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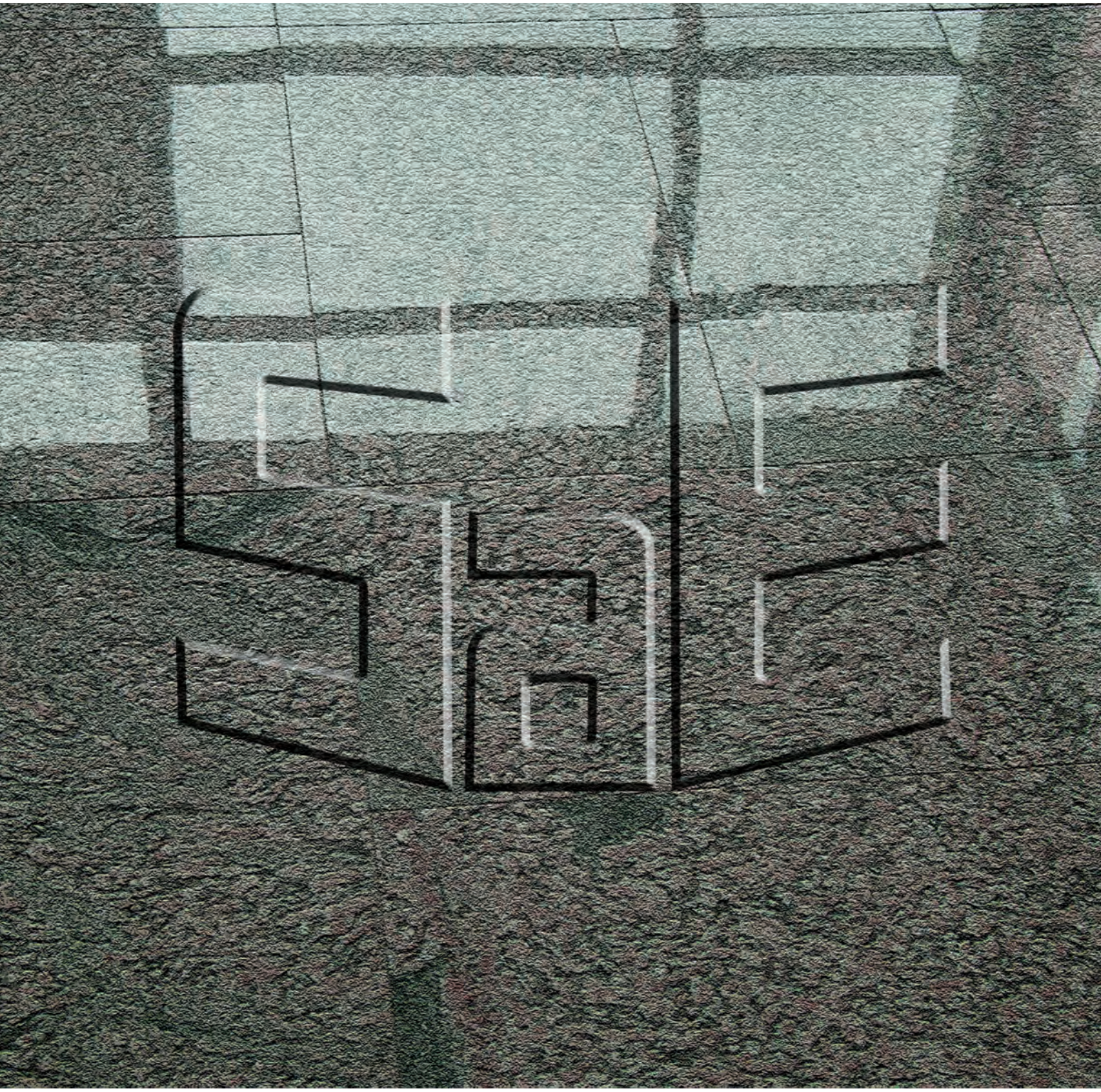

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RENOVATION OF BUILDINGS AS AN ESSENTIAL ELEMENT OF ACTION IN "GREEN DEAL" – A CASE STUDY

RENOWACJA BUDYNKÓW JAKO ISTOTNY ELEMENT „ZIELONEGO ŁADU" – STUDIUM PRZYPADKU

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Abstract

The article highlighted that renovation buildings are an essential action in the European Green Deal. The objective of this study was to assess the energy performance of renovation concepts selected building components on multi-family house. Typical Polish 1950s building was used as a baseline reference, and it was shown that very similar renovation concepts can be successfully applied in other buildings that provides good bases to develop standardized solutions. Energy performance of common renovation concepts was assessed both by in situ tests (with an unaided eye and including the use of a thermal imaging camera) and with national calculation methodologies. The renovation concepts included selected building components: improved envelope insulation with exterior windows and doors and heating system. The effects of the performed renovation were supplemented by the calculation of reduction of greenhouse gas emissions into the atmosphere, as a result of reducing the demand for heat supply to rooms.

Keywords: building renovation, energy efficiency targets, in situ test methods, causes of greenhouse gas emissions

Streszczenie

W artykule podkreślono, że renowacja budynków jest istotnym działaniem w ramach Europejskiego Zielonego Ładu. Celem omawianego badania była ocena charakterystyki energetycznej zaproponowanej metody renowacji wybranych elementów budynku wielorodzinnego. Jako punkt odniesienia wykorzystano typowy polski budynek z lat 50. i wykazano, że bardzo podobne metody renowacji można z powodzeniem zastosować w innych budynkach, co stanowi dobrą podstawę do opracowania standardowych rozwiązań. Charakterystyka energetyczna zaproponowanej metody renowacji została oceniona zarówno za pomocą badań wykonanych bezpośrednio na terenie obiektu (okiem nieuzbrojonym i przy użyciu kamery termowizyjnej), jak też z wykorzystaniem krajowych metod obliczeniowych. Proponowane metody renowacji obejmowały wybrane elementy budynku: poprawę izolacyjności przegród zewnętrznych z oknami i drzwiami zewnętrznymi oraz system ogrzewania. Efekty wyżej wymienionej metody renowacji uzupełniono o obliczenia redukcji emisji gazów cieplarnianych do atmosfery w wyniku zmniejszenia zapotrzebowania na ciepło dostarczane do pomieszczeń.

Słowa kluczowe: renowacja budynków, cele w zakresie efektywności energetycznej, metody badania bezpośrednio na obiekcie, przyczyny emisji gazów cieplarnianych

1. INTRODUCTION

The European "Green deal" is an international concept aimed at achieving environmental neutrality. Pro-environmental measures and, above all, reducing greenhouse gas emissions are gradually being implemented into all areas of work and life.

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Environmental measures in European Union countries are aimed at preventing climate change by, among other things, significantly reducing the consumption of fossil fuels. Renewable energy sources and waste processing are being promoted. For these measures to bring the expected success they should be implemented in all EU member states, including Poland. It is necessary to introduce them in all economic sectors, including the construction industry, where greenhouse gas emissions into the atmosphere are significant. The entire construction process, beginning with the extraction and transportation of raw materials, their processing to produce finished products, and then further transportation to customers and incorporation into buildings, contributes to the production of pollutants harmful to the atmosphere. However, it is not only the process of producing new building materials and their subsequent incorporation into facilities that is an indirect cause of carbon dioxide overproduction. Existing buildings are also a source of greenhouse gas emissions due to their inadequate thermal insulation and often, unfortunately, numerous places of heat loss. Currently, caring only about the high energy standards of newly designed buildings is insufficient to meet the intended environmental effects. Measures are also needed to drastically reduce the energy intensity and improve the technical condition of the existing building stock [1]. The existing building stock is estimated to need major renovations in the near future. At the same time, the EU energy-efficiency strategy entails upgrading the energy performance of renovated buildings to meet the nearly-zero energy standard. To upgrade existing buildings, two main groups of measures can be adopted: thermally-improved building envelope and energy-efficient technical devices [2]. Selection of building materials can significantly reduce the production primary energy and associated CO_2 emissions by up to 62% and 77%, respectively. The results suggest that a careful material choice can significantly contribute to reduce primary energy use and CO_2 emissions associated with energy renovation of buildings, especially when renewable-based materials are used [2-4]. Examples of percentages of heat loss through the building envelope are shown in Figure 1 [5].

Progressive climate change is forcing pro-environmental measures to reduce carbon dioxide into the earth's atmosphere, which can be achieved indirectly by reducing the demand for thermal energy. The effect of such actions on the Polish territory are amendments to the "Regulation on technical conditions to be met by buildings and their location" [6]. The latest amendments, introduced as of January 2021, tightened the requirements for the maximum permissible value of the heat transfer coefficient through the building envelope (U) of rooms heated with maintained temperatures of at least 16°C, respectively, no more than: for external walls – 0.20 W/(m²·K), for ceilings over unheated underground spaces – 0.25 W/(m²·K), for ceilings – 0.15 W/(m²·K), for windows – 0.90 W/(m²·K), for doors in external partitions – 1.30 W/(m²·K). Detailed rules and methods for calculating the above properties are included in the standards: PN-EN ISO 6946: 2017-10 "Building components and building elements – Thermal resistance and heat transfer coefficient – Methods of calculation" [7] and PN-

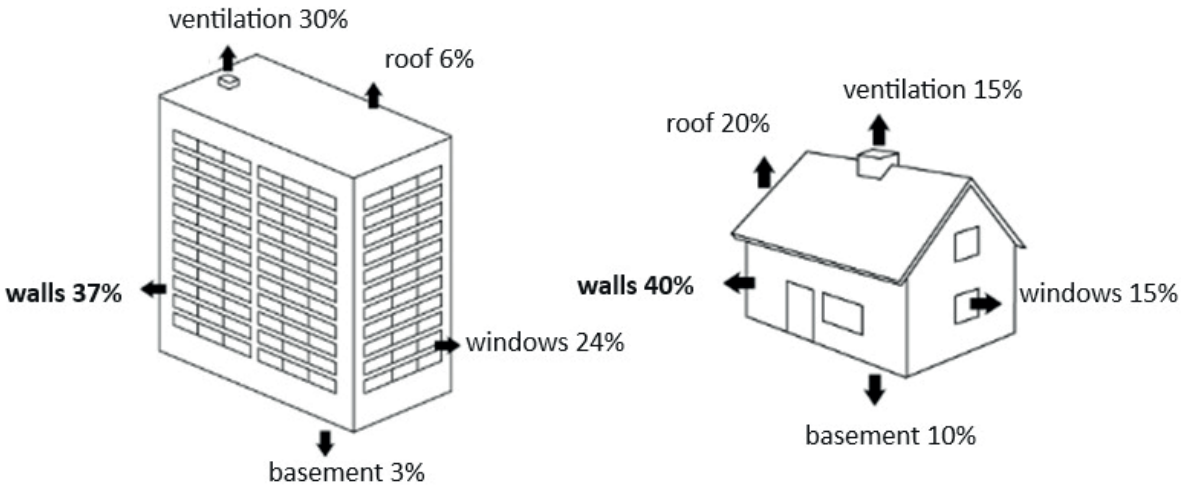

Fig. 1. Examples of percentages of heat loss through building partitions [5]

EN ISO 13370:2017-09 "Thermal performance of buildings – Heat transfer through the ground – Methods of calculation" [8].

Work on thermal modernization of building partitions is undertaken not only in older buildings, built according to previously applicable thermal and humidity requirements [6]. Renovations are also carried out in newer buildings when their users decide to reduce heating costs. Insufficient thickness of the thermal insulation layer on the surface of the building envelope is often accompanied by problems of leakage of the heating system or its low efficiency, which is an additional motive for its reconstruction. In this case, the solution recommended by the "green deal" is to replace the heat source with a heat pump using green energy. Modern ecological heat sources are becoming more and more common, and access to energy from renewable sources is steadily increasing.

The idea of creating a tight energy-efficient building requires, among other things, the use of a thermal insulation layer of such thickness that it guarantees the least possible heat loss, thus ensuring thermal comfort in the rooms in use.

Typical thermal insulation materials used in thermal insulation work include mineral wool boards conforming to PN-EN 13162 [9] and expanded polystyrene (EPS) boards conforming to PN-EN 13163 [10]. To obtain a satisfactory solution it is also necessary to choose the right insulation system. From its selection and proper execution depends not only the durability of the facade, but also the quality and comfort of life of the building's occupants and the energy efficiency of the investment. It is well known that proper insulation of a building's exterior walls can reduce its heating costs by up to 50%. Among the most popular insulation systems used in Poland is the ETICS system [11-13].

However, it should not be forgotten that a thermally protected building is not only insulated vertical and horizontal partitions, but also properly selected and installed window frames, a ventilation system to ensure circulation and an efficient heating system [14].

2. OBJECT UNDER STUDY AND TEST METHODS

2.1. The object under study

The object in question is a multi-family residential building located in Warsaw, consisting of seven above-ground floors and one underground floor. The total volume of the heated part is 17 thousand m^3. Longitudinal walls of the building with windows and external doors located in an east-west direction. The building was constructed in the 1950s in the column and rib technology, on reinforced concrete footings. The walls of the building are made of aerated concrete blocks with 15 cm thick polystyrene insulation. From the outside, thin-coat plaster laid on a grid. PVC window frames in with visible signs of use (age of windows about 15 years). Double-glazed windows with a design heat transfer coefficient of U = 1.9 W/(m^2·K), exterior doors with a design heat transfer coefficient of U = 2.50 W/(m^2·K). The roof covering was made in the form of a solid flat roof, with a base layer of trough panels on the surface of which a thermal insulation layer of mineral wool was laid, with a total thickness of 18 cm, covered with a roofing made of two layers of asphalt felt with an unidentified matrix.

The building is heated with heat supplied from the municipal network, with a thermal node located in rooms on floor –1. Water system and waste water discharge to a plumbing system connected to the municipal network. Gravity ventilation, with ventilation ducts only to the bathrooms and kitchen.

The object in question was tested in order to determine the causes of heat losses reported by its users, with particular emphasis on the evaluation of heat penetration through the walls of the building and the evaluation of the efficiency of the heating system.

2.2. Research methods

Only selected aspects of building renovation have been addressed.

All calculations have been made according to the calculation procedures formulated in the current European and international standards introduced into the set of national standards, so only research methods were established without prescribing standard provisions.

The following assessment/research methods were used to identify the problem:

- site visit - during which hot spots requiring further detailed assessment were identified. At this stage, only visual assessment with the naked eye was used. Particular attention was paid to the technical condition of window frames and thermal insulation of vertical and horizontal partitions. Information on the thickness of the layers of Styrofoam and mineral wool was obtained from the as-built documentation of previous renovation work. The visual inspection also included the central heating system (technical condition of insulation);
- testing with a thermal imaging camera of the central heating risers in accordance with the testing

methodology described in PN-EN 13187:2001 [15]. Examination of the object was done with a thermal imaging camera FLIR E8 Pro Kamera for the presence of thermal bridges outside the object. The results showed presence of hot spots. The basic technical data of the camera used are as follows: detector resolution 320 × 240 pixels, field of View (FOV) 33° × 25, Thermal Sensitivity <50 mK, Temperature Range –20°C to 550°C.

Outdoor measurements were made in the fall of 2022 from 7:00 to 9:00 pm i.e. prior to renovation, to identify problems in the building, with the following ambient conditions:

- outdoor temperature: about 1°C,
- average wind speed: 2 m/s,
- wind direction: west,

in contrast, indoor measurements were taken in the spring of 2023 from 10 a.m. to 2 p.m., i.e. after the renovation work has been carried out, in order to establish the effects of the repair work carried out, with the following ambient conditions:

- outdoor temperature: about 18°C,
- average wind speed: 4-5 m/s,
- wind direction: east;

➢ performance simulation calculations of the efficiency of the thermal node resulting from the specifics of the device and the heat transfer coefficients through the partitions using the computer program Auditor OZC and as the inverse value of thermal resistance for the layers in question.

The obtained results of the calculations additionally allowed estimating the effects of proposed renovation work in terms of the amount of reduction in greenhouse gas emissions resulting from the reduction of heat loss through the building envelope, found during the inspection of the facility.

3. RESULTS AND DISCUSSION

During the inspection of the building, no visible cavities or leaks were observed within the thermal insulation layers of the vertical and horizontal partitions. Thermal imaging camera examinations also revealed no leaks in the vertical partitions, in areas without additional window and door openings. Locally, leaks were found within the window frames, visible to the unaided eye, with a perceptible intrusion of cooler air around the window frames.

Table 1 summarizes the average values of the heat transfer coefficient of the building envelope of the subject building, for the existing technical state before the renovation work. These values are the average of 6 measurements taken for each partition in sensitive areas, i.e. those showing clear symptoms of insufficient thermal insulation, after evaluation with a thermal imaging camera and organoleptic method. The coefficient of variation was used to statistically evaluate the results. The coefficient of variation, is a measure of dispersion and is therefore used to measure the degree of variation in the value of a variable. A high value of the coefficient means high variability of the trait and indicates the heterogeneity of the population under study, a low value indicates low variability of the trait and homogeneity of the population under study. In the present case, the results obtained indicate homogeneity, as the values of the coefficients of variation are relatively low. The calculations were performed in accordance with the standard PN-EN ISO 6946: 2017-10 [7], taking as output values the readings from the thermal imaging camera determined during the object tests.

Table 1. Average values of heat transfer coefficients of selected building partitions (state before thermal modernization)

	Partition	Heat transfer coefficient of the partition [W/(m² K)]/ coefficient of variation [%]
1.	Exterior wall (south side)	0.24/2.05%
2.	Ceiling	0.22/2.35%
3.	Ceiling over basement	1.03/1.58%
4.	Exterior windows (south side)	2.34/1.05%
5.	Exterior doors leading to the building	2.00/1.98%

As a supplement to the evaluation of interior microclimate parameters of the building, the efficiency of the heating system was determined. which is derived from the specifications of the device and was defined in accordance with current legislation. Calculations were based on the Regulation on the methodology of calculating the energy performance of a building [16]. The values of seasonal heat demand for the existing state were compared with the required values, ensuring the comfort of the interior spaces. The results obtained

show the results of the tests carried out before the renovation, and simulated values calculated using the OZC auditor software [16] for the assumed state after renovation. Values are summarized in Tables 2 and 3.

Table 2. Component efficiencies of the heating system before thermomodernization

	Type of efficiency	Value [-]
1	Generation efficiency	0.94
2	Transmission efficiency	0.80
3	Utilization control efficiency	0.77
4	Accumulation efficiency	1.00

Table 3. Seasonal heat and power demand

Variant	Seasonal heat demand	Thermal power requirement (circulation pump drive)
	GJ	kW
Condition before modernization	2 510.97	425.78
Condition after modernization	960.06	234.64
Difference	1550.91	191.14

A visual assessment of the technical condition of the heat substation and the central heating system further confirmed, visible to the naked eye, mechanical damage to parts of the system and corrosion of fittings. In addition, locally on the central heating risers there are gaps in the thermal covers of the pipes, and the existing thermal insulation is damp. It can be presumed that that dampness originated in areas of pipe leaks, caused by damage to joints and lack of ad hoc maintenance work. An example of an image from a thermal imaging camera of the central heating riser of the building in question before the start of thermal upgrading work is shown in Figure 2. The distribution of isotherms around the CO pipe allows us to determine the dysfunctional areas in relation to the thermal insulation shielding the CO pipe from heat loss.

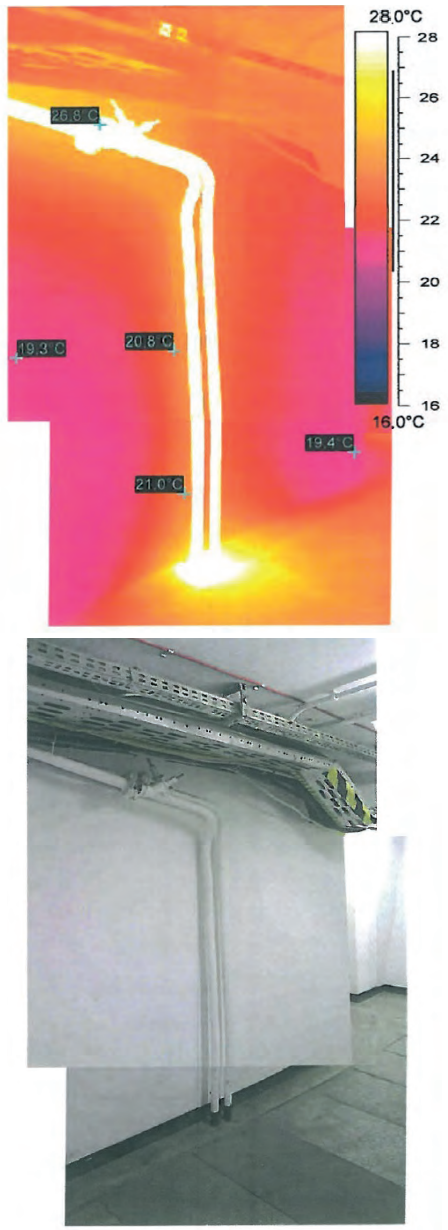

Fig. 2. Distribution of isotherms around the CO riser in the thermal imaging camera image (Flir System AB)

Figure 3 shows a section of the window along with the window frame on the surface of which traces of biological corrosion are visible, caused by a reduction in temperature on the internal surface of the partition at the thermal bridge (the junction between the external wall and the window). The risk of mould growth at the thermal bridge location is checked by comparing the design value of the temperature factor at the thermal bridge location f_{Rsi} (based on the minimum temperature at the thermal bridge location $t_{min.}$, indoor air temperature t_i, outdoor air temperature t_e) with the limiting (critical) value $f_{Rsi(kryt.)}$). It is assumed that when $f_{Rsi} \geq f_{Rsi(kryt.)}$ there is

no risk of surface condensation (i.e. no risk of mould growth). The critical temperature factor $f_{Rsi.(kryt.)}$ was determined according to regulation [6]:

– in a simplified way for t_i = 20°C, φ = 50%, $f_{Rsi.(kryt.)}$ = 0.72,
– in an accurate manner (taking into account the parameters of outdoor and indoor air).

Calculation procedures in this respect are presented, among others, in the work [17]. The critical value of the temperature factor $f_{Rsi.(kryt.)}$ for the third humidity class in the room at t_i = 20°C is for the Warsaw location $f_{Rsi.(kryt.)}$ = 0.789. Based on the inspection and measurements carried out, it can be concluded that in the analyzed building (at the junction of the external wall with the window) there was a significant decrease in temperature on the internal surface of the partition, which led to the risk of surface condensation – Figure 3.

It is necessary to carry out the above calculations and analyses at the stage of designing the thermal insulation of the envelope as part of thermomodernisation, taking into account the parameters of the external and internal air.

Fig. 3. Biological corrosion visible on the surface of the window reveal

The visual inspection of the building allowed a preliminary determination of the scale of the problem, and supplementing it with additional research and calculations, allowed the development of a concept for a repair solution. Based on a visual assessment of the building envelope, hot spots were selected that could be the main cause of heat loss. Visible symptoms of biological corrosion on the window frames (Fig. 3) allow us to assume that heat loss is occurring in these areas. In addition, local leaks within the plaster and thermal insulation layer are visible around the window frames, further adding to the identified problem. In contrast, no visible symptoms of this phenomenon were found on the wall surfaces and under the ceiling. Admittedly, the results of the calculations indicate that the permissible values of heat transfer coefficients are exceeded on all the tested partitions, but in the case of the external walls and for the ceiling, the calculated values are within the limits of the measurement error, confirming the conclusions established based on previous observations made during the inspection of the building. Thus, the calculated values of the heat transfer coefficient for these partitions are, respectively, for:

– sample exterior wall (south side) 0.24 W/(m²·K), with required ≤ 0.2 W/(m²·K);
– roof – 0.22 W/(m²·K), with the required ≤ 0.15 W/(m²·K).

The partitions analysed do not meet the basic thermal criterion in terms of U-value. The main heat losses occur within the ceiling above the basement, for which the calculated heat transfer coefficient is 1.03 W/(m²·K), with the required ≤ 0.25 W/(m²·K), and in the area of window openings and exterior doors. Heat loss around the window reveals on the west wall, as determined by the heat transfer coefficient, is of 2.34 W/(m²·K), with a permissible value of up to 0.90 W/(m²·K), and for exterior doors of 2.00 W/(m²·K) with a permissible value of up to 1.30 W/(m²·K). The aforementioned comparisons are shown graphically on Figure 4.

Identification of weak points in the building under consideration with a thermal imaging camera are shown in the Figure 5.

The research and analysis performed allowed the development of a renovation concept. The renovation work began with replacing the windows and sealing the window reveals, after first removing the effects of biological corrosion. The renovation work thus began with mycological tests, submitting samples taken from the window frames to a specialized

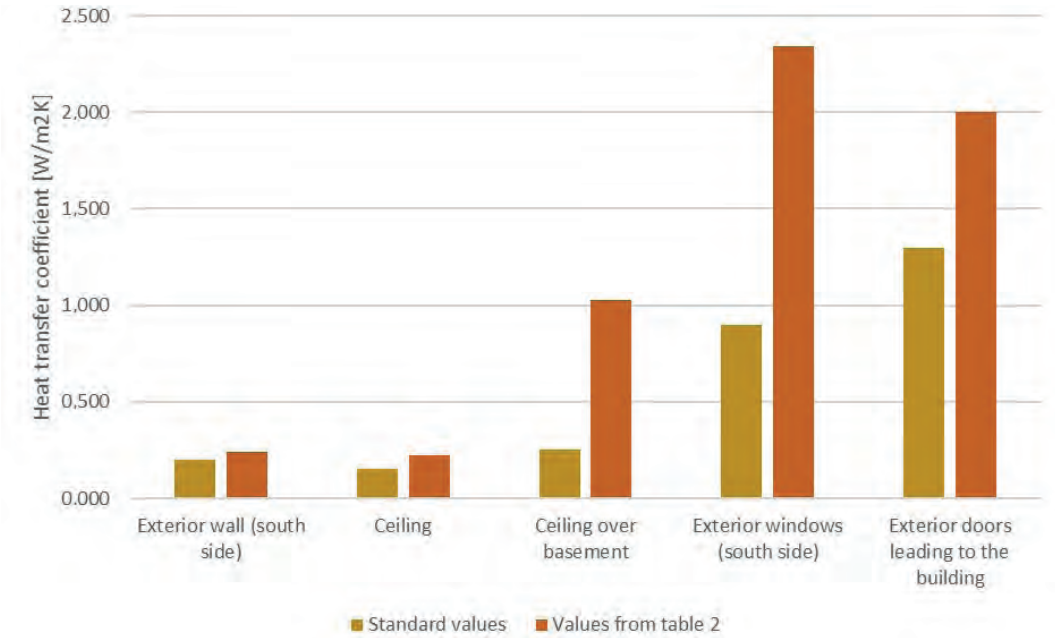

Fig. 4. Comparative comparison of the values of heat transmission through partitions from table 2 with standard values [6]

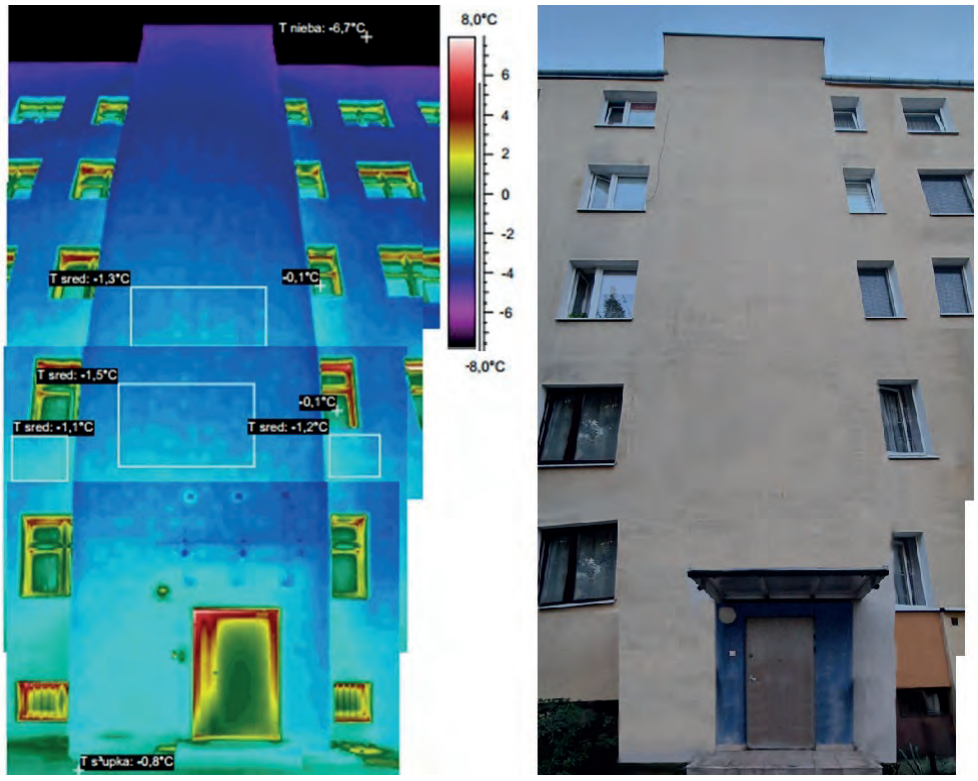

Fig. 5. Identification of weak points in the building under consideration with a thermal imaging camera (Flir System AB)

research laboratory in order to determine the type of fungus present and, based on this, to select the right fungicide. The found strain of *Aspergillus Niger* fungus turned out to be a typical type of mold fungus, often found on the surface of facade materials, including in the region of thermal bridges. Since this fungus produces toxic substances like aflatoxins, ochratoxins, which can be dangerous to health, it was important to completely deactivate it. Infected surfaces were thoroughly washed and then covered with a fungicide, additionally removing plaster in areas where the infection had progressed deep into this layer. Due to the toxicity of the preparation, the rooms were ventilated for up to 28 days. The next

step was to replace the windows in the building, with triple-pane windows with ventilators embedded in the window frames, while remembering to ensure effective ventilation of the rooms. The entrance doors to the building were also replaced, using doors with a heat transfer coefficient of no more than 1.0 W/(m^2·K). It was recommended that window jambs are sealed in the area where the frames are embedded, against the formation of thermal bridges, causing condensation on the inner surfaces of the windows (frames and sashes), the surfaces of the jambs or in the window/wall joints. The correct execution of the external wall-window joint should be carried out after an analysis of the physical parameters of the building joints in terms of additional heat loss (linear heat transfer coefficient) and limiting the occurrence of surface condensation (biological corrosion). Calculations and analyses in this respect are presented in works [17-19].

