Index Keys Method for Analyses of Urban Spaces

Methodological assumptions

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Abstract— **The paper proposes the index keys methodology of analysis of urban structures. The research stems from the descriptions of urban settings with regard to culture related issues. The geometrical analyses of public spaces, including the examination of streets and squares profiles and urban silhouettes, draw upon the writings of Kazimierz Wejchert, widely recognised for his contribution to the theory of urbanism in Poland. Cultural aspects of given settings require developing methods of description of public spaces. A few hypotheses are formulated concerning the relation between the crowd of people representing a given culture and the urban settings which constitute their *habitus*. Quantitative parameters describing the form of space are introduced, including: central angle, corrugation and regularity. The algorithmic method has been applied for the automatisation of the process. The preliminary results of analyses are presented as well as further research pathways.**

Keywords-urban design; public spaces; urban morphology.

I. INTRODUCTION

The requirement to establish the methodology of examination of physical urban settings has been recognised [1]. As it has been stated cities arise out of man's social needs, they are described as an embodiment of collective art and techniques [2]. Culture related aspects of everyday space usage are reflected first of all by internal organisation and arrangement of urban settings, their character and the meaning, which they convey. The issue of a theoretical exploration of the analysis of urban outdoor space should be addressed from a dual perspective: morphological and anthropological. The requirement to include culture related aspects of urban structures into the normative theory of urban design should be recognised and the epistemological apparatus included in the clearly defined ontology. The current paper attempts at the geometrical analyses of public spaces, including the examination of street and square profiles and urban silhouettes drawing upon the writings of Kazimierz Wejchert [3], a Polish post-war researcher and urban designer, widely recognised for his contribution to the theory of urbanism in Poland.

The paper is organised as follows: after this introduction, the anthropological perspective is briefly presented, which points out the understanding of situation and the definition of *habitus*, the main methodological assumptions are discussed, with an emphasis on the explanation of index keys concept. Section IV explores analytical methodology, introducing several parameters intended for the description of urban enclosures. Further on, the case study is introduced, which contains an explanation of the development of the methodology for detailed description of outdoor spaces and discusses the preliminary results of the research including the semi-automated analyses of selected parameters with Grasshopper. Section VI provides conclusions from the paper and presents further steps, which are to be taken in order to verify the presented methodology of analyses.

II. ANTHROPOLOGICAL PERSPECTIVE

When looking for the relation between urban structures and the culture of space usage there are three main issues that should be considered: (1) physical features, including distribution, shape and size of forms defining the space, (2) the distribution and behaviour of space users, which reflect their social order and (3) the flow of human movement, which finds its reflection in the sociometric layout of a given place. Flows are connected with movement/traffic and are related to space, following the definition by Yi Fu Tuan [4]. Concentrations enable contact and communication processes. They are static rather than dynamic, thus place related. Both types are closely interrelated, they inseparably interpenetrate each other. Whenever the human flow stops for a moment concentration occurs, though interrelations require more comfortable conditions to take place, among others: time and spatial arrangement. According to the theory formulated by Lynch [5], flows may be approached as paths and concentrations as nodes. Concentrations tend to a static form, while flows serve mainly as a means of getting to some destination. Taking into consideration mostly their static behaviour, the distribution of people in public spaces reflects social order. Contemporary research in anthropology clearly proves that lack of street or square boundary in modernists cities and districts is one of reasons for the absence of the traditional urban life. The form of physical enclosure should be subject of research to enable it to convey emotions and culture related meaning in a more conscious sense. The current paper is an extension of the former one [1], which elaborates more on the proposed methodology of examination of physical urban enclosures with the use of Grasshopper scripting for semi-automatised analyses.

A. The concept of situation

In anthropology, situation is defined as a theatre of human activities [6]. Goffman [7, p.18] refers to a situation as to *"the full spatial environment anywhere within which an entering person becomes a member of the gathering that is (or does then become) present"*. Anthropologists developed elaborated theories on ways in which a site is converted into a meaningful 'place', by inscribing human activities into the surroundings. The relationship between people and sites encompasses both: attaching meaning to space and *"recognition and cultural elaboration of perceived properties of environments in mutually constituting ways through narrative and praxis"* [8, p.14]. Schumacher [9] states that the role of architecture is to frame social communication [9, p.414]. Thomas, who introduced the concept of situation in the 1920s, defined it as a *"constellation of the factors determining the behaviour"* [10, p.8] after [9, p.420].

B. The definition of habitus

The morphological approach [11] refers the above concept to the urban structure introducing the notion of *habitus*. The set of identifiable cues, which may be qualified as culture-specific [12, pp.106-107], and referring to spaces, includes features like: *"quality, size, shape, enclosing elements, paving, barriers, and links, etc."*, requires examination with regard to the distribution of human flows and concentrations and their intensities, and consequently occasions for contacts. Both Gehl [13] and Whyte [14] point at similar rules of use of outside spaces. The territorial distribution and exchange of nonverbal cues serves the communication purpose and usually certain semantics may be attributed to it [7]. The behaviour of a given human group in concentrations reflects its culture. The movement component tends to be more universal and less culture dependent, as Hillier and Hanson [15] claim. The thesis is made that the rules, which govern the non-verbal communication component of the human group behaviour are the same ones that govern the distribution of buildings. They represent the same culture of space usage.

C. Issues related to proxemics

The proxemics approach, presented by Hall [16] and his successors, examines the relation between spatial patterns of space usage in different cultures and the material environment. The differences between morphological structures representing various cultures are particularly apparent in cities that, like Lodz, had become a melting pot of many cultures. Hall [17] identifies direct relationships between interpersonal distances and other characteristics of individuals and communities and the way they shape their own physical environment. Hillier and Hanson [15, p.27] refer to the usage of space and the patterns of behaviour appropriate for different communities and ethnic groups as the determinants of the final shape of urban structures. According to Hillier [18] a city is seen as a system of visual distances, strongly influenced by both perception and personal distances.

