterns created by sociologist Ernest Burgess in 1925. This model depicts urban land usage in concentric rings: central business district in a center surrounded by various functions as housing of higher society, industry, etc. The most important feature of this hierarchical, monocentric model is a presence of a clear spatial and functional center as the most essential core for functioning of a whole structure in terms of economic, cultural, social networks. This model was seen in the three investigated cities in 1939 and even, if it was based only on the intensity and diversity of the usage of public spaces, it is easy to guess that the same patterns would be identified on the base of allocation of shops, entertainment establishments, density of historical artefacts and might be even density and higher diversity of inhabitants.

The multiple nuclei model was created by Chauncy Harris and Edward Ullman in 1945. According to it, even if a city may have begun with a central business area, other smaller „clones“ of centre developed over time in various locations, possibly closer to more valuable housing areas. In comparison to the concentric pattern, this model could be described as monocentral and more horizontal.

The sector model was proposed by Homer Hoyt as a modification of concentric pattern in relation to a development along the main traffic corridors and could be seen as diachronically later phase of development of concentric patterns caused by an expansion limited by various geographical conditions, e.g. mountainous area, river, seashore, etc. This model was seen in 1939 in Kaunas and Klaipeda content analysis results.

In all three cities in 1987 and 2016 the multi-nuclei pattern of street culture hot zones were identified. What patterns based on the allocation of commercial objects and inhabitants will be found and will they repeat street culture allocation patterns?

Visualized data on commercial enterprises and density of inhabitants in three cities is presented in the figures 5.31., 5.32., 5.33. While determining patterns, we will treat commercial objects and inhabitants as a two parts one interrelated system where two elements need each other in order to function properly. In such a case the highest concentrations of the commercial objects could be treated as a central commercial district (CCD) while the highest or the lowest densities of inhabitants as a specific specialized districts if they do not coincide with the first ones. If the coincident happens then it means that even more multi-fledged CCD is formed.

\textsuperscript{599} Matt Burdett, \textit{Urban land use patterns and models}, [interactive], 2018, [viewed on 2019 06 03], https://geographycasestudysite.wordpress.com/urban-land-use-patterns-and-models/
In the case of Kaunas, if we look at the allocation of commerce, we can see, as well as in 1939, sectoral pattern very clearly: historical center represents the biggest concentration while the axe of Savanoriu prospect represents the prolonged sector of development. The less intensive so, it means not competing with the central district zones in Silainiai, Kalnieciai, Eiguliai and Dainava modernistic housing areas, create a kind of concentric ring around the core of the patterns thus giving features of concentric ring model to it. The highest density of inhabitants shares the same area with the concentric commercial zone of the lower intensity thus supporting the concentric ring model.
In essence, the concentric ring pattern is repeated in Vilnius where one clearly dominant CCD, which is located in the historical city center, is surrounded by two rings: the first one of high density of inhabitants and the second one of low. Three less intensive zones of commercial development could be seen as a presentation of either weak sectoral or the same concentric model.

![Fig. 5.33. Klaipeda 2016. Allocation of commercial enterprises on the left and density of inhabitants on the right presented in 250 meters on 250 meter cells. Red colour means higher numerical values.](image)

In the case of Klaipeda, the most intensive commercial zone could be identified as a linear pattern which could be seen as an extreme presentation of the sectoral model. The prolonged configuration of the highest inhabitant density zone, which covers CCD in a center, expands the same spatial configuration over a bigger territory.

So, the final stage of investigation of the three cities could be generalized by the following finding:

- If we look at a city as a complex system made of various interacting spatially localized patterns, then, it looks that in 1939 the same pattern is found in three investigated layers: spatial configuration itself, allocation of street culture and patterns of allocation of both economic activities and inhabitants.
- In 1987 and 2016 economic activities and densities of inhabitants, even if the usage of city territories becomes more specialized (e.g. creation of modernistic
housing areas as so called “bedrooms of a city”), but spatial-functional patterns demonstrate just an evolutionary change from 1939 in the all three cities: in the case of Kaunas we can see the same sectoral model with some fragments of concentric model added in 2016 if compared to 1939; in Vilnius we can see a slight transformation from sectoral to more concentric pattern; Klaipeda has moved from sectoral to the extreme form of this pattern – linear model.

- Since 1987 the allocation of street culture in all three cities is shifting to multi-nuclei model. Of course, it would be too daring to say that the concepts of modernistic urbanism were the only reasons for this transformations, but, because of such features as separated traffic flows, mono-functional zoning, destruction of the borders between private and public open spaces and a view on historical centers as a territory of not every day has taken services, they could be seen at least as catalyzers of the mentioned transformation.

