

Resilient Urban Form Assessment – Burgage Cycle and Morphometry

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Abstract. Over the years, cities and urban districts undergo constant transformations. Some areas are in their prime; others experience stagnation or, in the extreme case, collapse. We aim to contribute to the definition of the concept of urban resilience. Our goal is to expand its understanding from the normative perspective of urban design. We propose the method based on contemporary research in morphometrics. Our starting point is the Conzenian process of the burgage cycle. We begin with the approach developed by Marek Koter for several streets in Lodz. We expand the method further and relate it to the well-recognised attributes of urban resilience, i.e. diversity, connectivity, redundancy and modularity. Moreover, the key issue of this study was the proper relationship between the front width, plot area and Building Coverage Ratio (BCR). The case study showcases the method applying it to the case study of Zachodnia Street in Lodz, Poland.

Keywords: Urban resilience · Urban morphology · Urban form · Urban morphometry · Burgage cycle · Urban block · Urban design

1 Introduction

Urban areas undergo continuous transformations. The specific form of urban settings is the outcome of a given historical moment, stage of economic development and socio-political situation (Parysek 2015, p. 46). The development sine wave shows the periods of prosperity followed by stagnation and collapse (ibid. p. 47).

Sudden events left their mark on an urban system, its spatial, social, economic and environmental aspects. Cities able to restore functioning soon after major disruptions feature high resilience. Urban resilience gains researchers' attention, particularly concerning current climate change and sudden violent natural phenomena that degrade urban systems. In urban morphology, this concept has been increasingly applied to the analysis of physical urban form. Feliciotti et al. (2016, p. 2) claim that resilient urban form can be achieved at the architectural and urban design stage. Despite numerous studies, the issue has not been fully explored yet. Particularly the methodology that might support the objective assessment of the resilience level still welcomes new insights. The growth of mathematical and statistical methods for urban form assessment, as shown in publications describing the urban morphometry, opens new avenues for future research. Moreover, the search for relationships between specific elements of urban fabric becomes the subject of evaluation of resilient urban form.

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2 The Purpose of the Research

This article intends to supplement the definition of urban resilience with additional elements stemming from urban design. The analysis of physical form enables us to verify whether the evolutions of urban tissue can positively influence resilience in the long period perspective. The starting point is urban morphology and morphometry; we use and develop the current research framework in this field. Our goal is to enhance the current set of indicators to assess the resilience of urban form. For this purpose, we have performed a quantitative evaluation of selected 19th-century urban block. We measure elements such as front width, plot area, front-to-plot ratio and Building Coverage Ratio (BCR). The parameters mentioned above determine the quality of city centre tissue and its efficiency (Romice et al. 2020, p.47). Therefore, determining the proper relationships between them is necessary for the working urban system.

The parcels proportions, and the active fronts of buildings, have been researched before (e.g., Bobkova 2019; Dovey et al. 2017). The results show a clear relationship between active fronts and the FAR and BCR values. It also turns out that street fronts play a vital role in adding land value and shaping a resilient urban form. In order to verify this, we analyse the evolution of urban blocks located in the city centre, at Zachodnia Street in Lodz, Poland. We pay particular attention to the changing proportions between the front width, plot area, front-to-plot ratio and BCR. Scope of analysis is consistent with the research carried out in the 1990s by Professor Marek Koter (1990), who statistically and mathematically assessed the evolution of the urban form of the city centre of Lodz. In his research, he addressed plots located along the historical route and main transport axis of the city of Lodz, i.e. Piotrkowska Street. Therefore, this article continues the former local research on urban resilience with more contemporary urban morphometry.

3 Research Background

The concept of urban resilience is rooted in the theory of systems, described by the Austrian biologist and philosopher Ludwig von Bertalanffy (Van Assche 2019). Initially, this term was used in ecosystem research and means ability to keep essential functional characteristics, especially in the face of sudden threats and disruptions. Later it found its application in research on social-ecological systems. No less important is that, according to Bertalanfy's theory, complex systems, which are constantly changing, must also be resilient to violent and unexpected events. Therefore, building the resilience of complex systems is inevitable for a system to work without disruptions or, at least, to minimise the impact of adverse events.