III. METHODOLOGICAL ASSUMPTIONS

A proposal of the method for the analysis of public spaces is presented, based on the writings of Wejchert [3]. K. Wejchert's theory of urban composition is widely recognised for its contribution to the theory of urbanism in Poland. Similarly to methods developed by Collins and his followers, it allows discussion of the atmosphere of urban spaces.

Forgoing morphological descriptions of urban structures were based on the analyses of plans, i.e., Conzenian school of urban morphology [19]. The other group refers to the diachronic characteristics of constructions, i.e., Muratori's tradition [20]. They do not allow for considerations referring to the ambiance of the settings discussed as a whole. The actual, practice-based approach engages the definition of genius loci, notably in rehabilitation projects.

The research applies the anthropological approach to the description of cities and urban structures. It follows and develops the so far available, descriptive methods. E.g., Rapoport listed a comprehensive set of culture related characteristics of physical structures [12, pp.106]. Hillier and Hanson [15, p.224] ponder on the method of investigating encounters as morphic languages. They conclude that the aim is to establish how encounter systems get differential properties. The resulting peculiarities would have different manifestations in space.

A. Perception as a factor influencing the creation of space

Strzemiński [21] pointed at the evolution of visual awareness along with the development of civilisation. Visual awareness was transformed together with the changes of socio-cultural settings. He examined it as a consequence of economic and technical development. Both above factors as well as the social structure of a community in the defined historical context influenced the way people perceive spatial settings. The notion of visual awareness is understood as the *"cooperation of seeing and thinking"*. It emphasises the role of cognitive absorption of perceived visual stimuli. Strzemiński [21] identifies two ways of the development of visual awareness. In rural cultures, it is the observation of the interior of an object, which finds its expression in the studies of nature. The second form was a silhouette vision. It is said to develop from the primitive contour observation in economies based on hunting and breeding animals. This form is typical of tribes accustomed to vast open spaces.

The derivative of the silhouette vision was the perspective of simple parallel projection. In the further stage it was followed by the development of rhythm, including architectural rhythmisation. The last phenomena was a consequence of the inclusion of the afterimage effect, natural for the perception of vast open spaces. Another form of seeing was the one concentrated on ware attributes, with emphasis on the texture and weight of objects. Usually this form was devoid of larger perspectives. It was particularly apparent in communities, whose main occupation was commerce. Adorno [22, p.5] points at the role of artworks as a medium reflecting the unconscious aspects of culture. He states that *"artworks are afterimages of empirical life insofar as they help the latter to what is denied them outside their own sphere and thereby free it from that to which they are*

condemned by reified external experience." The same refers to the urban settings, which, perceived by a group of users, answer their needs, including the aesthetic criteria.

B. Rhythm - a component of unconscious contexting

Components containing the meaning of public spaces may 'speak' in different way. Some features are obvious and result from the functional conditions of a given development. They may be classified as direct communication. This group may include the elements of streets furniture such as: traffic lanes of various widths and surfaces, cycling paths, pavements, greenery, bollards, etc. It is a platitude to say that there are streets that are designed for driving fast and others inviting for a walk in the shade of trees. An elementary analysis of street profile allows one to distinguish a commercial street from a residential one. The general character of public spaces and their development through the ages is addressed in manuals of the history of urbanism.

Another part of communication may be classified as indirect, in analogy to non-verbal cues. According to Hall [23]: *"Nonverbal systems are closely tied to ethnicity (...) they are of the essence of ethnicity."* The consistency of urban pattern, as experienced in public spaces, is a consequence of the rules of crowd behaviour constituting part of a given culture. Kinesics is a way a person moves and handles their body. People specialised the language of the body making it integrated and congruent with everything they do, it is culturally determined and should be read against the given cultural background. Also, the presence of a synchronisation with settings is claimed, which takes place when the urbanscape belongs to the same culture as the visitor. Then a sense of belonging may be present and a place is perceived as more attractive than when the synchronisation is lacking. Settings which are out of phase are more likely to seem alien, unordered. As a consequence, the notion of rhythms may serve as an element connecting indirect communication with physical settings.

C. Theory of seeing – index keys concept

Like in the paintings of Van Gogh, seeing is concentrated around a few key points, which define how a scene is perceived [21]. The analyses should provide observation of processes: flows and forces, and concentrate on their key points. Situations that are the most important for the definition of cultural character, i.e., the moments of human interactions, particularly attract researchers' attention [17, p.56] – they are static rather than dynamic. The methodology of key points analogues to the anthropological method of taking photographs by members of the group that is observed, who are able to notice the clue activities important for their cultures and often unnoticeable for foreigners, allowing for observation of socially meaningful activities responsible for the formation of a cultural specific environment.

The application of the 'key points' methodology to the physical urban settings allows for the mathematical analyses of traditionally defined geometrical features of urban landscapes. It assumes the choice of the most obvious perspectives when observing the environment. In the case of urban spaces, it means choosing these view axes, which provide profiles and silhouettes respectively perpendicular or parallel to the main axe of a given path.

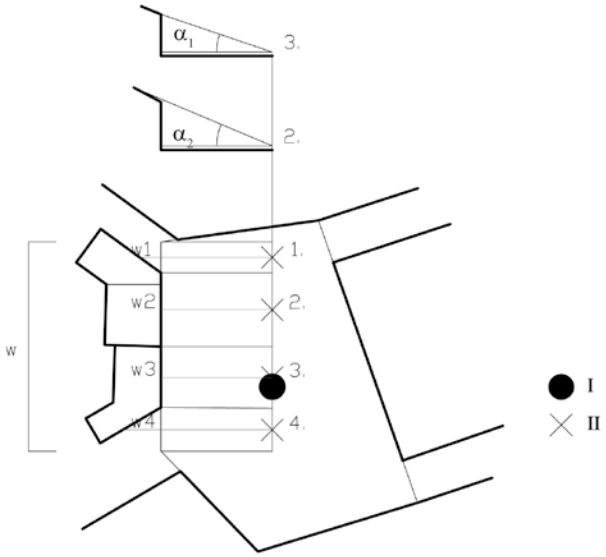

Figure 1. Index points and cross-sections definition. I – geometrical central point, II – index key points, α_n – central angles for each cross-sections, w_n – widths of each unique part of wall

In the proposed methodology the simplest way to extract cross-sections and silhouettes is used, based on orthogonal projection. The methods to acquire and analyse more realistic geometrical features including the perspective projection require further elaborations. The analyses of the profiles and of the silhouettes may use, among others, the highly efficient methodology proposed by Gal & Doytsher [24], which allows the replacement of the Line of Sight (LOS) methodology of extracting silhouettes of groups of buildings. The automatisation of profiles or silhouettes acquisition is also available using the Light of Sight (LOS) module of ArcScene by ESRI. There are also some preliminary attempts to model 3D isovist environment, in analogy to the method by Benedict [25] referring to the 2D plan drawing. These trials, some of them sophisticated, e.g., [26], equally require development of an analytical background.

