FOLIA GEOGRAPHICA • ISSN 1336-6157 (hard copy) • ISSN 2454-1001 (online)

APPLICATION OF CLUSTER ANALYSIS IN URBAN MORPHOLOGY RESEARCH. THE EXAMPLE OF INDUSTRIAL PLOTS IN ŁÓDŹ (POLAND)

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Received: June 19, 2020 | Revised: August 21, 2020 | Accepted: September 13, 2020
Paper No. 20-62/2-563

Abstract
The article presents the taxonomic method of cluster analysis used to identify morphological types of industrial areas. The authors examined three features of the industrial plot in several periods (Po - total area, K - shape index, Pz - built-up area [%]) and used the Ward classification method, which allowed them to identify the morphological types of industrial plots in Łódź, as well as certain representative types for individual periods of study. The development and position of the city is related to the development of the textile industry, built in Łódź from the 1820s. Initially a centre of crafts, it quickly transformed into a cotton and wool production centre in the mid-19th century. In this process, many distinguishing features were created, such as the spatial layout, industrial areas in the morphological and functional structure of the city, industrial and residential architecture. The collapse of the industry took place during the political transformation in Poland after 1989. These studies are among the most traditional in urban studies, focusing on the spatial traces of the city and are combined with statistical methods rarely found in historical research. The study included 10% of the overall number of industrial plots in 1986 in Łódź. The sample was selected intentionally; it consisted of the oldest plots, established in the period of the dynamic development of industrial areas in the late 19th and early 20th centuries. The applied taxonomic method allowed the authors to create a model for the transformation of industrial plots in Łódź (1896-1986).

Key words
Cluster analysis, urban morphology, industrial plots, Łódź, Poland.

INTRODUCTION

Morphological urban studies have often been discussed in geographical literature, especially regarding geographical-historical settlement studies. Research based on historical and geographical studies includes plan analysis with metrological aspects. The precursor of morphometric studies is Conzen, who started to study German and English cities in the 1920s. These were classical studies that, as Whitehand claims, were strongly influenced by Schlüter, Geisler and Fritz. (Whitehand, 2001) Conzen's work about Newcastle (Conzen, 1962) features all the stages of

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a classical morphological analysis, from the study of land topography, through the chronological reconstruction of the urban tissue growth and types of buildings, to drawing maps of morphogenetic units. Conzen's analysis (Conzen, 1960) comprised data spanning over 200 years, was descriptive and, most importantly, included novel aspects of urban morphology research, such as recreating the growth of the built-up area in the oldest part of the city. His examination of land coverage density and the patterns of changes made it possible to identify individual phases of development, the order in which they occurred and the land coverage saturation in individual phases. The process was referred to as an urban cycle. Moreover, (Conzen, 1962) described the reconstruction of urban blocks of tenement housing and the changes in the development of the outskirts of a medieval city. The study of development dynamics inspired many urban studies, for cities in Europe: British (Larkham, 2006), French (Darin, 1998), Italian (Marzot, 2002), German (Hofmeister, 2004), Polish (Koter & Kulesza, 1999), Slovak (Matlovič, 1995), Turkish (Ünlü & Baş, 2017), as well as elsewhere (Larkham & Conzen, 2014), and thus we refer to them as the Conzenian trend in urban morphology studies (Whitehand, 2001).

Mathematical methods have been applied for classification purposes for a hundred years and were first appreciated in anthropology (Czekanowski, 1911) or biology (Fisher, 1936). The 1960s brought significant developments, particularly in the field of cluster analysis, when it has been shown to be potentially very useful in different sciences for grouping similar objects. The similarity criterion in cluster analysis may be mathematically defined and has been described by R. R. Sokal and C. D. Michener. (Sokal & Michener, 1958). Mathematical methods have been more and more frequently used in recent geographical-historical studies. Researchers use simple statistical methods, as well as graph (Trigueiro & Soares de Medeiros, 2007), fractal (Batty & Longley, 1994) cluster analysis (Grimshaw et al., 1970) and other frameworks of spatial analysis, including GIS (Peeters & Etzion, 2012). They allow them to describe phenomena and point to certain transformation processes, typical of particular areas and common in historical studies.