Correctly installed windows should be:
– on the interior side of the rooms – vapor-proof,
– on the inside – thermally insulating,
– from the outside – vapor-permeable.

The first stage of the renovation work also included repairing the heat node to reduce heat loss on the central heating system. When trying to reduce energy consumption in a central heating system or in a domestic water heating system, it is necessary to consider the annual operating efficiency of the heating and the domestic hot water heating system. A boiler operates under dynamic conditions, so it essential to know the methodology and the model of annual operating efficiency calculation for thermo technical systems. For example the outlet temperature of the flue gases with conventional gas boilers is considerably higher than the ambient temperature and consequently the heat loss occurs; it is then vented off into the environment as a result of heat transfer. The heat loss may be reduced if a condensing heat exchanger is installed, which will, on the other hand, increase the boiler efficiency by more than 10% [20].

It was also assumed that the malfunction of the thermal node located in the basement floor could be one of the causes of inadequate heat flow within the –1/0 interstory ceiling. For this reason, the first stage of the renovation work refrained from insulating this ceiling, recommending that it is observed after the completion of the repair of the node and possibly carried out in the second stage of the work, if the need is still identified.

Confirmation of the effectiveness of the repair work performed is provided by the analysis of seasonal heat demand and heating power before and after the repair work. The values of these changes, presented in Table 4, were determined using the computer program OZC Auditor for this purpose.

After replacing windows and doors and overhauling the heat substation, seasonal heat demand was reduced by 60%. This contributes to energy savings of 1.500 GJ. In terms of power expressed in kilowatts, the gain after the renovation work is at 190 kW, compared to the original state.

The performed renovation work contributed both to improving the technical condition of the facility and the conditions of use of the premises and had a positive impact on the environment. As a result of the performed work, the demand for heat in the building decreased, i.e. the amount of fossil fuels consumed for this purpose was reduced, thus indirectly contributing to the reduction of carbon dioxide emissions, as shown in Table 4.

The data presented in Table 4, expressed in GJ/year or kW/year for the situation before and after the renovation, represent the demand for auxiliary energy and district heating (heating and hot water).

A comparative summary of energy demand before and after the renovation is presented below (Fig. 6).

Table 4. Comparison of energy demand before and after the renovation and the effect of reducing CO_2 emissions after the renovation work

Type of energy	Comparison of energy demand, [GJ/year] or [kWh/year]			Comparison of CO_2 emissions, [Mg]		
	before renovation	after renovation	final result of reduction	before renovation	after renovation	final result f reduction
District heat – heating and hot water	7 843.14	2 165.71	5 677.43	754.98	208.47	546.51
Auxiliary energy	273 668.90	247 791.90	25 877.00	193.76	175.44	18.32
Total emission reductions of CO_2 [Mg]				948.74	383.91	564.83

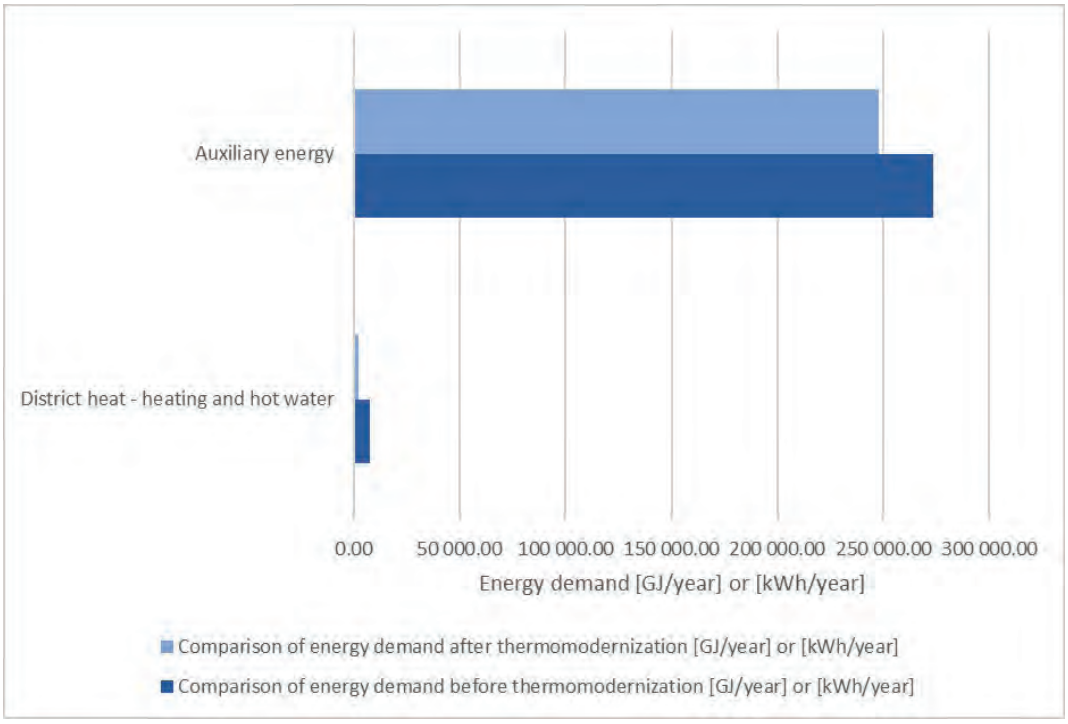

Fig. 6. Comparison of energy demand before and after renovation

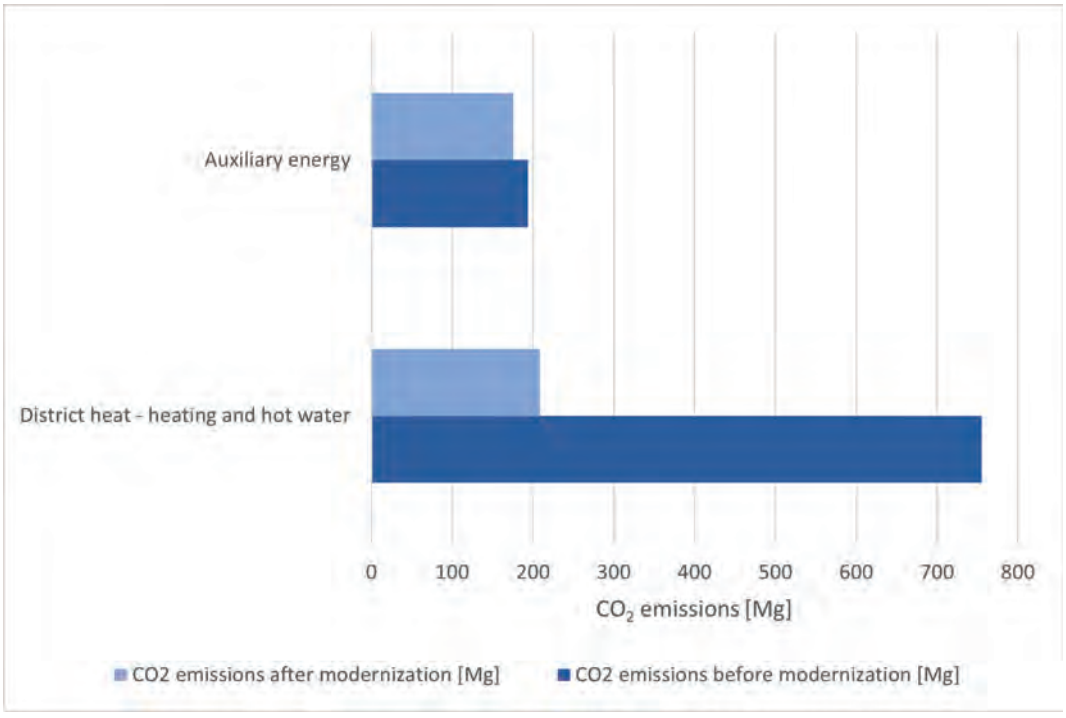

Fig. 7. Comparison of carbon dioxide emissions before and after thermal renovation

The renovation work contributed to a reduction in carbon dioxide emissions. The total amount of pollutants decreased almost threefold to 383.91 Mg. The resulting volume is 564.83 Mg less compared to the original state (Fig. 7).

According to calculations, it should be noted that there is a significant drop in CO_2 emissions in terms of both electricity and district heating (central heating and hot water) following the modernisation work.

The economic benefit of retrofit actions for old buildings depends on possibly increasing building value and rents and also on the achieved energy savings. To estimate the savings, usually the calculated energy demand before and after the renovation is compared. Several studies show [21], that calculated energy demand and consumed energy often show great differences, especially for old buildings before the 1970s. One important input parameter for the energy demand calculation is the u-value of the façade which is commonly chosen by the energy expert on site, out of a catalogue, where typical values for certain wall constructions are presented. The reduction of carbon dioxide emissions from dwellings was highlighted as a positive environmental impact of energy renovations, particularly due to the improvement of thermal insulation properties [21].

The economic benefit of retrofit actions for old buildings was found to depend on achieved energy savings, indicating the potential for reducing CO_2 emissions through energy-efficient renovations. It is clear that energy demand typically decreases after renovation, and there is a potential for reducing CO_2 emissions through energy-efficient renovation measures [21, 22]. However, it is important to note that the specific quantification of CO_2 emissions reduction may require additional data.

4. CONCLUSIONS

The article analysed selected, in the opinion of the authors, important problems, often occurring in construction, related to the improper functioning of the building envelope in the heat and humidity range. These analyses were performed on the example of a randomly selected multifamily residential building. This paper presents only selected aspects of building thermomodernisation resulting from changing thermal requirements according to the regulation [6].

As part of the research and analysis carried out, the main building partitions were evaluated for their susceptibility to heat transmission and the impact of these losses on increasing greenhouse gas emissions into the atmosphere. These analyses allow to formulate the following conclusions regarding areas that need to be assessed when assessing the energy efficiency of renovated buildings and methods of their tests:

- the following sequence of research and analysis is useful: a survey of the building to determine hot spots, measurements of temperature distribution in individual pre-selected sections, e.g. using thermal imaging cameras, determination of the type, condition and quality of materials used in building partitions, computer calculations of basic thermal properties including adoption of correct values for the thermal conductivity coefficients of materials in the building envelope;
- assessing the energy efficiency of a building should the basic building envelope, i.e. walls, ceilings, including roof coverings, but also sensitive places that contribute to the formation of thermal bridges in buildings such as: windows and exterior doors, and the efficiency of the central heating system, with particular attention to the technical condition of thermal insulation lagging of pipes;
- assessing the installation of window frames for elimination of thermal bridges, which are one of the causes of biological corrosion, negatively affecting the health of room users;
- assessing effective insulation of all components of the central heating system which has a significant impact on its efficiency and the reduction of heat loss in the building. Regular inspections and ad hoc repairs ensure that the equipment maintains its high efficiency over the period of its assumed life cycle.

Carried out analysis done for building under renovation confirms the relationship between the efficiency of the heating system, the tightness of the window frames and the amount of energy demand. Elimination of places generating heat losses in buildings contributes to a reduction in the demand for thermal energy, which consequently has a positive impact on the environment, due to a reduction in the amount of fossil fuels required to generate this heat. Only the correct and efficient operation of all building elements makes it possible to achieve satisfactory results by reducing heat losses by up to 60%, thereby contributing to lower maintenance costs of the facility, and by reducing the need for fossil fuel consumption, indirectly also, to environmental protection.

An indirect goal of above mentioned measures was to reduce carbon dioxide emissions into the atmosphere. The intention has been achieved for tested building, which can be seen in the total amount of carbon dioxide reduced. The amount of carbon dioxide has decreased almost threefold to 383.91 Mg, which translates into smaller environmental pollution.

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GENERATING AN IMAGE OF THE CITY STRUCTURE WITH THE USE OF MOCK-UPS, 3D MODELS AND ARTIFICIAL INTELLIGENCE ON THE EXAMPLES OF MODELS OF THE STRUCTURE OF SELECTED CITIES OF THE GZM METROPOLIS

GENEROWANIE OBRAZU STRUKTURY MIASTA Z WYKORZYSTANIEM MAKIET, MODELI 3D I SZTUCZNEJ INTELIGENCJI NA PRZYKŁADACH MODELI STRUKTURY WYBRANYCH MIAST METROPOLII GZM

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Abstract

Spatial analysis of cities and regions in the field of urban-architectural planning is usually presented in the form of drawings and diagrams. With the development of spatial information and the capabilities of GIS software and the use of database resources, the creation of illustrations of spatial analysis has become more accessible and easier. According to Kevin Lynch's theory, the image of a city cannot be determined in an automated way, and their identification requires an authorial approach and research. The article presents a series of experiments series, in which an attempt is made to represent the image of the city using mock-ups, 3D models, using augmented reality, as well as artificial intelligence. The authors put forward the thesis that a contemporary, proprietary representation of the city image in the form of models can be an alternative to traditional diagrams representing the basic elements that make up the city image.

Keywords: city image, spatial analysis, 3D models in analysis, artificial intelligence, city structure

Streszczenie

Analiza przestrzenna miast i regionów w zakresie planistycznym i urbanistyczno-architektonicznym najczęściej jest przedstawiana w postaci rysunków i schematów, które bazują na podkładach mapowych. Wraz z rozwojem informacji przestrzennej i możliwościami stosowania oprogramowania GIS i wykorzystywaniem zasobów baz danych tworzenie ilustracji analiz przestrzennych stało się bardziej dostępne i łatwiejsze. Według teorii Kevina Lyncha na obraz miasta składają się krawędzie, dominanty, obszary, ścieżki oraz punkty węzłowe, których nie można jednak wyznaczyć w sposób zautomatyzowany, a ich identyfikacja wymaga autorskiego podejścia oraz badań. W artykule przedstawiono serię eksperymentów realizowanych w ramach cyklu modele struktury miasta, w których podjęto próbę reprezentacji obrazu miasta z wykorzystaniem makiet, modeli 3D, z wykorzystaniem rzeczywistości rozszerzonej, a także sztucznej inteligencji. Autorzy stawiają tezę, że współczesne, autorskie przedstawienie obrazu miasta w formie modeli może być alternatywą dla tradycyjnych schematów przedstawiających podstawowe elementy składające się na obraz miasta.

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Wnioski z badań mogą mieć zastosowania w analizie przestrzennej miast i regionów oraz być wskazówką do rozwoju metod prezentacji ich struktury.

Słowa kluczowe: obraz miasta, analiza przestrzenna, modele 3D w analizie, sztuczna inteligencja, struktura miast

1. INTRODUCTION, STATE OF RESEARCH

Spatial analysis of cities and regions used in spatial planning and urban design is undergoing a major evolution nowadays thanks to the development of tools (most often based on GIS) and the widespread availability of data (shared informally, e.g. social media, or published as databases (big data). Mapping and graphical representation of spatial data nowadays is implemented in a systematic way, and its presentation in some cases is even possible in real time. The images generated in the above way can be considered new informal icons that create the image of cities. This is shown by a number of studies, of which those that allow imaging the structure of cities were considered key.

Abesinghe et al. examine how, with the help of social media data, a city's image changes, and with it its popularity in supralocal and international rankings. To achieve this, the study adopted the Capture-Understand-Present (CUP) model. The researchers emphasize that in the digital age there is no need to adopt complex methods for studying the image of a city. Social media messages, which allow for a deeper and closer understanding of the community's attitude to the city's image, prove to be sufficient [1].

A study using a similar approach to the use of geocoded social media data is also presented in the article by Huang et al. [2]. The perception of images of cities in the Tri-City Region in Poland was studied. Benchmarks established based on the official GIS database, surveys and map sketches made by residents were used to evaluate the results. The study proved the relevance and importance of Lynch's theory in the digital age, and that GSM technology and Instagram and Twitter data are a good complement to his original methods. The development of this type of survey method, also reduces the amount of field work and allows the measurement of images of cities on a much larger scale [2].

Another of the methods of studying the image of cities is the process proposed by Jinag B [3]. It consists, on automatic calculation of the image of the city from geospatial databases of the city, taking into account the hierarchy of scaling, grouped on layers of urban artifacts, e.g. streets, buildings, parks. Hierarchy of artifacts is done as a process of ranking in terms of semantic, geometric and topological information. This ranking makes it possible to divide the artifacts and the spaces adjacent to them into two parts: above and below the norm. This allows the

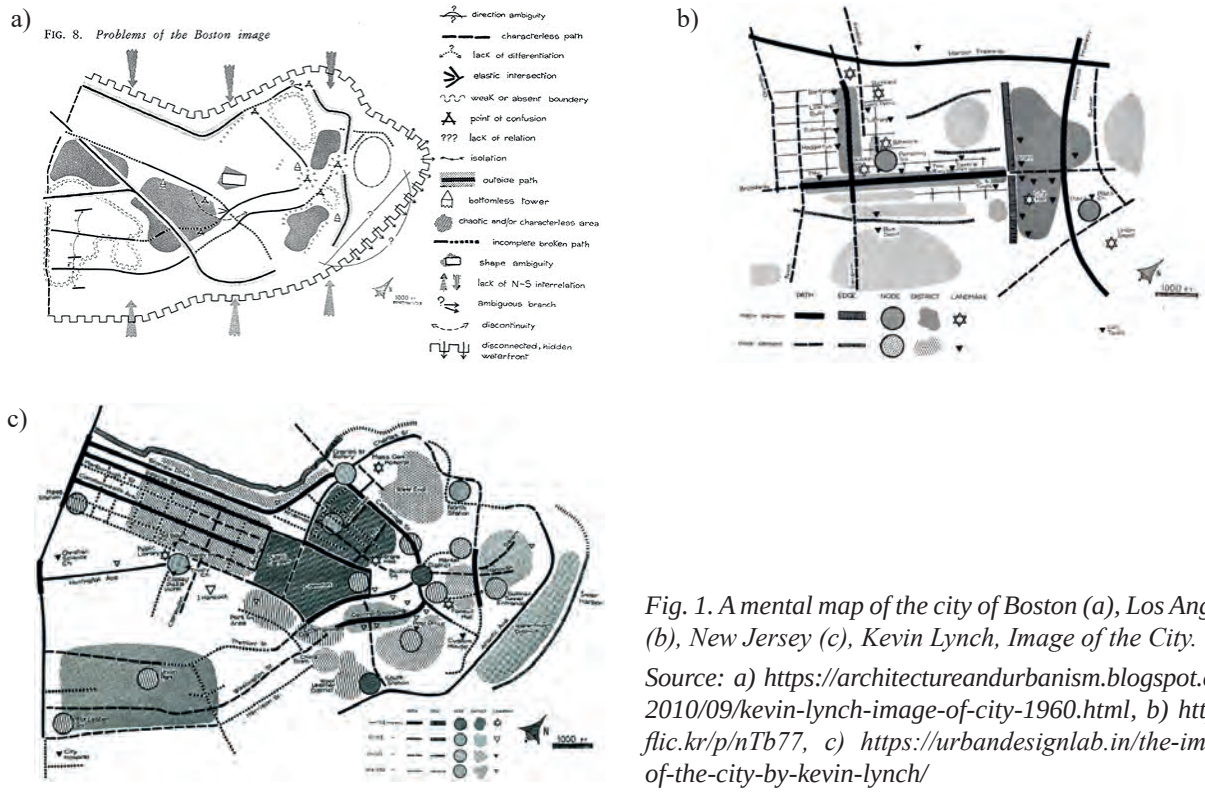


Fig. 1. A mental map of the city of Boston (a), Los Angeles (b), New Jersey (c), Kevin Lynch, Image of the City.

Source: a) https://architectureandurbanism.blogspot.com/2010/09/kevin-lynch-image-of-city-1960.html, b) https://flic.kr/p/nTb77, c) https://urbandesignlab.in/the-image-of-the-city-by-kevin-lynch/

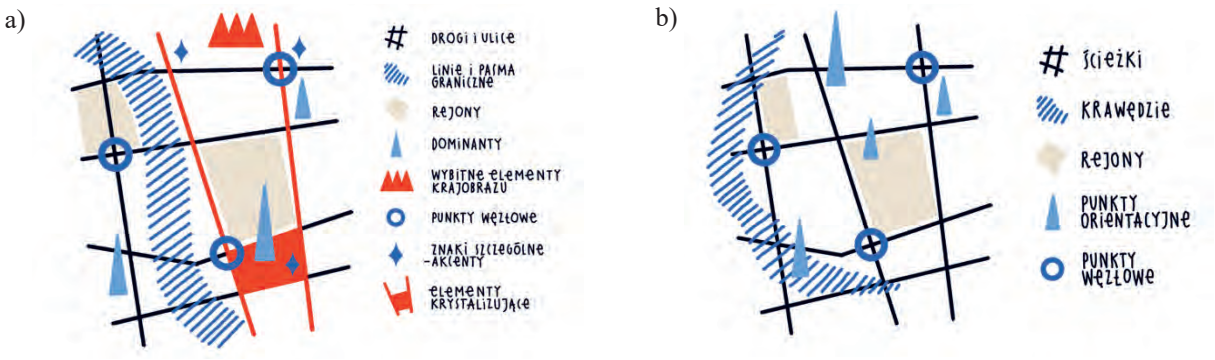


Fig. 2. Elements of city structure according to Kazimierz Wejchert a): roads and streets, border lines and strips, districts, dominants, prominent landscape elements, nodes, special characters, elements crystallizing the city plan and according to Kevin Lynch b): paths, edges, districts, landmarks, nodes

Source: https://ade.niaiu.pl/archipediapl/elementy-miasta, authors: Elżbieta Kusińska, Weronika Reroń

study to distinguish spaces that form important parts of the mental map and image of the city [3, 4].

Tang, Yang et al. [6] conducted experiments with image analysis of Wuhan city using a method that examined differences in respondents' attitudes toward the city's image and the relationship between attitude ratings and basic information about the respondents. Using a survey questionnaire, respondents' basic information and attitudes toward the city were collected. SPSS (Statistical Package for the Social Sciences) was also used for descriptive statistical analysis, correlation analysis, and ANOVA analysis on the data, in order to obtain information on the associations and relationships between images of the city and basic information about the respondents. Lynch also argued that image and the image of a city are shaped through people's perceptions and experiences [5]. The Wuhan study by categorizing the evaluation into three aspects i.e. degree of liking, degree of intimacy and degree of importance allowed for more in-depth analysis on the evaluation of the city's image and more importantly the image of the city itself through its relationship with its residents [6].

Referring to Kevin Lynch's method, Polish urban planner Kazimierz Wejchert [7] notes new factors shaping the image of a city. In addition to those corresponding to the components indicated by Lynch (Fig. 2b), Polak additionally distinguishes: elements crystallizing the city plan (EK), prominent landscape elements, and special characters (Fig. 2a). The first factor is found in cities mostly in the form of a market, often also as a compositional axis in the form of a main street. It must be a strong enough feature that makes the resident immediately associate it with the entire city. Prominent landscape elements are the most distinctive views, which are often the hallmark of a place. A landmark in a city's image can be, for example, a monument or sculpture, but also distinctive details of buildings or even temporary colorful advertisements.

Photos are a natural representation of a city's image, and are a fixation on the perception of the actual city. Sussana Moreira [8] describes the use of aerial photographs of selected cities to illustrate elements of Kevin Lynch's city image. Paths were shown through the street layouts of Brussels and the English town of Dagenham. Edges were illustrated through the example of the historic walls of the city of Lucca in Italy and the buildings of the city of Antofogasta in Chile, which is separated by a coast on one side and a mountain range on the other. The author showed the areas using the city centers of Madrid and Thessaloniki, Intersections and squares in Argentina's La plata and Spain's Plaça de Tetuan are good examples of nodes. As landmarks, the author presented photos of the Statue of Liberty and the Asinelli and Garisenda towers in Bologna, Italy. The author emphasizes the connection of Lynch's highlighted elements to the whole city and their setting in context: "(...) none of the elements proposed by Lynch exist in isolation in the real case, and therefore the author concludes that although his analysis begins with the differentiation of the data into categories, it must end with their "reintegration into the whole image" [8].

The mental mapping method that Lynch uses when creating a city image was used by Milena Stettner in her research on "building a city image by residents of selected small cities in the Lower Silesian province" [9].

It consisted of confronting mental maps created by the urban planner and residents of selected cities. Three cities were selected: Trzebnica, Siechnice, Świeradów-Zdrój. The city of Siechnice fared best in this comparison. The simple layout and small size of the city allowed it to be mapped very accurately with elements such as nodes, landmarks and edges. In the case of the last city, the respondents mapped all the city's landmarks and nodes in accordance with reality, while the drawings of the rest of the city's structure differed among the respondents. This was due to the respondents' different places of residence. The most important conclusion drawn by the author of the conducted research is that the legibility and perception of the city by its users is very much influenced by the diversity of space and characteristic elements in the city.

Milena Stettner used the same survey method for the residents of Wroclaw Angles [10]. She collected 22 residents and visitors, including people connected and familiar with urban issues, e.g. planner, official. The respondents started their drawing with the 3 most characteristic elements of the city: the Market Square, the main street and the edge in the form of the railroad tracks, the river and the highway. The worst in the juxtaposition of elements of the city image was the mapping of streets. Juxtaposition of the results showed that the respondents most remember their activities in the urban space, distinguishing, for example, the route to work, home or school.