Various definitions of resilience focus on continuity of urban systems (Meerow et al. 2016; Fuller and Quine 2016; Folke et al. 2010; Walker and Salt 2006, p. 1; Holling 1986, p. 296; Tobin 1999; Adger 2000; Zhou et al. 2008; Garschagen 2013). The concept changed since it was brought in the 1970s into ecology (Walker et al., 2004; Walker and Salt, 2006; Carter et al. 2015, Hanzl et al. 2021, Hanzl and Maldonado 2021). Holling (1973), who introduced the term to ecology from the engineering domain (Alexander 2013), highlighted the time needed by a system to return to the original after the disturbance. His definition assumes that at least some parts of the system continue. In the

ecological understanding of resilience, the system might accept some disruption before approaching a threshold (Holling 1996, p. 33; Wallington et al. 2005), although these are citizens who carry the weight of adaptation. The social-ecological perspective assumes that the local society is behind the ongoing transformations (Adger 2000; Tobin 1999).

The researchers pay attention to the ability of cities to adapt to rapid demographic changes, both depopulation, sudden population growth or the threat of terrorism. Resilience term is a part of a broader discourse on the concept of sustainable development (Davis 2013). The ambiguity also stems from its broad application since urban resilience also relates to other significant scientific issues such as sustainability, adaptability and system vulnerability. A wide field of interpretation may mean that it is a fluid term and should not constitute a basis for scientific considerations (Merrow et al. 2016). They propose to define the concept as follows: '*Urban resilience refers to the ability of an urban system and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity.*' (Merrow et al. 2016).

Resilience has also been implemented into urban morphology research; we find a comprehensive description in the work of Romice, Porta and Feliciotti (Feliciotti et al. 2016; Romice et al. 2020; Venerandi et al. 2017). The authors distinguish the five most important attributes that define a resilient urban form: diversity, connectivity, redundancy, modularity, efficiency. The same researchers popularise the concept of urban morphometry to assess the resilience of an urban form.

Morphometry is a method that has been developing recently in research on urban form. Nevertheless, the term has its origin in biology, where it means the quantitative characterisation, analysis and comparison of biological forms (Dibble et al. 2015). According to Roth and Mercer (2000), morphometry is a way to obtain information about biological material and biological processes (Dibble et al. 2019). Thanks to the quantitative evaluation employing statistical methods, biologists determine the degree of similarity and the relationship between elements taking into account form evolutions. Thanks to many groundbreaking scientific articles and publications in urban morphology (e.g. Berghauser Pont and Haupt 2021; Dibble et al. 2015; Dibble et al. 2019; Venerandi et al. 2017), the research perspective is already well recognised.

Nevertheless, the methodology is still evolving, and there is no single objective and commonly accepted way to quantify urban form (Venerandi et al. 2017). This paper contributes to developing a mathematical and statistical method to assess the resilience of urban form. In order to use morphometry, it is necessary to properly define elemental objects for quantitative assessment (Dibble et al. 2019). Therefore, an exercise was carried out in which the main aim was to an appropriate variable that could define individual proxies using the quantitative method.

4 Methodology

A starting point in our efforts to analyse urban form from the perspective of resilient thinking has been the concept of the burgage cycle developed by M.R.G. Conzen (1960). This theory describes five phases of transforming urban form, namely: institutive, repletive, climax, recessive and fallow. The first of them covers the gradual filling of the

original morphological plots – changes concern increasing FAR. The second repletive phase is the creation of new morphological units through the subdivision of existing ones. The third transformation phase often entails a complex reconstruction of existing spatial structures. It aims to create new, more efficient, more functional and aesthetic forms and usually has a chiefly qualitative dimension (Pireveli 2011, p. 511). The last two phases are strictly related to the erosion of city substance. Conzen's method has been recognised in the scientific literature as an appropriate tool to describe the evolution of spatial structures. In Poland, this method was popularised by Koter (1970). Continuing the research of M.R.G. Conzen, Koter (1990) presents the evolution of urban fabric adjacent to the principal street in Łódź, i.e. Piotrkowska Street. Based on historical cartographic data, Koter (ibid.) assesses basic features such as the BCR of an entire urban block, the minimum and maximum BCR values for individual lots, numbers of new streets and derivative cut lots. The results supplied a quantitative evaluation of the diachronic transformations of urban blocks. Koter (ibid.) concludes that BCR depends on the phase of the burgage cycle and the proportion between plot front and plot depth. His research should be seen as one of the first Polish quantitative analyses defining urban form. It might also be considered a precursory example of a morphometry study.