OBJECTIVES

The main aim of this article is to present the potential of hierarchical clustering in urban morphology studies, especially for tracing the transformations of urban industrial plots of land. Industrial plots are a particular type of urban plots, as they undergo development processes leading to the transformations of urban morphological units.

For the purpose of studying the morphology of industrial plots, the authors chose Łódź, a Polish city which owes its development to the industrial function. Between 1815 and 1989, textile manufacturing was the predominant type of industry in the city. After 1989, following the political and economic transformation

in Poland, the textile industry declined, and many industrial areas changed their functions. Therefore, the studied plots had to be carefully chosen – they performed industrial functions from the moment they were established until 1986.

THE STUDY AREA

The city of Łódź has been chosen as the area of study. Located in central Poland, it is currently the third largest city in the country (772 thousand inhabitants in 2015), the capital of the voivodeship, as well as a big economic, academic and cultural centre. It dates back to the Middle Ages, but the real development and position of the city is related to the progress in textile industry, built in Łódź since the 1820s. It was initially a handicraft centre, which underwent rapid transformation into a cotton and wool manufacturing centre in mid-19th century. This dynamic development can be seen, among others, in population growth, from 18.6 thousand in 1840 to 321 thousand in 1900 and 500.5 thousand in 1914. This process helped form many distinguishing characteristics, such as the spatial layout, industrial areas in the morphological and functional structure of the city, industrial and residential architecture. Industrial areas could be found at all stages of development. They emerged before the first craftsmen, industrialists and workers came, as craft settlements were first planned, then populated with willing persons. For nearly 200 years, the industrial areas were undergoing changes, with many of them serving their industrial function in the same location until the 1980s, when the textile industry broke and collapsed due to political and economic transformations. Currently, there are textile factories in Łódź manufacturing cotton, flaxen or wool fabrics. Only one plant, Ariadna Thread Factory SA, has been continuously operating since 1897.

The layout and features of the first industrial plots in Łódź

The first industrial plots in Łódź were established in craft settlement. Those settlements emerged in the 1820s in areas that were prepared and regulated under the wide-spread industrialisation effort in Poland. During this time, craft settlements of Nowe Miasto and Osada Łódka were founded in the outskirts of a small agricultural town of Łódź, with manual production of wool and cotton fabrics. These settlements were located in free and undeveloped areas (agricultural or forest), and their planning followed the rules of founding craft settlements at the time. Osada Łódka consisted of several colonies: weavers', Spinnlinie, Buschlinie, Ślązaki and Kąty. Artisans living in the colonies cultivated and processed flax and wove cloth. Individual crafts and agricultural parcels in the colonies varied in size, depending on the tasks assigned to a given colony. The weavers' parcels were smaller, while flax growers needed bigger plots. All were rectangular. In the weavers' colony, the plots were 0.56 ha, with dimensions of 291 m x 21.6 m or 19.2 m, the wool weavers'

garden were 0.75 ha, with dimensions of 216 m x 34.6 m. In flax-growing colonies, the plots were from 1.6 ha to over 2 ha in size, also rectangular and elongated, 390 m x 40 m, with some parcels in Nowa Łódka exceeding 500 m (own calculations). (Koter, 1969)

The final stage of production, i.e. linen finishing and bleaching, took place in the industrial district, located centrally in relation to the colony. The district was dubbed with an old Polish term "posiadło wodno-fabryczne" (water and factory settlement). The industrial zone was planned along the river Jasień, due to the use of water in the finishing and bleaching process, as well as the plans for a mechanical flax spinning mill powered by falling water. The demarcated industrial district was large, over 200 ha, and elongated. It extended along the river for over 2.8 km, while its width gradually changed from 200-250 m in the western part to 900 m near its eastern border. The water and factory settlements were the first planned industrial zone in Łódź, located in craft settlements. Good economic situation of the town sparked its spatial expansion. In 1840, the area to the east, the so-called New District, was annexed. Its south-western fragment, directly adjacent to the colonies and the industrial zone, was regulated. A rectangular network of streets was created with small plots adapted to urban housing. Despite the small size of the plots in the New District, this is where future factories were built. In the 1860s, urbanisation outside of colonies progressed. Agricultural lands to the west, owned by urban farmers, were regulated. Plots meant for tenement housing were demarcated. These were sized from 0.15 to 0.3 ha. In later years, especially in early 20th century, this area also became the location of industrial enterprises. Starting in the 1860s and 70s, when the development of textile manufacturing, already industrial at that point, accelerated rapidly, the whole area of craft settlements and colonies saw the transformation from crafts to industrial production. Plots turned into factory, industrial, or residential zones. The residential and industrial functions mixed heavily throughout the city. Both small factories and larger multi-division plants were created on original plots demarcated in the initial phase. The industrial development of production, especially in the large multi-division ones, required plots larger than those available in the colonies. Such areas were acquired outside of the city, in suburban spaces of the nearest villages. This process began in the 1870s, with most of these villages included in the city by 1915. Large industrial plots in rural areas were created on agricultural land by accumulating farming plots (source: archival plans).