Another author's method of research was proposed by Beata Komar [11] using the example of the Tysiąclecia housing estate in Katowice. An urban audit was conducted, which involved examining the estate according to 11 guidelines. They concerned issues of sustainability, including, among others, the urban composition and legibility of the settlement's spatial layout according to Kevin Lynch's theory. The author adopted separate criteria for this issue and evaluated them. After analyzing all elements of the structure, the estate received the highest score, the criteria of which were: "holistic fulfillment of the theory's assumptions, i.e. the settlement has all the elements mentioned in the theory: edges, nodes, paths, landmarks, neighborhoods" [11]. A survey was then conducted with 12 seniors living in the settlement, during which the audit results were confronted. The two-phase nature of the research made it possible to confront the results. The most important of the conclusions drawn by the author is the introduction of additional objects with different functions into the structure of the settlement, in addition to buildings with a residential function. The author also notes the need to maintain a legible urban space, for example, by not cluttering existing pedestrian routes with new elements or introducing a visual identification system.

Despite the growing popularity of artificial intelligence, it is not yet as widely used in the field of urban planning as it is in other fields. However, as outlined in the article "The Sustainability of Artificial Intelligence: An Urbanistic Viewpoint from the Lens of Smart and Sustainable Cities", in recent years, AI applications have become an integral part of the city, where, for example, artificial intelligence manages transportation systems or monitors the state of air quality. Researchers emphasize the increasing use of AI in city planning, and thus its greater impact on sustainability [12].

Bibri, Krogstie et al. [13] analyzed the links between artificial intelligence and smart cities, and as a result observed rapid development in sustainable green smart cities between 2016 and 2022. This is related to the digitization program and the development of data-driven technologies, which is characteristic of AI in smart city analysis.

Cugurullo et al. [14] point out, artificial intelligence is having an increasing impact on the management of 21st century cities. AI applications can be found in cities that are most suitable for its implementation, due to the concentration of high-tech infrastructure and high population density that determines the need for new AI technologies. Artificial intelligence can be a tool used by urban planners to generate scenarios for the future of urban development. According to Peng, Lu, Liu and Zhai [15], this is expected to optimize urban planning and design, and direct attention to sustainable development. For planners, AI-processed textual information from various plans can be important to facilitate and streamline data analysis and improve the efficiency of city planning. As Parasa [16] points out, one of the main functions of AI in urban planning is also predictive modeling, i.e. collecting and analyzing data, such as historical data, to predict future trends in urban development and its infrastructure needs. Despite the use of AI for various urban planning purposes, no attempt has been made before to generate images of cities using it.

2. MATERIALS AND METHODS

For the purpose of the research, the following were implemented: literature search, in situ research,

research using GIS software and quantitative data, experiment, research by design and comparison method. During the series of classes entitled. "Models of city structure" conducted in the Department of Urban and Spatial Planning at the Faculty of Architecture at the Silesian University of Technology, students have been performing analyses on the structure of various Polish and European cities for several years now. These are classes conducted as part of the course "Urban Design – City Structure". The series began with analyses on the city of Bologna in Italy (2019) [17], then Aachen in Germany was studied (2020) [18]. Subsequent editions focused on Polish cities and included Zabrze (2021) [19], Gliwice (2022) [20], as well as the Upper Silesian and Zagłębie Metropolis (2023) [21]. The studies are of a scientific nature: the research and experiments carried out by students together with their supervisors are based on theory, and their results are published.

The research used information from local databases, such as the Municipal Spatial Information System (MSIP) [22] and the Study of Land Use Conditions and Directions [232 for a given city, as well as national databases such as the Central Statistical Office (CSO) [243, Geoportal [25] and OpenStreetMaps [26]. The geo-information software QGIS was also used, which allowed the creation of many analytical maps with preset criteria. One of the more specialized tools, for example, was Databout. LIS – Locate It Smart [27], a program that analyzes the accessibility and surroundings of selected locations (Gliwice). The program was previously used, among others, during the creation of the Development Strategy of the City of Kutno 2030 [28]. Using it, accessibility models of social infrastructure were made. For example, pedestrian accessibility to bus stops or city bike stations was checked, and the data obtained was incorporated into the draft City Strategy.

Various tools such as Cadmapper, Autocad were used in developing the acquired data. Sketchup and Blender were used to work on 3D models. The use of dedicated applications Sketchfab.com and Augment.com, as well as working with VR goggles, made it possible to make the created 3D models available in virtual and augmented reality. In addition to traditional photos, photographic documentation was made in the form of photopanoramas in the Teliportme.com application, as well as with images taken by drone. Other tools used to create physical mock-ups include a Styrocad thermal plotter and a 3D printer.

In the case of the development of the Upper Silesian Metropolis, attempts were also made to create development scenarios using artificial intelligence "Midjourney". Places such as the highway interchange, the Silesian Stadium and the Market Square in Gliwice, for example, were selected, and then positive and negative versions of the development of the selected locations in 100 years were created and compared.

3. CASE STUDY

For the purpose of preparing the case study, analyses of the city's structure carried out as part of the research are presented. These include historical, share of built-up area, technical and blue-green infrastructure, road communication, accessibility of public transportation or land use taking into account residential, service and industrial areas separately. Analyses of public spaces and inspired by Kevin Lynch's methodology were also prepared. These formed the basis for further research discussed in the article.

3.1. Models of the Bologna city structure

The analysis of the city of Bologna according to Kevin Lynch's method is presented using a large-scale physical mock-up (Fig. 3). It shows the outline of the city's boundaries, along with a simplified sub-image of the solids of the buildings. Roads are depicted on the mock-up using orange threads. Depending on the frequency of use of a given road, the amount of line/thread guidance was increased or decreased. Nodes, or key communication links, were depicted on the mock-up with vertically placed sticks of different heights. High sticks mark the most significant nodes while low sticks indicate the less significant ones.

Fig. 3. Mock-up showing analysis of the city of Bologna according to Kevin Lynch's method

Source: https://www.polsl.pl/rar/ps_aktualnosci/nietypowe-modele-miast-wystawa-modele-struktury-miasta-bolonia-28-maja-informacja-prasowa/

Areas are depicted as cut-out 3d solids, the edges of which are the boundaries of the areas, while the edges are depicted on the mock-up with black threads. In the case of Bologna, these include railroads, airport runways, the city's ring road and selected roads. Landmarks were visualized on the mock-up with photos of selected points, and then pasted in their corresponding locations. The authors highlighted the following landmarks for Bologna, among others: Ducati Factory and Museum, Bologna Airport, Navile Canal, Park di Via dei Giardini, Sacred Heart Church, Fiera District, Fico, CUS Bologna Sports Club, Monumento Brigata Partigiana Maiella historical site, Polish War Cemetery.

3.2. Models of the Aachen city structure

3.2.1. Analysis of the city of Aachen according to Kevin Lynch's method

The analysis of the city of Aachen according to Kevin Lynch's method was presented using a spatial model (Fig. 4), which was then made available in augmented reality.

Fig. 4. Analysis of the city of Aachen according to Kevin Lynch's method – 3D model

Source: https://agmt.it/m/zL3d9gm9

The model shows a section of the city center with gray building blocks. Roads are depicted in the model as light green lines, and are mostly the main streets of the city. The nodes, or intersections of the main roads, are depicted in the model as green rollers. Areas are depicted in the model as orange outline fills. Areas highlighted are the inner city (around the city hall), Elisengarten Park, the commercial zone in the eastern part of the center (includes a house and a department store), the RWTH Aachen Polytechnic Campus, Ludwigsalle Park and school with sports areas, Campus Campus Mitte, and Kurgarten Park. The edges are depicted in the model as red, continuous lines. These included Road 57 and 264, the city's ring road (Road 1), as well as railroads (especially near the train station and the northwestern part of the center). Landmarks of the city of Aachen include the Aachner Dom Cathedral, Elisenbrunnen, RWTH Aachen University, Aquis Plaza Aachen, Neues Kurhaus Aachen, Marienturm and the main train station. The listed building blocks have been turned blue.

3.2.2. Analysis of selected public spaces in Aachen

Studying the public spaces of the city of Aachen, it was decided to check their accessibility on a section of the city center. In the 3D model (Fig. 5) that was made, in addition to the underlay containing buildings and railroad lines, areas of places/markets/squares (red fill), green areas (green fill), pedestrian spaces (orange fill), and spaces for all types of transportation (light green lines) were marked. The study selected several specific public spaces for each city district. These included the Elisengarten park, the Market Square with the town hall and cathedral, the Brander Wald nature reserve, the Indemann viewpoint and the former Walheim quarry.

Fig. 5. 3D model presenting the accessibility model of public spaces in the city of Aachen

Source: https://agmt.it/m/YwrSnzD7

3.3. Models of the Zabrze city structure

Zabrze was the first city in the Upper Silesian Metropolis to be analyzed.

3.3.1. Analysis of the city of Zabrze according to Kevin Lynch's method

The analysis of Zabrze according to Kevin Lynch's method was presented using maps of the entire city and a spatial model of a selected part of the city, which was then made available in augmented reality.

Four maps of the city were drawn up showing separately the location of landmarks (Fig. 6a), areas (Fig. 6b), edges (Fig. 6c), and nodes and roads (Fig. 6d). A section of the city was then selected to create a 3D model. The area includes the vicinity of the House of Music and Dance, identified as one of the city's landmarks.

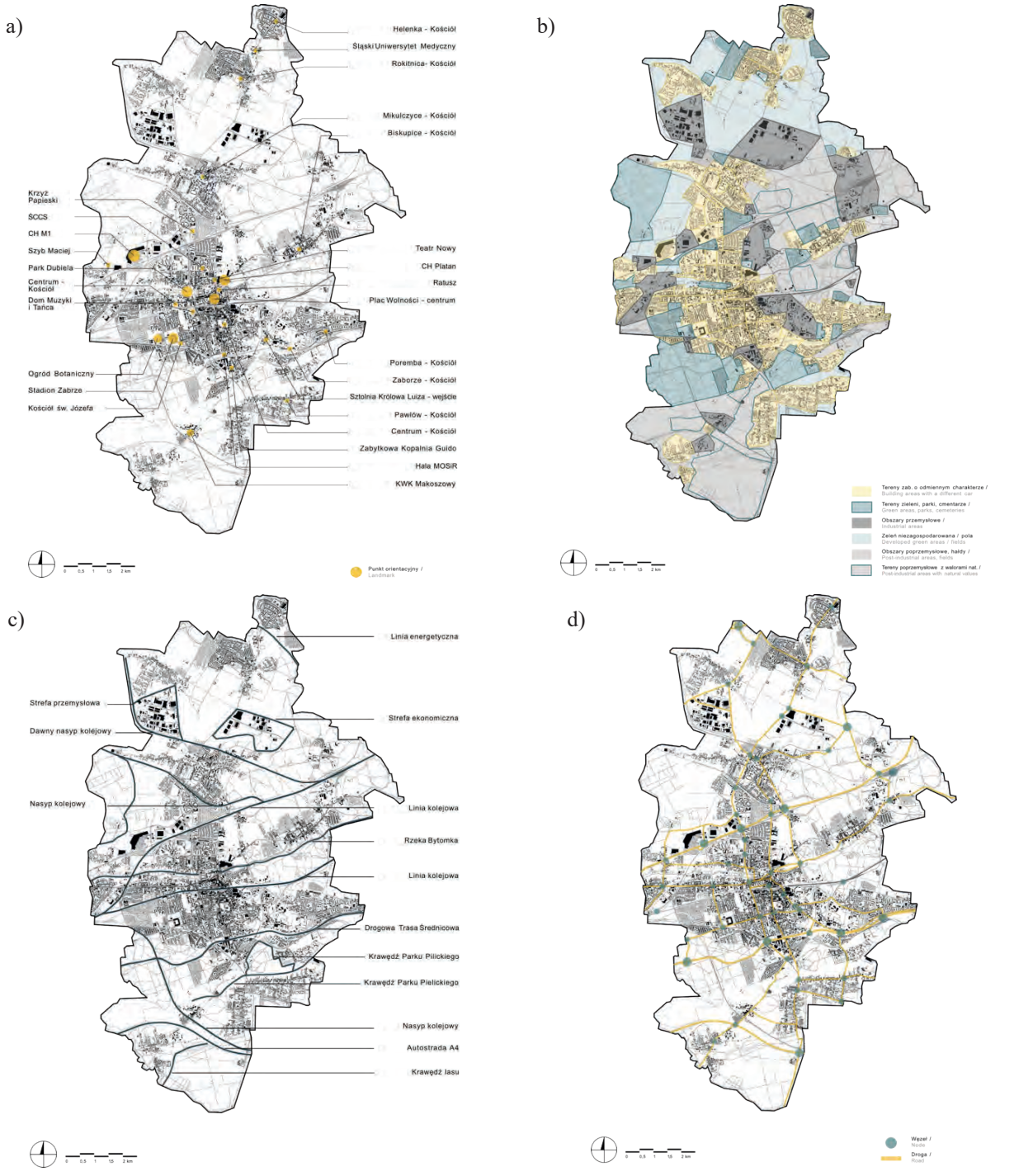


Fig. 6. Analysis of the city of Zabrze according to Kevin Lynch's method – landmarks (a), districts (b), edges (c), nodes and roads (d)

Source: Modele struktury miasta Zabrze [18], authors: Paweł Białas, Michał Ciebień

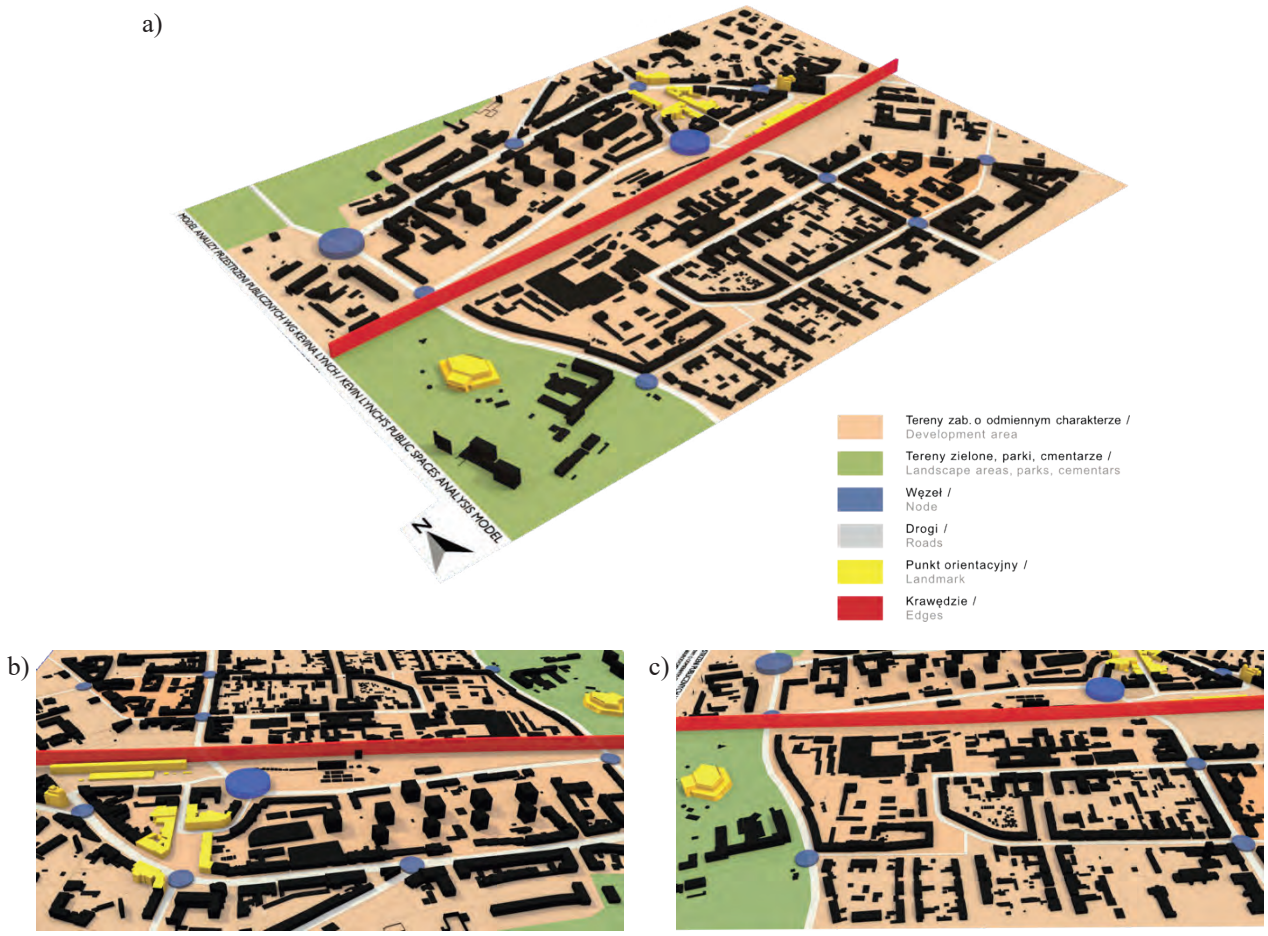


Fig. 7. Analysis of the city of Zabrze according to Kevin Lynch's method – 3D model (a), close-ups of the model (b, c)
Source: Modele struktury miasta Zabrze [18], author: Kamil Bryłka

Roads are depicted in the model as gray, continuous lines. Three national roads are indicated: 88, 78, 94, the Drogowa Trasa Średnicowa, as well as a section of the A4 highway running through the city and Wojciech Korfanty Avenue, one of Zabrze's most important streets. The nodes are depicted in the model as blue cylinders. Areas were depicted in the model as outline fills of corresponding color. The following areas were distinguished: buildings of a different character, green areas, parks, cemeteries, undeveloped greenery and fields, industrial and post-industrial areas, dumps, and post-industrial areas with natural values. The edges are depicted in the model as red, continuous lines. For Zabrze, these are railroad lines, main roads, railroad embankments, remnants of former mines (heaps), an economic and industrial zone, power lines, the Bytomka River, the Drogowa Trasa Średnicowa, the edges of Pilecki Park, a section of the A4 highway and the edge of the forest. Landmarks are depicted in the model as yellow solids. Such places are indicated as, for example, the Silesian Medical University, the New Theater, City Hall, Liberty Square, the Królowa Luiza Adit, the historic Guido Mine, Maciej Shaft, Dubiel Park, the House of Music and Dance, Zabrze Stadium and churches.

3.3.2. Analysis of selected public spaces in Zabrze

A spatial model and corresponding mock-up were drawn up for each public space in Zabrze. Several squares (Traugutta, Theater Square, Wolności Square, Krakowski Square), public buildings (AdmiralsPalast Hotel, House of Music and Dance), and former mine buildings (Guido Mine, Queen Luisa Adit) adapted for a museum were selected.

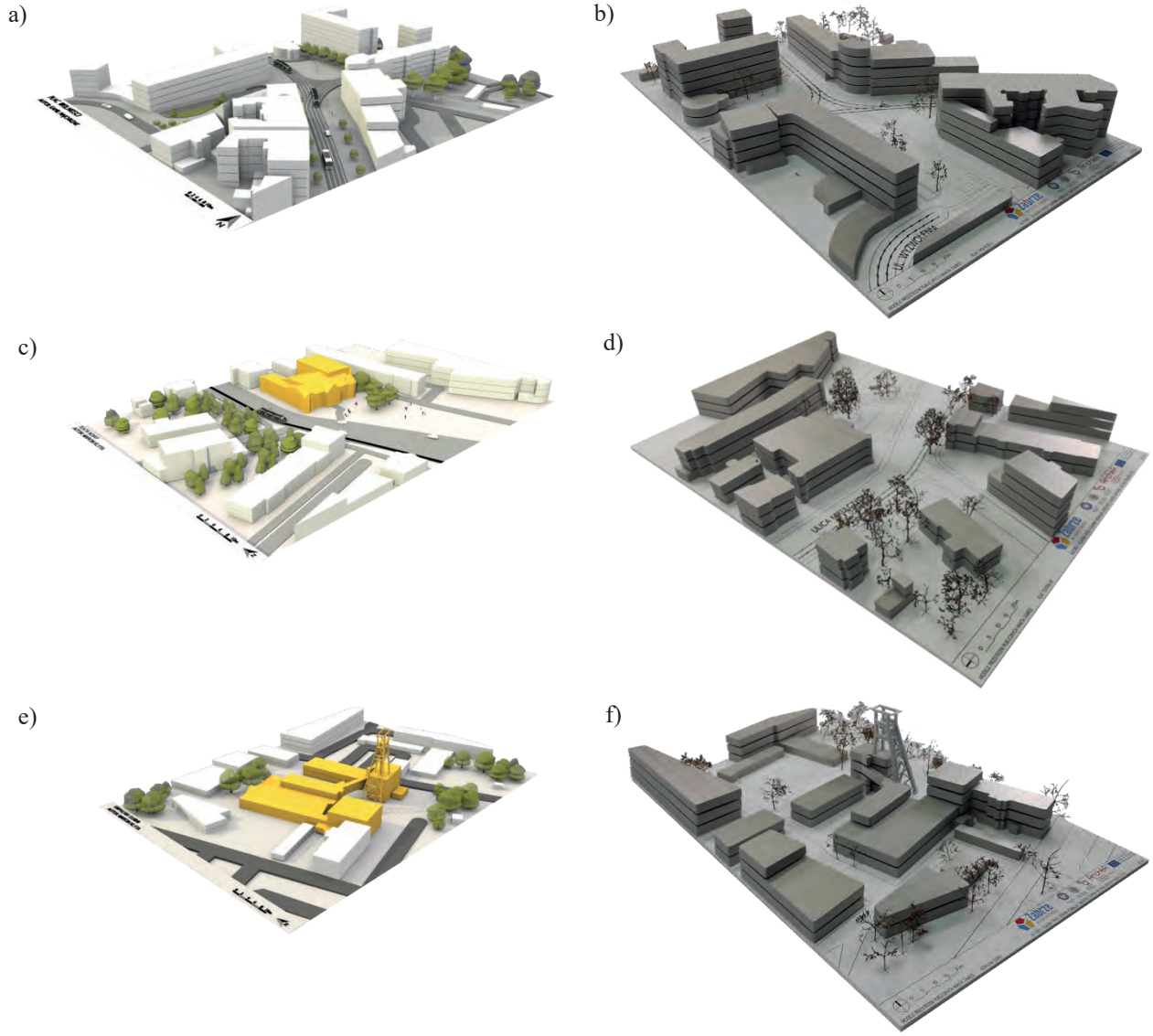


Fig. 8. Wolności Square – 3D model (a), mock-up (b), New Theater – 3D model (c), mock-up (d), Guido Mine – 3D model (e), mock-up (f)

Source: Modele struktury miasta Zabrze [18], authors: Kamil Majchrzak (a), Paweł Białas (a, c, e), Marcin Klyta (c, e), group work (b, d, f)

3.4. Models of the Gliwice city structure

During the study of Gliwice, two distinctive areas were selected in addition to analyses of the entire city. These were the Academic District of the Silesian University of Technology and Nowe Gliwice, an area formerly occupied by the Gliwice coal mine, which was rehabilitated and where the "Nowe Gliwice" Education and Business Center was built.

In addition to performing basic analyses of the city's structure on the basis of the map, such as the analysis of residential areas, service and industrial areas or blue-green infrastructure, analyses were also performed with the help of spatial 3D models, which were made available in augmented reality and virtual reality, as well as mock-ups which were their physical representation. Using mock-ups, it was also decided to depict several selected public spaces of Gliwice, such as the aforementioned area of New Gliwice, the Academic District, the Gliwice Market Square or the Gliwice Radio Station with its surrounding area.

3.4.1. Analysis of the city of Gliwice according to Kevin Lynch's method

Using Kevin Lynch's method for creating a "city image", it was examined how the elements he highlighted apply to the city of Gliwice. A 3D model

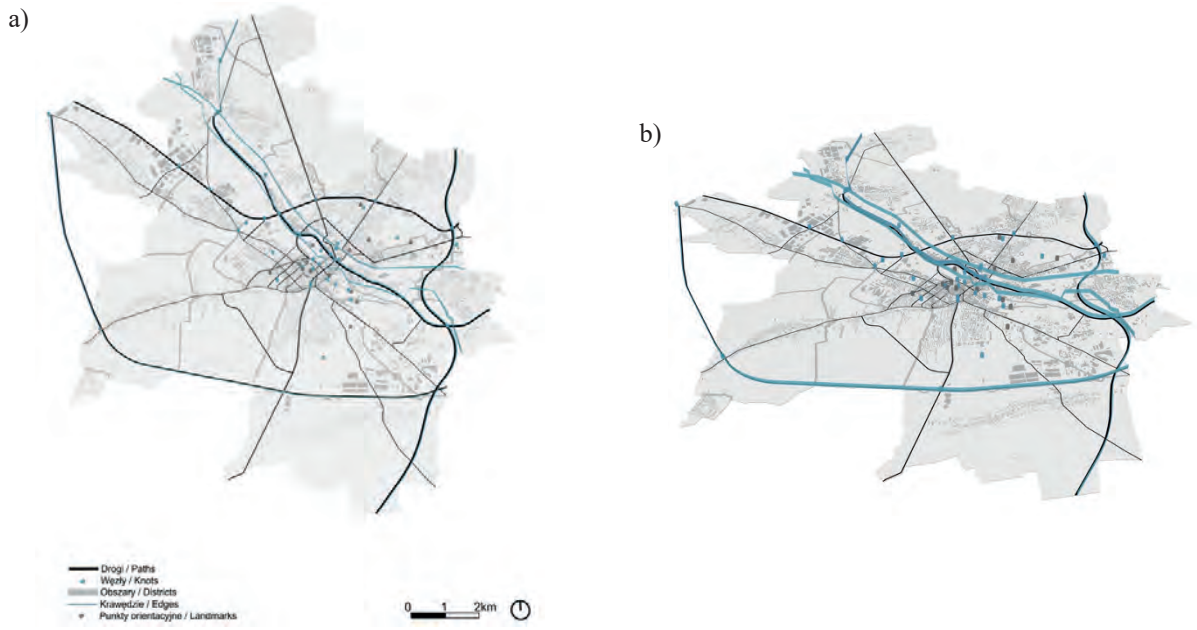


Fig. 9. Analysis of the city of Gliwice according to Kevin Lynch's method – map (a), 3D model (b)
Source: Modele struktury miasta Gliwice [19], authors: Agnieszka Bonczek, Natalia Hulbój

was drawn up showing the listed features of the city's structure (Fig. 9b). Roads were depicted in the model with black lines. Roads include the Drogowa Trasa Średnicowa and the A1 and A4 highways. Nodes were depicted in the model with blue cylinders. They included the highway interchange and public spaces such as the Market Square, the square in front of Arena Gliwice, Piast Square and the railroad station. The areas were depicted in the model with gray outlines. The area of the Silesian University of Technology campus and the Gliwice Aeroclub are highlighted here. The edges are visualized in the model with blue lines. For Gliwice, they are: Drogowa Trasa Średnicowa, A1 and A4 highways, railroad lines and the Klodnica River. Landmarks are depicted in the model as gray cylinders and are: Gliwice Radio Station, Gliwice City Hall and Arena Gliwice.

3.4.2. Analysis of selected public spaces in Gliwice

In the compiled model of accessibility of public spaces (Fig. 10), in addition to the primer containing buildings, areas of squares/markets (orange fill), green areas (green fill), pedestrian spaces (light orange fill), pedestrian and roadways (light orange fill), as well as spaces for all types of transportation (gray lines) are marked.

