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Compliance calculator

Introduction

One of the more important reasons for undertaking research on the scientific method supporting the contemporary transformation or expansion of existing urban structures is the often negative author's assessment of these processes. This phenomenon is not exclusively related to our cultural zone. Examples of faulty transformations of urban structures can be observed in many other latitudes and longitudes. Three such transformations of urban structures are presented below. The first of them is Toronto. Standing in Nathan Phillips Square (Fig. 1), one observes a cluster of skyscrapers forming a very contrasting backdrop to the neo-Romanesque building of the old City Hall, erected in 1899.

In London, the scenic intrusion of skyscraper The Shard (Fig. 2) into the silhouette of the Palace of London can be observed from the main walkway. The latter – built in 1078 – is one of the most important historical buildings of great significance to European and world cultural heritage.

It is equally inappropriate to locate high-rise buildings amongst the historic homogeneous, usually four-storey buildings in the centre of Szczecin dating from the turn of the 19th and 20th centuries (Fig. 3).

In everyday design practice, these activities are often not supported by appropriate analytical studies. In many cases, urban structures are transformed, leading to the loss of the original cultural values of existing buildings, and in extreme cases to the deformation of urban space. The main purpose of the article is to describe a new research instrument called the "compliance calculator" which is

Fig. 1. View of the old Toronto City Hall
with a cluster of skyscrapers in the background
and concrete elements in the foreground
(2020, photo by W. Marzęcki)

Il. 1. Widok na stary ratusz w Toronto
ze zgrupowaniem wieżowców w tle
oraz betonowymi elementami na pierwszym planie
(2020, fot. W. Marzęcki)

Fig. 2. View of the Tower of London
with The Shard in the background
(2020, photo by W. Marzęcki)

Il. 2. Widok na Tower of London
z wieżowcem The Shard na drugim planie
(2020, fot. W. Marzęcki)

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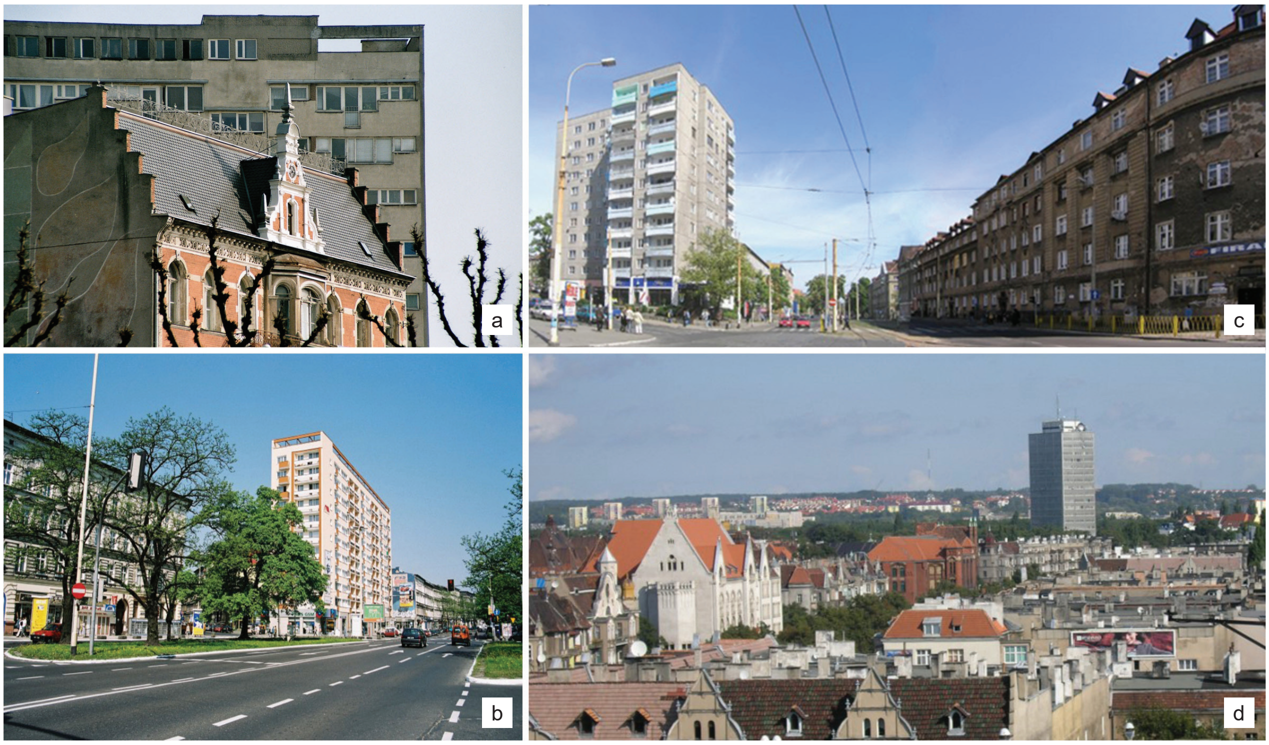