The study included 38 industrial plots in Łódź, which made up 10% of the overall number of this type of plots in 1986. The sample was selected intentionally; it consisted of the oldest plots, established in the period of the dynamic development of industrial areas. 22 plots were established in 1889 (one of them was later divided into two), 15 were set up later, in the late 19th and early 20th centuries. The

authors selected plots situated in different morphogenetic units, as delimited by Koter. Five of them originate from former colonies of weavers, nine – from former colonies of spinners, three were situated in the gardens of the New Town, three in the New District, four in the water and factory areas, nine in the agricultural areas of Łódź, and four outside the 19th-century Łódź city limits, in the nearby villages of Widzew (1), Dąbrowa (2) and Karolew (3). Each of the selected plots was described at several points in time, i.e. in 1889, 1917, 1928, 1975 and 1986. Further analysis comprised 174 items.

DATA AND METHODS

The analysis of the transformation process of the industrial plot in Łódź can be divided into the following stages:

1. a study of the origins of the spatial layout of the city based on historical sources (maps, historical and geographical studies),
2. the selection of morphological features,
3. the selection of industrial plots to be studied in detail,
4. statistical analysis,
5. an attempt at typology,
6. the determination of transformation phases of the industrial plot.

The authors conducted a hierarchical cluster analysis, which requires a specific procedure consisting of the following stages:

- selecting a set of objects (observations)
- selecting a subset of attributes and establishing an information matrix
- descriptive statistical analysis of the attributes and their rescaling
- cluster analysis
- dendrogram analysis
- an attempt at making a typology
- specifying transformation phases of an industrial plot.

Morphological characteristics of industrial plot

Three characteristics were used to describe a plot in terms of morphology. They were: total area, plot development and shape.

The total area, or the plot's size, is the characteristic most often used in studies of urban morphology, as well as in studies of land use. This is the area enclosed by the boundaries of ownership as described by law. Its size was expressed in square metres or converted into hectares.

The development of industrial plot may vary, there may be different objects and devices depending on the industry and production profile. In the process of ana-

lysing all industrial plots in Łódź before 1989, it was noticed that the development of textile plots did not vary as much. They mostly included factory buildings, some had water reservoirs, and only a few had railway sidings. None of them included residential buildings. Therefore, the percentage of developed land in the overall surface area of the plot was used to characterise the development of an industrial plot in Łódź. The developed area was marked as the projection of buildings on the plan of the plot.

Shape is a morphological characteristic, which specifies the outline of a plot and may be described using a geometric figure. The original plots in craft colonies of Łódź were rectangular, as dictated by the urban planning regulations of craft settlements in early 19th century. After thorough observation of the transformations of industrial plot in Łódź, it was noted that the changes to plot boundaries usually result in the change of the number of angles in the figure describing the shape of the plot. A shape indicator was proposed, which corresponds to the number of angles in the figure describing the boundaries of the plot. It is expressed as a natural number. Shape indicator for a rectangle (the model figure) is 4. This indicator is independent of the size of the plot, it does not react to the length of the boundaries and is only sensitive to changes in the number of sides of the polygon describing the industrial plot in the plan.

RESULTS AND DISCUSSION

In the first stage of the research, the authors selected subset of attributes and establish a matrix of information. In the procedure, the authors did not consider each period separately, but each plot was analysed at all periods simultaneously. Each plot was seen as a polygon characterised by three attributes: total area (hectares), shape, percentage (%) of built-up area.