Further methodology development should also take into consideration the processes described by the Gestalt psychology, e.g., the shortening of distances in the perception of distant buildings. Other field of studies are the ways in which humans perceive the environment, e.g., perception of meaningful entities [27].

IV. THE ANALYTICAL METHODOLOGY

A. Convex - definition

Hillier and Hanson [15] defined a series of rules governing the spatial order of analysed settlements. They noticed that the definition of the basic spatial unit for analyses, which would be distinguishable in the geometrical way, is essential for further considerations. Referring to their

theoretical apparatus, a basic spatial unit that may serve for the description of public spaces is a convex. A *"fully convex fat space"* is defined as *"a part of a space, which represents the maximum extension of the point in the second dimension given the first dimension"* [15, p.91]. In Hillier logic of space, the implicit assumption is made that all the cells, representing spaces, are similar units, both in size and in shape. It does not describe the actual form of urban closures and the spatial edges are lacking. The critique concerns a lack of geometrical description of buildings, which form urban settings, including their size, shape and distribution (e.g., [28]).

Spaces, which are not defined spatially but by the presence of some other edges – like property borders, remain problematic. A more complete picture, which may serve to describe reality in a reliable way, requires the introduction of the shape and size parameter(s) and multiplying them by three dimensions. Studies in human perception show a trend to generalise objects to wholes, when the compounds are located close to each other, have similar attributes, may be described with the same contour line and their meaning, recognised from former experience, remains similar.

B. Description of the form of space

The way in which an observer perceives space in the urban interior depends on the parameters of cross-section. Wejchert [3]. The basic features important for describing convex spaces are profiles and wall silhouettes. The analysis of a wall's silhouette allows for identification of required index points, which may further on serve for the creation of profiles. Cross-sections may be created for any cue point of any unique physical form of objects surrounding the space change, i.e., the height and the shape of buildings.

Each index point is referred by one profile, various profiles require association with distinguished index points. The starting point for each profile is located on the line, which is parallel to the wall and goes through the geometrical centre of the given convex; see Fig. 1. Cross-sections are by definition perpendicular to the convex wall. In the case of buildings or other constructions that are set back from the convex edge and not perpendicular to it, the middle point of a building/construction is the location of an index point. Similar situation occurs in the case of buildings that are located behind other buildings but whose height exceeds the height of the front building.

The method may also serve for the description of some concavity closures. Yet, as their perception as one spatial unit is more the result of tradition than of their geometrical attributes, these shapes should be defined manually, i.e., divided into two or more basic convexes and then reconsidered as one whole. An example of a concavity space widely recognised as single urban interior is the L-shaped Piazza della Signoria in Florence.

C. Central angle

One of the most important parameters describing cross-sections is the central angle. The central angle is an angle between a horizontal plane parallel to the floor at the height of 1.5m (the medium level of sight for humans) and a line going through the highest point of the building defining the closure in a given index point. The point belongs both to the silhouette line and to the cross-section, see Fig. 2.

Wejchert [3] provides general rules for classification of closures based on the description of heritage sites, which are widely recognised as beautiful for their great proportions. The central angle values in most of the discussed squares range from 25° to 30°, e.g., Piazza Saint Marco in Venice - 28° to 30°, Old Market in Warsaw - 30°. The angle smaller than 10° refers to closures, which are feebly read in space. Either the plan dimensions are too vast or the vertical dimension is not adequate to provide the proper definition of space.

The closures of a central angle parameter higher than 60° rarely serve as public piazzas. An important feature for their evaluation are lighting conditions appropriate for a given climate. The general attitude towards more densely built spaces has changed recently, their values being widely recognised after the end of Modernism. The former pejorative connotation of terms such as "canyon" or "well" [3] lost their previous importance along with the common scarcity of defined spaces and dispersion of development. The central angle analysis is made for each of the cross-sections created at each of the index-points of the distinguished walls, and then combined for the walls forming the convexes, using the following formula (1), where α_1, α_2, α_3, α_n are values of central angles of each of the defined cross-sections, n is the number of index points for each wall, w_n is the width of a piece of a wall represented by a given index point and w is the length of the whole wall.

$$\alpha = \alpha_1 \times \frac{w_1}{w} + \alpha_2 \times \frac{w_2}{w} + \alpha_n \times \frac{w_n}{w} = \sum \left(\alpha_n \times \frac{w_n}{w} \right) \quad (1)$$

D. Corrugation and size

The urban spaces must be also measured using metric values. Humans, as Gehl asserts in the interview in a documentary film 'Urbanized' by Gary Hustwit, *"remain a small walking animal"* and require spaces of human scale. The spaces that are too large seem undefined. Gehl recognises a distance of 100m as a maximum that allows for proper reception by the observer of the environment. The assumed research methodology refers to the width of half of the closure, thus the distance should not exceed 50m. The actual dimensions of physical spaces reflect also the requirements defined by proxemics. The differences in personal distances influence both the perception of space and its production [16], [23], which means that we may assume that the size of space is perceived and designed differently by people of various cultural background. Continuing this thread, the analysis of the dimensions of public spaces proves that they remain culture specific.