Fig. 3. Series of photos illustrating the location of tall buildings in the historic center of Szczecin built at the turn of the 19th and 20th centuries:
a) historical building on the Żołnierza Square with a tall building in the background,
b) a tall building located in the historic buildings of Wojska Polskiego Avenue,
c) a tall building built in the historic district of Szczecin at the intersection of Jagiellońska and Bohaterów Warszawy Avenue,
d) one of the tallest buildings in Szczecin, built in the historic area of the city (2008, photo by W. Marzęcki)

Il. 3. Seria zdjęć ilustrujących ulokowanie obiektów wysokich w historycznym centrum Szczecina wzniesionym na przełomie XIX i XX w.:
a) historyczny obiekt na placu Żołnierza z wysokim budynkiem w tle,
b) wysoki budynek ulokowany w historycznej zabudowie alei Wojska Polskiego,
c) wysoki budynek zbudowany w historycznej dzielnicy Szczecina przy skrzyżowaniu ul. Jagiellońskiej z al. Bohaterów Warszawy,
d) jeden z wyższych obiektów w Szczecinie zbudowany w historycznym obszarze miasta (2008, fot. W. Marzęcki)

another research module included in the analytical method called the Spatial Continuity Diagram (DCP). However, in order to understand the principle of the compliance calculator, the article first briefly introduces the DCP method. The rest of the article describes how to analyse urbanized structures using the "homogeneity range line", which is part of the compliance calculator.

Research status

In the available scientific literature on analyzing urban spaces using digital tools, the research conducted by Klara Czyńska and Paweł Rubinowicz is noteworthy. Both of them not only theoretically, but also practically implement copyrighted computer programs and analytical methods to study urban development. They have developed numerous studies assessing the impact of tall and high-rise buildings on the urban structures of many Polish cities. An example is the publication by Klara Czyńska *Tall buildings in historical urban context – analysis of selected examples* [1].

However, not all of the research conducted by individual scientists is aimed at supporting the processes of transforming or expanding existing urban spaces, which are in the area of scientific interest of the author of this article. Nonetheless, this type of scientific inquiry, even indirectly addressing these issues, can be found in the scientific literature. In *Parametric Urban Design: Joining morphology and urban indicators in a single interactive model* by José Beirão, Pedro Arrobas, José Duarte [2], existing buildings are analysed in terms of their morphological characteristics using research instrumentation for comparing design alternatives with each other. IT techniques, used by the authors, support stakeholders in the process of transforming urban spaces in making the right investment decisions. A team of researchers, i.e. Cheng Chen, Chaoyi You, Xianmin Mai, in their article *Research on Spatial Morphology of Traditional Settlements Based on Spatial Syntax – A Case Study of Xiuxi Village, Li County, Sichuan Province* [3], using Space Syntax software, analyse the spatial morphology of the traditional settlement of Qiang in the process of renewal and restoration of its spatial identity. In a sense, these activities coincide in terms of intent with the assumptions of the Spatial Continuity Diagram, but using different analytical procedures and software tools. The article *A configurational approach to analytical urban design: "Space syntax" methodology* by Kayvan Karimi [4] considers the problem of supporting urban design, as an analytical activity, with computer methods of analysis and spatial modelling techniques. On the other hand, Ilha Pereira in the article *Master planning* *with urban algorithms. Urban parameters, optimization and scenarios* [5] uses Grasshopper software to mathematically interpret the features of existing urban spaces, such as roads or basic services. These activities are used to create scenarios that optimize existing urban complexes. The method of analysing urban space presented by Robert Szmytkie in his article *Application of graph theory to the morphological analysis of settlements* [6] involves studying the morphology of an urban complex and then creating a corresponding settlement pattern based on quantitative measures that define the spatial settlement module.

The aforementioned method was used by Robert Szmytkie to determine the complexity of the street network. This kind of analysis goes in a similar direction to the analyses of the degree of homogeneity of the various features determined by the DCP method. Also, the depiction of the collected data in the form of diagrams shows some technical similarities with the method presented in this article. In the work of Engin Zeka *A methodology for measuring the form of organic settlements* [7], another method for studying the morphology of urban structures is described. In this case, it was decided to analyze and categorize three of its most important elements. These included streets, lots and buildings. With regard to the aforementioned elements, detailed measurements were taken regarding particular distances, areas, proportions. In the conducted research, graphics were also used to synthetically illustrate the conducted research.

The article *A methodology for measuring the form of organic settlements* also postulates the use of computer software in the future, with the help of which it will be possible to automate the process of taking the relevant measurements and compare the results obtained during the survey of different urban complexes. From reading this material, it is possible to infer some intentional convergence with the research goals of the DCP. However, the method is based on different analytical mechanisms. In addition, DCP research already uses software specifically designed to conduct relevant analyses. A review of the state of research indicates a clear trend towards an increase in the importance of methods for objectifying design activities in the field of urban planning with extensive use of computer-assisted techniques. However, they mostly focus on optimization analyses of urbanized structures.