A spatial model and corresponding mock-up were drawn up for each public space in Gliwice. Two main areas were selected: Nowe Gliwice and the Campus of the Silesian University of Technology, as well as the Market Square, areas near the Gliwice Radio Station and the Mickiewicz and Grunwald Parks. Photos and 360 panoramas were also used during the analysis.

Fig. 10. A map presenting the model of accessibility of public spaces in the city of Gliwice
Source: Modele struktury miasta Gliwice [19], author: Daria Bal

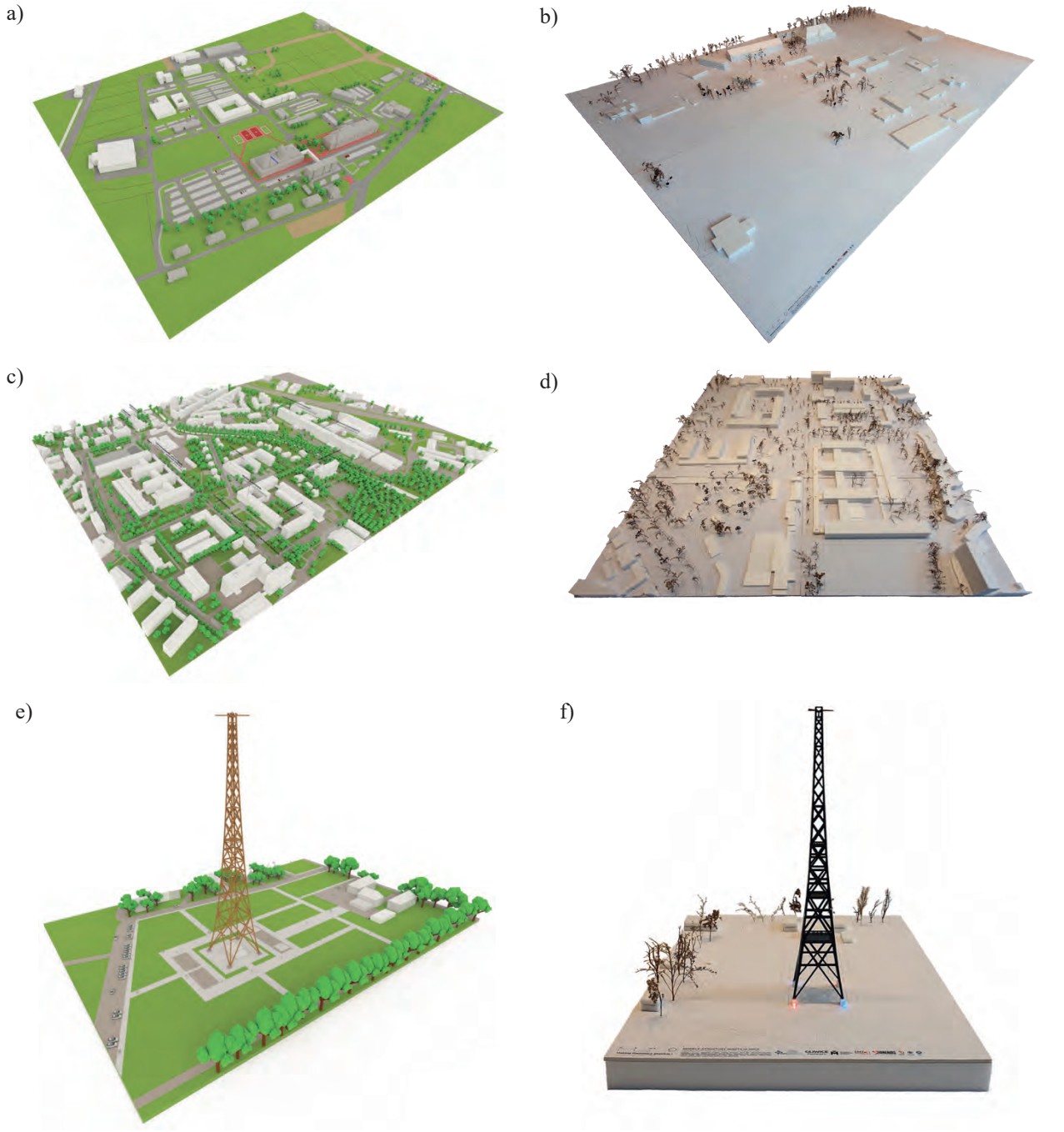


Fig. 11. New Gliwice – 3D model (a), mock-up (b), Akademicka District – 3D model (c), mock-up (d), Gliwice Radio Tower – 3D model (e), mock-up (f)

Source: Modele struktury miasta Gliwice [19], authors: Aleksandra Barańska (a), Adam Michałowy (c), Julia Wiśniewska (a, c, e), Magdalena Fijał (e), group work (b, d, f)

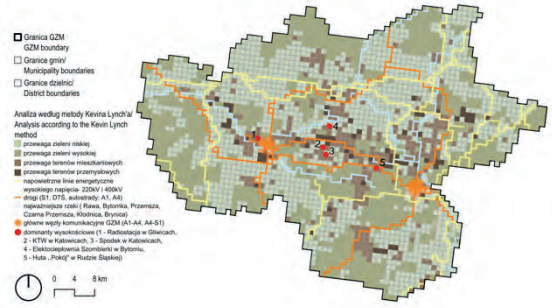
3.5. Models of the structure of the GZM metropolis

In the analysis of the Upper Silesian Metropolis, a kilometer grid model was adopted as the cellular model and the division into districts. This method allowed for a more accurate representation of the data, despite the complexity of the metropolis, which consists of 41 municipalities. The analysis is based on the synthesis of data using GIS software and 3D models, which are available in augmented and virtual reality. A number of analyses were performed, related to, among other things, buildings, communications, demographics or infrastructure of the entire GZM area.

3.5.1. Analysis of the GZM structure according to Kevin Lynch's method

Elements of Kevin Lynch's theory were also used to create an analysis of the Upper Silesian Metropolis (Fig. 12a), so as to show it on a broader scale than the city. Its versatility of application in image analysis and multifaceted operation was highlighted. Its various elements were highlighted in the 3D model (Fig. 12b). Roads are depicted in the model as orange 3D lines and are: Drogowa Trasa Średnicowa, A1, A4 highways, S1 expressway. Nodes are depicted in the model as orange cylinders. For the GZM, these are the A1-A4 and A4-S1 interchanges. Landmarks are depicted in the model as red cylinders. Prominent examples are the Gliwice Radio Station, the "Room" steel mill in Ruda Śląska, KTW in Katowice, the Szombierki Combined Heat and Power Plant in Bytom and Spodek in Katowice. The edges were visualized in the model as blue and yellow three-dimensional lines. The 220 kV and 400 kV overhead electromagnetic voltage lines, as well as the Rawa, Bytomka, Przemsza, Czarna Przemsza, Klodnica, Brynica rivers were depicted in this way. The areas were depicted in the model by color-coding the predominant type in a given square kilometer, from among: low greenery, high greenery, residential areas and industrial areas. A kilometer grid division of the metropolitan area was used to delineate the areas, in order to more accurately depict the data in individual squares of 1 square kilometer, and to more clearly perceive a given section of the GZM.

a)



b)

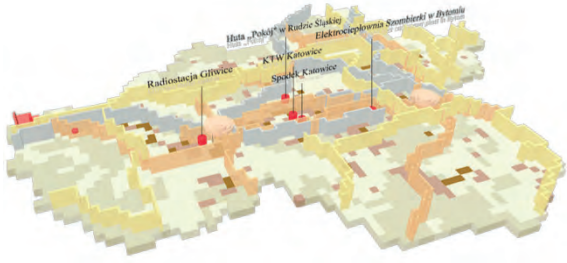


Fig. 12. Analysis of the Upper Silesian-Zagłębie Metropolis according to Kevin Lynch's method – plan (a), 3D model (b)
Source: Modele struktury Metropolii GZM [20], author: Karolina Wąsińska

4. EXPERIMENTS USING ARTIFICIAL INTELLIGENCE

The authors undertook an experiment using the artificial intelligence platform "Midjourney". Images, representing elements of Kevin Lynch's theory, were generated for the city of Gliwice. Attempts to generate images and identify individual image elements are presented below.

Attempts were made to generate two snapshots of images showing a 2D city plan and a 3D model. The following different combinations of keywords were tested, in order to get the effect as close as possible to the effects we know from studies carried out without AI. Trials of different keywords and evaluation of the images generated based on them are presented in the discussion. The best results were obtained based on the keywords: "'The image of the city' by Kevin Lynch, urbanism 2D analysis map of Gliwice, Poland, with highlighted elements of paths, edges, districts, nodes and landmarks" and "'The image of the city' by Kevin Lynch, urbanism 3D analysis model of Gliwice, Poland, with highlighted elements of paths, edges, districts, nodes and landmarks".

Artificial intelligence presented an image of the city of Gliwice, according to Kevin Lynch's theory, on a 2D map (Fig. 13a) and a 3D model (Fig. 13b), by highlighting its various elements. Roads were visualized as white, orange and blue lines. Edges were visualized as separating areas with blue and white zones and highlighting in orange the demarcating development. Areas were depicted as white, gray, black and orange zones. Nodes were depicted as intersections of lines. Landmarks were visualized as orange and white circles where they occur and highlighted on the 3D model as, for example, height or volume dominant.

With reference to the morphology of Gliwice, the church tower shaped like All Saints' Church can be identified in Figure 13b. Another element is the river, which can be identified as the Klodnica River. The scale of similarity can be estimated at 40%.

a) b)

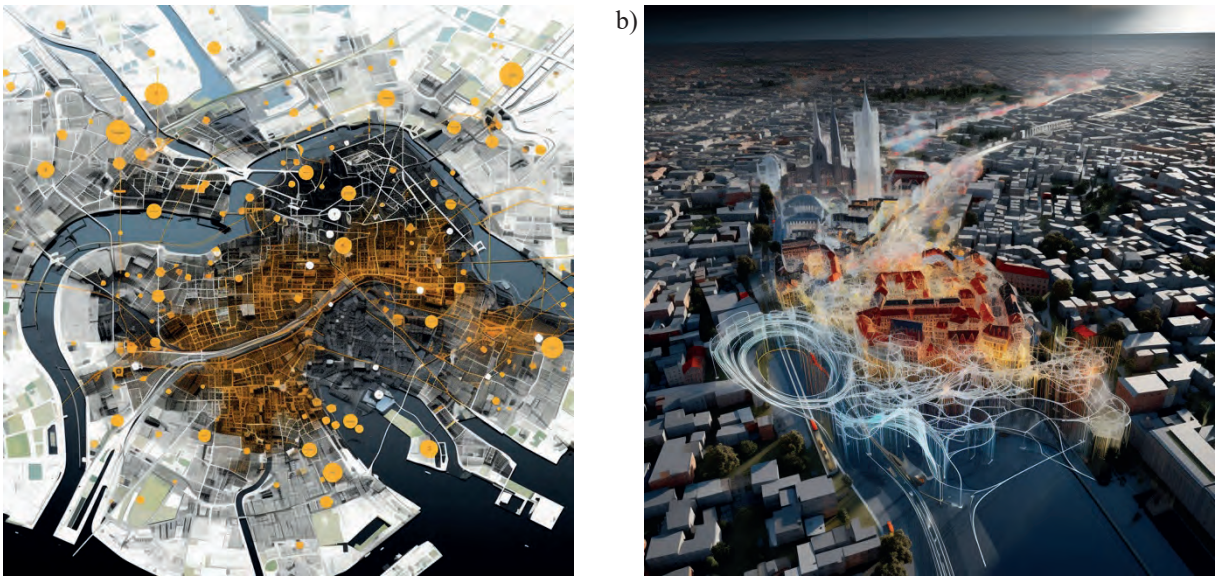


Fig. 13. Illustrations showing the image of the city of Gliwice using artificial intelligence – plan (a), 3D model (b)
Source: Image generated by the artificial intelligence platform "Midjourney"

4.1. Paths of the city of Gliwice using artificial intelligence

The AI depicted the paths of the city of Gliwice, according to Kevin Lynch's theory, on a 2D map (Fig. 14a) and a 3D model (Fig. 14b), by depicting them as blue, orange and white lines. AI, on the model, does not show all the paths, and their markings are not fully legible.

Figure 14a shows a river that can be recognized as the Klodnica River. The church tower, visible in the foreground of Figure 14b, is similar in form to a garrison church. A noticeable feature is the rectangular square, which resembles a market square in shape. The scale of similarity of Gliwice's morphology can be estimated at 40%.

a) b)

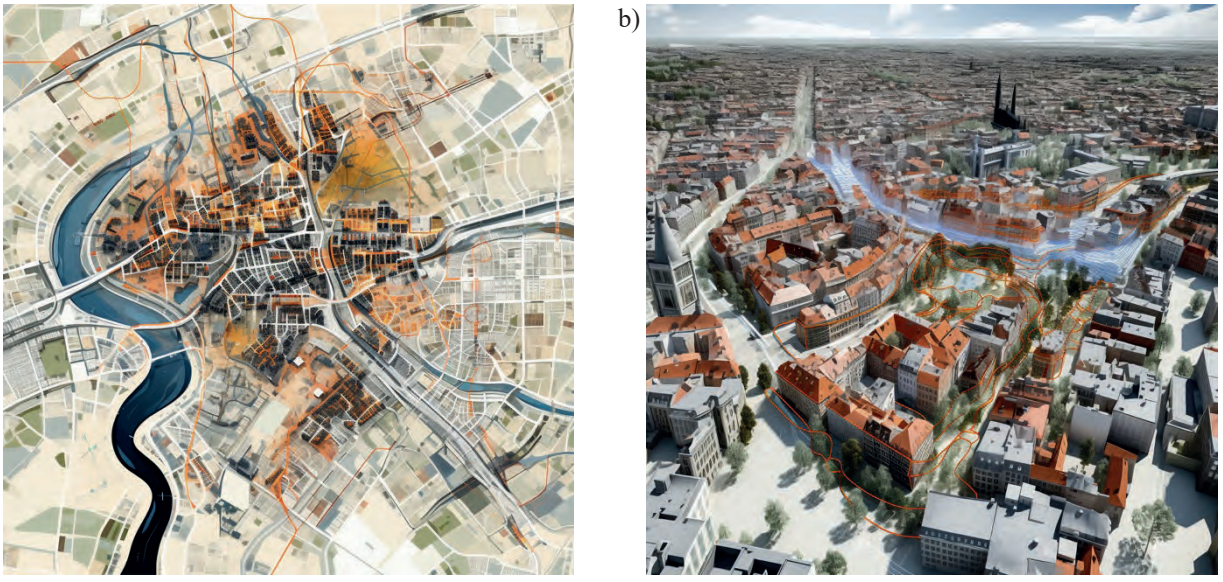


Fig. 14. Illustrations of the paths of the city of Gliwice using artificial intelligence – plan (a), 3D model (b)
Source: Image generated by the artificial intelligence platform "Midjourney"

4.2. Edges of the city of Gliwice using artificial intelligence

Artificial intelligence depicted the edges of the city of Gliwice, according to Kevin Lynch's theory, on a 2D map (Fig. 15a) and 3D model (Fig. 15b), by depicting them as separated by blue and white zones and highlighting in orange the demarcating buildings. AI has retained Gliwice's characteristic elements in the analysis, such as the river, the DTŚ expressway and the quarter buildings.

With reference to the morphology of Gliwice, in Figure 15b, the expressway – reminiscent of the Drogowa Trasa Średnicowa – and the river – reminiscent of the Klodnica – can be identified in the foreground. Among the buildings, a tower can be seen, which is similar in shape to the Radio Station. The scale of similarity can be estimated at 40%.

a) b)

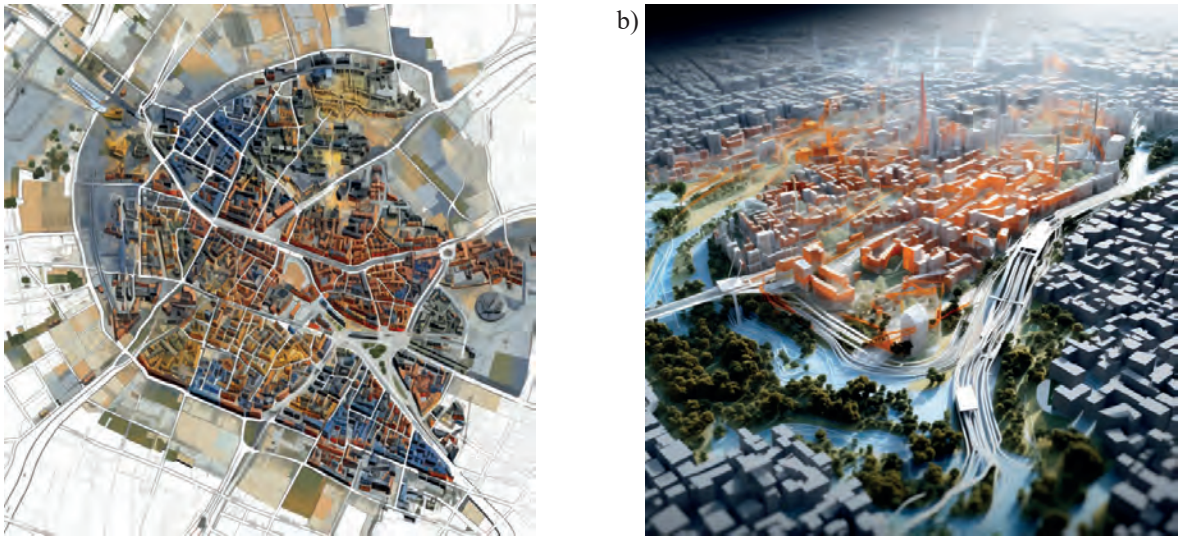


Fig. 15. Illustrations of the edges of the city of Gliwice using artificial intelligence – plan (a), 3D model (b)
Source: Image generated by the artificial intelligence platform "Midjourney"

4.3. Areas of the city of Gliwice using artificial intelligence

Artificial intelligence depicted areas of the city of Gliwice, according to Kevin Lynch's theory, on a 2D map (Fig. 16a) and a 3D model (Fig. 16b), by depicting them as color-coded zones. The AI, with its variety of colors, highlights the presence of many types of areas in Gliwice.

Figure 16b highlights the quarter buildings, which are developments characteristic of the structure of Gliwice. The scale of similarity can be put at 15%.

a) b)

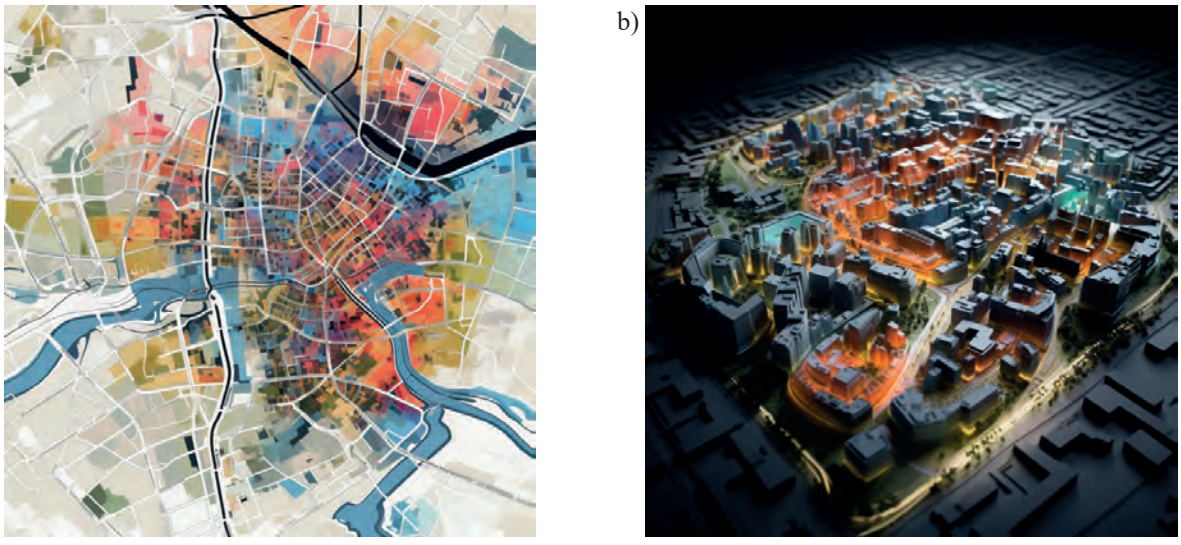


Fig. 16. Illustrations of the areas of the city of Gliwice using artificial intelligence – plan (a), 3D model (b)
Source: Image generated by the artificial intelligence platform "Midjourney"

4.4. Nodes of the city of Gliwice using artificial intelligence

The AI depicted the nodes of the city of Gliwice, according to Kevin Lynch's theory, on a 2D map (Fig. 17a) and 3D model (Fig. 17b), by depicting them as circles where the blue lines intersect. AI, on the model, does not highlight the nodes fully legibly.

In reference to the morphology of Gliwice, elements such as the expressway, which resembles the Drogowa Trasa Średnicowa, and the church, located among the development, which was identified as All Saints' Church, were highlighted in Figure 17b. The scale of similarity can be estimated at 40%.

a) b)

Fig. 17. Illustrations of the nodes of the city of Gliwice using artificial intelligence – plan (a), 3D model (b)
Source: Image generated by the artificial intelligence platform "Midjourney"

4.5. Landmarks of the city of Gliwice using artificial intelligence

Artificial intelligence depicted the landmarks of the city of Gliwice, according to Kevin Lynch's theory, on a 2D map (Fig. 18a) and 3D model (Fig. 18b), by depicting them as circles on a map and color-coded objects. AI, with the help of colors, shows the division into different types of landmarks (e.g., height or volume dominants) and marks the areas of their prevalence in a given area.

In Figure 18b, a church tower is highlighted, which can be identified as St. Bartholomew's Church through its form and shape. The scale of similarity can be estimated at 20%.

a) b)

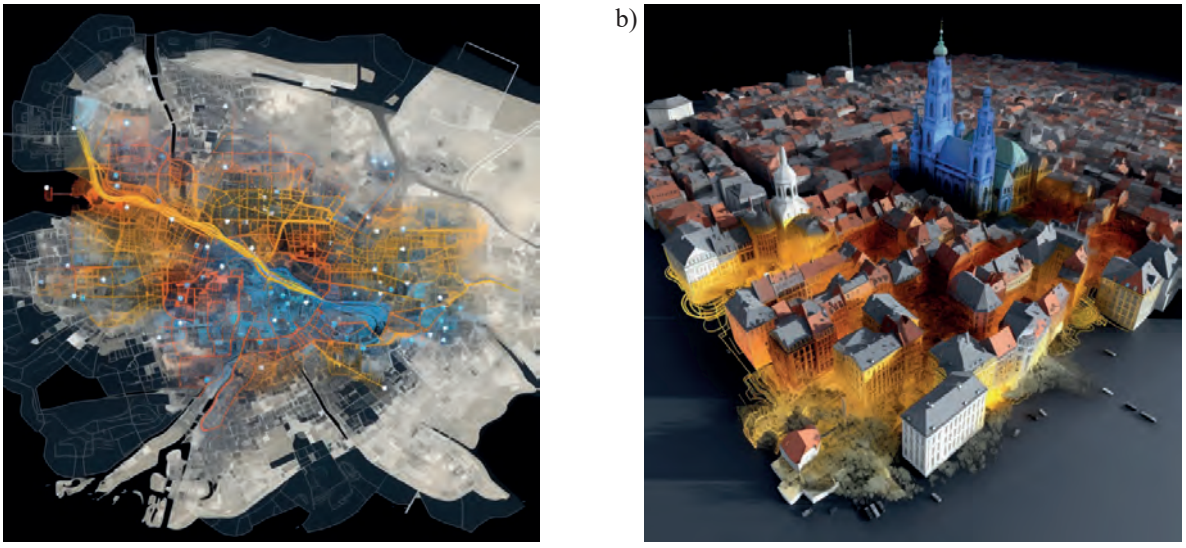


Fig. 18. Illustrations of the landmarks of the city of Gliwice using artificial intelligence – plan (a), 3D model (b)
Source: Image generated by the artificial intelligence platform "Midjourney"

5. DISCUSSION

Table 1 shows the different methods used in the representation of city image elements. Included in the comparison is the method pioneered by Kevin Lynch and the other methods the authors analyzed in the case study: mock-ups, 3D models, panoramic photos, augmented reality, virtual reality and AI. All those mentioned are intended to illustrate mapping.

In the course of experimenting with AI, 10 attempts were made to generate images of the city's structure using AI. These attempts are summarized in Table 2 and describe the effects that were obtained. The emphasis of the study was on obtaining clear and readable effects in the images. A three-point scale was adopted to evaluate the generated images as the effects of the keywords used: (–) not present, (+/–) partially present, (+) present.

Table 1. Comparison of different methods used to represent city image elements

CITY	METHOD	DISTRICTS	NODES	PATHS	EDGES	LANDMARKS
Boston, New Jersey, Los Angeles, K. Lynch	drawing	filling with hatch	circle with hatch	black continuous lines	black dashed lines	star, triangle
Bolonia	Mock-up	solid	vertical sticks of different heights	orange threads	black threads	photos of the objects in their locations
Aachen	3D model	orange flat outlines, trace of the city's buildings	green cylinders	light green continuous lines	red thick continuous line	blue solids
Zabrze	3D model, panorama	colorful flat outlines, trace of the city's simplified geometry	blue cylinders	grey continuous lines	red thick continuous line	yellow solid of the building
Gliwice	3D model, panorama, augmented reality	grey flat outlines, trace of the city's simplified geometry	blue cylinders	black thick continuous line	thin blue continuous line	grey cylinders
GZM	3D model, augmented reality	trace of the GZM in terms of a kilometer grid with a color-coded breakdown of the predominant type of terrain in a given quadrant	orange cylinders	orange three-dimensional lines	blue and yellow three-dimensional lines	red cylinders
Gliwice	AI-generated image	color-coded areas	circles where the blue lines intersect	blue, orange and white lines	separate with blue and white zones, highlight in orange delineating development	circles and color-coded highlights

Source: own work

Table 2. Comparison and rating of the effects of using different keywords for image generation using AI

Attempt No.	KEYWORDS	Readability of city image elements in 2D plan	Readability of city image elements in 3D image	Rating of the connection between the generated image and the city
1.	The image of the city Gliwice	–	–	–
2.	'The image of the city' by Kevin Lynch, Gliwice	–	–	–
3.	'The image of the city' by Kevin Lynch, Gliwice, urbanism	–	–	–
4.	'The image of the city' by Kevin Lynch, Gliwice, urbanism analysis	–	–	–
5.	'The image of the city' by Kevin Lynch, urbanism analysis of Gliwice, Poland	–	–	–
6.	'The image of the city' by Kevin Lynch, urbanism analysis map/model of Gliwice, Poland	–	–	+/-
7.	'The image of the city' by Kevin Lynch, urbanism 2D/3D analysis map/model of Gliwice, Poland	+/–	+/–	+/–
8.	'The image of the city' by Kevin Lynch elements, urbanism 2D/3D analysis map/model of Gliwice, Poland	+/–	+/–	+/–
9.	'The image of the city' by Kevin Lynch, urbanism 2D/3D analysis map/model of Gliwice, Poland, elements of paths, edges, districts, nodes and landmarks	+/–	+/–	+
10.	'The image of the city' by Kevin Lynch, urbanism 2D/3D analysis map/model of Gliwice, Poland, with highlighted elements of paths, edges, districts, nodes and landmarks	+	+	+

Source: own work

Trial 1 generated graphics showing the city in abstract and unreal form. Trials 2 and 3 produced results without results, they did not show the urban structure either as a map or as a model, they showed the city as a painted, even fairy-tale, image. In sample 4 and 5, the urban structure began to take shape, but in a very schematic form – with links and points. In sample 6 the images were presented in the form of a plan and model of the city, the structure of the city of Gliwice began to be identified. In sample 7 and 8, maps and models were already presented in more detail, and the results showed individual elements characteristic of the city image, but in a very general form. In sample 9, the individual elements that make up the city image were shown, but they were not quite clear and noticeable. The most authoritative results were obtained in sample 10, where the individual elements of the city were properly highlighted for easier reading and understanding.

