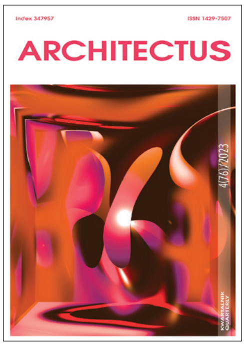

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Exploring the potential for balcony addition to tenements' backyard elevation in Wrocław – spatial challenges related to shade and indoor daylight illumination

Introduction

The operation of existing buildings constitutes 30% of the global final energy consumption and 26% of global CO_2 emissions [1]. As the European Union (EU) aims to achieve the goals of The United Nations Framework Convention on Climate Change's Paris Agreement on limiting global temperature increase all the EU buildings should be renovated by 2050. This implies that the current modernization pace needs to increase from 1% to 3% per year [2]. Residential buildings constitute 75% of the EU building stock and 36% of them are urban apartment blocks [3]. The urban heat island amplifies the effects of climate change further increases the vulnerability of residential buildings to overheating Urban sprawl, despite offering individuals residents an escape from the urban heat island, contributes to climate change, therefore is regarded as a harmful development pattern. Improving the standard of existing urban housing by offering a viable and attractive alternative to the new-built suburban homes could help reverse this trend. For this reason, to address climate change, the expected intensification of refurbishments should address not only energy efficiency challenge but also living quality improvement. In contrast to demolition, preservation of existing buildings brings far-reaching social, environmental, and economic benefits [4].

Circa 22% of residential buildings in the EU were constructed before 1946 [3]. Significant part of these are recognized as heritage buildings. Spatial, technical and energy upgrade of heritage buildings stock poses specific challenges, including the need to abide to conservator's guidelines. However, retaining the usability of a heritage building is necessary for its preservation and avoiding neglect and abandonment e.g. with dwellers' moving to the outskirts looking for better living quality [5].

An access to a private outdoor space such as garden, terrace, loggia or balcony is a multi-family house feature that significantly improves the living environment [6]. In post war multi-family housing, characterised by uniform repetitive façades and rectangular forms, balconies or loggias can be added as an extra layer to elevations at thermal retrofitting stage [7]. The Lacaton Vassal architectural practice has managed to save a derelict social block of flats from demolition and change the image of social apartments into luxurious dwellings thanks to extending the elevations with spacious, well-lit, in-built loggias. In the literature the theme of balcony additions in housing focuses mostly on exploring the technical challenges such as overall energy or acoustic performance of the envelope [7], thermal bridges, indoor air quality, or daylight and visual comfort [8]. Also their influence on urban living quality such as enhancing apartment's usability and adaptability or acting as a proxy for a private garden [9], particularly during the global experience of Covid-19 pandemic lockdowns has been studied. An impact of an access to private outdoor space on human well-being has been established [10], as well as the need to consider contextual features in balcony design to make the most of usability potential of balcony spaces [9].

The recent discourse about monument conservation agrees that, in order to preserve buildings, their usability must be enhanced [5]. For this reason additive elements on external parts of the buildings adjusting building to current technical requirements and dwellers' needs are becoming increasingly common. However, they need to meet the conservators' guidelines to preserve the character of the monument [11].

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A balcony constitutes a significant part of elevation, shaping the street image [12]. Nevertheless, the role of the balcony as an architectural element has been developing with time. In front façade tenements it was mostly functioning as a view platform for the street, meeting at the same time an aesthetical demand as a part of elevation. During the modernist movement balconies became more quotidian architectural elements provided in social residential buildings with a mission to raise the hygiene of apartments with fresh air ventilation for a massive population. From the 1970s spacious balconies and terraces started to appear in residential buildings serving for leisure functions as well [13]. Although the balcony is an old architectural element, and its advantages in residential buildings has been noticed it is not enforced within construction law. Through, in several European countries regulations or guidance about the minimum size is suggested, they still do not consider the users' comfort, need for privacy and more space for various functions happening [9]. The specific position of balconies, as private spaces, but visible from the public cause tensions about e.g. pressure to subordinate to public norms or expectations, what limits the balcony usage, and individual domestication, which may trigger various emotions [14].