Research methods

“Compliance calculator” is a new research module attached to the Spatial Continuity Diagram method. The method has been described in detail in a monograph [8], a computer program manual [9] and numerous scientific articles. The most recent article entitled *Spatial Continuity Diagram* was published in 2020 as part of the 25th International Conference of the Association for Computer-Aided Architectural Design Research in Asia1 (CAADRIA 2020) [10]. The DCP method is used to identify basic architectural and spatial features of existing urban development. The purpose of the research is to formulate guidelines to support the process of harmonious transformation or expansion of existing urban development – particularly its architectural and urban design features in the spirit of creative interpretation of cultural heritage. In the DCP method, it is very important to extract all the relevant features concerning both architectural objects and the urban structure of the analysed urban complex. The list of these features is always defined individually and is closely related to the nature of the analysed development. There are sets of features that are constant and recurring in any urban structure. These include, for example, in the area of architectural studies: the height of individual buildings, the angle of inclination of roof slopes or the material used to cover them. In the area of urban studies, these include, for example, the length and width of streets, distances between intersections, etc. There are also features that are typical only of a particular development and testify to a certain uniqueness of the analysed urban area. Each of the studied features has its own categories. For example, the architectural characteristic “height of buildings” has categories such as one, two, three or more stories – depending on how tall the buildings are. The set of urban features includes, for example, “urban interiors”. In this case, the categories of this feature can be the areas of each interior. For each feature, its degree of homogeneity is assigned. It is the result of calculations made by means of an author’s mathematical formula:

$$SJ_C = \sum_{i=1}^{n} {C_{KC1}}^2 \, x \, 100\% \tag{1}$$

where:

SJ_C – the degree of homogeneity of the feature,

KC – feature category.

With the help of this formula, the degree of homogeneity is calculated, which is an emanation of the percentage share of the individual categories included in a given feature in all objects located in the area of the analysed urban development complex. Degrees of homogeneity of features are a very important guideline in the process of transformation or expansion of existing urban complexes. An extremely important assumption of the DCP method is that design solutions for planned developments are also subjected to analogous studies. If the distribution of data on the categories of features of existing and planned developments coincides within certain ranges, it can be assumed that the planned investment processes will proceed in the spirit of preserving spatial and architectural continuity with regard to the urban structure undergoing transformation. By definition, these activities are not intended to lead to the copying of the existing development, but to the creative interpretation of its archetypal and urban features. Since the DCP method is usually used to study large sections of a city, thousands of architectural and spatial data are analysed. Processing such a large amount of information by traditional methods is extremely labour-intensive and, in design practice, extremely inefficient. For this reason, special software has been developed to maximally support the analytical procedures included in this method. It is a fully automated computer-based analytical process. The software that enables research using the DCP method is an open source overlay, working in the environment of the most widely used Excel spreadsheet. The use of this well-known