Generating an image using AI may not be efficient, due to the operation of the algorithm and building associations based on the data found by AI in the web space. Prompting according to a very detailed key gives better results, because the greater amount of information, presented in the generated image, is not the result of individual data completion by AI. For this reason, a sample of 10 prompts was presented in the results of the study, aimed at obtaining the most authoritative effect.

The above experiments contradict the systemic, data-driven and GIS-based approach to city analysis that Filomena, Judith A. Verstegen, Ed Manley (2019) [29], Dalton and Bafna [30], Bim Jiang [31], among others, attempt to implement.

The trials conducted allow the following conclusions. In most cases, the resulting images are not consistent with the location in terms of scale and city-specific elements. Some of its elements were overscaled, for example, rivers (Fig. 13a, 13b, 14a), dominants (Fig. 13b). The generated city plans should also be considered random: although attempts were made to generate images of Gliwice, which has a medieval origin and the structure of the former outline of the oval shape of the city walls is still legible, most images do not reflect this.

6. CONLUSIONS

The city image mapping experiments described in the article should be considered promising. The use of

mock-ups, 3D models, augmented reality and virtual reality should be considered effective in the symbolic and spatial virtualization of city image elements. Panoramic shots or simplified 3D geometries superimposed on city plans that synthesize images should be considered to concretize selected places, corresponding to objects that we can easily identify with selected familiar places. AI-generated images intended to represent elements crystallizing the image of a city, referring to Kevin Lynch's theory, should be considered useless in the study of selected cities due to their lack of consistency with selected places. It should be conjectured that the methodological thinking characteristic of the theory is not obvious to be used by AI, so as to generate precise images, relating to locations at the same time. It can be guessed that system wide mapping of city image elements can be implemented using dedicated algorithms, based on GIS probably using machine learning or using neural networks. The reliability of the results of future studies of this type will mainly depend on data that are increasingly available. Therefore, the future of city image generation may soon change significantly.

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THE ROLE OF THE TECHNICAL DUE DILIGENCE PROCESS AT THE STAGE OF LAND ACQUISITION FOR CONSTRUCTION INVESTMENT

ROLA PROCESU TECHNICAL DUE DILIGENCE NA ETAPIE ZAKUPU NIERUCHOMOŚCI GRUNTOWYCH W CELU REALIZACJI INWESTYCJI BUDOWLANYCH

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Abstract

The process of planning the implementation of a construction investment is usually preceded by a decision on the purchase of land property, which in turn is typically accompanied by a process known as technical due diligence (TDD). During this process, the feasibility of the planned construction project is verified. The preliminary design concept of the building, prepared at the request of the buyer – a potential investor, is analysed in detail. Legal, technical, environmental, social, or economic obstacles that may prevent the planned investment may already be apparent at the stage of issuing the early finding TDD report. In such cases, purchase negotiations are then typically broken off immediately. In the absence of such obstacles, a final TDD report is issued, containing recommendations for the implementation of the project. There is a lack of research in the scientific literature on the preparation of TDD reports for land properties. This article develops a proprietary algorithm for the TDD process based on the authors' professional experience and interviews with experts. This algorithm is adapted to the TDD process for land property acquisition. The purchase of a plot of land, along with the preparation of a TDD report, marks the initial step in the planning process for construction investment, which can significantly impact its success.

Keywords: technical due diligence, building plot, construction investment

Streszczenie

Proces planowania realizacji inwestycji budowlanych jest przeważnie poprzedzony decyzją dotyczącą zakupu nieruchomości gruntowej, której z kolei zazwyczaj towarzyszy proces technical due diligence (TDD). W trakcie tego procesu weryfikowana jest możliwość zrealizowania planowanej inwestycji budowlanej. Szczegółowej analizie poddawana jest wstępna koncepcja projektowa budynku, przygotowana na zlecenie kupującego, potencjalnego inwestora. Już na etapie wydawania raportu wstępnego TDD są sygnalizowane ograniczenia prawne, techniczne, środowiskowe, społeczne czy ekonomiczne, które uniemożliwiają zrealizowanie planowanej inwestycji. W takim przypadku już na tym etapie zwykle przerywane są negocjacje zakupowe. W przypadku braku takich ograniczeń wydawany jest raport końcowy, który zawiera rekomendacje i zalecenia przydatne do realizacji projektu. W literaturze naukowej brakuje badań dotyczących przygotowania raportów TDD dla nieruchomości gruntowej. W artykule został opracowany autorski algorytm procesu TDD na bazie własnych doświadczeń zawodowych oraz wywiadów przeprowadzonych z ekspertami, który dostosowuje proces

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TDD na potrzeby zakupu nieruchomości gruntowych. Zakup działki wraz z opracowaniem raportu TDD jest pierwszym etapem w procesie planowania realizacji inwestycji budowlanych, który może zadecydować o jej powodzeniu.

Słowa kluczowe: technical due diligence, działka budowlana, inwestycja budowlana

ABBREVIATION:
TDD – technical due diligence
AHP – analytic hierarchy process
DD – due diligence
RICS – Royal Institution of Chartered Surveyors
Q&A – question and answer
VDR – virtual data room

1. INTRODUCTION

According to [1], the investment process in construction is a challenging endeavour that requires multiple skills, a lot of time, and significant financial resources. The actions undertaken during this process encompass purely technical aspects related directly to the implementation of projects, as well as planning, design, and logistical tasks associated with preparing for the realization of these investments.

The investment process in construction generally consists of three stages: preparation, implementation, and utilization of the investment. The beginning of the investment preparation stage for buildings is typically considered the purchase of a building plot. According to the regulation of the Council of Ministers [2], a building plot is understood as a land property or land plot whose size, geometric characteristics, access to public roads, and provision of technical infrastructure facilities meet the requirements for the construction of buildings as stipulated by regulations, separate provisions, and local laws.

In accordance with market practice, the purchase of a building plot is preceded by a due diligence (DD) process. According to the American Legal Dictionary [3], due diligence is a process of critical analysis that companies undertake prior to making business decisions in such areas as corporate mergers/acquisitions or major product purchases/sales. The due diligence process is in essence an attempt to provide business owners and managers with reliable and complete background information on proposed business deals so that they can make informed decisions about whether to go forward with the business transaction. According to an article [4], the aim of due diligence analysis is to limit risk, that is, to protect the buyer from unexpected costs resulting from facts that may be revealed after the transaction is finalized, when the transaction cannot be reversed. The DD process may involve various aspects (e.g., legal, environmental, or technical).

The TDD process, which is the subject of this article, primarily focuses on technical issues related to a specific real estate plot, while also verifying legal, environmental, social, and economic aspects. The investor's expectations are compared with the technical condition of the real estate plot, zoning decisions, and all other documents provided by the seller of the building plot. The feasibility of implementing the planned construction investment in accordance with the prepared preliminary design concept is also assessed. According to market practice, the successful completion of the TDD process is a necessary condition for carrying out the purchase transaction of the specific real estate plot.

The preparation of technical due diligence (TDD) reports concerning the technical condition of buildings has become an important new area of practice for consulting firms. Prior to the financial crisis that began in the fall of 2008, the preparation of TDD reports was the fastest-growing activity in some consulting firms [5]. Currently, the market for preparing TDD reports continues to evolve, with a significant portion of it consisting of reports prepared for building plots.

The primary goal of the article is to analyse the state of knowledge in the literature on TDD.

The second goal of the article is, based on interviews with experts, to adapt a well-known algorithm from the literature for conducting the TDD process for buildings, for the purpose of land acquisition. Additionally, these interviews aim to identify the demand for a tool that could assist investors in making decisions regarding the purchase of land.

2. MATERIALS AND METHODS

2.1. Selection of literature for analysis

To search for scientific publications, the Scopus database was utilized. The primary criterion applied was the search term "technical due diligence".

This search encompassed titles, abstracts, and keywords. Literature from the years 1998-2023 was examined. A total of 41 publications were found, with 11 related to the mining industry, 10 directly addressing commercial real estate sales, 9 discussing issues related to renewable energy sources, 3 concerning electrical infrastructure, 2 relating to building renovations, 2 to ecological issues of CO_2 emissions, and the remaining 4 describing mergers and acquisitions of companies as well as the history of the TDD formulation, maintenance of gas turbines, pharmaceutical product assessment, and production processes. Ultimately, one article describing the history of TDD formulation and 7 articles regarding the application of the TDD process for construction investments and the real estate market were selected.

2.2. Interviews with experts

To adapt the TDD process algorithm for land properties based on the algorithm described in the literature for building properties, interviews were conducted with experts involved in carrying out TDD processes. Two basic criteria for selecting experts were adopted: professional experience of at least 10 years and location of employment (one expert was chosen from each city). The experts came from 7 cities: Warsaw, Krakow, Poznań, Katowice, Wrocław, Łódź, and Gdańsk, where the highest number of TDD processes are conducted. Therefore, the research results can be considered representative for the entire area of Poland. Seven experts comprised the purposive sample of this study. The subject of the conducted interviews was the process of carrying out TDD for building plots.

2.3. Review of Literature

The term DD [6] originates from the 1930s in the United States of America, where it referred to the obligation of sellers of financial instruments to provide the necessary documents required by local legislation. This obligation served as a mechanism to protect buyers of financial instruments, ensuring transparency in various business activities and helping to prevent investors from being misled by dishonest actions and information.

In the 1970s, the term DD meant a legal process of document analysis, ensuring the accuracy of information in financial, capital, and securities markets, attesting that commercial activities conducted by the business and industrial sector were entirely legal.

Currently, in business practice, the term DD is used to verify various areas of business activity, such as financial, commercial, tax, operational, technical, environmental, technological, human resources, and legal. This verification ensures transparency in various transactions that are to be conducted.

In the article concerning the construction of a hydroelectric power plant [7], the TDD report was prepared for the bank as a decisive criterion for making a decision on financing the project. The analytic hierarchy process (AHP) method was applied in the article, which ultimately allowed for the selection of investments that meet the required financial criteria. Based on interviews with experts, 11 key criteria were identified (e.g., feasibility study quality, geological and hydrological conditions, designed turbine specification, local power grid parameters) that directly impact the success of planned investments. Three hydroelectric plant locations were analysed, out of which two locations received a positive recommendation, enabling the financing of the investment.

In article [8], an attempt was made to optimize the transactional process of real estate purchase at the TDD preparation stage in German-speaking countries. The process of purchasing a new property and transferring it to a new owner was described in detail. Special attention was paid to the process of transferring necessary property documents from the selling party to the buying party. Document exchange typically occurs on a virtual data room (VDR) platform, which is a key element of the transaction and TDD process. The authors emphasized the importance of preparing documents in a suitable manner, ensuring they are useful, structured, and standardized. They also suggest defining a clear organizational structure with responsibilities divided on the buyer's side. Improving document accessibility and communication, especially on the buyer's side, will positively impact the transaction process.

In another article [9], TDD utilised the AHP, which was applied in evaluating mergers and acquisitions of power plants in the Chinese market. In this case, four criteria were identified concerning equipment assessment, environmental protection, energy savings, and management. The applied method enabled effective resolution of issues related to difficulties in quantification in the TDD reports previously issued.

A comprehensive description of the TDD process for buildings can be found in article [4]. The process includes defining the scope of the TDD report

with the client, engaging experts, site visits, report preparation, and its final acceptance by the client. The article describes the typical scope of the TDD process, general principles of report preparation, the necessary sequence of actions, and the organizational structure of the consulting team. The conclusions indicate that a set of good practices, thoroughness, reliability, and impartiality of auditors combined with deep and interdisciplinary knowledge of team members allows for the creation of a survey of the building, which it calls the TDD, which according to market practice is essential for property sales.

Another comprehensive description of the TDD procedure can be found in the 2020 RICS guidelines [10]. The document covers four types of TDD reports for commercial properties, assigned to the following building life cycles (acquisition, operation, sale, renovation or development). The document includes guidelines for document verification, process schedule, engaging experts, building inspection, and report preparation. According to the TDD guidelines, the aim is to identify significant physical defects or non-compliance with local regulations before selling the property, which may impact the property value in the commercial market.

A detailed description of the DD process can be found in the book "Real Estate Due Diligence" [11]. The final chapter edited by Sebastian Reich focuses on TDD. Despite the absence of formal requirements for the TDD process, the author provides a very detailed description of the entire process from the perspective of both the buyer and the seller. The author pays particular attention to identifying issues that may lead to the termination of the transaction within the TDD framework. The entire process is divided into four phases: preliminary, documentation verification, on-site inspection, and contractual. The publication includes specific examples of organizing documentation into catalogs for a given property, as well as examples of conflicts of interest.

In article [5], a case study analysis of TDD processes conducted in Denmark and Italy was carried out. The research was conducted using a survey method. Surveys were sent to companies involved in TDD processes. The article compared market practices with international guidelines. It was found that the applied market practice varies between the two countries and in many cases could be improved through a more structured approach and stricter adherence to international guidelines.

In summary of the literature review, we can conclude that building purchase transactions or financing approvals for specific projects are typically associated with the TDD process. This process involves the engagement of experts and conducting an analysis of the technical condition of the property. In many cases, TDD is prepared using the AHP, which is widely discussed in the literature, e.g. [12]. The literature describes the course of the TDD process itself and its staging depending on the best practices prevailing in the market. It can be observed that scientific literature lacks publications regarding the development of a TDD process algorithm for building plots.

3. RESULTS

The TDD process algorithm described in the literature has been adapted for the implementation of TDD for land properties. The scope includes: obtaining the assignment, organizing a team of experts/consultants, acquiring necessary documents, conducting inspections of the land property, preparing preliminary and final reports, and delivering the final version of the report to the client. Figure 1 illustrates the main stages of the TDD process implementation.

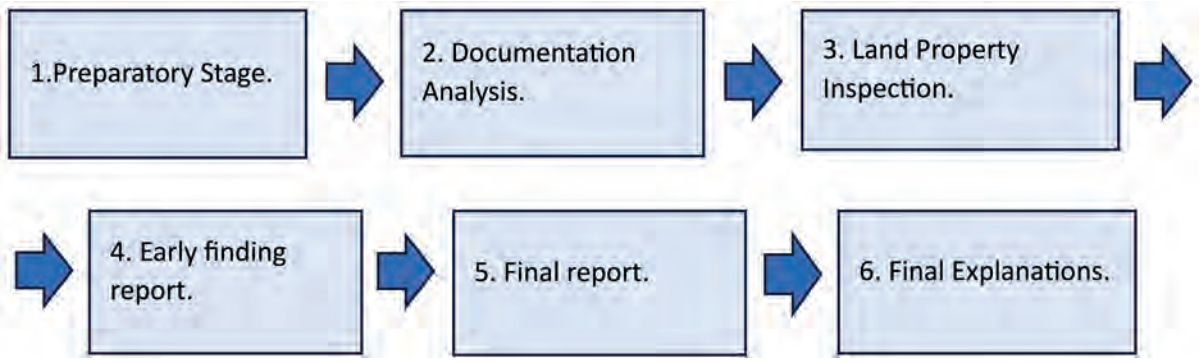

Fig. 1. Stages of implementing the TDD process for land properties. Own development

1. Detailed description of actions taken in the preparatory stage of implementing the TDD process for land properties.
   - Sending requests for proposals to consulting firms (auditors) regarding the preparation of the TDD report for the building plot.
   - Verification whether there is any conflict of interest. In most cases, this verification boils down to checking whether the consulting firm does not have business relationships with the company selling the land property.
   - Submission of a proposal by the consulting firm to carry out the service of preparing the TDD report for a specific building plot.
   - Acceptance of commercial terms by the client interested in purchasing the land property, which are attached to the proposal (e.g., hourly rates for additional work, or required insurance coverage).
   - Approval by the client of submitted proposal.
   - Determining the confidentiality status of the process. In cases where the process is confidential, the auditor is obliged to sign a non-disclosure agreement to maintain confidentiality of all information regarding the planned transaction.
   - Agreements between the client and the auditor on the following issues:
     - Establishing the precise scope of the reports. Identifying the issues that are most important to the client for analysis.
     - Agreement on the templates for the early findings and final reports, as well as the language in which the reports will be prepared. According to market practice, report templates are most commonly presented in tabular or descriptive form.
     - Agreement on the potential scope of examinations, inventories, or measurements to be conducted on the land property. Based on market experience, it can be observed that geological surveys are typically conducted, including environmental tests to check for contaminated soil on the subject plot. Additionally, a decision is made on the potential need for greenery inventory.
     - Confirmation of the address where the land property is located, as well as agreement on access to the plot and determination of how the plot is used.
     - Determination of whether non-standard analyses are needed (e.g., regarding mining damage).
     - Establishing the potential scope of cost calculations and the significance threshold, i.e., the minimum value of works included in the cost calculations. Based on the mentioned significance threshold, significant cost-related issues can be identified (e.g., land contamination requiring costly remediation works).
   - Engagement of a standard team of experts, typically consisting of a project manager, electrical specialists, and plumbing installation specialists.
   - Agreement with the multidisciplinary consulting team engaged by the client on the schedule of activities related to the TDD process (e.g. setting the schedule for regular online meetings).
   - Preparation of a list of required documents necessary for TDD preparation, with particular emphasis on preliminary design concepts or absorption analysis.
   - Agreement on the method of transferring documents related to the plot and access to documentation.
   - Confirmation of whether the documentation is available electronically on a VDR platform or in paper form at the location indicated by the plot seller.
   - Determination of the method of asking questions regarding the provided documentation within the online Q&A platform.
   - Establishment of the plot inspection schedule and access rules to the land property.
   - Confirmation of deadlines for issuing early finding and final reports and meeting other deadlines agreed upon between the auditor and the client.

2. Detailed description of actions undertaken as part of the documentation analysis stage in the implementation of the TDD process for land property:
   - Obtaining access to the VDR by the auditor in case the documentation is available electronically.
   - Verification of the provided documentation.
   - Review of the preliminary project concept or absorption analysis.
   - Posting any questions regarding the provided documentation on the Q&A platform.

3. Detailed description of actions taken during the stage of on-site inspection in the implementation of the TDD process for real estate:

- Conducting inspections by a standard team of experts.
- Performing necessary tests, inventories, or measurements by specialists from various fields (e.g., by geologists regarding soil conditions and potential site contamination [13], environmental specialists).
- Conducting greenery inventory.
- Verifying the following issues:
  - Location and general information about the property,
  - Immediate and extended surroundings of the property,
  - Existing buildings on the plot, if any,
  - Existing underground infrastructure,
  - Connections to public roads.
- Taking photographs of the plot and its surroundings to document the condition of the real estate.
- Conducting interviews with the manager of the subject plot and, if necessary, with the users of neighbouring plots in order to obtain all information related to the use of the subject plot (e.g., information regarding soil conditions).
- If the plot is developed, conducting a detailed inspection of existing buildings and infrastructure, verifying whether hazardous materials to the environment have been used in the construction of existing buildings.
- Reviewing available documentation and conducting interviews with individuals knowledgeable about the property to verify its previous use, which is crucial for assessing the risk of soil contamination (e.g., with petroleum derivatives or heavy metals).

4. Detailed description of actions undertaken in the early findings report stage of the TDD process for real estate properties.
   Verification of legal, technical, environmental, social, or economic constraints to identify potential obstacles that may prevent the transaction from taking place. For example, provisions in the local zoning plan allowing only residential development on the real estate property where the buyer intends to construct an office building would be an obstacle preventing the investment and purchase of said real estate property. All mentioned constraints are described by the auditor in the early findings report, which is then submitted to the client for approval. If any significant obstacles are discovered and prove to be dealbreakers, the procedure is terminated at this stage.

5. Detailed description of actions undertaken as part of the final report stage in the implementation of the TDD process for real estate properties.
   At this stage, all information relating to the issues raised in the early findings report is supplemented and thoroughly described in the final report, which typically includes: an abstract, introduction, technical, environmental, economic, legal, and social findings. It also contains a summary, limitations, reservations, an appendix with photographic documentation, and a list of documents on the basis of which the report was prepared.

Technical issues typically relate to the following matters:

- General description of the land property.
- Detailed description of the plot's location in local and global terms.
- Description of the property's surroundings, analysis of neighbouring buildings.
- Verification of the property's use.
- Verification of access to public roads.
- Verification of provisions in planning decisions regarding the required number of parking spaces,
- Examination of geological conditions and assumptions regarding the building's foundation method.
- Description of technical aspects regarding the potential investment (e.g., the proposed investment implementation method).
- List of potential demolition objects.
- Mining damages and other geotechnical hazards.
- Installation connections:
  - Sanitary sewer,
  - Storm sewer,
  - Water supply,
  - Electrical,
  - Telecommunications,
  - Heating,
  - Gas.
- Verification of the preliminary project concept.

Environmental issues typically pertain to the following matters:

- Environmental conditions,
- Ground environmental status, identification of potential soil contamination,
- Flood risk,
- Greenery inventory,

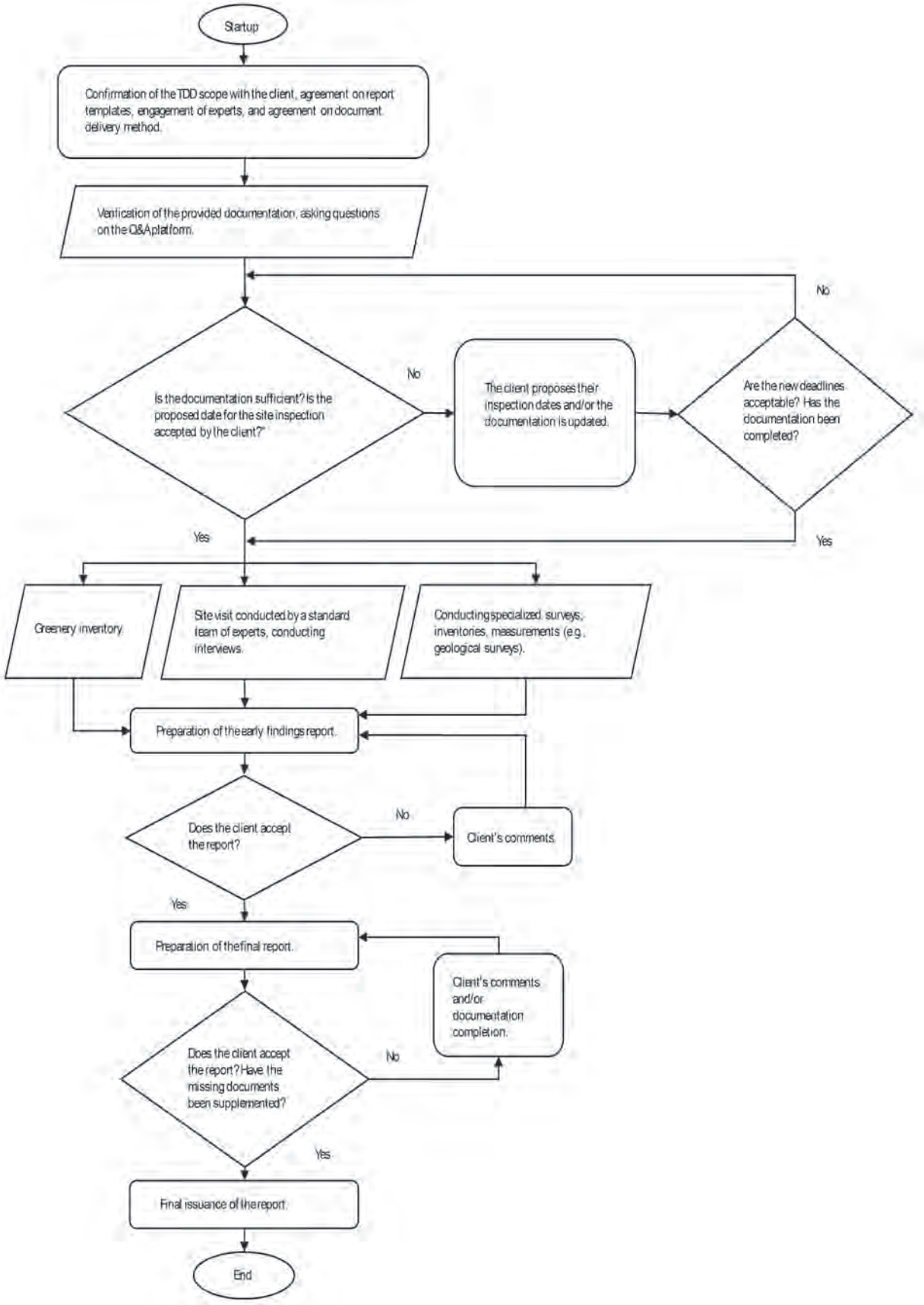

Fig. 2. TDD Process Algorithm for Real Estate. Own development

- Verification of materials used in the construction of existing buildings (if the plot is built-up),
- preliminary verification of the impact of the future investment on the environment, in case of potential or significant impact [14], recommendation to obtain an environmental decision,
- Preliminary assessment of the possibility of obtaining BREEAM or LEED certification.

Legal issues typically pertain to the following matters:

- Analysis of local zoning plan or zoning decisions,
- Conservation protection of the area,
- Analysis of potentially established easements, verification of whether any administrative decisions or rulings issued for the subject property have been subject to appeals or challenges.

Regarding social issues, typically, based on interviews with experts and residents of neighbouring properties, the social attitude toward the investment is verified. A negative attitude increases the risk of appeals or challenges to administrative decisions and rulings, which ultimately translates into extended project implementation timelines or, in some cases, complete project blockage.

As part of economic considerations, typically, an analysis is conducted regarding the impact of raised concerns during the TDD process on the costs of future investment.

After analysing the mentioned issues and confirming that all key documents have been submitted, the final report is prepared and sent to the client for approval.

6. Detailed description of actions taken in the final explanations stage of implementing the TDD process for land properties.

Upon delivering the final report, in line with market practice, the following actions are taken: participation in several explanatory meetings, making amendments to the final report, and delivering the final version of the document.

The adapted algorithm for the TDD process for a building plot is presented in Figure 2.

4. DISCUSSION

This research adapted the TDD process algorithm for buildings described in the literature for the purpose of land property purchase transactions. The presented algorithm identifies potential obstacles to investment realization in the initial phase of the TDD process, which may lead to the termination of land property purchase negotiations and help avoid additional costs in this regard. The final report prepared according to the described algorithm takes into account all information influencing further investment planning, although it is primarily based on experience of experts as opposed to scientific methods. An additional unresolved issue is whether or not it is viable to create a budget for the potential investment which reflects all reservations identified in the final TDD report. Currently, in the construction market, investors expect clear recommendations based on scientific methods rather than suggestions developed based on the experience of individual auditing firms. The aim of further research by the authors is to apply scientific methods that would enable the inclusion of all reservations raised in the final TDD report in the planned investment budget.

5. CONCLUSIONS

The purchase of a plot along with the TDD assessment constitutes the first part of the investment preparation stage, which can help determine its success. Any discrepancies detected during the TDD process between the investor's requirements and the technical condition of the land property should be included in the final report and discussed in detail with the investor.

The lack of legal regulations regarding the preparation of TDD results in their lack of standardization. TDD reports are prepared based on the market experience of individual auditing firms and the good market practice specific to a particular country/region rather than an uniform set of principles.