The definition of space may be either precise or hazy. In the first case walls form clearly cut edges, in the second one buildings and other objects are scattered, forming a kind of fuzzy boundary. As Wejchert [3] argues, sight tends towards forms that are '*strong'*, which means: clearly defined, and

towards layouts that are concise. Parts or the whole of the observed constructions may be hidden behind other objects, which occurs both in the vertical as in the horizontal plane. In the case of breaks in the structure - i.e., openings in the walls, the closest object closing the perspective visible in the silhouette view is taken into consideration. Similarly, a higher building located in the background should be taken into account as, constituting a part of a silhouette, it influences the actual central angle parameter. The index points, where there are no visible constructions, are described with central angle value 0.

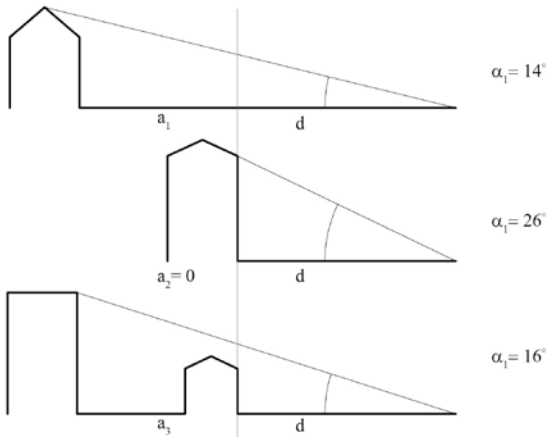

Figure 2. Corrugation of the wall, a_n- set back or behind of a part of a wall, d – a distance of the wall from the central point of the cross-section.

In a situation where buildings are set back from the line of frontages, the method allows for the description of an angle in a way similar to other cases. Variations of a buildings' offset are another parameter important for the definition of the space's character. The line of frontages may be located in the edge of a given convex or set back, the offset may be regular or irregular, any of these attributes influence the perception of the space (Fig. 2).

Corrugation may be defined using the formula (2), where φ symbolises corrugation value of the wall and γ - the offset of a single part of the wall. The possibilities of comparison of different situations are enabled thanks to the normalisation of offset values as in formula (3), where *a* represents the offset in metric units and *d* – the distance of the wall from the central point of the cross-section. In the case of some elements, offset of the lines of frontage shift should be given as positive numbers.

$$\varphi = \frac{\sum \gamma_n}{n} \quad (2)$$

$$\gamma_n = \frac{a_n}{d} \quad (3)$$

E. Distribution of index points

Further analyses include the distribution of index points, which reflects the distribution of buildings – each point belongs to a single building and the points are located in the middle of the facade. Such an analysis allows for easy detection of rhythms, repetitions, symmetries, axial layouts, etc. Distribution of index points may be described as clustered, spaced or scattered. It should be noticed that similar words are applied to the characteristics of the groups of people forming a crowd [29].

When analysing index point distribution the parameter of regularity may be defined referring to an ideal pattern, which for each case would mean equal distribution of the number of points defined for a given wall (Fig. 3). Any shift from the point resulting from an equal division should be measured and normalised by the width of the wall represented by each index point. The sum of all shifts divided by the number of index points describes the value of regularity for each wall. The regularity of the whole closure is described by the average value. The regularity may be described with the use of the formula (4), where τ is the regularity parameter, *r* represents a single shift, ϖ - width of an average part of a wall, *w* – width of a piece of a wall represented by a given index point and *n* is the number of index points for a given wall (5).

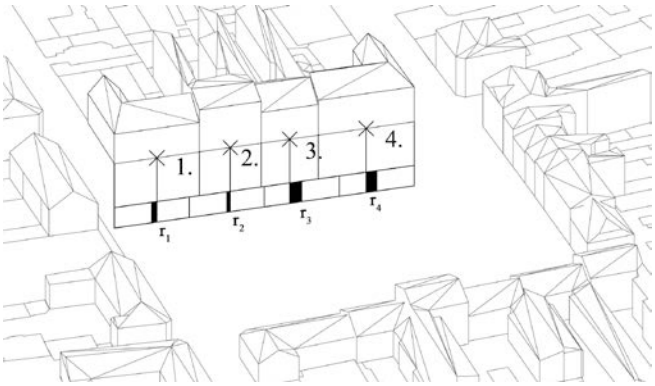

Figure 3. Regularity of the wall – method of description.

$$\tau = \frac{\sum r_n}{\varpi_n * n} \quad (4)$$

$$\varpi_n = \frac{\sum w_n}{n} \quad (5)$$

V. THE CASE STUDY

The case study pertains to two areas located in Lodz, Poland. One of them is Zgierska Street, located in the Old Town, in the former 'Jewish district'. In the 19th century, the district served as a habitat of the multiethnic society, in

which orthodox Jews constituted a majority. These settings were commonly described as possessing a special 'Jewish' character. This notion is evoked by the form of public spaces, different than in other parts of the city. The other place is the Old Market in Lodz, located in the same neighbourhood. The subject of analysis is its former appearance, before the demolition during World War II and later. The other settings, used for reference, are an example of workers houses built for employees of the textile factory by Karol Scheibler in Plac Zwycięstwa as well as the first villa of this entrepreneur located on the other side of the same square. The square was later cut through by an important traffic route, Aleja Piłsudskiego. The remnants of the cultural heritage are however preserved even in the changed settings. Photographic analyses use the results of an inventory by students of the Institute of Architecture and Town Planning of Lodz University of Technology, 4th sem., tutor M. Hanzl.

The examples of the regularity analyses are presented in Fig. 4, results are included in Table I. The rhythm is described by the regularity parameter, which in case of Zgierska Street is lower than half and in the case of Plac Zwycięstwa is close to 0. This confirms the observation that the second case is a regular one in opposition to the first. The square was conceived as a single design, assuming repetition of identical workers buildings. The other site also remains regular although here it was not a requirement. We may assume that in this case a designer made a decision choosing this kind of solution appropriate in these settings.