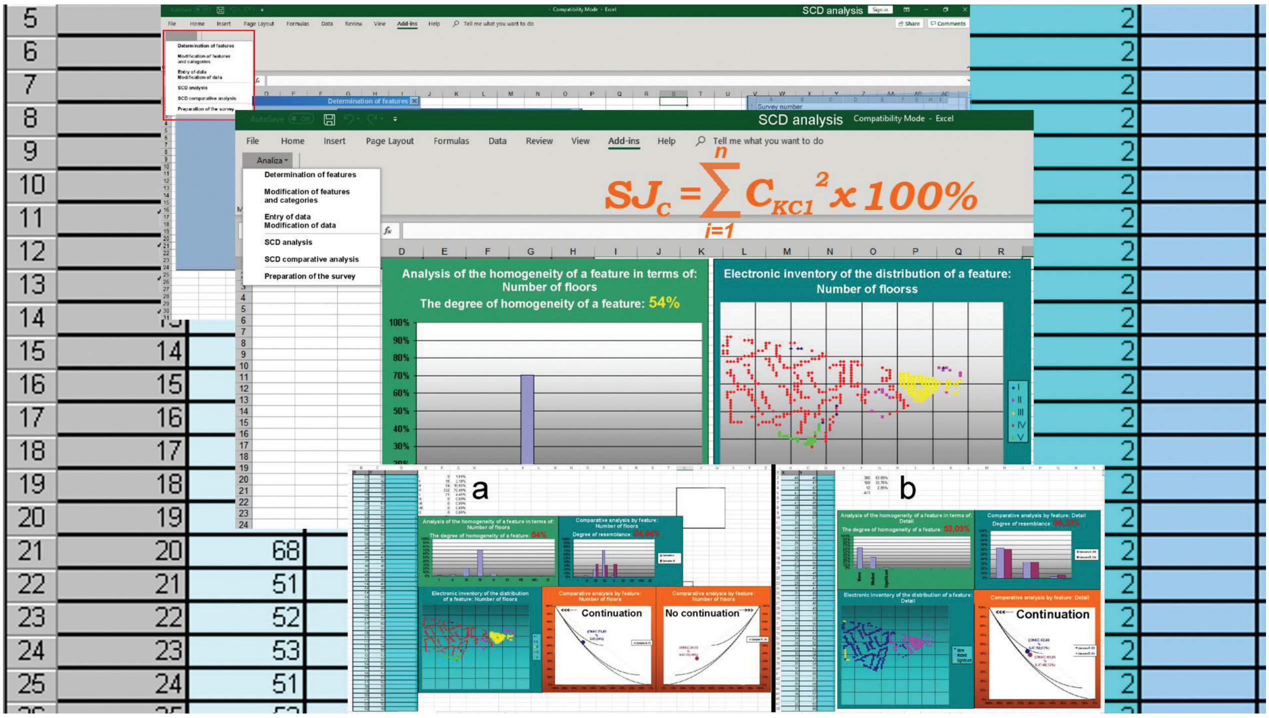

Fig. 4. Computer process of conducting research with the use of Spatial Continuity Diagram carried out with the help of author's software running in Excel environment (2002, elaborated by W. Marzęcki, R. Sokołowski)

Il. 4. Komputerowy proces prowadzenia badań z użyciem Diagramu Ciągłości Przestrzennej przeprowadzany za pomocą autorskiego oprogramowania działającego w środowisku Excel (2002, oprac. W. Marzęcki, R. Sokołowski)

computer platform was intended to make the analytical tool as user-friendly as possible for designers (Fig. 4).

The DCP method found practical application in the design of a 50-hectare single-family housing development in Gryfino. Its prototype is an existing single-family development district in Szczecin (Fig. 5).

The DCP method continues to be refined. The article describes a module called the compliance calculator, which is a new analytical tool included in the process of studying urban structures using the DCP method. One of the fundamental features of this method is that both the existing development and the project for its transformation or expansion are analysed. As a result, it is possible to predict already at the design stage whether the investment decisions made will promote the transformation of the existing urban buildings in a spirit of respect for their most essential features, or whether they may cause their architectural and spatial deformation.

Description of the study

In designing practice, we have to deal with different scales of construction decisions. In one case, it may involve single buildings, and in another – an area-significant development. According to the author, in each of these situations, the overall results of the study of the original urban development, which we intend to transform or expand, should be interpreted slightly differently. "Compliance calculator" is designed to determine to what percentage the general results of existing development features should be included in the newly designed urban structure. On the surface, the task seems simple. But only on the surface, because two factors must be taken into account in the study. Firstly, the result of the study depends on the degree of homogeneity of the studied features of the model complex, as the basic parameters of the DCP method, and secondly, it depends on the size of the new development in relation to the urban space under development. The results taking into account these two parameters will always be unitary and difficult to determine without the use of a compliance calculator. The compliance calculator takes the form of a two-dimensional Cartesian coordinate system (Fig. 6).

On the abscissa x-axis the percentage of projected facilities in relation to existing facilities is marked. Of course, the existing complex – regardless of the occupied area – always represents 100% of the development. In contrast, the percentage of the newly designed complex in relation to the existing one is a variable value. In calculations using the compliance calculator, two values are also placed on the ordinate y-axis. The first is a constant value for a specific study and is the same as the degree of homogeneity of the studied feature of the existing complex. The second value, on the other hand, is variable and depends on the percentage of new development in relation to the existing one. And it is this value that is the expected result of a survey conducted using a compliance calculator. To obtain the aforementioned result, it is necessary to draw a line between the value of homogeneity of the studied feature of the existing complex and the value of 100% on the y-axis. This section is called the "homogeneity range line". The angle of the "homogeneity range line" depends on the degree of homogeneity of the model complex fea-