Industrial plots in Łódź varied widely in terms of size. Considering all plots, throughout the while industrial development period in Łódź, it may be surmised that the smallest plot was only 100 m^2, while the biggest, where Widzewska Manufaktura operated, was 75 ha. The distribution of surface areas was very asymmetrical, with plots below 2 ha dominating throughout the whole period of study. 38 plots chosen for more detailed study had characteristics similar to the whole group (see table 1).

Most of the oldest industrial plots founded before 1889 were rectangular. Over 73% had a shape indicator equal to 4, while the mean shape indicator for all plots under research for this period amounted to 4.85. It was determined that none of the oldest industrial plots in Łódź maintained its original boundaries. They all underwent various changes, both expanding and contracting their overall surface areas, so that the mean shape indicator for this group in the final period of study, 1989, increased to 10.38. Plots established at the turn of the century were also

Table 1 Descriptive statistics values for selected attributes of industrial plots in Łódź (N=174), in 1889 – 1986

Attributes	Statistics values					
	Min.	Max.	Mean	σ	S	K
Total area [ha]	0,33	33,67	5,1	6,3	2,104	4,556
Shape indicator	4	36	8,8	6,5	1,858	3,568
Built-up area [%]	2,60	80,00	39,8	17,6	0,098	0,551

σ - Standard dev., S – Skewness, K - Kurtosis
Source: *author's compilation*

mostly rectangular, with 68% of them having the indicator of 4. The mean shape indicator for these plots in the initial phase was 4.81. Shape changes that occurred in this group resulted in the mean shape indicator of 8.15 in the final period for this group. In the final study period, after numerous and varied changes, 1/3 of the plots had a high shape indicator of 10 or more, including 6 plots with an indicator higher than 20. The highest value of 36 was noted in the plot located at ul. Ogrodowa 17 (former K. Poznanski's factory). A pattern was found where, due to the overall area changes, plots change from rectangles with k = 4 to various polygons with k > 4. Industrial plots chosen for more detailed study had size indicators similar to the whole group (table 1).

The percentage of the developed area in industrial plots in Łódź has always been heavily diverse, as this majority has been determined to a large extent by the size of an industrial enterprise and the dimensions of its plot. It was changing as the enterprise developed. The growth of the development in industrial plots was a continuous process. The developed are was larger than the measurement for the previous period every time. Over more than a hundred years, the mean value of the developed area grew from 16.8% to 46.3% of the overall area. A relationship between plot size and its degree of development was noticed. Small plots always had a higher degree of development than the larger ones. In the 1880s, the value of the percentage of built-up area for small plots was approx. 33%, while it was below 10% for big plots. In 1970s, the values changed to 57% and 33%, respectively. Industrial plots chosen for more detailed study had the percentage of built-up area similar to the whole group (table 1).

Descriptive statistical analysis of the attributes and their rescaling

The next stage of the analysis included the evaluation of the plot distribution, and especially its deviation from the standard distribution. Descriptive statistical analysis was conducted for each of the three attributes mentioned above.

The distribution of all attributes differed from a standard distribution (see table 1); only the percentage of the built-up area on industrial plots was close to standard. Therefore, it was decided to rescale the data (see table 2). The rescaling of each morphological feature into 5 size classes caused a change from interval to ordinal scale. While rescaling actual values, distractions of variables were considered and the natural break classification method was chosen.

Table 2 Actual values of the morphological attributes rescaled into classes

Class	1	2	3	4	5
Total area [ha]	< 1 ha	1 - 2	2,1 - 5	5,1 -10	> 10
Shape indicator	4	5 - 7	7 - 11	12 - 20	> 20
Built-up area [%]	< 30	30 - 40	40,1 - 50	50,1 - 60	> 60

Source: *author's compilation*

Cluster analysis

Hierarchical clustering is one of frequently used taxonomic procedures. It can be described as:

1. It is assumed that each object forms a one-element cluster.
2. A method of clustering the objects is selected.
3. The matrix of distances between pairs of clusters is calculated using the selected method.
4. Pairs of clusters least distant from each other are looked for.
5. Clusters are combined into one new cluster.
6. Steps 3 to 5 are repeated until all objects form one cluster.