Figure 4. The analysis of regularity: current buildings (1) and parcels (2), historical buildings (3) and parcels (4). Values of shifts (r) for each key point shown in grey. Zgierska Street, Lodz, drawing uses results of inventory by students of the Institute of Architecture and Town Planning of Lodz University of Technology, 4th sem., tutor M. Hanzl

A. Parametric approach

In order to automatise the process of analysis, the Grasshopper for Rhinoceros 3D, a well known and widely recognised parametric modelling system, has been used. The analysis was performed on the sketchy reconstruction of the former appearance of the Old Town in Lodz, located in the very heart of the former so called Jewish quarter, not far from the first location analysed. The geometrical data has been acquired directly from the Sketchup model based on the archive photographs of the settings. The analyses of regularity and of central angle were performed. The value of corrugation has been counted as well. The details of the process of parametric modelling are presented in the illustrations (Fig. 5, Fig. 6, Fig. 7, Fig. 8, Fig. 9, Fig. 10). The numerical values are collected and ordered in the Table II and in the Table III. The summary values of central angle, corrugation and regularity are enbolden.

TABLE I. THE ANALYSIS OF REGULARITY: T - THE REGULARITY PARAMETER, R - A SINGLE SHIFT, W – WIDTH OF A SINGLE WALL, N - THE NUMBER OF INDEX POINTS FOR A GIVEN WALL

West side of Zgierska Street				**East side of Zgierska Street**			
n	***r [m]***	***w [m]***	***τ***	***N***	***r [m]***	***w [m]***	***τ***
1	1.59	16.37		1'	5.81	35.71	
2	9.80	6.73		2'	17.15	34.49	
3	14.72	22.03		3'	16.15	11.26	
4	13.55	19.48		4'	9.41	23.04	
5	10.77	20.47		5'	9.10	23.74	
6	10.93	19.31		6'	8.92	24.43	
7	11.48	19.71		7'	7.78	19.88	
8	11.05	20.26		8'	2.96	18.24	
9	9.68	21.59					
10	9.30	18.72					
11	5.56	26.64					
12	0.05	21.97					
r_n	9.04	19.44	0.46		9.66	23.85	0.41
σ	4.46	4.70			4.82	8.11	

TABLE II. THE ANALYSES' VALUES FOR THE RECONSTRUCTION OF THE OLD MARKET IN LODZ: CORRUGATION AND CNETRAL ANGLE

	North facade	**West facade**	**East facade**	**South facade**	
Corrugation (φ)	0.003623	0.101632	0.014923	0.163982	
	0.009263	0.22144	0.264982	0.289413	
	0.013601	0.13674	0.558645	0.380535	
	0.00796		0.830679	0.437859	
			0.841983	0.452478	
			0.506262	0.47934	
			1.078754	0.341997	
Average corrugation	0.0086118	0.153271	0.585175	0.363658	**0.27767889**
Central angle (α)	0.217827	0.134396	0.233878	0.236677	
	0.192346	0.083026	0.17665	0.197135	
	0.259558	0.143964	0.153952	0.157785	
	0.185947		0.258512	0.173245	
			0.163747	0.189091	
			0.143275	0.191368	
			0.141501	0.146875	
	21.391969	12.0462	18.16452	18.45967	**17.5155888**

TABLE III. THE ANALYSES' VALUES FOR THE RECONSTRUCTION OF THE OLD MARKET IN LODZ: REGULARITY

Regularity (τ)	1.274003	0.237062	0.028775	1.652843	
	0.891403	0.098132	0.893457	1.497418	
	3.035771	0.335194	2.577649	1.420905	
	2.653172		3.06436	4.331363	
			2.686072	8.04802	
			7.255301	6.223592	
			5.978173	1.241455	
	0.103669	0.007883	0.22197	0.339451	**0.16824325**