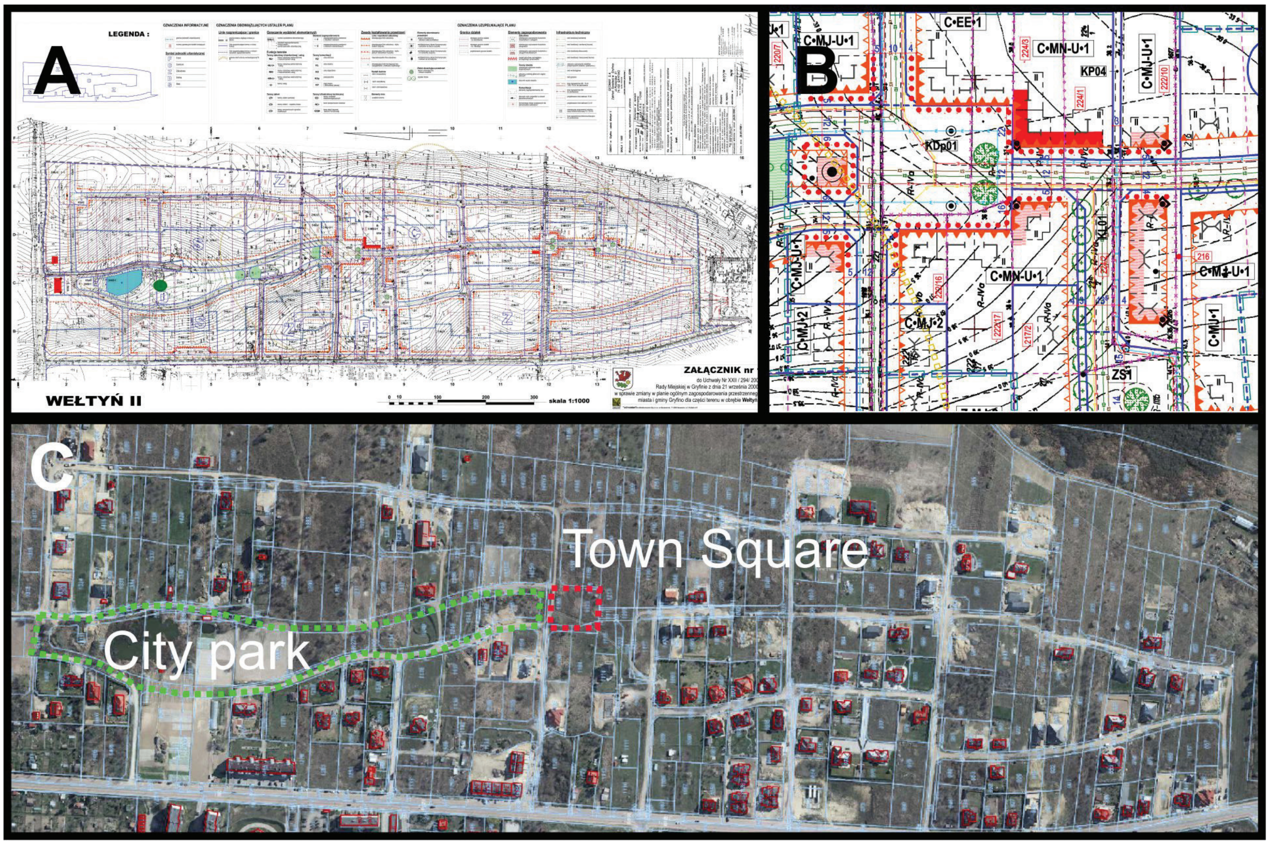

Fig. 5. Planning documentation and orthophotomap illustrating the status of construction of the "Wełtyń II" housing estate in Gryfino, erected on the basis of Resolution NR XXII/294/2000 of the Gryfino Town Council of September 21, 2000 on amendments to the general spatial development plan of Gryfino town and municipality for part of the area within Wełtyń II: A – planning documentation, B – part of the planning documentation, C – orthophotomap illustrating the state of construction of the Wełtyń II estate (2020, elaborated by W. Marzęcki)

Il. 5. Dokumentacja planistyczna i ortofotomapa ilustrująca stan budowy osiedla „Wełtyń II" w Gryfinie, wznoszonego na podstawie uchwały NR XXII/294/2000 Rady Miejskiej w Gryfinie z dnia 21 września 2000 r. w sprawie zmiany w planie ogólnym zagospodarowania przestrzennego miasta i gminy Gryfino dla części terenu w obrębie Wełtyń II: A – dokumentacja planistyczna, B – fragment dokumentacji planistycznej, C – ortofotomapa ilustrująca stan realizacji osiedla Wełtyń II (2020, oprac. W. Marzęcki)

ture. To illustrate the operation of the compliance calculator, a development complex consisting of objects of five different heights was analysed (Fig. 7).

The principle of the compliance calculator was illustrated by a series of three-dimensional diagrams showing different variants of development of our theoretical urban complex (Fig. 8). The degree of homogeneity of the feature "building height" in the designed complex is 35% (Fig. 8A). Such a low degree of homogeneity means that this is a development that varies greatly within the "building height" feature. For example, the developer decided to expand the existing complex by erecting a single building (Fig. 8B). Its degree of homogeneity of the feature "building height" will be 100%. If its height is one of the heights found in the model development, there will not be any deformation of the existing development, despite the fact that the model complex is characterized by low homogeneity of this feature. This case justifies the connection of the "homogeneity range line" specified individually for a given percentage set of the degree of homogeneity with a value equal to 100%. From the assumptions underlying the creation of the "compatibility calculator" it follows that any single object of the height found in the existing development does not cause deformation of the model development.

It is also worth analysing the situation when the investor decides to expand the development in question by increasing the number of buildings. In the theoretical model, the expansion by 30% and 45% is illustrated successively (Fig. 8C, D). Then, by putting down on the *x*-axis the increasing percentages of the new development in relation to the original one and using the reading of the results by means of the "homogeneity range line", the desired degrees of homogeneity of a certain feature are obtained. For a 30% expansion, the desired degree of homogeneity of a feature should be about 84%. Increasing the development by 45%, the degree of homogeneity of the new development should be closer to 71%. From a mathematical point of view, there is nothing to prevent obtaining precise results without any rounding. Approximate values for the degree of homogeneity of the feature relating to new development were used intentionally to indicate that slight deviations from the precisely determined result do not have a significant impact on the quality of urban space. The analysis of items C and D indicates that the greater