The preparatory phase of the construction process is typically initiated by the purchase of a building plot, often accompanied by the TDD process. This is the earliest stage of investment implementation, which in most cases determines its final financial success. Making a decision to purchase a plot without conducting the detailed TDD process can have an adverse effect on the ultimate economic success of the investment and, in extreme cases, may even hinder or significantly delay the project's realization

schedule. Based on the professional experience of the authors, it can be concluded that there are currently no perfect building plots available in the real estate market that meet all investor expectations. Drawing from professional experiences and interviews with experts, considering the complexity of the TDD process and the amount of data required for analysis, as well as the evolving investor requirements, there is an observable need for developing a decision support system at the stage of purchasing land properties. The proposed future research, based on decision tree methods or random forests, would fulfil investor requirements concerning recommendations for future buildings, contributing to the ultimate success of investments.

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THE INFLUENCE OF THE TYPE OF LOW-EMISSION CEMENT AND AIR-ENTRAINING ADMIXTURES ON THE QUALITY OF AIR ENTRAINMENT OF CONCRETE – UNEXPECTED IMPACT OF GRANULATED BLAST FURNACE SLAG

WPŁYW RODZAJU CEMENTU NISKOEMISYJNEGO I DOMIESZKI NAPOWIETRZAJĄCEJ NA EFEKT NAPOWIETRZENIA BETONU – NIEOCZEKIWANY WPŁYW GRANULOWANEGO ŻUŻLA WIELKOPIECOWEGO

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Abstract

The test results indicate that it is possible to obtain the appropriate quality of air entrainment in concrete with low-emission cement with granulated blast furnace slag, such as CEM II/B-S, CEM III/A and CEM III/A-NA. However, the literature on the subject reports that this is not the rule, and a slag content that is too high is not conducive to the effectiveness of the air-entraining admixture and the stability of the air entrainment. The possible reason for the beneficial effect of slag on the stability of air entrainment was the influence of surfactants used for its grinding. The research also proved that the effectiveness of the air-entraining impact and the stability of air entrainment in concrete with slag cement depend on its type (natural or synthetic) and the alkali content in the cement.

Keywords: low-emission cement, granulated blast furnace slag, alkali, concrete, air-entraining admixture, porosity, frost resistance

Streszczenie

Rezultaty badań wskazują, iż możliwe jest uzyskanie odpowiedniej jakości napowietrzenia betonu z cementem niskoemisyjnym z żużlem granulowanym wielkopiecowym S, jak CEM II/B-S, CEM III/A i CEM III/A-NA. Jednak literatura przedmiotu donosi, iż to nie jest regułą, a zbyt duża zawartość żużla nie sprzyja efektywności działania domieszki napowietrzającej i stabilności napowietrzenia. Zatem granulowany żużel wielkopiecowy może pozytywnie bądź negatywnie wpływać na efektywność działania domieszki napowietrzającej oraz stabilność napowietrzenia. Za możliwą przyczynę korzystnego wpływu żużla na stabilność napowietrzenia wskazano wpływ środków powierzchniowo czynnych zastosowanych do jego przemiału. Na podstawie badań dowiedziono także, że efektywność działania domieszki napowietrzającej i stabilność napowietrzenia betonu z cementem żużlowym zależy od jej rodzaju (naturalna bądź syntetyczna) oraz od zawartości alkaliów w cemencie.

Słowa kluczowe: cement niskoemisyjny, granulowany żużel wielkopiecowy, alkalia, beton, domieszka napowietrzająca, porowatość, mrozoodporność

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1. INTRODUCTION

Low-emission cement is the most effective way to reduce the carbon footprint of concrete, as much as 85% – Figure 1. The European Cement Industry Association CEMBUREAU has prepared a Road Map [1] which assumes that cement and concrete producers will achieve CO_2 emissions by approx. 40% and achieve climate neutrality in 2050. Since, as mentioned, Portland clinker is responsible for the carbon footprint of cement and concrete, this goal will be achieved, among others, by significantly reducing the amount of clinker in cement [2, 3].

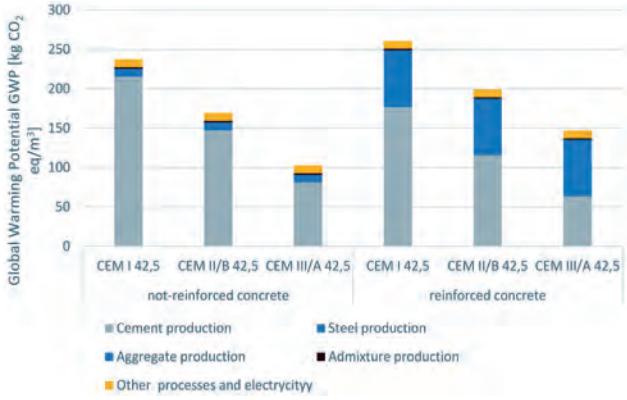

Fig. 1. Global Warming Potential, GWP, depending on the type of cement of the same strength class (300 kg of cement/ m^3 of concrete was assumed) on the basis of [1] [3] and [4]

The production of CEM II/A Portland cement with an addition of 18% and CEM II/B with an addition of 33% slag or ash reduces CO_2 emissions by 162 kg and 297 kg, respectively, per Mg of cement, compared to CEM I Portland cement. For Portland cement multi-component CEM II/B-M 42.5 R, the total emission is 562 kg CO_2 per tonne of cement, which is as much as 1.54 times lower than in the case of CEM I 42.5 R. Production of metallurgical cements: CEM III/A containing 61% slag, CEM III/B containing 76% slag and CEM III/C with 90% slag content allows for a reduction in CO_2 emissions by approximately 65, 80 and 95% per Mg of cement, respectively, compared to CEM I Portland cement. However, it should be remembered that currently, slag resources are running out [3, 5], and it will be a component of other cement, such as CEM II/A (S-LL) and others, provided, of course, it is still available. Currently, using low-emission cement is not a choice but a necessity.

The use of the cement mentioned above with reduced CO_2 emissions has been proven and widely practised on a global scale for decades, and concrete with low-emission cement has advantages in many exposure classes over Portland cement concrete [1, 3, 4] (including better consistency, workability of concrete, resistance to sulfates, protection against alkaline corrosion, long-term strength, higher tightness, low shrinkage). However, concrete with low-emission cement requires special attention due to its durability in the frost and carbonate exposure class [6-13], as well as the protection of steel against corrosion. Problems with their frost resistance may occur even in conditions of moderate frost exposure, especially when exposed to de-icing salts [7, 9, 14, 15, 39].

The condition for concrete to become frost-resistant is its adequate air entrainment and ensuring sufficient tightness of the concrete [6, 7, 17]. From the point of view of frost resistance, it is not essential to total air content but the quality of air entrainment [16]. Frost resistance is promoted by increased air content and reduced pore size, as both of these factors reduce the distance between pores [13, 18, 19]. Other parameters characterising concrete's air entrainment structure are the surface area of the air pore system α and the content of micropores A_{300}. The specific surface area is determined by dividing the total surface of the air pores by their volume, which is expressed in mm^2. The A_{300} parameter specifies the content of air pores with a diameter of 0.3 mm (300 μm) or smaller.

As proven in many publications [6, 8, 9, 21], the type of ingredients other than clinker also significantly affects the stability of air entrainment. It is believed that replacing Portland clinker with another ingredient does not promote the effectiveness of air-entraining admixtures and the stability of air-entrainment (Fig. 2) [7, 13, 19, 20, 22, 24]. It is also recommended to increase the amount of air-entraining admixture above the recommended amount in cases where the cement has an increased specific surface. In publications [15, 14] it was proven that granulated blast furnace slag also has a negative impact on the air entrainment of concrete. Another factor that negatively affects the effectiveness of the air-entraining admixture is the low alkali content [7, 22, 24, 25]. According to Committee 225 (Guide to the Selection and Use of Hydraulic Cement) and Committee 201 (Guide to Durable Concrete) of the American Concrete Institute (ACI), different varieties of Portland cement and multi-component cement make it possible to achieve the same level of frost resistance of concrete, provided the correct proportions ingredients and proper air-entrainment of the mixture.

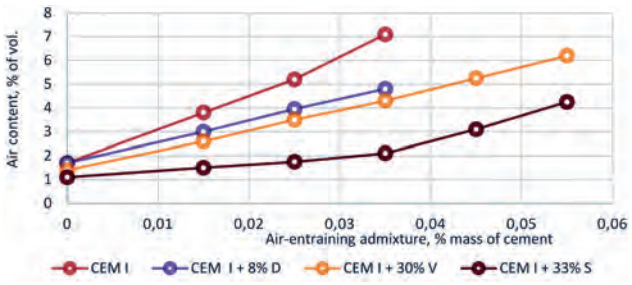

Fig. 2. The influence of silica fume – D, silica fly ash – V, and slag – S on the air-content of concrete [7]

The use of cement with a higher slag content, especially with a significantly developed specific surface, may reduce the total amount of air in the hardened concrete (Figs. 3 and 4). Moreover, the presence of slag causes disturbances in the distribution of air bubbles, causing a reduction in the content of pores smaller than 300 µm and an increase in the average distance between air pores [23, 26]. As shown in Figure 10, the increase in the demand for an air-entraining admixture occurs only after exceeding 60% of the amount of slag in the cement, and in the case of CEM III/A, the amount of slag is usually 60-65%. Between 80% and 90% slag content, twice the amount of air-entraining admixture is required to obtain the same amount of air-entrainment.

Fig. 3. Impact of the slag content on the effect of air-entraining of concrete [27]

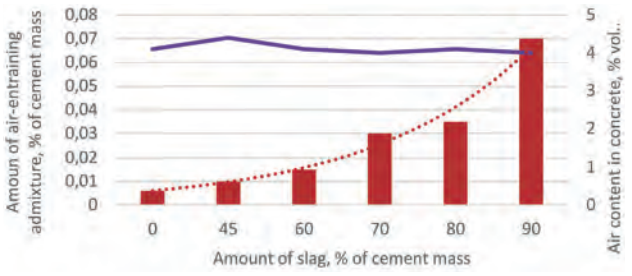

Fig. 4. Air-entraining admixture demand and air content in concrete relative to the content of slag in cement [28]

Obtaining pores with a precisely defined diameter and appropriate spacing in concrete with low-emission cement requires the use of a proper amount and type of air-entraining agents. Agents with a potential air-entraining effect can be divided into [6, 14, 29, 30]:

- synthetic – very efficient, requiring short mixing time. Synthetic surfactants have great potential and constitute the largest group of surfactants. It is believed that they create air bubbles with smaller diameters and, therefore, with a more excellent content of micropores.
  Natural is the oldest and most well-known group of products, and they are very compatible with other admixtures. It is believed that natural surfactants are less efficient than their synthetic counterparts and are also characterised by limited resistance to the influence of alkalis (which, however, occur to a limited extent in the case of low-emission cement, which theoretically should favour their effectiveness);
- mixed – the synergistic effect of natural and synthetic ingredients allows the creation of more specialised products. Mixtures offer a wider scope for manoeuvre and set new trends in the field.

The research undertaken in this article aims to compare the quality of air entrainment in concrete with low-emission cement and granulated blast furnace slag (S): CEM II/B-S, CEM III/A and CEM III/A-NA, depending on the air-entraining admixture used: natural or synthetic.

2. METHODOLOGY OF RESEARCH

2.1. Materials

In the first stage of the study, the effect of the type of cement on the demand of two kinds of admixtures was compared: synthetic (S) based on mixed, synthetic polymers and natural (N), constituting an aqueous solution of a complex mixture of organic acid salts on the air-entrainment of mortar and concrete according to PN-EN 480-1 [31] (Tables 2, 3 and 4, Fig. 5) with slag cement CEM II/B-S 42.5 R, CEM III/A 42.5R and CEM III/A-NA 42.5 R (Table 1) with the characteristics of the components given in Tables 4 and 5.

Table 1. The percentage amount of granulated blast furnace slag S in the composition of types of cement, %

Cement type	CEM I 42.5R	Slag S	Setting regulator*
CEM I	100%	0	0.0
CEM II/B-S	65.5	33	1.5
CEM III/A	45.5	53	1.5
CEM III/A-NA	32	65	3.0

*amount of SO_3 about 2.8-3.1%.

Table 2. Composition of mortar acc. PN-EN 480-1, gram

Cement	Water	Sand acc. to EN 196-1
450.0	225.0	1350.0

Table 3. Concrete composition acc. PN-EN 480-1, kg/m³

Cement	Water	Sand 0-2 mm	Gravel 2-8 mm	Gravel 8-16 mm
350.00	175.00	522.00	511.90	853.10

Table 4. The mechanical, physical and chemical properties of Portland clinker

Compressive strength	Unit	Average value		Requirement
		CEM I 42.5	CEM I 42.5 NA	
after two days	MPa	28.2	25.0	≥20.0
after 28 days	MPa	57.1	56.2	≥42.5
	MPa			≤62.5
Start of setting time	min	203	226	≥60
Water to the standard consistency	%	27.8	27.9	No requirements
Volume constancy	mm	0.4	0.7	≤10
Specific surface area	cm^2/g	4158	4037	No requirements
SO_3	%	2.87	2.92	≤4.0
Cl^-	%	0.076	0.041	≤0.10
Loss of ignition	%	2.83	2.61	≤5.0
Insoluble residue	%	0.51	0.71	≤5.0
Na_2O_{eq}	%	0.62	0.56	No requirements

Table 5. Components of slag S [%]

Component	Blast furnace slag S
loss on ignition	+0.40
SiO_2	38.24
Al_2O_3	5.99
Fe_2O_3	1.01
CaO	44.99
MgO	6.52
SO_3	0.88
K_2O	0.56
Na_2O	0.51
Content of the glassy phase	99%

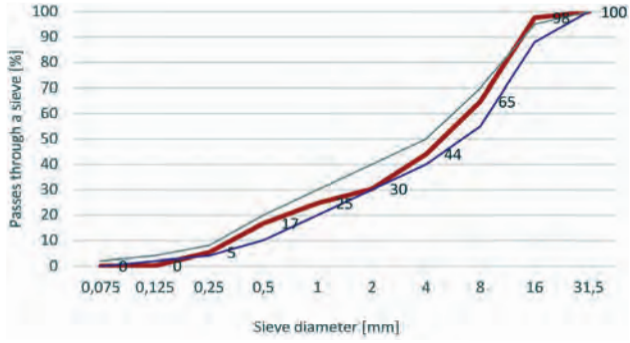

Fig. 5. Gravel aggregate grain size distribution

2.2. Methods

First, the air-entrainment of the mortars was determined in accordance with the procedure described in PN-EN 1015-7 [32], and then the air-entrainment of concrete mixtures according to PN-EN 12350-7 [33] after 4, 20, and 40 minutes. If the mixture was aerated after 5, 20, and 40 minutes and was in the range of 4-7%, the determined amount of air-entraining admixture was left unchanged; otherwise, it was corrected.

After 28 days of concrete maturation in water, the values of concrete air-entrainment parameters according to PN-EN 480-11 [34] were determined by means of a CT scanner and computer image analysis (Fig. 6) in two directions, parallel and perpendicular.

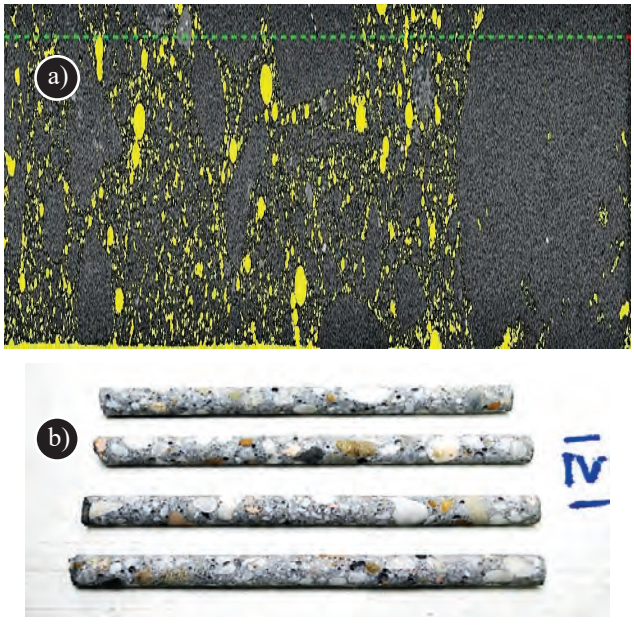

Fig. 6. View of a) the analysed porosity of concrete using a computer program (air pores are marked in yellow) and b) the concrete core cut out of 15x15x15 cm concrete cubes in the direction perpendicular or parallel to the direction of formation

3. RESEARCH RESULTS AND ANALYSIS

3.1. Research results

Figures 7 and 8 summarise the amount of natural or synthetic air-entraining admixture necessary, depending on the type of cement, to obtain the air content given in Table 5.

Table 6. Compares the air content in mortar and concrete according to PN-EN 480-1 [% vol.]

Cement type	Air volume in mortar, % vol.	Air volume in fresh concrete, % vol.
CEM II/B-S	2.7	1.2
CEM III/A	3.2	1.5
CEM III/A-NA	3.5	1.6

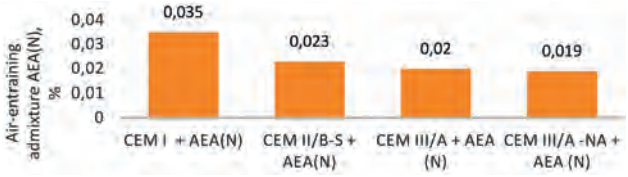

Fig. 7. Amount of natural air-entraining admixture depending on the type of cement CEM II/B-S, CEM III/A and CEM III/A-NA

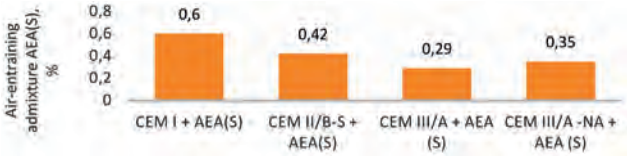

Fig. 8. Amount of synthetic air-entraining admixture depending on the type of cement CEM II/B-S, CEM III/A and CEM III/A-NA

Table 7. Results of the determination of air pore parameters of concrete with synthetic air-entraining admixture (N)

Cement type	Total Pore Content in Concrete	Specific surface area of air pores	Pore Distribution Indicator	Micropore content	Total Pore Content in Concrete	Specific surface area of air pores	Pore Distribution Indicator	Micropore content
	parallel direction				perpendicular direction			
	A, %	a, mm²	L, mm	A_{300}, %	A, %	a, mm²	L, mm	A_{300}, %
CEM II/B-S _ AEA (S)	5.86	42.43	0.11	4.59	5.83	40.33	0.12	4.29
CEM III/A + AEA(S)	5.65	42.99	0.11	4.26	5.81	43.99	0.11	4.24
CEM III/A-NA + AEA(S)	5.06	42.48	0.12	3.48	4.88	41.61	0.12	3.50

Table 8. Results of the determination of air pore parameters of concrete with natural air-entraining admixture (N)

Cement type	Total Pore Content in Concrete	Specific surface area of air pores	Pore Distribution Indicator	Micropore content	Total Pore Content in Concrete	Specific surface area of air pores	Pore Distribution Indicator	Micropore content
	parallel direction				perpendicular direction			
	A, %	a, mm²	L, mm	A_{300}, %	A, %	a, mm²	L, mm	A_{300}, %
CEM II/B-S + AEA (N)	6.20	38.10	0.12	3.99	5.98	37.28	0.13	4.00
CEM III/A + AEA (N)	6.11	40.77	0.11	4.82	6.43	40.74	0.11	5.06
CEM III/A-NA + AEA(N)	5.74	37.00	0.13	3.55	5.62	36.39	0.13	3.55

Tables 7 and 8 summarise the results of determining the parameters of the porosity structure of hardened concrete obtained using a tomograph of samples taken parallel and perpendicular to the direction of formation of a concrete sample with dimensions of 15 × 15 × 15 cm.

3.2. Analysis of research results

Figures 9 and 10 compare the required amount of synthetic and natural air-entraining admixtures to obtain proper air-entrainment of the concrete mixture according to PN-EN 480-1 (Fig. 11). As evidenced by the test results presented in Figures 6, 7 and 8,

the required amounts of air-entraining admixtures are significantly different depending on the type of cement. In the case of cement with S slag (CEM II/B and CEM III/A, CEM III/A-NA), the necessary dosage of air-entraining admixtures to obtain adequate air-entrainment of the mortar and concrete is lower than in the case of Portland cement (CEM I). Moreover, the natural admixture was characterised by better air-entrainment efficiency (Figs. 6-8). As can be seen from the data analysis presented in Figures 9 and 10, the amount of the required natural admixture is ten times lower than in the case of a synthetic admixture.

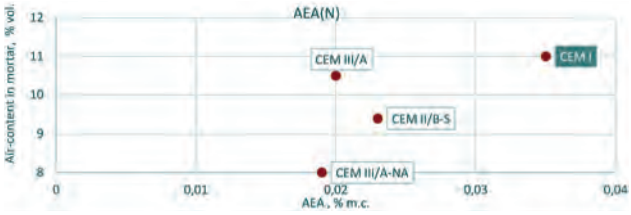

Fig. 9. Influence of the type of cement on the required amount of natural air-entraining admixture AEA to obtain adequate air-content (Ac) mortar and concrete according to PN-EN 480-1 [31]

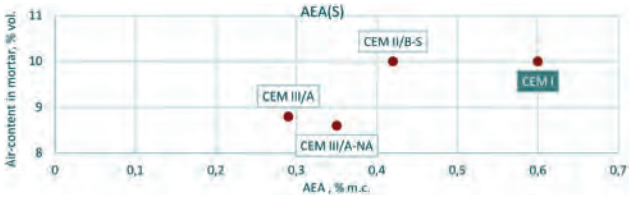

Fig. 10. Influence of the type of cement on the required amount of synthetic air-entraining admixture AEA to obtain adequate air-content (Ac) mortar and concrete according to PN-EN 480-1 [31]

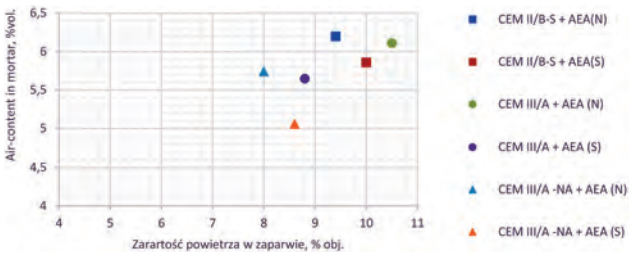

Fig. 11. The relationships between air content in mortar and concrete acc. to PN-EN 480-1 with CEM II/B, CEM III/A and CEM III/A-NA

As it turns out, CEM III/A also achieved the greatest stabilisation of air entrainment over time (Figs. 12 and 13), also compared to CEM I. Slightly worse air-entrainment stability is achieved when the cement is characterised by a low alkali content (CEM III/A -NA).

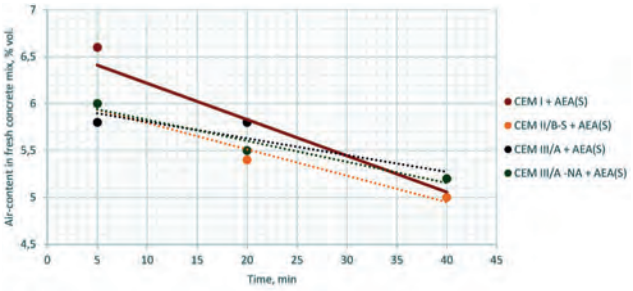

Fig. 12. The stability of air entrainment of the concrete mixture depends on the type of cement with a synthetic air-entraining admixture

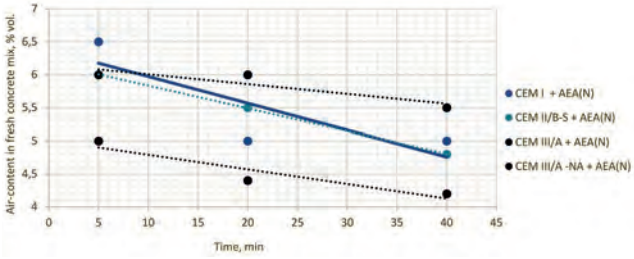

Fig. 13. The stability of air entrainment of the concrete mixture depends on the type of cement with a natural air-entraining admixture

To protect concrete against the destructive effects of frost, it is necessary to provide [11, 18, 35-38]:
- the total air content will be between 4 and 7%, depending on the size of the aggregate grains [36];
- the air pore distribution index $\bar{L}$ (spacing factor) will have a value below 0.20 mm;
- the specific surface area of air pores α will be below 15-20 mm^2/mm^3;
- content of pores with a diameter of less than 0.300 mm: $A_{300} > 1.5\text{-}1.8\%$.

The recommended values mentioned above also depend on the type of concrete (w/c, kind of cement, and others) as well as on external conditions [13, 39, 40, 42]. As evidenced by the test results in Tables 6 and 7 and in Figures 14-17, concrete with slag is characterised by the correct porosity structure. Air-entrained concrete with a synthetic admixture is more advantageous regarding frost resistance and mechanical properties; pores are smaller and more closely spaced, as achieved in the publication [41]. However, the test results analysed above have proven that the synthetic-based air-entraining admixture is less resistant to the impact of ingredients other than clinker on the stability of concrete air entrainment (Figs. 9 and 10). Therefore, an increased amount of it should be used at the beginning so that the concrete is properly aerated after a specific time.

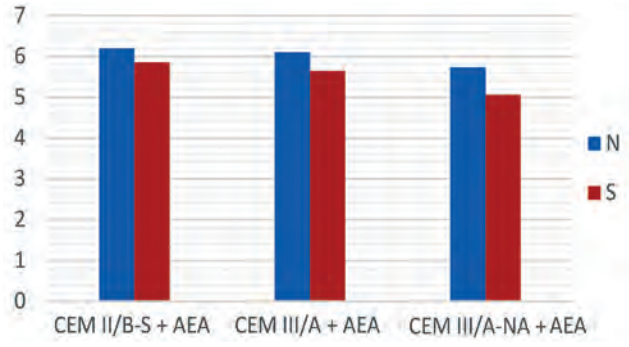

Fig. 14. Results of determining the air content A in concrete according to PN-EN 480-11 in concrete with CEM II/B-S, CEM III/A, CEM III/A-NA with a natural (N) or synthetic (S) admixture

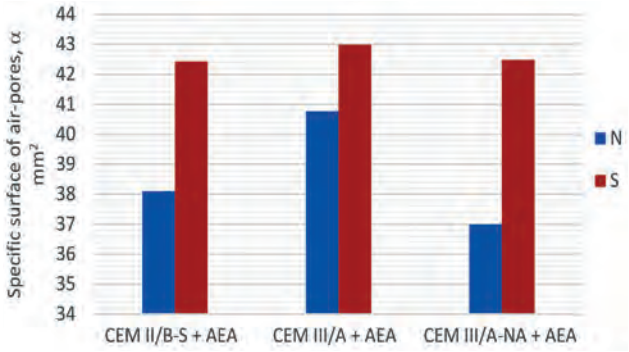

Fig. 15. Results of determining the specific pore surface in the concrete according to PN-EN 480-11 in concrete with CEM II/B-S, CEM III/A, CEM III/A-NA with a natural (N) or synthetic (S) admixture

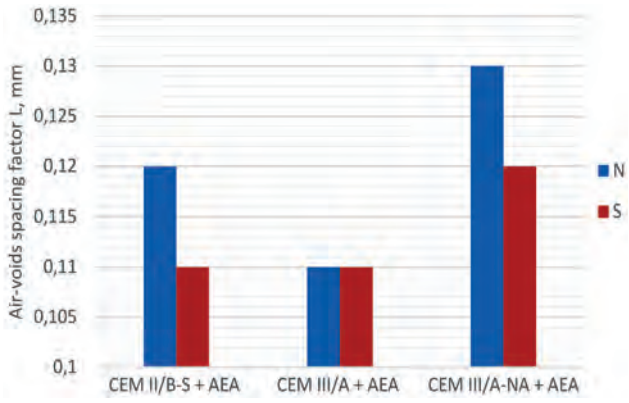

Fig. 16. Results of determining the pore spacing index L in concrete according to PN-EN 480-11 in concrete with CEM II/B-S, CEM III/A, CEM III/A-NA with a natural (N) or synthetic admixture (S)

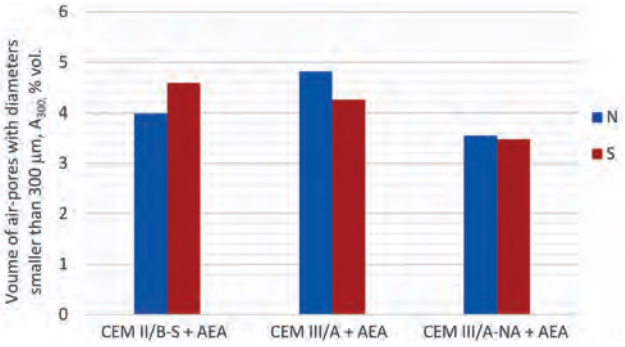

Fig. 17. Results of determining the A300 pore content in concrete according to PN-EN 480-11 for concrete with CEM II/B-S, CEM III/A, CEM III/A-NA with a natural (N) or synthetic (S) admixture

As shown above, concrete with slag cement may have a porosity structure suitable for frost resistance, even with a higher proportion of slag relative to cement, as in the case of CEM III/A. However, this is not the rule, given the research results mentioned in the introduction to the article (Figs. 2-4). In the case analysed by the author, the reason for the exceptional stability of air entrainment (Figs. 11 and 12 and the negligible demand for an air-entraining admixture, even lower than in the case of CEM I (Fig. 7), is the influence of a surface-active admixture that facilitates slag grinding, cooperating with the air-entraining admixture because both the mortar and the concrete without an air-entraining admixture did not show excessive air content (Table 6). Only introducing an air-entraining admixture caused interactions between the admixtures used for grinding the slag and air-entraining the concrete. Although it is mentioned in the publication [43] that the surfactant may cause problems obtaining a low air content in the case of concrete with CEM III/A. Publication [44] also emphasises the need to test the compatibility of surface-active admixtures used for grinding cement or slag and admixtures used for concrete, especially fluidising admixtures.