In order to verify assumptions concerning the evaluation of urban form, we based our approach on the research by Feliciotti et al. (2020, 2016). As mentioned earlier, they indicate five elemental proxies of resilient urban form. After reviewing over forty scientific publications, authors pick up a few of the essential attributes that best suit urban form and explain how these concepts can be reflected in the urban tissue. The attributes of the resilient urban form include (Feliciotti et al. 2016):

- Diversity is understood in an urban form as heterogeneity of function within one building or a variety of function within an urban block. Moreover, diversity can also be considered in the context of transport. Differentiating transport may improve accessibility and quality of life. The well-designed facades also positively affect diversity in urban form.
- Connectivity is conditioned by a level of connections between elements of an urban system. In this context, we shall consider streets, their length (which results from the size of the block) and the number of intersections per square kilometre. Well-developed connectivity allows for the free flow of people, which contributes to the greater intensity of activities. Small and compact urban blocks improve connectivity.
- The redundancy of an urban layout means an excessive number of streets or connections. This feature proves useful, notably when a sudden failure or traffic incident on one road cuts it off. From the point of view of urban resilience, redundancy protects against sudden damage or failure.
- Modularity is defined by the presence of all essential morphological elements in the appropriate scale: the higher modularity, the higher resilience of urban form. For instance, if an urban block consists of one lot, it is less resilient than an urban block with many plots.
- The efficiency of the urban structure is determined by small urban blocks, proper street scale, the suitable number of streets with pedestrian priority, and easy access to public transport and services.

Resilient thinking spans across scales, from a district through an urban block, street and down to a single lot. Urban resilience can occur at the architectural and urban design level. Since transformations of urban tissue are slow, proper solutions need to be implemented at the early stage to avoid time-consuming and costly works and to minimise disruptive events in future. Feliciotti (2016) claims that the designer might improve resilience by proposing proper configurations and relations between individual morphological urban elements. In this sense, the author admits that the above provisions should become principles of urban design. These research assumptions should be examined empirically. This might be done through the analysis of past transformations and the impacts of disruptive events.

We aim to quantify and objectively assess the resilience of the urban form. The primary assumption is to isolate a few essential elements, i.e. front width, plot area, front-to-plot ratio and BCR and to measure these features at each stage of the burgage cycle. This approach stems from the literature review, which shows that the width of the front of the plot located along the streets directly affects the plot's attractiveness and land value. Moreover, buildings located along an attractive street are more susceptible to changes (Le Fort and De Vissher 2020; Torma et al. 2017; Dovey et al. 2017). Besides, researchers observe the relationship between the width of the frontage and the intensity of plot development (Bobkova 2019). It turns out that the relations between these elements influence accessibility (Oliveira 2013, p. 25; Sharifi and Yamagata 2018, p. 175), which Feliciotti et al. (2016) interpret as affecting the resilience of the urban form. In turn, double access to the street front in the case of a through plot or a wide frontage available from the street favours diversification. Plots with narrow fronts and greater depth are more exposed to structural changes under high economic pressure (Törmä et al. 2017). In the current study, we have investigated all the above assumptions. The research has used the available cartographic data:

1. 1823 – The original plan of Łódź by F. De Viebig (https://atlas.ltn.lodz.pl/)
2. 1849 – Map by J. Lenartowski (https://atlas.ltn.lodz.pl/)
3. 1873 – Map by R. Miciński (https://atlas.ltn.lodz.pl/)
4. 1907 – Map by W. Starzyński (https://atlas.ltn.lodz.pl/)
5. 1989 – Satellite imagery (https://lodz.retromapy.pl/)
6. 2021 – Satellite imagery (https://lodz.retromapy.pl/)

The Quantum GIS software has been applied as a tool supporting the use of the method described above. The following parameters have been included in the table of attributes and measured. The Front-to-plot ratio was calculated using the equation:

$$\frac{Front\ width}{Plot\ Area} = Front - to - plot\ ratio \tag{1}$$

The BCR values have been calculated using the equation.

$$\frac{Summary\ Building\ Area\ in\ one\ plot}{Plot\ Area} \times 100\% = \mathrm{BCR} \tag{2}$$

Based on this material, the stages of spatial development were traced, and the socio-economic situation at various stages of transformation of plots was also considered.