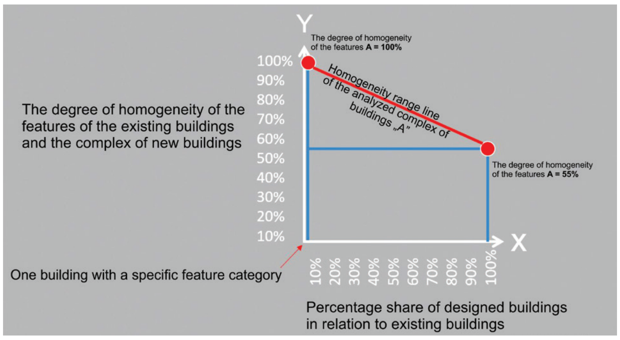

Fig. 6. Compliance calculator (2023, elaborated by W. Marzęcki)

Il. 6. Kalkulator zgodności (2023, oprac. W. Marzęcki)

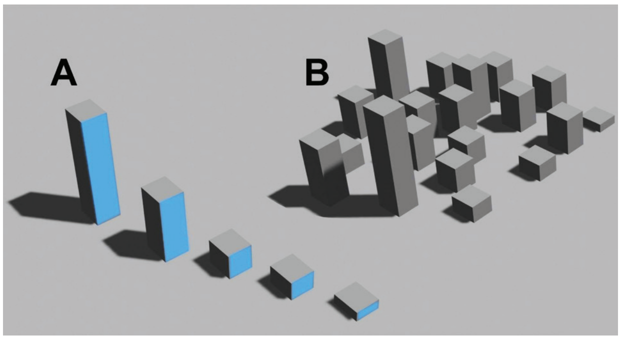

Fig. 7. Simulation illustrating the principle of operation of the compliance calculator:
A – a list of objects of different heights, used to construct a theoretical urban complex,
B – theoretical model of the urban complex used to illustrate the operation of the "compliance calculator" (2023, elaborated by W. Marzęcki)

Il. 7. Symulacja ilustrująca zasadę działania kalkulatora zgodności:
A – zestawienie obiektów o różnych wysokościach, służących skonstruowaniu teoretycznego zespołu urbanistycznego.
B – teoretyczny model zespołu urbanistycznego, służący zilustrowaniu działania „kalkulatora zgodności" (2023, oprac. W. Marzęcki)

the percentage of expansion of the existing complex, the degree of homogeneity of the feature increasingly approaches the degree of homogeneity of the model complex feature. If the same size of the new complex relative to the existing one is achieved, the compliance calculator indicates that in order to maintain spatial continuity of the two complexes, their degrees of homogeneity should be equal (Fig. 8E). The compliance calculator makes the