In the study, the authors used methods of hierarchical cluster analysis; they selected the squared Euclidean distance as the similarity metric.

Dendrogram

Hierarchical clustering of 174 industrial plots, carried out using Ward's method, resulted in distinguishing eight classes, considered to be morphological types. It is interesting that already at the first level of clustering all the objects were put into groups and there were no outliers, as can be observed on the dendrogram (see figure 1). This proves that each plot belonged to a cluster and there were no items in the set were fundamentally different from the others.

The dendrogram is composed of two very distinct branches, referred to as Mp and Dp. The first branch (Mp) consists of three subtypes, and the other one (Dp) – of five subtypes, which are more diverse than the ones on the first branch (Mp).

An analysis of the morphological characteristics of individual types leads to the conclusion that the attribute which differentiates the plots the most is their total area. The Mp type contains all small plots (class 1-2), while the Dp type includes the largest ones (class 2-3).

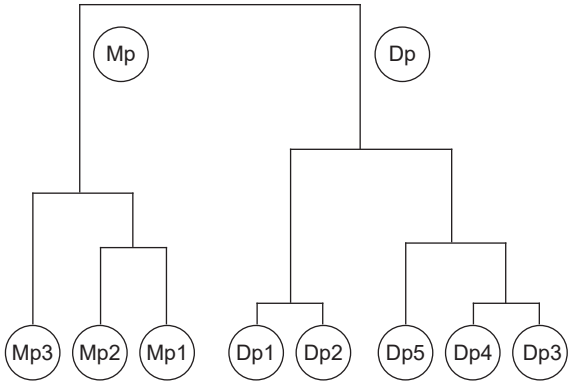


Figure 1
A dendrogram illustrating the process of clustering industrial plots in Łódź, using Ward's method
Source: *author's compilation*

An attempt at making a typology

The two distinct branches of the dendrogram prove the existence of two contrastive groups of morphological types of industrial plots in Łódź. The analysis of the morphological attributes of individual types and the comparison of the types aggregated into clusters enabled the authors to distinguish both features common for these groups and those which make them different.

The first branch consists of types Mp1, Mp2 and Mp3. Their common feature is a small area, usually belonging to the first, sometimes to the second size class, a rather undeveloped shape, usually in the first, only occasionally the second or third class, as well as an extremely varied built-up area development, with the percentage of built-up area ranging between the lowest and the highest values (see figure 2).

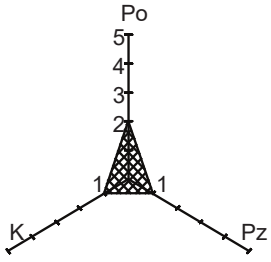
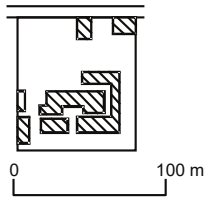
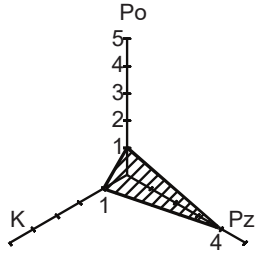
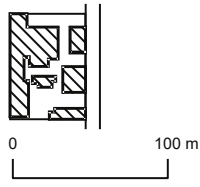
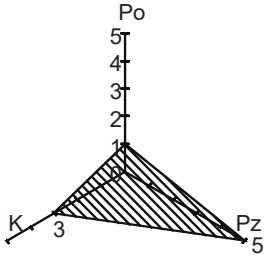
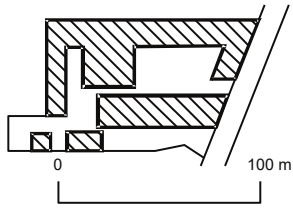
Type	Typogram	Address/street	year
Mp1		Kopernika 58/60 	1889
Mp2		Brzozowa 5/7 	1917
Mp3		Żeligowskiego 3/5 	1975

Figure 2
Morphological types of Łódź industrial plots Mp1, Mp2 and Mp3
(Po – total area, K – shape indicator, Pz – built-up area [%])
Source: *author's compilation*