5 Case Study Selection

Continuing the study by Koter (1990) we have chosen a site located in Lodz, in central Poland. Founded back in the Middle Ages, Lodz went through rapid economic and spatial growth during the industrial revolution, i.e. the turn of the 19th and 20th centuries. Initially planned as a handicraft settlement, Lodz was one of the pilot planning activities of the then authorities of the Kingdom of Poland. Its spatial arrangement stands out as a typical street village, i.e. short fronts and deep plots (21,5 m × 285 m). In the second half of the nineteenth century, handicraft gave way to mechanised industry, and violent and uncontrolled urbanisation and poor administration became the main factors in the lack of coordinated planning. The city has characteristic large quarters reaching 180 × 230 m. Besides, as a result of raging urbanisation processes, the city has relatively scarce public space, which negatively affects accessibility. The first attempt to repair the spatial structure of Lodz took place when the general plan was developed in 1915, the principal designer of which was Christoph Ranck (Olenderek 2004, p. 23). One of the essential planning decisions was the decrease of the proportion of urban blocks and the creation of local nodal points and city squares. The latter, due to the specific nature of a handicraft settlement, were not initially planned. The bold design decisions were aimed at "healing" the dense inner-city tissue of the agricultural origin. The elaboration of the plan lasted until 1935 when the City Council adopted the General Development Plan for the City of Lodz in a limited version. The essential alteration covered resignation from changing the proportions of urban blocks to increase the length of the fronts and from punching the streets through the middle of the quarter.

The enlarging of the streets right of way was proposed as a substitute along with the demolition of the street facade on one side. Christoph Ranck, who was the designer of the original version of the General Plan, opposed such an idea; he considered destroying the entire frontage an action contradicting rational urban management (Holcgreber et al. 1930, p. 311–314). Wacław Ostrowski, after a careful analysis of potential breakthroughs and street widening, concluded that both options are burdened with too much risk and uncertainty in the implementation, even assuming the support of private and public capital (Ostrowski 1935b, p. 365). However, he pointed out factors that might have had a decisive influence on the success of street widening. These observations remain valid. Not only is the success of the widening scheme determined by creating a new communication route enabling active fronts. Another condition is defining the proper intensity ratio and the frontages height (Ostrowski 1935a, p. 321). An indisputable benefit is the increase of real estate value located on the new street. Despite several decades of discussion conducted by town planners and architects in Lodz, finally, in the 1960s, a decision was made to demolish the entire street frontage of Zachodnia Street in the New Town. This street was delineated in the original plan from 1823.

The demolition belongs to the category of sudden events in the face of which urban form should be capable of efficient adaptation and reorganisation. In the free market economy, the high value of plots located in the city centre contributes to a gradual increase in rent, which has a significant impact on the variability of functions and form; in Lodz, however, this was not the case. Unfortunately, the centrally planned economy in the years after the Second World War hindered the development of the frontage of Zachodnia Street.

6 Analysis of the Urban Blocks Transformations

6.1 1821–1827 – the Original Plan of Lodz by F. De Viebig – Institutive Phase

The analysed part of the city of Lodz was originally planned as a handicraft settlement. Its core was the octagonal market square of the new city. The dimensions of the analysed block are 172 × 215 m, the minimum dimensions of a single lot are 21.5 m × 43.0 m, and the maximum dimensions are 21.5 m × 86 m. The settlement outlined in this way was to form the basis of a later development model, which assumed the construction of a front one-story building and the use of the remaining part of the lot for production.

6.2 1849 – Map by J. Lenartowski – Repletive Phase

Until 1849, the filling of the analysed blocks with buildings proceeded relatively slowly (see Fig. 1). It is possible to distinguish twelve masonry buildings and thirty-six wooden buildings, the average BCR of a single lot was from 9% to 22.2%. Notably, some lots were not built on at all. There was no division or merger of the lots. There is no setback; all buildings facades were placed on the edge of the street. Most probably, most of the buildings were single-story buildings. The following Table 1. gives a summary of all measures and calculations.

6.3 1873 – Map by R. Miciński – Repletive Phase

There is a noticeable tendency to develop the plot deeper (see Fig. 1). It could have resulted from the development of handicraft processes and the need to build farm buildings. Significantly, new buildings are usually placed along one border; they are single-bay buildings with a depth of about 5 m, lit only from the inside of the plot. These structures are often independent, not connected to the front building. Despite various depths, most lots are developed up to a depth of forty meters, even lots that are 86 m deep. This is also the stage of the construction of the first urban tenement houses.

We can observe the most prominent construction activity near the new market and along the main road, i.e. Piotrkowska Street. The front tenement houses have two outbuildings leading into the plot with an average depth of 5 m. The bias towards the exterior of the lots closest to the edge of the street is still noticeable. As an outcome, the central areas of the analysed blocks are undeveloped because they do not fulfil any active urban function. The following Table 1 gives a summary of all measures and calculations.