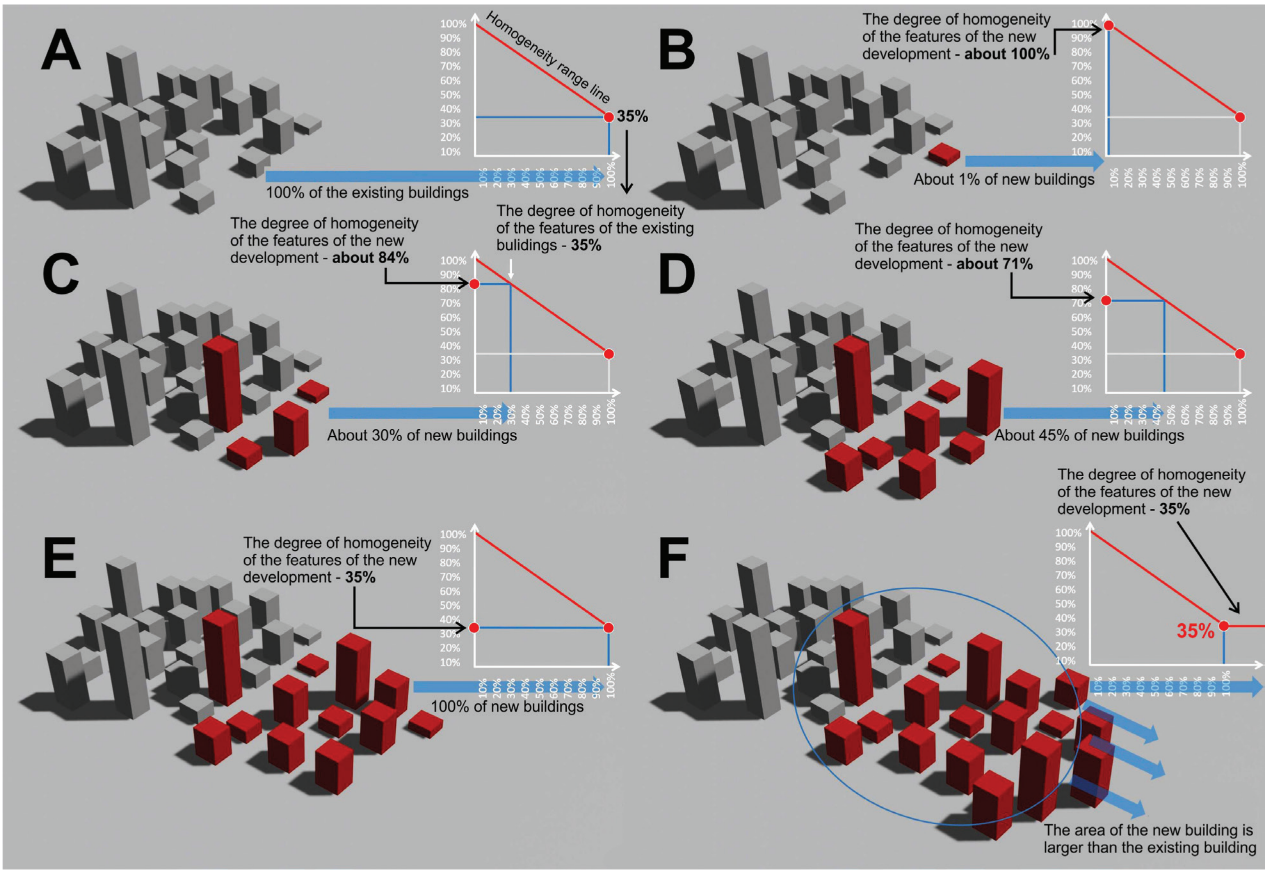

Fig. 8. Summary of the various phases of simulation of the operation of the compliance calculator in the process of expanding an urban development complex: A – theoretical model of the urban development complex subject to the expansion process, B – expansion by 1%, C – expansion by 30%, D – expansion by 45%, E – expansion by 100%, F – expansion above 100% (2023, elaborated by W. Marzęcki)

Il. 8. Zestawienie poszczególnych faz symulacji działania kalkulatora zgodności w procesie rozbudowywania zespołu zabudowy miejskiej: A – teoretyczny model zespołu urbanistycznego podlegającego procesowi rozbudowy, B – rozbudowa o 1%, C – rozbudowa o 30%, D – rozbudowa o 45%, E – rozbudowa o 100%, F – rozbudowa powyżej 100% (2023, oprac. W. Marzęcki)

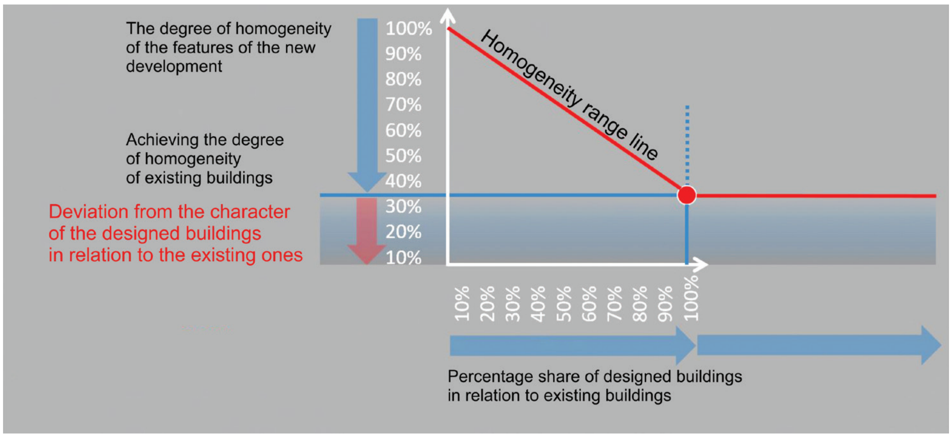

Fig. 9. General diagram for interpreting the results obtained using the compliance calculator in the process of expanding the urban development complex (2023, elaborated by W. Marzęcki)

Il. 9. Ogólny schemat interpretacji wyników uzyskanych z wykorzystaniem kalkulatora zgodności w procesie rozbudowywania zespołu zabudowy miejskiej (2023, oprac. W. Marzęcki)

assumption that in the case of an expansion larger than the original complex (Fig. 8F), its homogeneity should no longer decrease, but should remain at the level of the degree of homogeneity of the reference development. Such an assumption should protect the transformed or expanded existing buildings from spatial and architectural deformation.

The principle of interpreting the results obtained by using the compliance calculator is shown in the diagram (Fig. 9).

Conclusions

In general, the Spatial Continuity Diagram method, together with the newly developed compliance calculator, allows one to take a broad look at the urban structure under study, revealing architectural and urban dependencies that are often invisible in a sectional view. These dependencies often constitute the perceived atmosphere of a place. Without a broader view of the analysed development, they can be lost. The DCP method – as a tool for objective computer analysis of thousands of data – gives a chance to define the specific genius loci of the analysed place. Thanks to this, a designer "armed" with this type of knowledge will be able to consciously and, most importantly, creatively transform an urban space in the spirit of preserving its cultural continuity. An example is the "Wełtyń II" housing development currently under construction in Gryfino, the design of which used the DCP method. There are studies on various similar spatial problems, which use computer techniques, however, with different methodologies. Also original in the DCP method seems to be the fact that the analytical process at the design stage includes not only the existing development, but also the investment intention. The purpose is to check whether future investment activities will promote the harmonious transformation or expansion of the urban space under study.