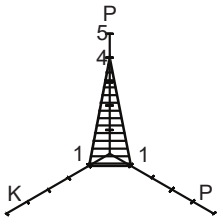
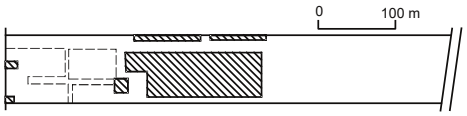
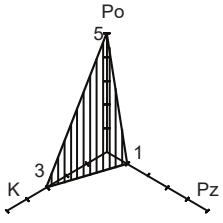
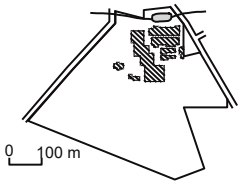
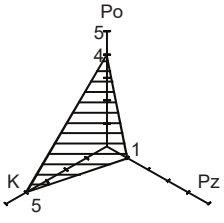
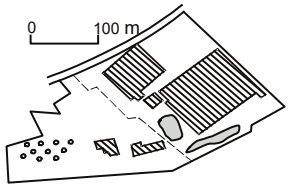
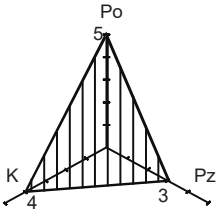
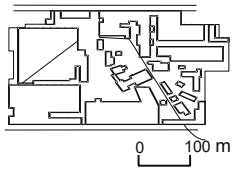
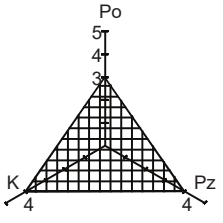
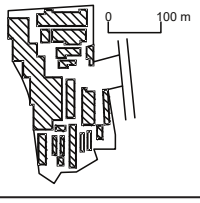
Type	Typogram	Address/street	year
Dp1		Kilińskiego 228 	1917
Dp2		Rzgowska 17 	1889
Dp3		Smugowa 11 	1928
Dp4		Piotrkowska 293/295 	1975
Dp5		Rzgowska 17 	1986

Figure 3
Morphological types of Łódź industrial plots Dp1 – Dp5
(Po – total area, K – shape indicator, Pz – built-up area [%])
Source: *author's compilation*

Defining transformation phases of industrial plots

The taxonomic method used by the authors enabled them to conduct a dynamic analysis of the changes in the morphological types of the studied plots at individual study periods. It was thus possible to identify those which were typical of the initial period in the 19th century and were gradually disappearing, as well as those from later or final periods which were appearing along with the morphological transformations.

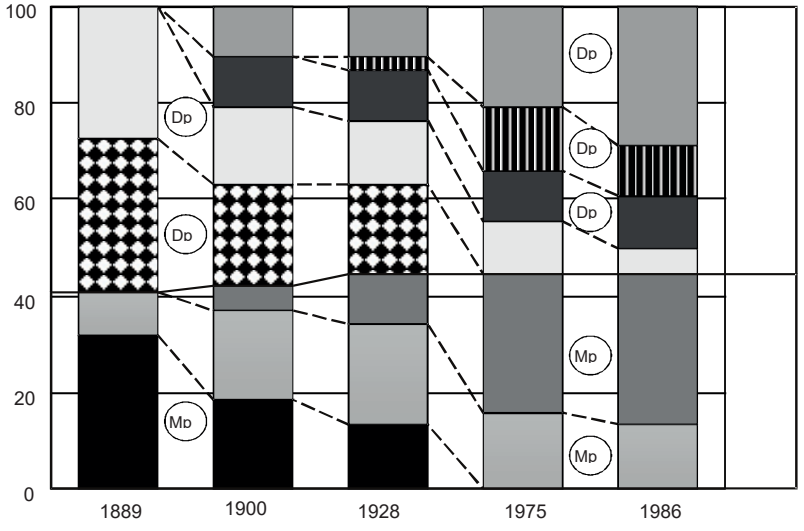


Figure 4
Structural graph of the morphological types of industrial plots.
Source: *author's compilation*

Initially, in the 1880s, the diversification of the morphological types of industrial plots was small (see figure 4). There were four types – Dp2, Dp1, Mp2, and Mp1. At the turn of the 20th century their morphological diversification increased and new types appeared (Mp3, Dp3 and Dp5), which then constituted 25% of the studied plots. At that time, nearly all the small plots were tetragonal; the building-up of Mp1 plots did not exceed 30% and reached about 50% in Mp2 plots.