Admixtures that intensify the slag and cement grinding process are substances that, when mixed with the mill contents, increase the rate of grain reduction, which translates into a decrease in the energy consumption of the process. The most frequently used additives to facilitate grinding are surface-active substances, e.g. glycols, triethanolamine (TEA), and diethanolamine (DEA) [44]. As a result of adding agents that intensify the grinding process, they are adsorbed on the grains. Ethylene glycol distearate (EGDS) or glycol stearate is a chemical compound

used as an emollient in cosmetics and other consumer products.

Diethanolamine, DEA, is an organic chemical compound from the group of amino alcohols. It belongs to the group of biogenic amines. It is alkaline. Diethanolamine is a solid below the freezing point. Above the freezing temperature, it becomes a syrupy liquid. It has a characteristic, slightly ammoniacal smell. It is a product of the breakdown of natural phosphatides. It is obtained from ethylene oxide and ammonia. Apart from cement production, the primary uses of diethanolamine are in the following areas:
– agrochemicals, herbicides, glyphosate,
– ingredient of surfactants and detergents,
– ingredient of washing agents,
– used in cosmetics,
– absorbent in gas purification scrubbers,
– an ingredient in the paper dyeing process,
– emollient,
– emulsifier,
– plasticiser,
– corrosion inhibitor,
– in the textile industry.

Triethanolamine (TEA), in turn, is a tertiary amine and a triol. It is a bifunctional compound that has the properties of both alcohols and amines. It belongs to viscous, colourless organic compounds. The pH of the compound is alkaline. In addition to its use in cement production, TEA is used. It is widely used as a pH regulator (pH regulation in cosmetic products) and surfactant in industrial and cosmetic products and liquid detergents, etc.

The above-mentioned surface-active admixtures have favourable conditions for air stabilisation in aerated concrete, especially when larger amounts are used in the blast furnace slag grinding process.

Finally, it should be clearly noted that the conclusions obtained regarding the influence of slag and the type of air-entraining admixtures apply only to those used by the author. Other types of air-entraining admixtures, due to their high variability in their elemental composition and polymer structure (in the case of synthetic admixtures – anionic, cationic and others), may give slightly different results compared to the air entrainment of low-emission concrete and require experimental testing before their application.

In addition, it is essential to confirm the frost resistance of properly air-entrained concrete made with low-emission cement such as CEM II/B-S, CEM III/A, or CEM III/A-NA, and other concrete properties after a period stipulated in the recently revised standard PN-B-06265 [44], which is either 56 or 90 days (see Table 9). It is crucial to emphasize that during this period, intensive moisture maintenance is necessary due to the extended development of concrete tightness with hydraulic additives. Figure 18 illustrates the progression of tightness (waterproofness) and strength of concrete with CEM III/A and a synthetic admixture.

Table 9. Equivalent time according to PN-B-06265 [44]

Cement type	Equivalent time [days]
CEM I (R); CEM II/A (R)	28
CEM I (N); CEM II/A (N); CEM II/B (N, R); CEM IV/A	56
CEM II/C-M; CEM III; CEM IV/B; CEM V; CEM VI	90

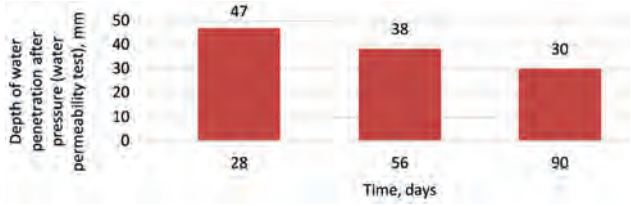

Fig. 18. Permeability test results (W8) of concrete with CEM III/A and air-entraining synthetic admixture after 28, 56 and 90 days of hardening in water

As mentioned in the introduction, today, using low-emission cement is not a choice but a necessity. So, knowing how to achieve proper air entrainment in low-carbon footprint concrete is crucial. The composition of low-emission cement will continue to evolve due to the decreasing resources of blast furnace slag and silica fly ash. The problem of low carbon footprint concrete and cement will continue to be relevant. The best way to ensure its frost resistance is to take two parallel paths, improve tightness because of a significant reduction in the amount of water to approximately 0.35 [38] and ensure a dense distribution of air pores with the minor possible diameters in the volume of concrete. To achieve this, it is necessary to take into account not only the type of low-emission cement and air-entraining admixture but also the influence of other ingredients and factors, especially temperature and the concrete production process discussed, for example in publications [15, 16, 25, 39, 46, 47-49].

4. CONCLUSION

Based on the obtained research results, it was found that:

- the influence of analysed slag on the air-entrainment of concrete is unstable because depending on the

type of collapse, the method of its preparation, and, more precisely, the admixture facilitating its milling, the effectiveness of the air-entraining admixture and the stability of the air-entrainment are different;
- in the case of the slag analysed in the article, either too much of our factory was used, or such a type was used that it was not recorded that the negative impact of slag mentioned in the literature was noted on the air entrainment;
- an air-entraining admixture is essential from the point of view of efficiency in its operation (air-entrainment) and stability of air-entrainment of concrete. On the attitude of the results of air-entrainment of air-entrainment during and the results of determining the parameters of the porosity structure, it can be concluded that the natural air-entraining admixture more stabilises the air-entrainment of low-emission binders than a synthetic admixture. To ensure adequate air entrainment of concrete over time, increasing the content of the synthetic admixture in the concrete mixture is necessary;
- air-entraining admixture is also essential because of its air-entrainment characteristics. A more favourable impact in the scope of obtained parameters of air-entrainment of low-emission concrete is characterised by a synthetic than natural admixture. The air season has smaller sizes and are closer to each other;
- the amount of alkali in cement CEM III/A affects the effectiveness of air-entraining admixture and air-entrainment stability, which also depends on the air-entraining admixture used. The lower alkali content in CEM III/A requires an increase in the amount of air-entraining admixture to obtain the right amount of air-entrainment of concrete. The low content of alkali in cement could also be more conducive to stabilising the air-entrainment of concrete obtained because of the action of synthetic air-entraining admixture instead of natural. This problem requires further explanations and research.

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DESIGNING CITIES FOR FUTURE SENIORS

PROJEKTOWANIE MIAST DLA PRZYSZŁYCH SENIORÓW

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Abstract

This paper presents the results of research conducted at the (Faculty of Architecture, Poznan University of Technology) in the area of urban design geared towards the new needs of ageing residents. The first part presents the original proposal of a typology of residential environments for seniors based on own research, supported by the realisations of architectural objects in the last 15 years in Poland and worldwide. Then, the article also draws on research carried out on a group of over 800 young residents of Poznań to assess the potential of architectural and urban space to support health and living comfort, referring to the basic functional and spatial needs of the living environment for seniors. The text is accompanied by an introduction describing the contemporary conditions and historical context related to senior housing in Poland.

Keywords: aging societies, quality of life, city, residential units

Streszczenie

W artykule przedstawiono wyniki badań prowadzonych (na Wydziale Architektury w Politechnice Poznańskiej) w obszarze projektowania urbanistycznego ukierunkowanego na nowe potrzeby starzejących się mieszkańców. W pierwszej części omówiono autorską propozycję typologii środowiska zamieszkania dla seniorów w oparciu o badania własne, poparte realizacjami obiektów architektonicznych z ostatnich 15 lat w Polsce i na świecie. W dalszej części artykułu przedstawiono badania przeprowadzone na grupie ponad 800 młodych mieszkańców Poznania w celu oceny potencjału przestrzeni architektoniczno-urbanistycznej do wspierania zdrowia i komfortu życia, odnosząc się do podstawowych potrzeb funkcjonalno-przestrzennych środowiska życia seniorów. Tekstowi towarzyszy wprowadzenie opisujące współczesne uwarunkowania i kontekst historyczny związany z mieszkalnictwem senioralnym w Polsce.

Słowa kluczowe: starzejące się społeczeństwa, jakość życia, miasto, moduły mieszkalne

1. INTRODUCTION

„Affordable housing is an issue that is not only important for politicians and architects, it is not just aimed at the poorest, and housing policy is not about the culture of handouts and has many non-financial tools at its disposal. It is high time to change the way we talk about housing" [1][authors' translation].

Analysing the housing environment, it is important to note that the main attention of public authorities and spatial planners is directed towards meeting the housing needs of people of reproductive age. This is certainly due to the demographic collapse observed in Europe, including Poland. For example, in our country, housing programmes for the young, such as "Housing for the young", "Family on their own" etc., are being launched. In contrast, less attention is paid to identifying the housing needs of the elderly and the resulting challenges facing housing policy in the context of healthy ageing [2]. At this point, it is impossible to ignore the historical conditions related to the contemporary attitude to the phenomenon of old age. According to the authors, this attitude developed

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in two historical periods that had the greatest impact on the perception of old age in Western culture. In ancient Greece, elderly people who needed care relied on their children or extended family. Athenian law required children to look after their ageing parents, and the penalty for neglecting this duty was to deprive the guilty of citizenship. This was, next to the death penalty, the second most severe sanction for Athenians. The elderly enjoyed great authority. The Spartans appointed a council of elders, called the Gerusia, which was the most important governing body consisting of 30 men over the age of 60. The council also acted as a supreme court with the power to overturn decisions made by the Spartan assembly. This seemingly unrelated information directly related to the title of the chapter provides a basis for understanding that in ancient Greece old people enjoyed a very high degree of authority, which was directly related to the environment of their residence under the caring care of their family.

Similarly, in ancient Rome, old age was equated with wisdom and prestige. Cicero, in his treatise On Old Age, wrote: "For what is more agreeable than an old age surrounded by the enthusiasm of youth? Or do we not concede to old age even strength enough to instruct and train young men and equip them for every function and duty? And what more exalted service can there be than this?"; "[...] and no teachers of the liberal arts should be considered unhappy, even though their bodily vigour may have waned and failed" [3].

Seneca [4] saw old age as a period that prompts man to reflect on the consequences of his deeds and choices, to reassess his achievements in life. The widespread respect for old age and the familial care of seniors meant that there was no practical need in ancient Rome for specialised places equivalent to today's nursing homes for the elderly. This situation changed dramatically after the fall of the Roman Empire. Shahar [5] draws attention to the specific approach to old age in medieval Europe. This approach flowed directly from the Scriptures, where old people were not directly mentioned among those who deserved help. Records of due support referred to widows, orphans, the sick and the lame (incapacitated), but not to old people. In medieval Europe, the old man was most often alone.

It is noteworthy that old age was treated differently depending on gender and social position, with old age generally being viewed unfriendly. This is confirmed, for example, by the Latin terms used by Jan Długosz [6] to refer to old age: "gnarled old age" (decrepita aetas), "burdened with senile impotence" (morbo et senio gravatus), "weary of age" (senio confectus). Against this backdrop, old age was particularly difficult for women, who, as incapable of procreation, were treated with contempt and even hostility. This is well reflected in the pejorative medieval term "old woman" (vetula) in relation to older women [7]. In medieval literature, an old woman was very often portrayed as a false person, accused of witchcraft, magic, casting charms, to be feared. Images of old women can be found that had the grotesque repulsive forms of toothless and limping figures [8]. This negative attitude to old age even applied to rulers, who were reproached for their infirmity, which provided a pretext for younger successors to take over the reigns [9].

It is in this attitude that the origins of the segregated places where the elderly could find refuge can be traced. Although the idea of Christian charity called for people in need to be cared for, access to hospitals was severely restricted and these institutions were not directly intended for the elderly. Over time, secular authorities made an effort to organise care for seniors who were lonely and destitute. "Refuges", "homes for the poor" and "old people's homes" did not enjoy a good reputation until the end of the 19th century. The senior citizens living there were segregated by gender, often forced to wear uniform clothing and underwear, and had to participate in the work of maintaining the refuge. Conditions in these places were certainly not good.

It is easy to see that the need to organise institutionalised forms of care for the elderly, separated from the rest of society, is linked to the negative attitude to old age developed in the Middle Ages. Paradoxically, when we compare this attitude with modern times, we find many common features. In contrast to antiquity, when old age was identified with wisdom and authority, in modern society (just as in the Middle Ages) we still encounter symptoms of age discrimination. This can be seen in the market for consumer goods and advertising, which for a long time targeted mainly young people, or in the academic restrictions in the Polish higher education system, which discriminate against older, experienced scientists. It may not be surprising that social care homes for the elderly, isolated from society, still evoke very negative associations and are not identified with healthy ageing environments. Research carried out at the Institute of Public Affairs by Bojanowska

[10] shows that only 0.5 per cent of respondents in Poland allow the prospect of living in a state or local government nursing home in their old age. This data is in line with results from other European countries. As can be seen from the research already presented, the most preferred forms of care for seniors are solutions that provide opportunities for these people to remain in their natural surroundings, which is also confirmed by the original research presented in Chapter 3. Here we turn to further types of residential environment that provide such opportunities. These solutions, on the one hand, provide a sense of non-exclusion, independence and self-reliance and, on the other hand, create opportunities for healthy ageing.

The following types of housing environment are distinguished:
- strictly senior architecture;
- controlled social-mix;
- synergic habitat: creative partnership between generations;
- assisted housing for the elderly;
- creative co-housing;
- care farms [11].

When talking about the current state of senior citizens' housing, it is important to bear in mind that the vast majority of them use the dwellings in which they have spent their previous lives [12]. Most of these were designed without taking into account the specific needs of a particular type of user. In such housing structures, both the very young, the middle-aged and senior citizens reside. The form of the building itself, its type, is of little relevance here, whether it is a prefabricated housing estate or a townhouse in the centre of a large city. Today, the majority of older people live in these types of buildings, which were not intended to be designed for senior citizens.

A diverse social cross-section is naturally formed in such complexes, which facilitates older people's existence by creating communities and closer neighbourly relations. However, in many cases, due to various mechanisms of urban transformation, e.g. urban sprawl, this efficient social structure breaks down among the inhabitants of such buildings, as exemplified by the depopulated council tenements, where the remaining tenants tend to be seniors. Younger generations are eager to move to the suburbs, and the type of family functioning is also changing; it is becoming increasingly rare to find multi-generational families, with two generations living together. Therefore, older people live alone in inadequately sized flats. The quality of the space they live in is greatly reduced, the excess space, previously occupied by several families, proves costly to use, so the running costs far exceed the financial possibilities of senior citizens. The lack of lifts, platforms, wide accesses and ramps to the building makes them an involuntary trap for the elderly over time. As seniors' abilities decrease, buildings do not support them in their daily lives and even make it impossible to be independent and function independently in their homes.

2. RESEARCH METHODS

This research process adopted a two-stage procedural model. The first stage used the method of contextual knowledge discovery, desk research and literature studies. On the basis of the knowledge gathered and case studies of selected housing schemes, the schemes were grouped in terms of their leading characteristics and the author's criteria were then formulated [11]. The process led to the formulation of the author's typology, which reflects the current state of seniors' housing.

In the second stage, on the other hand, an anonymous quantitative study – a questionnaire survey – was carried out. The survey form was made available digitally and resulted in responses from 813 respondents. The aim of the survey was to obtain precise answers about the expectations of future seniors with regard to the senior living environment, taking into account the potential to promote health at home. The results of the survey are presented in graphs and discussed later in the paper (see section 4).

3. AN ATTEMPT TO CLASSIFY THE HOUSING ENVIRONMENT FOR SENIORS

This chapter is a review and is based on the research findings published in the academic monograph 'Housing for health. Designing for future seniors' by A. Gawlak. As illustrations for the forms of senior housing defined by the author, contemporary examples of the architecture of buildings erected in the last 15 years are indicated.

3.1. Strictly senior architecture

Buildings that are aesthetically pleasing, devoid of the stigma of health care centres or nursing homes and designed with the elderly in mind have been around for more than two decades. This senior architecture,

which prioritises functionality, accessibility and affordability, is determined by legislation and financial instruments and incorporates the use of modern technology, recognises the individual needs of an ageing person. An example of this is a house for an ageing couple located in Madrid. Ignacio G Galán and OF Architects designed an unusual building with a façade finished in blue ceramic panels and corrugated sheet panels, as well as a roof reminiscent of saw teeth. The avant-garde façade is complemented by details such as balustrades, shutters, blinds and green furniture. The interior of the house, meanwhile, is complemented by oak furniture and a light tiled floor. The building is designed to allow residents to age in place and to foster social relationships, so the architecture opens onto the street, at the front. A ramp leads to the entrance, and once you cross the threshold, you can access the living room, dining room and kitchen directly. The building incorporates technologies such as solar panels, heated flooring and automatic blinds to control heat gains and illuminate the interiors accordingly. On the lower floor, there is an independent living unit that the owners can rent out to maintain financial stability. This space can also be used for a potential future caretaker [13].

Fig. 1. Home for an aging couple in Madrid, designed by Ignacio G Galán and OF Architects
Source: https://www.dezeen.com/2024/01/12/ignacio-g-galan-of-architects-madrid-home/

Another interesting initiative is the BoKlok modular home adaptation project for the elderly and people with dementia, a collaboration between IKEA, Skanska and the Queen of Sweden. SilviaBo is intended as a response to the country's ageing population and the resulting demand for accessible housing. The housing complex was constructed from prefabricated wooden modules and assembled on site. Its functional layout has been adapted to the needs of people with dementia. This solution is intended to support independent living for residents for as long as possible. The project includes buildings with different numbers of storeys and includes one- and two-bedroom flats. Senior-friendly solutions have been planned, such as wide entrances, automatically opening doors, flat surfaces, which are also suitable for wheelchair users, and low thresholds. Additional lighting and a visual identity system were also provided. Technological solutions such as heat sensors in the cookers have been used. The interiors are characterised by muted, friendly colours, and the furniture is from the IKEA collection. Various accompanying amenities are envisaged, including gardens with flowers and vegetables, a building with pergolas and a barbecue. Environmentally friendly solutions such as green roofs and solar panels have been implemented on the estate [14, 15].

Fig. 2. SilviaBo – project of adapting BoKlok modular houses for the needs of the elderly and people with dementia
Source: https://www.dezeen.com/2019/08/20/ikea-boklok-prefabricated-silviabo-elderly-housing/

3.2. Assisted housing for the elderly

The concept of sheltered or assisted housing for the elderly provides an alternative to the offer of residential care homes, as well as part of the care services (community care) in the senior citizen's

place of residence. As an example, the Willow Barns project in the UK offers 75 independent living units for people aged 55 and over and includes 24-hour care support and an alarm service. The functional layout includes an individual living space, kitchen, bathroom and also a dressing room. The complex is equipped with a lift and includes communal spaces such as a laundry room, garden, gym, hair and beauty salon, restaurant and even a wellness centre or hobby room. The aspect of affordability for seniors is extremely important. The project, inspired by agricultural buildings from the early 19th century, won the HAPPI Housing Design Award in 2017 [16].

Fig. 3. Willow Barns, England
Source: https://housingcare.org/housing-care/facility-info-161314-willow-barns-stokeontrent-england/

3.3. Creative co-housing

Co-housing – could it be the way forward for better living conditions and improved quality of life? UK research shows that co-housing is not as niche a form of living as the model's reputation suggests, and that shared living is not for a niche audience [17].

An interesting example of a form of co-housing that supports independent living for older people is the Hogeweyk housing complex in the Netherlands. The complex consists of 27 houses, each housing six to seven residents with dementia, with similar lifestyles. The area has amenities such as a supermarket, restaurant, café, hairdresser and theatre, which can also be used by residents of surrounding estates. Each home is supported by a team of carers and the development ensures accessibility and safety, promotes autonomy and neighbourly connections. It was awarded the Homes4Life pilot certificate as part of a project by an international consortium of 5 European countries [18].

Nowadays, new housing models are increasingly being searched for that would contribute to solving the key challenges of our time, such as, among others, loneliness as a new disease of civilization, changes in the demographic structure and the related growing need for care. Co-housing/co-living, as a system proposing to share facilities of various kinds, could significantly improve the living conditions of many in social terms at least. An equally important aspect in favour of the benefits of such a housing model is the economic factor.

3.4. Controlled social-mix

The creation of strictly senior citizens' housing, as well as mono-functional larger developments, small developments just for senior citizens, can

Fig. 4. Hogeweyk housing estate in the Netherlands
Source: https://hogeweyk.dementiavillage.com/

unfortunately also have negative effects on this community. There is a risk of alienation of residents, so-called secondary exclusion created, paradoxically, by creating almost luxurious enclaves. A much better solution may be to design layouts enabling the comfortable coexistence of various age groups (the so-called social mix) on the scale of an individual building, architectural complex, housing estate or neighbourhood, where the interaction of residents would additionally benefit all parties. Targeting the needs of only one user group automatically discriminates against the others and in practice also works to the disadvantage of the apparently privileged. The point is that functional and spatial solutions should always take into account the regulations at the legislative level in order to consistently create a pleasant living environment for different social groups, on a scale and in proportions determined by the architect. The symbiotic co-existence of generations, taken into account at the stage of the programme for the building or estate and further on in the architectural and construction design phase, supported by legal regulations, can provide a guarantee for the quality of the space.

Fig. 5. Warburton House, England
Source: https://housingcare.org/housing-care/facility-info-161749-warburton-house-cambridge-england

One of the more interesting concepts is the Swedish Sällbo project, located in Helsingborg. This multicultural and multigenerational living space with communal spaces is focused on stimulating social interaction. Young people, refugees and the elderly have been brought together in order to offset loneliness. Half of the residents are therefore over the age of 70, and the remaining residents are 18-25 years old. The seniors can support the newcomers in learning the language, and the younger residents can reciprocate with education on social media or new technologies [19, 20]. Another interesting development is Warburton House, Ninewells, an intergenerational, human-scale housing complex located in Cambridge, surrounded by nature, where 74 of the 240 flats are designed for people aged 55 and over. The development is characterised by accessible spaces and services. It includes communal spaces such as a hairdressing salon, cinema room, garden, laundry, guest room and communal lounge with kitchenette. In addition, it is equipped with a 24-hour emergency alarm [16].

3.5 Alternative care farm

In Europe and throughout the world, alternative forms of providing and implementing care services for older people are constantly being explored. Consideration is being given not only to the creation of new care models, but above all to the possibility of adapting existing solutions so that existing potential can be used to create large-scale systemic arrangements to meet the ever-growing demand. At the same time, the search also revolves around non-institutional solutions. One fairly new form, which has not been disseminated in Poland, is the so-called care farms. This is an innovative concept combining agricultural – multifunctional – and social functions [21]. Social farming is defined in a European Union document as "a cluster of activities that use agricultural resources – both animal and plant – to generate social services in rural or semirural areas, such as rehabilitation, therapy, sheltered jobs, lifelong learning and other activities contributing to social integration" [22]. This form of care is most developed in the Netherlands, but also in Italy, France or Norway. Farms qualifying their activities as so-called social agriculture are defined as e.g.: farming for health, care farming, green care, green therapies. Through the diversity of their activities, they provide therapy, rehabilitation, education and, above all, care services, both in the form of short (24 h) and long-term stays.

The Care farm De Hulst in Oterleek, the Netherlands, designed by the design office FARO Architecten, can serve as an example. The facility is designed for elderly residents with dementia. The complex consists of a historic bell-shaped building with two barns, and three attached barns. The overall

Fig. 6. Care farm De Hulst designed by FARO Architecten
Source: https://faro.nl/projecten/zorgboerderij-de-hulst/

design is stylistically coherent, and the development is distinguished by sustainable water management, sustainable energy management, and the use of environmentally friendly materials [23].

In Poland, too, an attempt has been made to implement a project involving the expansion of rural agritourism farms, in the form of family care homes. They have the advantage over traditional nursing homes that, through their individualised character, intimacy and family approach, they break all the stereotypes associated with so-called old people's homes, such as exclusion, seclusion and dehumanisation. And, above all, a stay in such a household is associated with less anonymity and has greater potential in terms of meeting sociological and psychosocial needs. It certainly also facilitates integration into a new environment. This is of great importance, especially for the elderly and lonely at the same time, who for various reasons cannot count on support from their families. The change in the family model, including the increasingly rare model of a multigenerational family living together, as well as living alone without starting a family, is encouraging an increase in the number of lonely older people (over 65), so all aspects of non-institutional care are gaining importance.

Another revolutionary project is a conceptual model for next-generation retirement homes, combining residential function and health care facilities in a single concept, in the form of vertical urban farms, in Singapore. Although the project in question was made for Malaysia, it originates from a European cultural background. The concept was created with the private sector and a specific location in mind, but the idea itself has great potential for adaptation. It is the architects' response to the ageing of the Asian population and the increased demand for food. The concept addresses two problems of Asian society: rapid ageing and access to their own food – around 90% of food products are imported. Based on Research-based Design, the architects proposed a solution that is a self-sustaining organism that guarantees employment, healthcare and prevents exclusion for the elderly. By designing market mechanisms related to work, such as production, the circulation of goods, etc., it is also a commercial premise. In addition, the project ensures that very important aspects of older people's lives are realised: a sense of security, including financial security, a sense of acceptance and group functioning, physical activity, a sense of belonging. This makes it a real vision and not just another utopian concept [24].

Fig. 7. Home Farm designed by SPARK Arch
Source: https://sparkarchitects.com/work/home-farm

3.6. Synergic habitat: creative partnership between generations

The idea behind this concept is to create compact 'self-sufficient' residential areas for the compatible integration of old and young people and harmonious social development. The result is socio-economic synergy, thanks to functional and spatial solutions that foster the cooperation of people of different ages, the utilisation of their potential and their creativity.