6.4 1907 – Map by W. Starzyński – Climax Phase

The turn of the nineteenth and twentieth century is a moment of intensive urbanisation, which is reflected in a significant increase in the built-up area of plots. At this stage, the urban development in the form of two wings of four-storey outbuildings fills in the rest of the plots (see Fig. 1). The front buildings often remain intact. This results in a one-story front building adjacent to the four-storey outbuildings at the back of the plot. Moreover, there are several changes in the proportions and sizes of plots (plots A6, A23, A25 and A7). The time just before First World War marked an evident slowdown

Table 1. Table with measures and calculation of urban block from 1849 on the left and from 1873 on the right.

Plot number	Front width (meters)	Plot Area (square meters)	Front-to-plot ratio	BCR %	Plot number	Front width (meters)	Plot Area (square meters)	Front-to-plot ratio	BCR %
A1	21,5	1849	0,01116	9,5	A1	21,5	1849	0,0116	23,4
A2	21,5	1849	0,0116	0	A2	21,5	1849	0,0116	16,7
A3	21,5	1849	0,0116	9,5	A3	21,5	1849	0,0116	18,2
A4	21,5	1849	0,0116	9,5	A4	21,5	1849	0,0116	21
A5	21,5	1849	0,0116	9,5	A5	21,5	1849	0,0116	25
A6	21,5	1849	0,0116	9,5	A6	21,5	1849	0,0116	30,2
A7	21,5	1849	0,0116	0	A7	21,5	1849	0,0116	10,4
A8	21,5	1849	0,0116	9,5	A8	21,5	1849	0,0116	30,6
A9	21,5	1849	0,0116	0	A9	21,5	1849	0,0116	15,4
A10	21,5	1849	0,0116	9,5	A10	21,5	1849	0,0116	19,9
A11	64,5	924,5	0,0698	0	A11	64,5	924,5	0,0698	42,8
A12	21,5	924,5	0,0233	0	A12	21,5	924,5	0,0233	40,6
A13	21,5	924,5	0,0233	0	A13	21,5	924,5	0,0233	32
A14	21,5	924,5	0,0233	19	A14	21,5	924,5	0,0233	35
A15	21,5	924,5	0,0233	19	A15	21,5	924,5	0,0233	23,1
A16	64,5	924,5	0,0698	19	A16	64,5	924,5	0,0698	49,54
A17	21,5	924,5	0,0233	19	A17	21,5	924,5	0,0233	36,9
A18	21,5	924,5	0,0233	19	A18	21,5	924,5	0,0233	19
A19	21,5	924,5	0,0233	19	A19	21,5	924,5	0,0233	44,5
A20	21,5	924,5	0,0233	19	A20	21,5	924,5	0,0233	37,6
A21	64,5	924,5	0,0698	19	A21	64,5	924,5	0,0698	45
A22	21,5	924,5	0,0233	7,8	A22	21,5	924,5	0,0233	37,1
A23	53,75	1213,4	0,0443	21,8	A23	53,75	1213,4	0,0443	53,3
A24	53,75	1213,4	0,0443	22,2	A24	53,75	1213,4	0,0443	67,7
A25	22,8	1300	0,0175	15,8	A25	22,8	1300	0,0175	34,3
A26	22,8	1300	0,0175	15,8	A26	22,8	1300	0,0175	45,3

in urban development, but this was also the moment when lots gained the maximum level of investment (BCR). The First World War left an imprint on the development dynamics of the city, and from that moment on, the recession started. In the analysed area, the structures start gradually degrading. The following Table 2. gives a summary of all measures and calculations.