In European tenements built at the turn of the 19th and 20th centuries not all of the apartments were equipped with a private outdoors such as balcony. Although extending an elevation with balconies in heritage tenements is challenging due to unique elevation features such as ornaments and preservation guidelines protecting the form of the building, there are examples of practices of adding them during the renovation in countries such as Germany, Denmark, Austria [15] (Figs. 1, 2). In Wrocław, where 21% of the housing stock and 75% of social housing are located in tenements [16], this practice is still uncommon. In Wrocław, adding a balcony onto a street façade would be questionable, due to monument preservation requirements, the limited space for addition and unfavourable spatial context in terms of usability. Nevertheless, Wrocław's tenements quarters have spacious courtyards [17], which constitute an untapped potential for adding balconies to backyard elevations. However, irregular building line of tenements' backyard elevations (Figs. 3, 4), proves challenging for any extensions due to a need to individually assess the risk of obscuration and overshadowing of any apartments below balcony level. The current research state about balcony addition is focused on technical aspects (improving energy efficiency by in-built balconies' extension [7], [8]) and social impact (enhancing the dwelling standard by adding access to private outdoor space [6] or evoking social expectations about proper usage and realizing lack of privacy sense after providing extension with balconies [18]). Although studies suggest that balcony addition during retrofitting enhances dwelling quality,

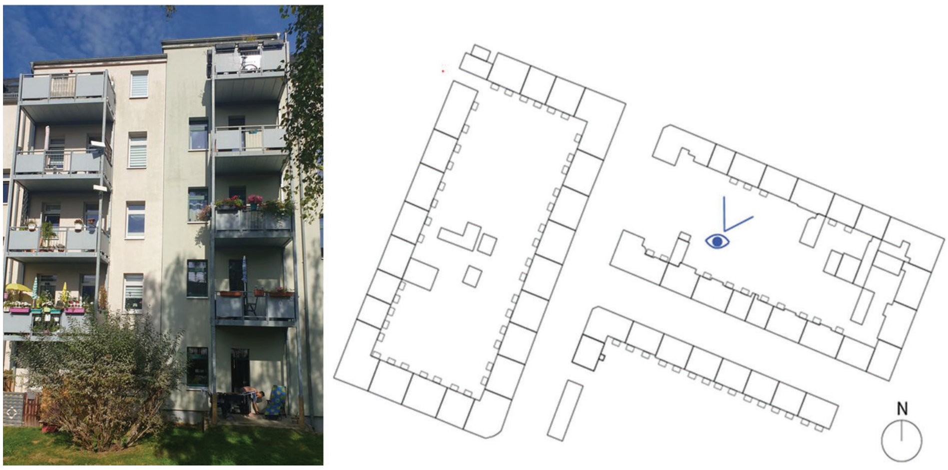


Fig. 1. An example of add-on balconies to the backyard elevation of tenement houses situated in quarters, Karl Liebknecht Street, Chemnitz, Germany (photo and plan by M. Smektała)

Il. 1. Przykład balkonów opartych na zewnętrznej konstrukcji dostawianych do podwórkowych elewacji kamienic w zabudowie zwartej, Karl Liebknecht Straße, Chemnitz, Niemcy (fot. i plan M. Smektała)

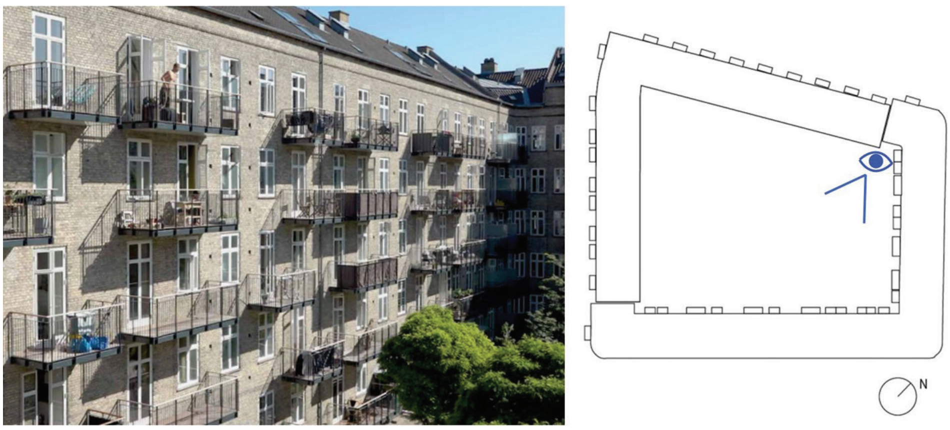


Fig. 2. An example of add-on cantilevered balconies to the elevation of pre-war tenement houses situated in quarters, Nørrebro district in Copenhagen, Danemark (photo by N. Nielsen, source: Altaners Sociale Liv, plan by M. Smektała)

Il. 2. Przykład balkonów na wsporniku dostawianych do elewacji przedwojennych kamienic w zabudowie zwartej w dzielnicy Nørrebro w Kopenhadze, Dania (fot. N. Nielsen, źródło: Altaners Sociale Liv, plan: M. Smektała) disregarding the spatial challenges may negatively impact on apartments' indoor daylight, balcony functionality or feeling of privacy limiting the balcony usage [9]. The aim of this research is to define spatial conditions for balcony additions to Wrocław tenements' backyard elevation based on Polish legal requirements regarding the obscuration and overshading the adjacent buildings. Also the impact of balcony addition on indoor daylight in adjacent apartment is explored. The study addresses the following research questions:

– What are the spatial conditions in Wrocław tenements' courtyards that would allow adding balconies to backyard elevations within the context of Polish building regulations?