The concept of a synergic habitat formulated by W. Bonenberg in the project "Visions of tomorrow's architecture" is based on the following assumptions [25]:

– the needs of the representatives of the older generation generate a demand for a wide spectrum of specialised services, referring to fashionable trends related to a healthy lifestyle, care for fitness and figure, improvement of well-being and physical condition (the desire to retain youth). These are services such as: wellness, recreation and health services, fitness, swimming pool complexes, wellness salons, massages, saunas, gyms, aromatherapy, specialised beauty and cosmetic treatments. There are also restaurants with healthy food, cafés, interest clubs, discos designed to maintain social contacts among the older generation;
– this kind of service for clients recruited from the older generation is at the same time a workplace for creative young professionals, who can find employment in the vicinity of their homes located in a "synergic habitat". It is a very convenient solution for parents bringing up young children, young people looking for flexible forms of employment with the possibility of working part-time;
– it is also an opportunity for additional social activation of elderly people, who can devote their free time to the children of young professionals living in the habitat, organising common games, meetings, talks, neighbourhood celebrations.

It is at the same time "the opposite of anonymous architecture with impersonal crowds of constantly hurrying people, alienated, looking only at themselves. Urban formations that condemn us to arduous car journeys to services and to work. Estates, with forgotten elderly people whose future is planned in isolated old people's homes. Housing estates with parents who are eternally busy, children who sit alone in front of their computers and young people for whom social contact is determined by Facebook and Twitter [25]" [authors' translation].

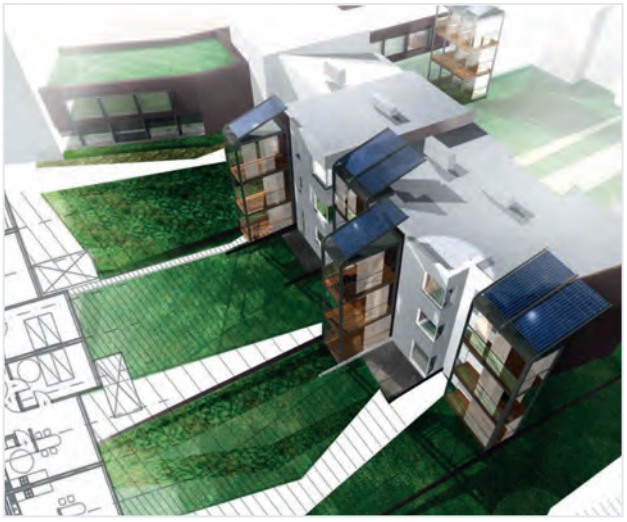

Fig. 8. Multi-generational housing complex, designed by W. Bonenberg
Source: Catalog of the project "Visions of tomorrow's architecture" organized by Architektura & Biznes

One of the first applications of this idea in Poland is the project for a compact multifunctional urban complex in Pobiedziska, designed by W. Bonenberg, J. Grochulski, R. Jurkowski and R. Loegler. The aim of the project was to revitalise a section of Pobiedziska by designing a space that would create a new urban quality that could become a recognisable brand of the city, in line with the described idea of a 'partnership of generations'. The project in the residential part includes 115 flats with an average size of 61 m^2 (50-95 m^2) with a total area of 7044 m^2. The characteristic feature of the proposed solution is, on the one hand, the direct and close contact of the flats with services and greenery, and on the other hand, the possibility of "covered access" from each flat to an area offering a wide range of services for seniors (in our climate this is important for most of the year) [25].

4. EXPECTED PARAMETERS OF HOUSING DEVELOPMENT FOR SENIORS

4.1. Survey research

The survey entitled "Survey on the quality of health support spaces" was carried out between 2018 and 2020, as an online survey among 813 respondents. The survey was divided into two main parts: Part 1 'Hospital space. A survey of perceptions of the residential space' and part 2 'Space of ageing.

Table 1. The survey questionnaire. Prepared by Authors

Please assess which type of housing is most beneficial for the (1-5)					
Nursing home	☐	☐	☐	☐	☐
Day care home	☐	☐	☐	☐	☐
Private caregiver at home	☐	☐	☐	☐	☐
Co-housing for older people	☐	☐	☐	☐	☐
Current place of residence	☐	☐	☐	☐	☐
Please assess the truthfulness of the following statements (yes, no, don't know)					
I am considering the possibility of living in a nursing home			☐	☐	☐
I am considering the possibility of changing the apartment to one suitable for older people			☐	☐	☐
I am considering the possibility of changing my place of residence to cohousing for older people			☐	☐	☐
I am considering the possibility of living with a family, e.g. with my children			☐	☐	☐
I do not consider changing my place of residence in old age			☐	☐	☐
Please assess facilities for older people in the place of residence (1-5)					
The apartment space adapted for disabled people	☐	☐	☐	☐	☐
Nursing supervision available 24/7	☐	☐	☐	☐	☐
Online medical consultations available 24/7	☐	☐	☐	☐	☐
Online psychological consultations available 24/7	☐	☐	☐	☐	☐
Internet access	☐	☐	☐	☐	☐
Proximity to services such as: pharmacy, shop, bank, etc.	☐	☐	☐	☐	☐
Access to recreation and sports space for seniors	☐	☐	☐	☐	☐

Expectations of the space of ageing'. For the purposes of this thesis and the research topic undertaken, part 2 of the survey will be discussed in detail. The survey (part 2) contained a set of 3 closed multiple choice questions. Respondents completed a rating on a scale of 1-5.

The evaluation form indicated to respondents 5 types of living arrangements for an older person: *nursing home*, *day care home*, *private caregiver at home*, *co-housing for older people* and *current place of residence* with a request to indicate a preference for each.

The results are shown in Figure 9. The most desirable solution was considered to be the possibility to stay in the current residence, which fulfils the common idea of 'aging in place'. The least desirable option was an institutional solution, i.e. a nursing home.

In the next step, respondents were asked to refer to the veracity of the indicated sentences (see Figure 10):

- *I am considering the possibility of living in a nursing home;*
- *I am considering the possibility of changing the apartment to one suitable for older people;*
- *I am considering the possibility of changing my place of residence to cohousing for older people;*
- *I am considering the possibility of living with a family, e.g. with my children;*
- *I do not consider changing my place of residence in old age.*

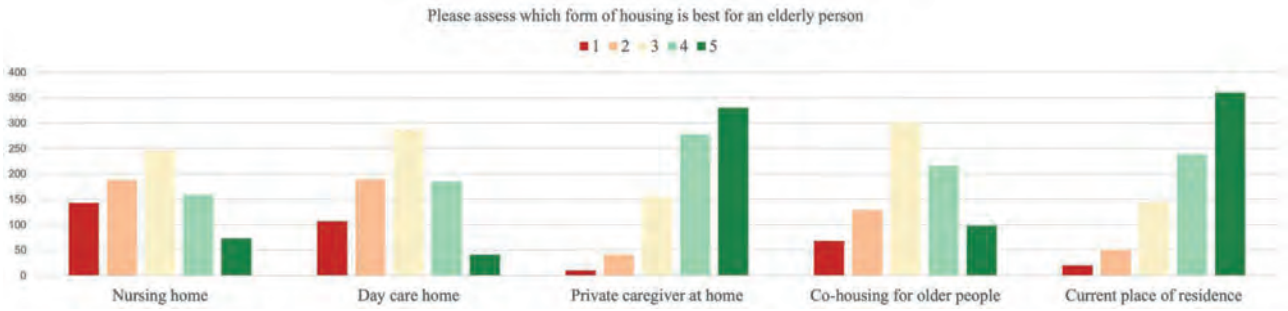

Fig. 9. Preferred forms of residence according to older people. Prepared by Authors

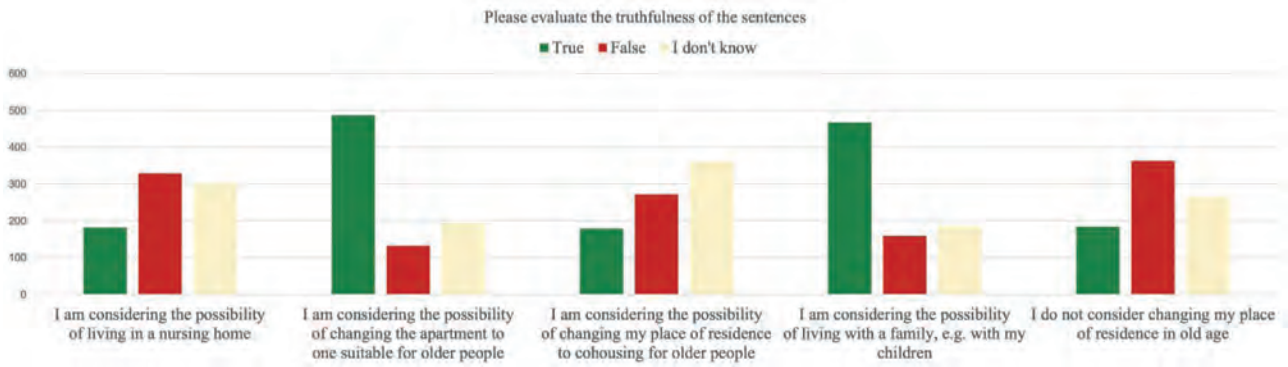

Fig. 10. Assessment of the truthfulness of opinions regarding housing issues. Prepared by Authors

Fig. 11. Weights of facilities for older people in the place of residence. Prepared by Authors

The aim of this question was to address the various forms of senior housing support through the prism of one's own expectations and experiences.

In the last question, the residents were asked to give weights (1-5) to the possible amenities envisaged in their place of residence for seniors (see Figure 11):

- *the apartment space adapted for disabled people;*
- *nursing supervision (nursing station in the building) available 24/7;*
- *online medical consultations available 24/7;*
- *online psychological consultations available 24/7;*
- *proximity to services such as: pharmacy, shop, bank, etc.;*
- *internet access;*
- *access to recreation and sports space for seniors.*

4.2. Conclusions

It is important to note that those taking part in the survey were between the ages of 18-27. Respondents significantly indicated that their preference would be to remain in their own and current place of residence in their senior years, while allowing for the function of a carer or other person to support their independence and safety. The least desirable form of care was found to be a nursing home or day care home. This confirms previous surveys and the declarative aversion to institutional forms of senior living.

In the next question, respondents indicating the veracity of the statements made basically confirmed their answers from the first question. Here, they additionally indicated the possibility of not only living in their current place, but also with their family. At the same time, respondents are aware that their current place of residence may be insufficiently adapted (i.e. not equipped with a range of amenities for seniors), which may become a reason to change it in the future.

In the final part of the survey, respondents prioritised the amenities of their place of residence. They considered the absence of architectural barriers at the place of residence to be the most important, followed by the proximity of important functions in the vicinity of the place of residence, such as a shop, pharmacy etc. The ability to access nursing or medical support in the form of online consultations was also important.

The above results allow for ongoing monitoring of public preferences in relation to the living environment for the elderly, and the priorities given support decision-making in the process of designing architectural and urban planning solutions that promote the well-being of residents in ageing cities.

5. SUMMARY

The combination of factors influencing the health of older people in their place of residence is the basis for a typology of the residential environment that takes into account two main elements. The first is the environment in which most older people currently reside. The second element is the historically shaped attitudes to old age operating in contemporary society. For example, in large Polish cities (Warsaw, Krakow, Poznan, Gdansk, etc.) these are dwellings in houses built 70-30 years ago in big slab housing estates. For young people at that time (migrants from the countryside or small towns), the "allocation" of such a flat (usually a cooperative flat) was a kind of social ennoblement and a dream come true to live and work in a big city. We can also mention the large group of young tenants at the time, who immediately after the Second World War settled in the inner cities of large cities, flats located in old tenement houses.

Depending on their legal status, these new tenants were quartered in large private flats subdivided into smaller units, or were given "allotments" in flats whose former pre-war owners were dead or had emigrated abroad. Most of these apartments (both in large prefabricated housing estates and in old downtown tenement houses) were devoid of basic amenities for older people (driveways, handrails, elevators, etc.). This group of young tenants at the time is today the senior "core" of the local community in many areas of Polish cities. This situation results in a characteristic age differentiation of these regions, with a noticeable "aging" tendency of the population living in inner-city areas and former "modernist" large-panel housing estates.

Interestingly, according to Bojanowska's study [26], the vast majority of seniors want to continue living in their previously occupied flats with various options for support:

- occasional help from relatives and neighbours,
- sharing the flat with children, grandchildren or extended family,
- having privately paid or free institutional assistance from the PCK (eng. Polish Red Cross), Caritas, etc.

The OECD report 'Ageing in Cities' [27] indicates that this way of living is the predominant type of housing environment for older people in European cities. At the opposite typological pole can be located the residential environment associated with spatially segregated homes for the elderly (the so-called nursing homes). This is a traditional form of so-called institutional care. These homes are intended for older

people who cannot receive the necessary care and support in their homes.

How to spend the autumn of life is an increasingly explored area of research and interest. Above all, it is observed that the activity of today's senior citizens is increasing and is more visible in society. A number of initiatives undertaken by older people are strictly organised for this age group. On the one hand, these activities enhance quality of life, but on the other they do not result in assimilation into other social groups. Examples include proposals such as the university of the third age and senior citizens' clubs.

Some similar initiatives are run by municipal or non-governmental organisations, often local. While the range of activities aimed at older people is visibly expanding to involve new audiences, there is still a large group of socially inactive people. Exclusion or social isolation may be caused by disability, lack of motivation or poor mental health. Social isolation and loneliness are still noticeable on a large scale, especially in cities. Multigenerational families living together are an increasingly rare model, which further accentuates generational loneliness. A consequence of these changes is the need for older people to live more independently and autonomously and to seek social interaction outside the home. All this means that not only the needs of future generations are evolving, but also their social perception. It can therefore be considered that the desired forms of residence should be an aggregation of future social needs on a physical, psychological and psychological level. Research clearly shows that currently the most popular, and usually the only possible form of housing involving comprehensive care, i.e. nursing homes or retirement homes, is mentally unacceptable to older people or those just contemplating impending old age.

Various proposals for the configuration of spatial forms of housing for the elderly can be observed: from closed, concentrated large-scale systems such as gated communities, to individual units exemplified by senior citizens' homes; to separate housing units dispersed in existing structures, supported by health care services. As a matter of principle, they should be dispersed in existing structures without causing exclusion, but on the contrary, in a symbiotic way, engaging in social and cultural life. The housing of the future will increasingly also be a place for both work and care. Thus, properly designed living spaces, easily adaptable to the changing needs of residents, will bring many benefits and savings over the years.

Housing development for seniors, in addition to architectural accessibility, should provide them with economic accessibility. This should be interpreted in such a way that the assumed costs of maintaining a house or flat do not exceed the capabilities of older people, most of whom are already less economically active. However, economic accessibility should not result from a reduction in the architectural quality and comfort of the building. Instead, it should be a feature to be taken into account by planners at the programming and design stage of an investment and should result, for example, from low-cost technologies or financial instruments providing, for example, co-financing of running costs as benefits guaranteed by the state or local authorities, etc.

A therapeutic role is guaranteed by social communal spaces in the living environment, designed for different social activities of the seniors. The solutions allow for the establishment and maintenance of social relationships, important for the proper functioning of older people who are often lonely. Such spaces are, as a rule, easier to plan in multi-family developments, both inside and around the buildings, incorporating them into the landscaping design. Optimal examples are co-housing solutions for senior citizens, where communal spaces also include the more private functional areas of the flats, such as kitchens, dining rooms or living rooms.

Another aspect taken into account was the support of housing units for seniors in terms of direct access to medical services at the place of residence (supported housing). Such solutions are also more common in multi-family buildings, due to both costs and space management. This is an important convenience because it allows older people to remain independent in their place of residence for longer, and often delays the moment when families take over the care of seniors or places the elderly person in an institutionalized form of care (nursing home, etc.).

The last aspect, resulting quite indirectly from functional and spatial solutions, and more from specific social policy, is programming the social structure of residents in buildings for seniors. Generational differentiation of users, but also those resulting from other differences, such as financial situation, social position or various support needs (e.g. students, young mothers, disabled people), through integration, increases the social potential of housing development, creating the possibility of symbiotic coexistence, in this meeting the various

needs of seniors. The coexistence of generations additionally means that it is assumed that young people who remain professionally active will be able to take up work in the service sector located near their place of residence, which will ultimately be used by older people living in the same housing estate and no longer professionally active.

Institutional forms of living are the least desirable solutions among both current and future seniors. Therefore, the potential offered by housing development should be used to solve the housing problem for older people, but also access to medical care, for which the demand is gradually increasing. Methods of valorization of housing space, with particular emphasis on its health-promoting role, are particularly important for the environments most commonly inhabited by seniors.

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RENOVATION OF BUILDINGS AS AN ESSENTIAL ELEMENT OF ACTION IN "GREEN DEAL" – A CASE STUDY

RENOWACJA BUDYNKÓW JAKO ISTOTNY ELEMENT „ZIELONEGO ŁADU" – STUDIUM PRZYPADKU

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Abstract

The article highlighted that renovation buildings are an essential action in the European Green Deal. The objective of this study was to assess the energy performance of renovation concepts selected building components on multi-family house. Typical Polish 1950s building was used as a baseline reference, and it was shown that very similar renovation concepts can be successfully applied in other buildings that provides good bases to develop standardized solutions. Energy performance of common renovation concepts was assessed both by in situ tests (with an unaided eye and including the use of a thermal imaging camera) and with national calculation methodologies. The renovation concepts included selected building components: improved envelope insulation with exterior windows and doors and heating system. The effects of the performed renovation were supplemented by the calculation of reduction of greenhouse gas emissions into the atmosphere, as a result of reducing the demand for heat supply to rooms.

Streszczenie

W artykule podkreślono, że renowacja budynków jest istotnym działaniem w ramach Europejskiego Zielonego Ładu. Celem omawianego badania była ocena charakterystyki energetycznej zaproponowanej metody renowacji wybranych elementów budynku wielorodzinnego. Jako punkt odniesienia wykorzystano typowy polski budynek z lat 50. i wykazano, że bardzo podobne metody renowacji można z powodzeniem zastosować w innych budynkach, co stanowi dobrą podstawę do opracowania standardowych rozwiązań. Charakterystyka energetyczna zaproponowanej metody renowacji została oceniona zarówno za pomocą badań wykonanych bezpośrednio na terenie obiektu (okiem nieuzbrojonym i przy użyciu kamery termowizyjnej), jak też z wykorzystaniem krajowych metod obliczeniowych. Proponowane metody renowacji obejmowały wybrane elementy budynku: poprawę izolacyjności przegród zewnętrznych z oknami i drzwiami zewnętrznymi oraz system ogrzewania. Efekty wyżej wymienionej metody renowacji uzupełniono o obliczenia redukcji emisji gazów cieplarnianych do atmosfery w wyniku zmniejszenia zapotrzebowania na ciepło dostarczane do pomieszczeń.

GENERATING AN IMAGE OF THE CITY STRUCTURE WITH THE USE OF MOCK-UPS, 3D MODELS AND ARTIFICIAL INTELLIGENCE ON THE EXAMPLES OF MODELS OF THE STRUCTURE OF SELECTED CITIES OF THE GZM METROPOLIS

GENEROWANIE OBRAZU STRUKTURY MIASTA Z WYKORZYSTANIEM MAKIET, MODELI 3D I SZTUCZNEJ INTELIGENCJI NA PRZYKŁADACH MODELI STRUKTURY WYBRANYCH MIAST METROPOLII GZM

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Abstract

Spatial analysis of cities and regions in the field of urban-architectural planning is usually presented in the form of drawings and diagrams. With the development of spatial information and the capabilities of GIS software and the use of database resources, the creation of illustrations of spatial analysis has become more accessible and easier. According to Kevin Lynch's theory, the image of a city cannot be determined in an automated way, and their identification requires an authorial approach and research. The article presents a series of experiments series, in which an attempt is made to represent the image of the city using mock-ups, 3D models, using augmented reality, as well as artificial intelligence. The authors put forward the thesis that a contemporary, proprietary representation of the city image in the form of models can be an alternative to traditional diagrams representing the basic elements that make up the city image.

Streszczenie

Analiza przestrzenna miast i regionów w zakresie planistycznym i urbanistyczno-architektonicznym najczęściej jest przedstawiana w postaci rysunków i schematów, które bazują na podkładach mapowych. Wraz z rozwojem informacji przestrzennej i możliwościami stosowania oprogramowania GIS i wykorzystywaniem zasobów baz danych tworzenie ilustracji analiz przestrzennych stało się bardziej dostępne i łatwiejsze. Według teorii Kevina Lyncha na obraz miasta składają się krawędzie, dominanty, obszary, ścieżki oraz punkty węzłowe, których nie można jednak wyznaczyć w sposób zautomatyzowany, a ich identyfikacja wymaga autorskiego podejścia oraz badań. W artykule przedstawiono serię eksperymentów realizowanych w ramach cyklu modele struktury miasta, w których podjęto próbę reprezentacji obrazu miasta z wykorzystaniem makiet, modeli 3D, z wykorzystaniem rzeczywistości rozszerzonej, a także sztucznej inteligencji. Autorzy stawiają tezę, że współczesne, autorskie przedstawienie obrazu miasta w formie modeli może być alternatywą dla tradycyjnych schematów przedstawiających podstawowe elementy składające się na obraz miasta. Wnioski z badań mogą mieć zastosowania w analizie przestrzennej miast i regionów oraz być wskazówką do rozwoju metod prezentacji ich struktury.

THE ROLE OF THE TECHNICAL DUE DILIGENCE PROCESS AT THE STAGE OF LAND ACQUISITION FOR CONSTRUCTION INVESTMENT

ROLA PROCESU TECHNICAL DUE DILIGENCE NA ETAPIE ZAKUPU NIERUCHOMOŚCI GRUNTOWYCH W CELU REALIZACJI INWESTYCJI BUDOWLANYCH

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Abstract

The process of planning the implementation of a construction investment is usually preceded by a decision on the purchase of land property, which in turn is typically accompanied by a process known as technical due diligence (TDD). During this process, the feasibility of the planned construction project is verified. The preliminary design concept of the building, prepared at the request of the buyer – a potential investor, is analysed in detail. Legal, technical, environmental, social, or economic obstacles that may prevent the planned investment may already be apparent at the stage of issuing the early finding TDD report. In such cases, purchase negotiations are then typically broken off immediately. In the absence of such obstacles, a final TDD report is issued, containing recommendations for the implementation of the project. There is a lack of research in the scientific literature on the preparation of TDD reports for land properties. This article develops a proprietary algorithm for the TDD process based on the authors' professional experience and interviews with experts. This algorithm is adapted to the TDD process for land property acquisition. The purchase of a plot of land, along with the preparation of a TDD report, marks the initial step in the planning process for construction investment, which can significantly impact its success.

Streszczenie

Proces planowania realizacji inwestycji budowlanych jest przeważnie poprzedzony decyzją dotyczącą zakupu nieruchomości gruntowej, której z kolei zazwyczaj towarzyszy proces technical due diligence (TDD). W trakcie tego procesu weryfikowana jest możliwość zrealizowania planowanej inwestycji budowlanej. Szczegółowej analizie poddawana jest wstępna koncepcja projektowa budynku, przygotowana na zlecenie kupującego, potencjalnego inwestora. Już na etapie wydawania raportu wstępnego TDD są sygnalizowane ograniczenia prawne, techniczne, środowiskowe, społeczne czy ekonomiczne, które uniemożliwiają zrealizowanie planowanej inwestycji. W takim przypadku już na tym etapie zwykle przerywane są negocjacje zakupowe. W przypadku braku takich ograniczeń wydawany jest raport końcowy, który zawiera rekomendacje i zalecenia przydatne do realizacji projektu. W literaturze naukowej brakuje badań dotyczących przygotowania raportów TDD dla nieruchomości gruntowej. W artykule został opracowany autorski algorytm procesu TDD na bazie własnych doświadczeń zawodowych oraz wywiadów przeprowadzonych z ekspertami, który dostosowuje proces TDD na potrzeby zakupu nieruchomości gruntowych. Zakup działki wraz z opracowaniem raportu TDD jest pierwszym etapem w procesie planowania realizacji inwestycji budowlanych, który może zadecydować o jej powodzeniu.

THE INFLUENCE OF THE TYPE OF LOW-EMISSION CEMENT AND AIR-ENTRAINING ADMIXTURES ON THE QUALITY OF AIR ENTRAINMENT OF CONCRETE – UNEXPECTED IMPACT OF GRANULATED BLAST FURNACE SLAG

WPŁYW RODZAJU CEMENTU NISKOEMISYJNEGO I DOMIESZKI NAPOWIETRZAJĄCEJ NA EFEKT NAPOWIETRZENIA BETONU – NIEOCZEKIWANY WPŁYW GRANULOWANEGO ŻUŻLA WIELKOPIECOWEGO

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Abstract

The test results indicate that it is possible to obtain the appropriate quality of air entrainment in concrete with low-emission cement with granulated blast furnace slag, such as CEM II/B-S, CEM III/A and CEM III/A-NA. However, the literature on the subject reports that this is not the rule, and a slag content that is too high is not conducive to the effectiveness of the air-entraining admixture and the stability of the air entrainment. The possible reason for the beneficial effect of slag on the stability of air entrainment was the influence of surfactants used for its grinding. The research also proved that the effectiveness of the air-entraining impact and the stability of air entrainment in concrete with slag cement depend on its type (natural or synthetic) and the alkali content in the cement.

Streszczenie

Rezultaty badań wskazują, iż możliwe jest uzyskanie odpowiedniej jakości napowietrzenia betonu z cementem niskoemisyjnym z żużlem granulowanym wielkopiecowym S, jak CEM II/B-S, CEM III/A i CEM III/A-NA. Jednak literatura przedmiotu donosi, iż to nie jest regułą, a zbyt duża zawartość żużla nie sprzyja efektywności działania domieszki napowietrzającej i stabilności napowietrzenia. Zatem granulowany żużel wielkopiecowy może pozytywnie bądź negatywnie wpływać na efektywność działania domieszki napowietrzającej oraz stabilność napowietrzenia. Za możliwą przyczynę korzystnego wpływu żużla na stabilność napowietrzenia wskazano wpływ środków powierzchniowo czynnych zastosowanych do jego przemiału. Na podstawie badań dowiedziono także, że efektywność działania domieszki napowietrzającej i stabilność napowietrzenia betonu z cementem żużlowym zależy od jej rodzaju (naturalna bądź syntetyczna) oraz od zawartości alkaliów w cemencie.

DESIGNING CITIES FOR FUTURE SENIORS

PROJEKTOWANIE MIAST DLA PRZYSZŁYCH SENIORÓW

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Abstract

This paper presents the results of research conducted at the (name of the University and Faculty) in the area of urban design geared towards the new needs of ageing residents. The first part presents the original proposal of a typology of residential environments for seniors based on own research, supported by the realisations of architectural objects in the last 15 years in Poland and worldwide. Then, the article also draws on research carried out on a group of over 800 young residents of Poznań to assess the potential of architectural and urban space to support health and living comfort, referring to the basic functional and spatial needs of the living environment for seniors. The text is accompanied by an introduction describing the contemporary conditions and historical context related to senior housing in Poland.

Streszczenie

W artykule przedstawiono wyniki badań prowadzonych w Politechnice Poznańskiej w obszarze projektowania urbanistycznego ukierunkowanego na nowe potrzeby starzejących się mieszkańców. W pierwszej części omówiono autorską propozycję typologii środowiska zamieszkania dla seniorów w oparciu o badania własne, poparte realizacjami obiektów architektonicznych z ostatnich 15 lat w Polsce i na świecie. W dalszej części artykułu przedstawiono badania przeprowadzone na grupie ponad 800 młodych mieszkańców Poznania w celu oceny potencjału przestrzeni architektoniczno-urbanistycznej do wspierania zdrowia i komfortu życia, odnosząc się do podstawowych potrzeb funkcjonalno-przestrzennych środowiska życia seniorów. Tekstowi towarzyszy wprowadzenie opisujące współczesne uwarunkowania i kontekst historyczny związany z mieszkalnictwem senioralnym w Polsce.