During the interwar period (1918-1939), the morphological diversification of industrial plots of land was the largest, with all eight types present at that time. Small plots were dominated by type Mp2 (undeveloped shape, densely built-up), but the percentage of type Mp3 (better-developed shape and even more densely built-up area – over 60%) increased, which shows a transition towards building up the area more densely and forming a better-developed shape.

In the second half of the 20th century, the number of morphological types of industrial plots went down to six, because the two types of the initial phase, Mp1 and Dp1, which dominated a hundred years earlier, ceased to exist. The percentage of types Mp2 and Dp2, previously common, also decreased. At that time, the predominant type of a small plot was Mp3, in which the plots were densely built-up (over 60%) and their shape was moderately developed (up to 12). The group of large area plots was dominated by type Dp5, followed by Dp3 and Dp4. It should be stressed that none of them occurred at the initial stage (see figure 4). Large plots became more densely built-up and acquired a well-developed shape (in type Dp3 and Dp4), as well as decreased their total area (type Dp4 and Dp5). They evolved towards a smaller total area, higher density of buildings and very well-developed, advanced shape.

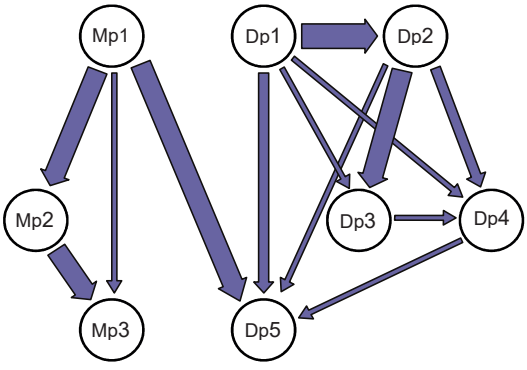


Figure 5
A model of the morphological transformations of an industrial plot. The width of vectors signifies the frequency of changes between the types.
Source: *author's compilation*

A detailed analysis of the transformations of the types of individual plots resulted in constructing a model of the morphological transformations of Łódź industrial plots (see figure 5). By analysing the order in which the morphological types occurred, the authors confirmed the increasing intensity of the use of these urban areas.

Examples of transformation

To provide an example of transformations of an industrial plot in Łódź over a period 100 years, the plot located at Rewolucji 1905 r. No. 52 was selected. It was established within the wool weavers' gardens of the Nowe Miasto district. In the initial phase, its surface area was 0.75 ha, with a regular shape of an elongated rectangle

and 31.8% built-up area (see figure 6). Due to the expansion of the enterprise, it grew to 1.13 ha. The shape was still rectangular, though the ratios changed. For dozens of years, the built-up area was gradually increased, to reach 46% of the overall surface area by 1928. In the mid-20th century, the plot was divided. The area of the industrial plot decreased to 0.9 ha, the whole industrial developed remained on it, which increased the percentage of built-up area to 52.4%. The shape also changed, which increased the shape indicator to 8. The front building excluded from the plot was converted into subsidised housing, and a new residential building was constructed in the 1950 in the previously undeveloped eastern part of the plot. As a result of these changes, the plot was converted from Mp1, through Mp2 into Mp3 in the final stage.