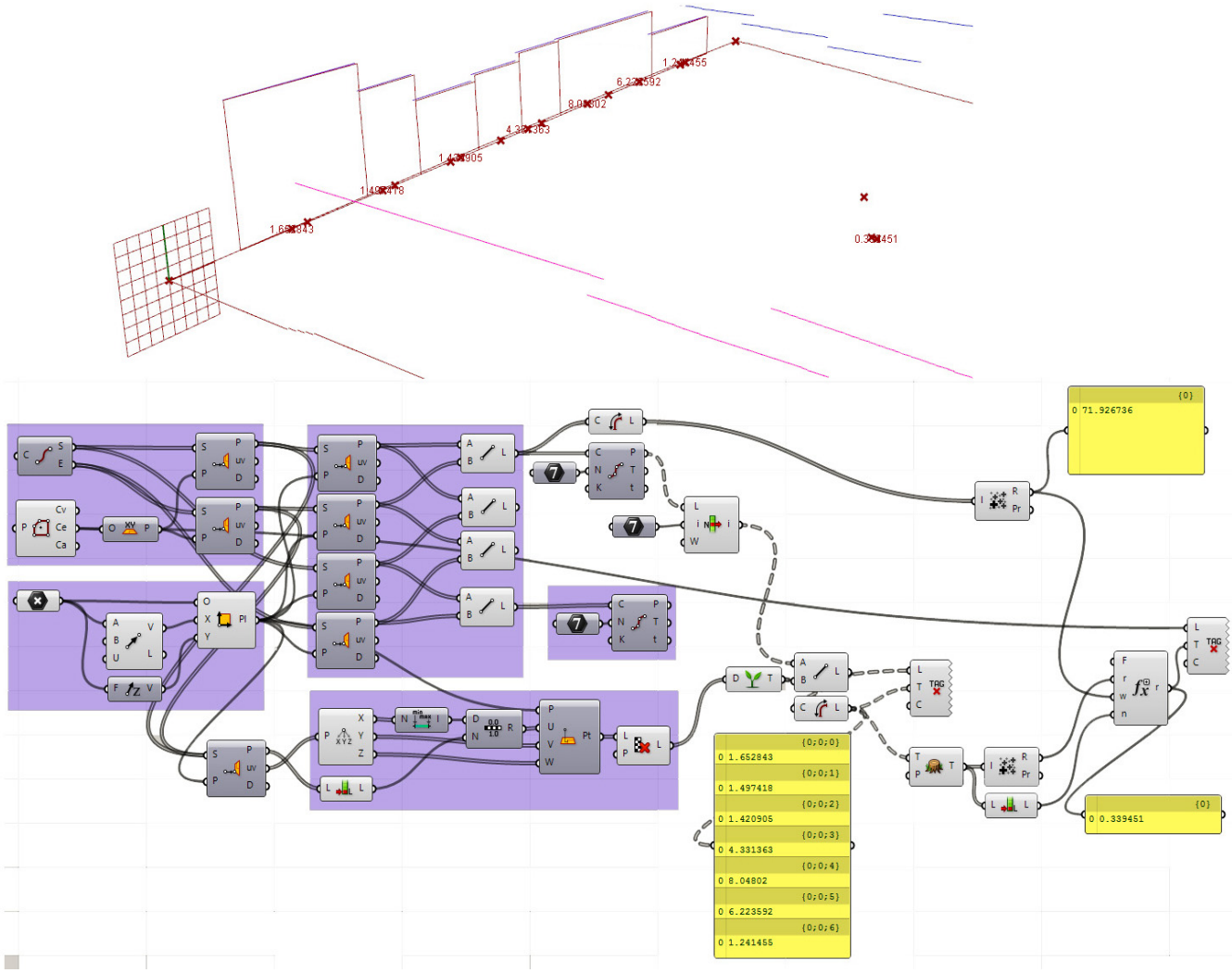

Figure 5. The analysis of regularity τ for the East facade of the Old Market in Lodz, reconstruction of the state before the World War II.

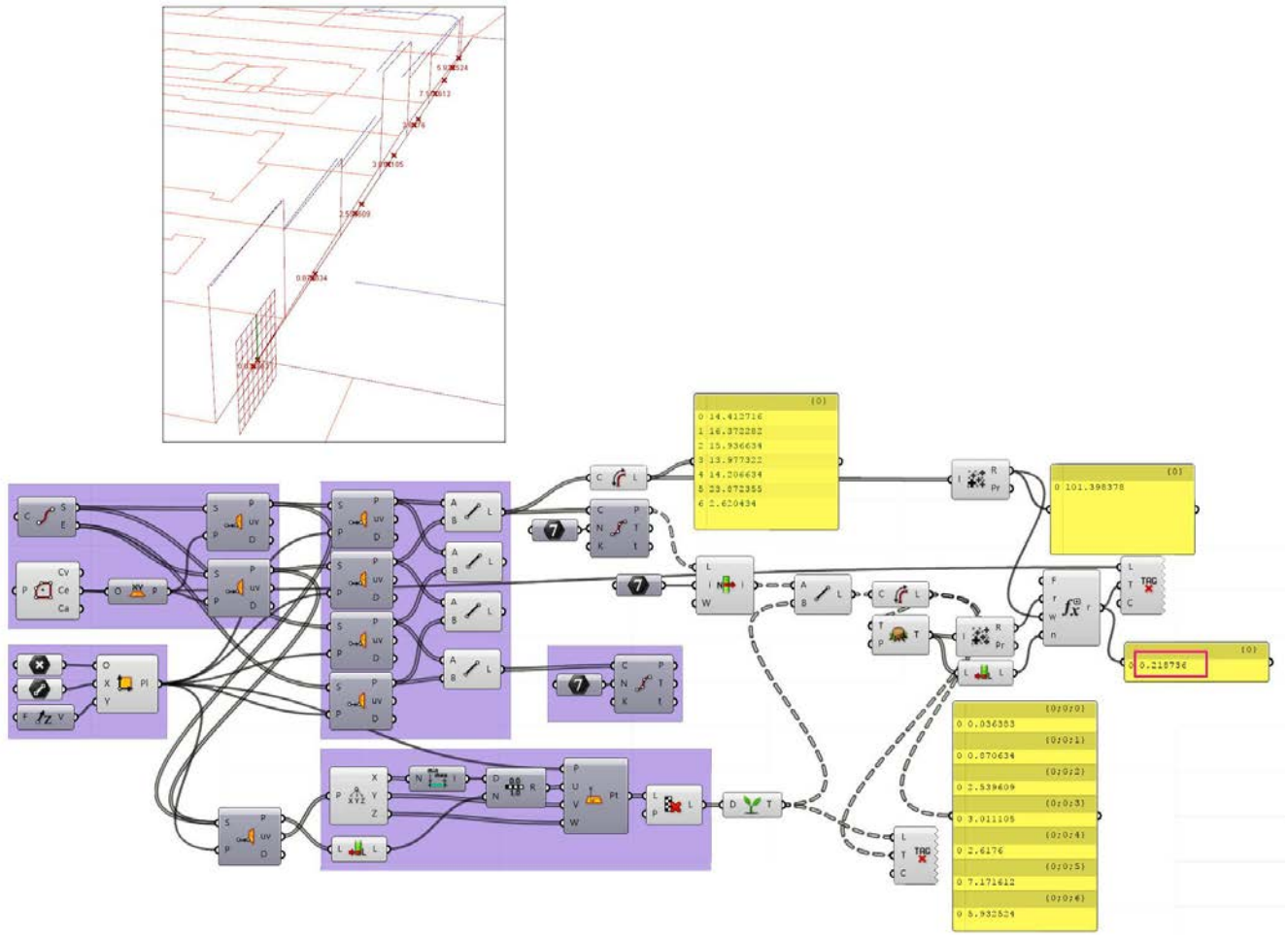

Figure 6. The analysis of regularity τ for the South facade of the Old Market in Lodz, reconstruction of the state before the World War II.

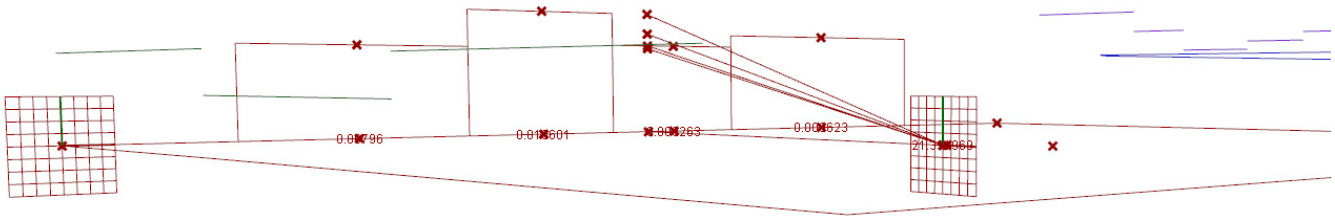

Figure 7. The analysis of the central angle α and corrugation φ values for the North facade of the Old Market in Lodz, reconstruction of the state before the World War II.