- Situation in 2016 remains the same thus demonstrating the deep impact of modernistic transformations upon city functioning.

- It looks like it would be worth to expand a multilayered pattern approach in the future with more data and more cities included as it might help to see some unexpected aspects of a city functioning.

5.6 Conclusions of the fifth chapter

The whole research presented in this monograph will be concluded at the end of the book, but, because the fifth chapter is based on both own modelling and the results of investigations presented in the previous chapters, some, more specific and detailed this part conclusions will be presented here.

- Both syntactic models were quite successful and demonstrated moderate and strong correlations with various activities of street culture in all three periods. The same findings supported by different mathematical graphs could be seen as more grounded. The weaker correlations in 1939 could be explained in two ways: the smaller amount of data; an increased number of optional activities as found in the chapter tree. Obligatory activities could be expected to depend on spatial configurations less as they should be performed in any spatial situation while optional activities should demonstrate opposite relation to space features.

- The functionality of the models was additional successfully tested while using open data on allocation of various enterprises and neural network modelling. As additional check data could be seen as at least indirectly related with street culture (e.g. as it was stated in the chapter one – more grouping of people noted in front of shops) this independent in terms of information confirmation of the effectiveness of syntactic models, could be seen as an additional confirmation of the results of the research as well.
Each investigated period could be described by a different set of syntactic indicators and combined indexes: longer radiiuses are more important in 1939 and less important in 1990 and 2016 thus demonstrating a higher degree of integrity of spatial co-presence activities in the investigated cities in the first period.

Diachronically, if starting from 1939, the importance of global spatial urban configurations (e.g. as closeness by public transport journey distance) for street culture and especially the adult social activities, is moving towards a higher significance of local spatial features e.g. reachable by walking distance street perimeter, the closeness of spaces by walking, etc. Situation at 1987 could be seen as a transit between 1939 and 2016 as one model demonstrated higher significance of some public transport radiiuses while the other – just local pedestrian ones.

The total transformation of a whole investigated city in terms of allocation of street culture should be noted. If modernistic urbanism models are seen as a catalyzes of the discussed transformations, then it could be concluded that their effect was not only limited to the newly created modernist parts of a city but essentially changed a whole structure including old parts as well.

It is interesting to note that despite the declared role of a car as the main integrator of a city in modernistic urbanism, at least in terms of social and cultural content of public spaces, the three investigated cities were fragmented into autonomous islands of street culture activities. It might be related to the already mentioned separation of the logistic networks and consequently transformation of a traditional street to a road with loss of its social-cultural dimension. Independently this statement could be supported by the investigation, based on the concept of social-spatial control in modernistic neighbourhoods. It demonstrated that in Eiguliai modernistic district in Kaunas the highest degree of social-spatial control, which is traditionally associated with street culture, is inside the courtyards of houses and the lowest at the main streets. On the other side it could be thought that public transport in 2016 and 1987 is not organized in the most effective way in Kaunas because of the peculiarities of street network more favourable for the usage of an individual car. As an example, comparison of Kaunas and Gdansk could be mentioned: in Kaunas max and mean values of the syntactic choice, which shows attractiveness of a street for transit flows, differ significantly less than in Gdansk which could be seen as a linear city with optimally developed public transport network. The lover max/mean choice ratio

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600 Akkelies van Ness, “Measuring the urban private-public interface”, in: WIT Transactions on Ecology and the Environment, 2008, p.389-398.
601 Kestutis Zaleckis, Erdvės sintaksė urbanistinei analize: koncepcijos, apskaičiavimai ir pavyzdžiai, Vilnius: Lietuvos architektų sąjunga, Vilniaus dailės akademijos leidykla, 2018, p.29.
602 Kestutis Zaleckis, Erdvės sintaksė urbanistinei analize: koncepcijos, apskaičiavimai ir pavyzdžiai, Vilnius: Lietuvos architektų sąjunga, Vilniaus dailės akademijos leidykla, 2018, p.72-84.
means that there exist more alternative routes in a street network what is more attractive for an individual car users; higher max/mean ration means that there is a smaller number of streets attractive for transit and this situation is more favourable for public transport usage in order to avoid traffic jams.

- The potential way for a further continuation of the investigation was identified: it could be oriented towards usage of more reliable data for content analysis (e.g. social media pictures or texts) and introduction of additional weighting to a graph, e.g. based on allocation of objects which can generate some street culture activities; social groups, etc.

- One weakness of the used models in terms of investigation of street culture is a low sensitivity to such parameters of public spaces as its width besides its length. This problem will be separately addressed in the following chapter while using visual graph analysis. This model will allow addressing such aspects of social-spatial interaction as readability of a space network, which might be actual for investigation of street culture as well.