Summary

In design practice, it is the data obtained through the compliance calculator, and not the overall degree of homogeneity of the features of the analysed development that will guide the design of future developments. Of course, the compliance calculator is only a tool for refining the results and in no way contradicts its general findings.

The research conducted and the results obtained indicate that:

1. The degrees of homogeneity of the various architectural and urban design features of the existing urban development, obtained through analyses using the DCP method, are open to further interpretation depending on the type of subsequent investment activities.

2. The basis for interpreting the degrees of homogeneity of individual characteristics is a new research module called the compliance calculator.

3. "Compliance calculator" indicates that in the process of expanding the existing urban structure, it is possible to achieve various degrees of homogeneity of the features of the new development in the range of 100% to a value analogous to the expanded development.

4. The greater the percentage of a new development in relation to an existing development, the degree of homogeneity decreases in value, approaching the value of homogeneity of the features of an expanded development.

5. With identical areas of existing and expanded buildings, the degree of homogeneity of features should be the same.

6. In the case of expansion with a percentage greater than the existing development, the previously observed decline in the degree of homogeneity of features should be halted at the level of the value corresponding to the existing development. Otherwise, further expansion with decreasing values of the degree of homogeneity will lead to the formation of urban structures with different architectural and spatial characteristics, and in extreme cases to their progressive deformation.

The Spatial Continuity Diagram method is still being developed. Therefore, within the framework of the new research postulates, it is planned to expand the research field with another analytical module. It will concern the degree of spatial concentration of the various categories of both architectural and urban features studied in the analysed urban complexes. It will be called "degree of concentration".

Translated by
Wojciech Czacharowski

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Abstract

Compliance calculator

The article describes the "compliance calculator". This is a new research module of the Spatial Continuity Diagram method. It is used to support the processes of transformation and expansion of existing urban structures in the spirit of respecting their spatial continuity.

The article presents a method of calculating the degrees of homogeneity of architectural and urban features for complexes that are extensions of the existing urban fabric. The purpose is to show by means of a compliance calculator the mechanism for determining the appropriate degrees of homogeneity of the features of a new development depending on what percentage they represent in relation to the existing development. A theoretical model has been developed to simulate the development process of an urban complex consisting of buildings of five different heights and low feature homogeneity. The model illustrates the methodology for calculating, using a compliance calculator, the relevant results for the degrees of feature homogeneity of a new development.

It was shown that the compliance calculator, which is a new research module, refines the general findings of the Spatial Continuity Diagram used in the process of harmonious expansion of urban structures. The research shows that the larger the percentage of the expansion area, the closer its degree of homogeneity should be to the degree of homogeneity of the urban structure being expanded. However, it should not be lower than that. Otherwise, it may lead to spatial degradation of the existing development.

Key words: mathematical simulations, urban composition, Spatial Continuity Diagram (DCP), compliance calculator

Streszczenie

Kalkulator zgodności

W artykule został opisany „kalkulator zgodności". Jest to nowy moduł badawczy metody Diagramu Ciągłości Przestrzennej. Służy on wspomaganiu procesów przekształcania i rozbudowy istniejących struktur miejskich w duchu poszanowania ich ciągłości przestrzennej.

W artykule przedstawiono sposób obliczania stopni jednorodności cech architektonicznych i urbanistycznych dla zespołów będących rozbudową istniejącej tkanki miejskiej. Celem autora pracy jest pokazanie za pomocą „kalkulatora zgodności" mechanizmu ustalania odpowiednich stopni jednorodności cech nowej zabudowy w zależności od tego, jaki stanowią one procent w stosunku do istniejącej zabudowy. Został opracowany teoretyczny model symulujący proces rozbudowy zespołu urbanistycznego, składającego się z obiektów o pięciu różnych wysokościach oraz niskiej jednorodności cechy. Model ten ilustruje metodykę obliczania za pomocą „kalkulatora zgodności" stosownych wyników dotyczących stopni jednorodności cech nowej zabudowy.

Wykazano, że kalkulator zgodności, będący nowym modułem badawczym, doprecyzowuje ogólne ustalenia Diagramu Ciągłości Przestrzennej wykorzystywane w procesie harmonijnego rozbudowywania struktur miejskich. Z przeprowadzonych badań wynika, że im większy jest procentowo obszar rozbudowy, tym jego stopień jednorodności powinien być bardziej zbliżony do stopnia jednorodności rozbudowywanej struktury urbanistycznej. Nie powinien on być jednak od niego niższy. W przeciwnym razie może to doprowadzić do degradacji przestrzennej istniejącej zabudowy.

Słowa kluczowe: symulacje matematyczne, kompozycja urbanistyczna, Diagram Ciągłości Przestrzennej (DCP), kalkulator zgodności