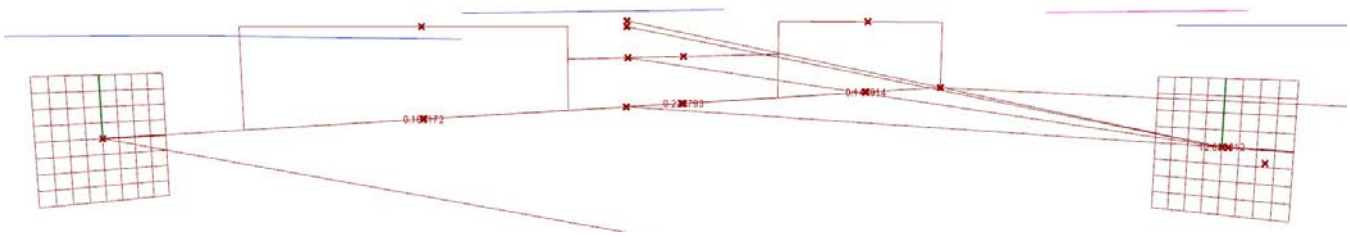

Figure 8. The analysis of the central angle α and corrugation φ values for the West facade of the Old Market in Lodz, reconstruction of the state before the World War II.

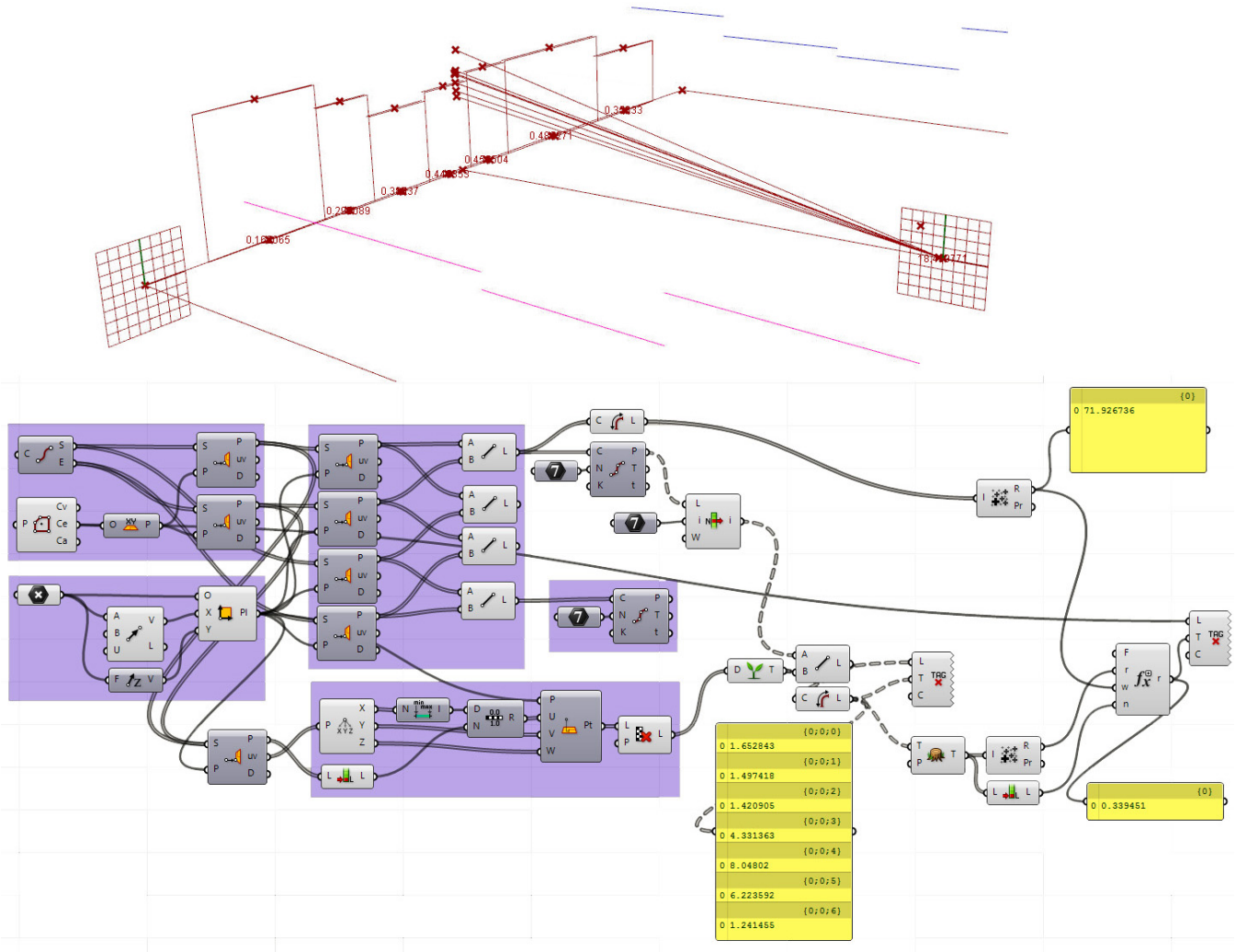

Figure 9. The analysis of the central angle and corrugation values for the East facade of the Old Market in Lodz, reconstruction of the state before the World War II.

The semi-automatic analyses presented in figures and tabular data collected as a result enabled work with large set of data and thus improvements of the method developed formerly and presented in [1]. Some small lapses were eliminated. Application of the semi-automatic method allowed significant acceleration of analyses. At this stage it is possible to switch between subsequent facades and analyses are performed automatically. The results will be further presented in the form of charts, showing rhythms of facades as waves, separate for each wall. Their overlap is going to be subject of the further analyses. There is also the possibility to write results of analyses to the separate Excel file for further research. For now this process is not fully automatic.