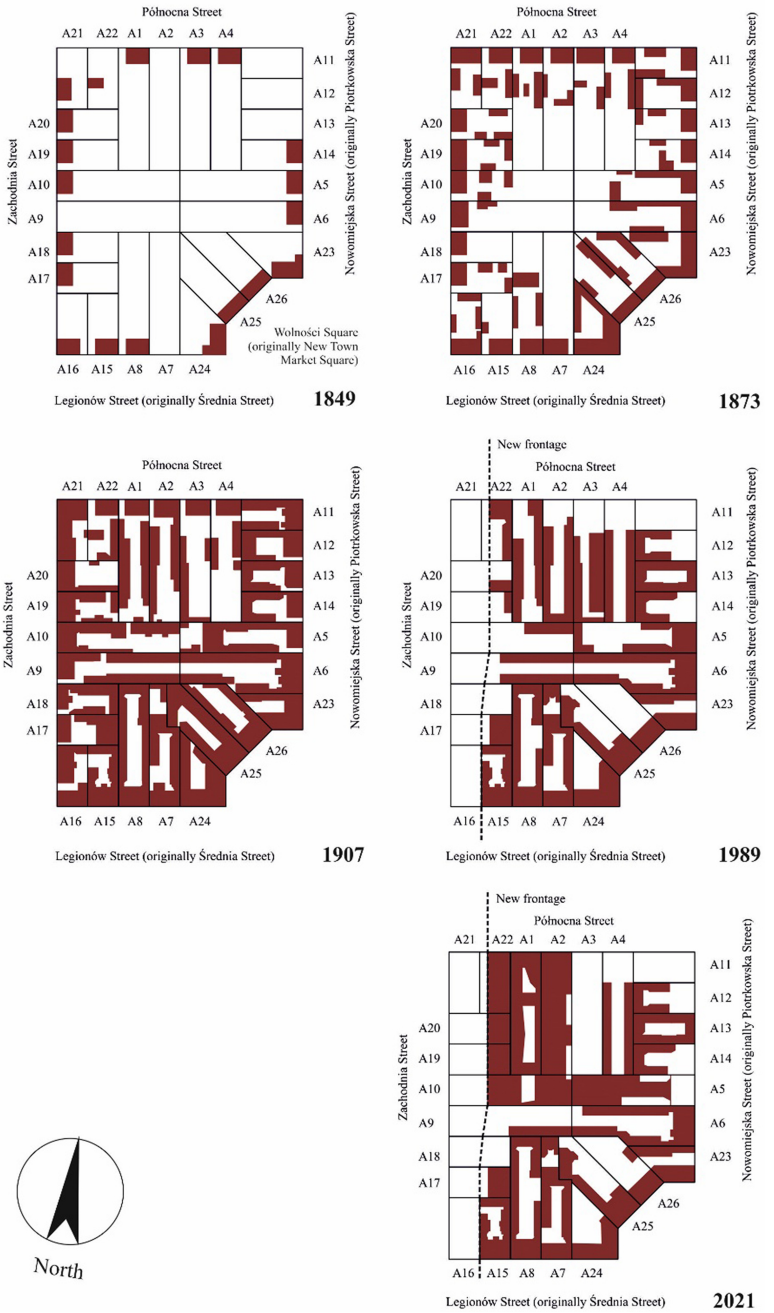

Fig. 1. This figure shows urban tissue drawn up on the basis of Lenartowski's Map from 1849, on the basis of Miciński's Map from 1873, on the basis of Starzyński's Map from 1907, on the basis of Satellite imagery from 1989 and on the basis of Satellite imagery from 2021.

Table 2. Table with measures and calculation of urban block from 1907 on the left and from 1989 on the right. Cells with outlines shows plots whose proportions changed as a result of the demolition of the eastern frontage of Zachodnia Street.

Plot number	Front width (meters)	Plot Area (square meters)	Front-to-plot ratio	BCR %	Plot number	Front width (meters)	Plot Area (square meters)	Front-to-plot ratio	BCR %
A1	21,5	1849	0,0116	51,6	A1	21,5	1849	0,0116	48,6
A2	21,5	1849	0,0116	49,5	A2	21,5	1849	0,0116	49,8
A3	21,5	1849	0,0116	34	A3	21,5	1849	0,0116	51,2
A4	21,5	1849	0,0116	26,8	A4	21,5	1849	0,0116	42,7
A5	21,5	1849	0,0116	57,1	A5	21,5	1849	0,0116	45,9
A6	28,3	2190	0,0129	61	A6	28,3	2190	0,0129	62,2
A7	21,5	1574	0,0137	62,5	A7	21,5	1574	0,0137	63,8
A8	21,5	1849	0,0116	63,7	A8	21,5	1849	0,0116	59,2
A9	21,5	1849	0,0116	59,2	A9	21,75	1304	0,0167	52,77
A10	21,5	1849	0,0116	53,8	A10	21,5	1268	0,017	21,21
A11	64,5	924,5	0,0698	71	A11	64,5	924,5	0,0698	0
A12	21,5	924,5	0,0233	66,5	A12	21,5	924,5	0,0233	39,4
A13	21,5	924,5	0,0233	69,7	A13	21,5	924,5	0,0233	72
A14	21,5	924,5	0,0233	63,3	A14	21,5	924,5	0,0233	41,1
A15	21,5	924,5	0,0233	71,3	A15	64,5	924,5	0,0698	74
A16	64,5	924,5	0,0698	69,6	A16	–	–	–	–
A17	21,5	924,5	0,0233	65,5	A17	21,5	462	0,0465	71,4
A18	21,5	924,5	0,0233	65,9	A18	21,5	924,5	0,0233	–
A19	21,5	924,5	0,0233	62,3	A19	21,5	343,8	0,0625	22,7
A20	21,5	924,5	0,0233	44,5	A20	21,5	343,8	0,0233	36,36
A21	64,5	924,5	0,0698	71,2	A21	–	–	–	–
A22	21,5	924,5	0,0233	49,6	A22	59	687,9	0,0857	58,6
A23	46,95	872,4	0,0538	75,2	A23	46,95	872,4	0,0538	67,2
A24	53,75	1213,4	0,0443	78,8	A24	53,75	1213,4	0,0443	50,8
A25	22,8	1575	0,0145	80,5	A25	22,8	1575	0,0145	54,5
A26	22,8	1300	0,0175	64,2	A26	22,8	1300	0,0175	22,8