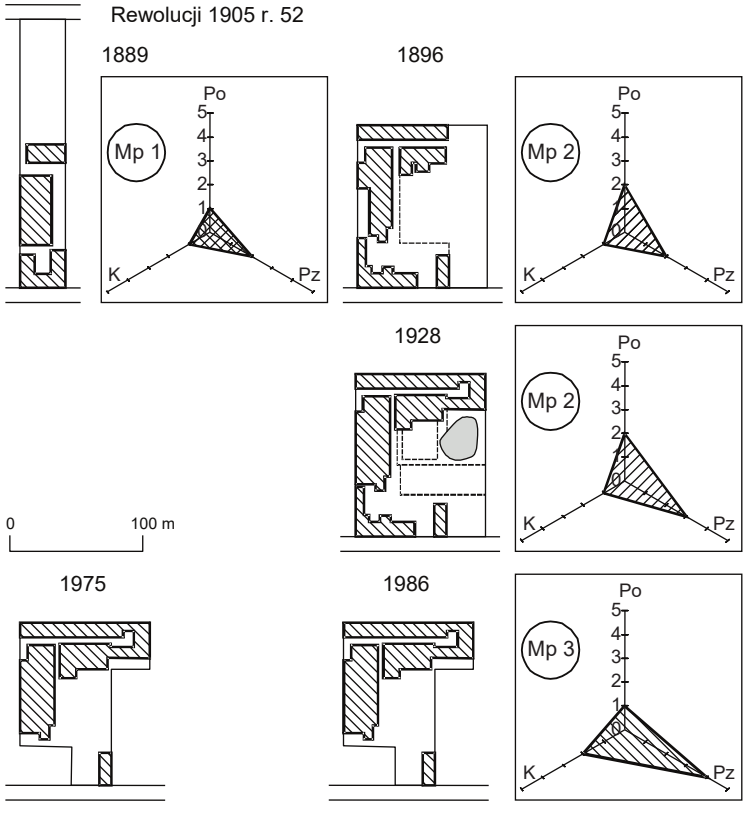


Figure 6
Model of the morphological transformations of an industrial plot, street Rewolucji 1905 r. No. 52
Source: *author's compilation*

The plot at Łąkowa No. 3/5 was founded on urban farmland belonging to farmers in Łódź. In the initial phase in the 19th century, the plot already doubled in size from 4.4 to 8.8 ha (see figure 7). The expanding enterprise increased the built-up area to 15.3 thousand m^2, or 17.4% of the total area in the interwar period. In the mid-twentieth century changes were made, involving the merger of two companies into one. Thus, adjacent plots were combined, but not entirely. Only the parts that were developed industrially were combined. As a result, the area of the plot was slightly reduced to 8.01 ha, but the percentage of built-up area doubled to 38.9%. Free space in the back of both plots, along with other free adjacent areas were allocated to a housing estate, while excluded non-production buildings, mainly located along the street, were allocated to different, mostly social, functions. After these changes, a rectangular plot was transformed into a polygon with 16 sides and angles. The plot, initially a Dp1, turned into a type Dp4 in the final phase.

The plot at J. Kilińskiego No. 228, located in the former colony of Nowa Łódka, maintained its original area of 5.3 ha and its rectangular shape until mid-20th century, gradually increasing its built-up area to 15.5 thousand m^2 or 29.1% of its overall area (see figure 8). In the mid-20th century, part of the adjacent plot was added, along with its buildings. Soon after, the free space in the back of the plot was added. These changes resulted in the increase of the overall area to 6.7 ha, with built-up area growing to 2.7 ha or over 40% of the overall area. These transformations also led to the increase in the shape indicator to 10. The plot was converted from type Dp1 in its initial phase, through Dp4 to Dp5 in the final phase.

The plot located at Rzgowska No. 17 is an example of a plot established in late 1870s in a rural area, outside the boundaries of Łódź, in Dąbrowa village (see figure 9). The plot was initially big, 19.1 ha. It was located between two main roads in this area, Rzgowska and Pabianicka. In the 20th century, fragments of the plot were gradually allocated to residential buildings along the streets. Within the industrial part, a park and palace complex were established, apart from the industrial buildings of a multi-division textile enterprise. In the second half of the 20th century, the complex, along with other non-industrial fragments, were separated from the plot, which reduced its size to 4.9 ha and, consequently, increased the percentage of built-up area to 56.4% of the overall area in the final stage. At the same time, the shape indicator was steadily growing from 11 in the initial phase to 21 in the final period. The plot went from type Dp2 through Dp3 and Dp4 to become a Dp5 in the final stage.

CONCLUSIONS

The taxonomic methods used in the study provided interesting, if not surprising results. Apart from the expected classification used to distinguish the morphological types of industrial plots, they enabled the authors to identify the most common types in individual study periods. The study has shown which of them were characteristic towards the end of the 19th century and disappeared over time, as well as those which appeared in the consecutive decades of the 20th century.

Another result of the applied taxonomic method was a model of the transformations of an industrial plot in Łódź. Its features should be verified through morphological studies of other industrial cities in Poland, similar to what (Musiaka et al., 2020) described for the largest Polish cities. It is worth checking whether the model works well for examining changes in plots related to the textile industry or other industries.

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