The analyses performed allow one to state that the corrugation of walls of the old market was significant, which, in comparison with the current settings, is an important difference. Similarly, the rhythms of current facades, constructed after World War II in socio-realism style, are very regular - the overall value is close to 0.

The application of an algorithmic method of analysis enables easy comparison of parameters for various settings. It has allowed verification of assumed mathematical apparatus and its validation. Use of Grasshopper, which is a the Rhino3D extension very popular among architects, may in future allow implementation of these types of analyses in the design process, similarly to other extensions of this type. The further work assumes creation of an extension for Grasshopper allowing the above analyses.

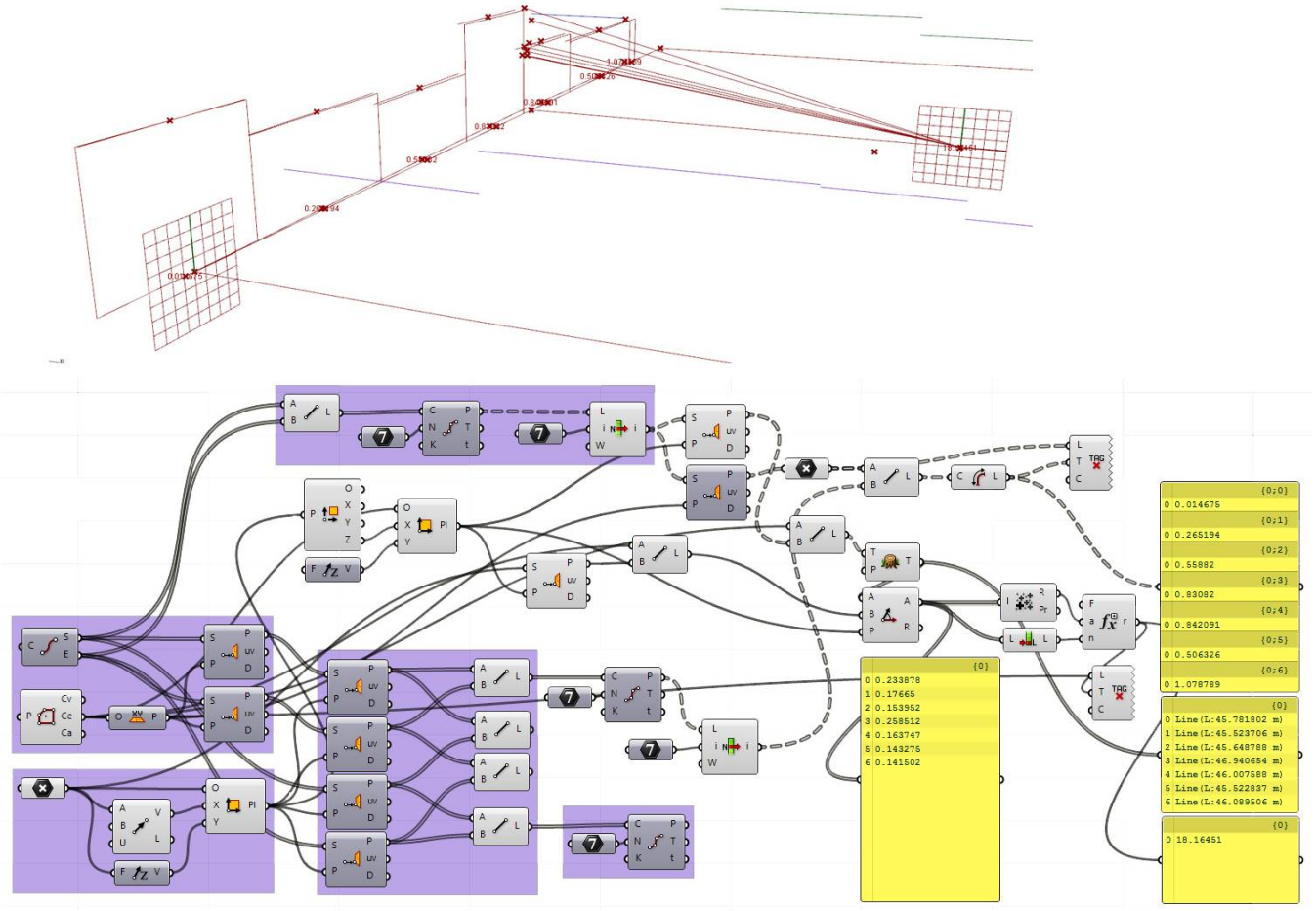

Figure 10. The analysis of the central angle α and corrugation values φ for the South facade of the Old Market in Lodz, reconstruction of the state before the World War II.

VI. CONCLUSIONS AND FUTURE RESEARCH

The challenge defined by Hall [23, p.55] that in a globalising world man must find out how *"basic cultural systems such as time and space are used to organise behaviour"* starts to influence contemporary urban design thought, as numerous studies show [9]. The thread of cultural studies imports viable content to the proposal of ontology for urban design, which is being developed, e.g., by Duarte et al. [30], Beirão et al. [31] or Beirão [32]. The requirement to define the methodology of description of public space character has been recognised. The studies of urban morphology are going through a period of intensive revival after a break associated with the activities of modernists [33] and attract the attention of numerous researchers all over the world, as Gauthier and Gilliland [9] describe in their comprehensive résumé.

An extensive set of culture dependent features was defined by Rapoport [12]. The current study provides assumptions to the quantitative description of public spaces based on the theory by Wejchert [3]. The concept of index points is introduced, which enables examination of the physical form of urban settings with the use of geometrical description. Basic values are defined, including the parameters of central angle, regularity and corrugation of an enclosure. Further development of the current theory is envisaged, including different approaches to the analyses of urban silhouettes and cross-sections, as well as its verification for the description of the assumed case study.

The current research is an ongoing one. Further steps include validation of the proposed methodology in an experimental way and comparison of various urban environments. This may help to understand the diachronic aspects of urban development. The first step covered exploratory modeling of various urban environments with the use of available software, including: (1) Google SketchUp; (2) CityEngine; (3) Rhino and comparison of results with the two-dimensional analysis explained hitherto [19]. The further steps assume comparison of resulting values with the extended analyses of kinetics patterns.

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