6.5 1989 – Satellite Imagery – Recessive Phase and Fallow

Having survived two world wars and changes of spatial development directions of Lodz in line with the spirit of the era and modernist ideals, the analysed area entered a period of a deep recession. Poor technical conditions, abandonment of conservation and technical activities contributed to the erosion of the urban substance. The deep transformations in this part of the city, including the demolition of the eastern frontage of Zachodnia Street, enhanced the process (see Fig. 1). This disruption became the spiritus movens

of the subsequent degradation of this part of the city. The organised undertaking of demolishing the frontage was to be a cure for the growing spontaneous movement and, in a sense, also to heal the urban tissue. However, this did not happen; the changes in the proportions of the lots of the eastern frontage of Zachodnia Street would not happen over the next 50 years. This stems partly from the abandonment of further construction activities by the city authorities before 1989 and insufficient efforts to develop this part of the city after 1989 in the realities of a free market economy. The following Table 2 gives a summary of all measures and calculations.

6.6 2021 – Satellite Imagery – Fallow and Repletive Phase

The current condition indicates changes towards the revival of the urban form. There is a clear attempt to repair the degraded tissue of city quarters. The city, regaining its development dynamics, fills up empty plots again (see Fig. 1). At the same time, steps have been taken to create new communication routes while reducing the size of the urban blocks. Thus, the city gained new public spaces and a chance to develop new fronts. The intensification of redevelopment processes is also, in a way, caused by the implementation of new investments in the vicinity of the analysed quarter, among others, revitalisation of the factory complex of Izrael Poznański. The following Table 3. gives a summary of all measures and calculations.

Table 3. Table with measures and calculation of urban block from 2021.

Plot number	Front width (meters)	Plot Area (square meters)	Front-to-plot ratio	BCR %
A1 + A2 + A22 + A20 + A19 + A10	166,5	6342	0,0262	87
A2	–	–	–	–
A3	21,5	1849	0,0116	0
A4	21,5	1849	0,0116	42,7
A5	21,5	1849	0,0116	36,7
A6	28,3	2190	0,0129	62,2
A7	21,5	1574	0,0137	63,8
A8	21,5	1849	0,0116	59,2
A9	21,75	1304	0,0167	22,6
A10	–	–	–	–
A11	64,5	924,5	0,0698	0
A12	21,5	924,5	0,0233	39,4
A13	21,5	924,5	0,0233	72

(*continued*)

Table 3. (*continued*)

Plot number	Front width (meters)	Plot Area (square meters)	Front-to-plot ratio	BCR %
A14	21,5	924,5	0,0233	41,1
A15	64,5	924,5	0,0698	74
A16	–	–	–	–
A17	21,5	462	0,0465	71,4
A18	21,5	924,5	0,0233	–
A19	–	–	–	–
A20	–	–	–	–
A21	–	–	–	–
A22	–	–	–	–
A23	46,95	872,4	0,0538	67,2
A24	53,75	1213,4	0,0443	50,8
A25	22,8	1575	0,0145	54,5
A26	22,8	1300	0,0175	22,8

7 Results

This article aims to assess urban resilience based on urban plot transformation analysis and urban morphometry. Basic calculations were made with Quantum GIS software for each of the development stages of the site based on available cartographic data. From this study, we have drawn several conclusions:

1. The analysis shows a relationship between the front width and BCR. There is a clear rule that plots with more elongated fronts also feature a higher BCR. The practice to enlarge the front contributes to increasing profits from the real estate for the commercial premises.
2. Plots with a lower ratio of the front length to the plot area develop much slower (A1-A10). The shape of the lot was adjusted to the land use in the initial phase of the development. When the activity changed, such deep lots were no longer needed.
3. Plots with a higher front-to-plot ratio (A11, A16, A21, A23, A24) are more susceptible to changes than deeper plots with a shorter front. We can refer to this as the penetration of lots by active urban life. Smaller quarters are more susceptible to urban activity, i.e. their penetration rate with urban activity is higher.
4. Anomalies - despite alleged actions leading to a reduction in the proportion of plots and the entire quarter, plots along Zachodnia Street were not developed for a long time. A probable explanation of this situation may be the fact that the reality of the centrally planned economy did not create favourable conditions for this restoration after this disruption. It also means that the dimensions of the plots are not the only factor determining the city's resilience. In the case of some lots, this improved the

accessibility, efficiency and penetration of the plot by urban activity. However, it did not bring any effects that would affect the replacement of depleted buildings. This was partly because the shortening of plots with a proportion of 43 m to 15 m made it impossible, from an architectural point of view, to construct two-bay residential buildings (with light from both the west and the east). In other words, the replacement of buildings was uneconomical and unprofitable.

5. Anomalies - even though after 1989, conditions of the market economy made it possible to invest in empty plots of land, nothing changed. The situation improved when some plots were joined together. It was then that the interest in new investments appeared. The reason is as follows: the deep plot 21.5 m large does not allow for implementing an economically profitable investment. It is related not only to the available FAR and BCR but also to the possibility of arranging good-quality and well-litten premises. Moreover, we observe that corner plots are relatively more attractive and more susceptible to changes and market activities. While regarding the modularity of the urban form, the consolidation of plots should be assessed negatively, the outcome indicates that this remains the only possibility of healing this part of the city.
6. Extensive urban development projects are much more prone to failure than smaller-scale individual projects. In theory, reducing the quarter's dimensions by demolishing the frontage should positively affect the accessibility, efficiency, and connectivity of the urban form (Oliveira, 2013, p.25; Sharifi, Yamagata, 2018, p.175). Despite these actions that should bring a more resilient urban form, it was impossible to complete and implement all the assumptions. At the same time, it means that point actions seem essential for chain reactions in the market economy realities (the case of consolidation of plots).
7. The case of plot A3, A9, A10, A5 shows that deep plots with a short front take much longer to return to the repletive phase, i.e. refilling after fallow.
8. The buildings in the back of the plot react more slowly to the market, which means that marking a new street in the middle of the quarter (as an alternative to demolishing the street frontage) would be a driving force for changes. This intervention shall simultaneously shape two new street frontages, doubling the length of the fronts for plot owners. The key is access to public space and greater penetration with urban activity.
9. The improvements in car traffic did not increase the attractiveness of the site.
10. The current size of plots is too tiny to revive the city's functioning, which means that one should strive to consolidate smaller plots into larger ones, bearing in mind the architectural design aspects (availability of light and conditions of not obscuring the development).
11. In order to fully reflect the architectural issues and the quality of the urban form, it is also necessary to track changes in the intensity of development over time. The intensity of development is probably higher in the case of longer fronts, as shown by the conclusions from the last 30 years.

The analysed example of Zachodnia Street confirms that streets and organised transformations of spatial structures have varied potential to support or reduce urban resilience. Depending on the specific factors, the level of immunity can be positively or

negatively affected. In retrospect, the nineteenth-century activities led to the creation of a unique, multifunctional spatial structure, which at the same time was not free from defects. Even though the procedure of demolishing entire street frontages was commonly practised during Modernism, our case shows that such action can significantly weaken the city's spatial structure for many years. The realities of the centrally planned economy hindered the reconstruction, and market mechanisms could not have positively impacted the rapid reconstruction of the frontage. However, there was a noticeable change in the development of smaller plots.

In conclusion, in the light of the presented analyses, applying the concept of resilience in urban design has a strong foundation. For this reason, an attempt should be made to prepare broader analyses on this topic. This approach will help define the design framework. It is also reasonable to take all measures to minimise adverse events in the future. From the perspective of the urban system, making the right decisions at the design stage seems to be the easiest and least costly way to obtain a resilient urban form. Moreover, as our case shows, organised urban planning activities often leave permanent scars on the urban tissue.

8 Summary Conclusions

The current research proves the need to continue analysing urban resilience using computational and quantitative methods. The study based on the indicated attributes enabled an assessment of how the resilience changed at each stage of development. The proposed method shows significant dependencies between the width of the plot front, the plot area and the plot development area. These dependencies and the analyses of FAR and BCR can be the basis for the quantitative assessment of the resilience of the urban form. The mutual influence and proportions between the individual morphological elements of the city determine the pace and nature of the changes taking place in the urban form. The analyses on urban resilience might help to recommend good development directions.

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