– How would balcony addition impact indoor daylight of an apartment?

The paper is structured as follows: First, the methods of studies are introduced such as: desktop study of relevant documents, fieldwork observation, urban plan analysis with feasibility study, and daylight simulations. Secondly, the results are presented. In the beginning the technical requirements regarding balcony addition preventing building from obscuring and shading are presented briefly and juxtaposed with Daylight Factor (*DF*) and illuminance measurement. Next, the typologies of irregularities and guidance for minimum required distance between the buildings, and the result of computer simulations presenting the impact of balconies on indoor daylight. Later, the discussion, with focus on issues missing in Polish regulations and importance of the idea of adding a balcony with the need of individual proceeding of each case. Finally, the conclusion consists of research question responses about potentiality of this idea with balcony impact on indoor daylight, recommendation deriving from the study about assisting the design decisions with daylight simulation, and further research suggestions of a role of balcony addition in indoor daylight control.

Technical and legal capabilities of balcony assembly

Regarding balcony form three typologies can be distinguished: a recessed balcony (loggia), cantilevered and semi-recessed (Fig. 5) [19]. Providing a recessed and semi-recessed balcony typology to an existing building is complex since it requires the removal of an external wall, and dedicating part of floorage for outdoor space. The cantilevered balconies added to existing buildings are commonly used for example in Copenhagen (Fig. 2). However, this method is challenging for three reasons. The first is the structural capacity of the existing wall which not in all cases can hold additional hanging elements. Secondly, the cantilevered balcony hanging structurally to the exiting wall may contribute to thermal bridges. Thirdly, cantilevering elements may destroy ornaments in elevation. However, this research considers backyard elevations, which usually have technical character and are deprived of ornaments.

The exemplary balconies from Chemnitz, presented in Figure 1 are based on the external structure with separated, independent fundaments. Such a solution avoids the problems mentioned above and gives flexibility in terms of the balcony size and its potential disassembly. On the other hand, these balconies have a bigger visual impact on elevation in comparison to the light cantilevered ones, which may be troublesome in the case of heritage buildings. Additionally, balconies on external structures give rise to another problem. The tenements' plot border at the courtyard side is usually aligned with the backyard elevation. Thus, in such a solution, the additional external structure needs to be situated outside of the tenement's plot. Most of the tenements' courtyards belong to the municipality administratively (Fig. 6). For this reason, adding a balcony would require additional collaboration with authorities, in the form of for example, signing agreements about leases for using external area.

Monument preservation requirements regarding balcony addition

Many tenements are heritage buildings protected by *Ustawa z dnia 23 lipca 2003 r. o ochronie zabytków i opiece nad zabytkami* [The Monument Protection Act] [21]. In Poland, there are two types of protection: the first one, registering the monument in the national monuments list governed by the Voivodeship Monument Conservaton Officer, and the second one, is the register of architectural monuments, managed by the municipality or voivodeship, depending on the monument's rank. The Monument register entry contains the definition of the buildings' value and protected elements. However, the protection guidance does not constitute an ultimate decision but rather should function as a starting point of negotiations between an owner and a conservator [22]. Thus, the guidance shapes the overall approach to protection, nevertheless, more detailed decisions are determined during the modernization process. Therefore, adding a balcony requires consent from the relevant monument conservator and consultancy regarding its shape. As appropriate, the balcony form varies depending on monument's characteristics, building's materials, context, and local conservation practice. For instance, Copenhagen authorities decided on cantilevered balconies, which have a lighter visual impact on brick elevation outlook. In the case of Chemnitz, where inner courtyard elevations are insulated, the external structures are more useful.

Methodology

The study is based on three research methods. The first is a desktop study of the relevant regulations defining spatial requirements preventing a building from overshadowing adjacent buildings along with articles referring to indoor daylight analysis, focused in identification of different typologies of irregular building lines of tenements' backyards elevations, where adding a balcony could be challenging due to overshadowing prevention regulations. The third one is computer simulation, aiming to calculate Daylight Factor and illuminance of tenements' apartments rooms with varied scenarios in terms of balcony sizes and balustrades.

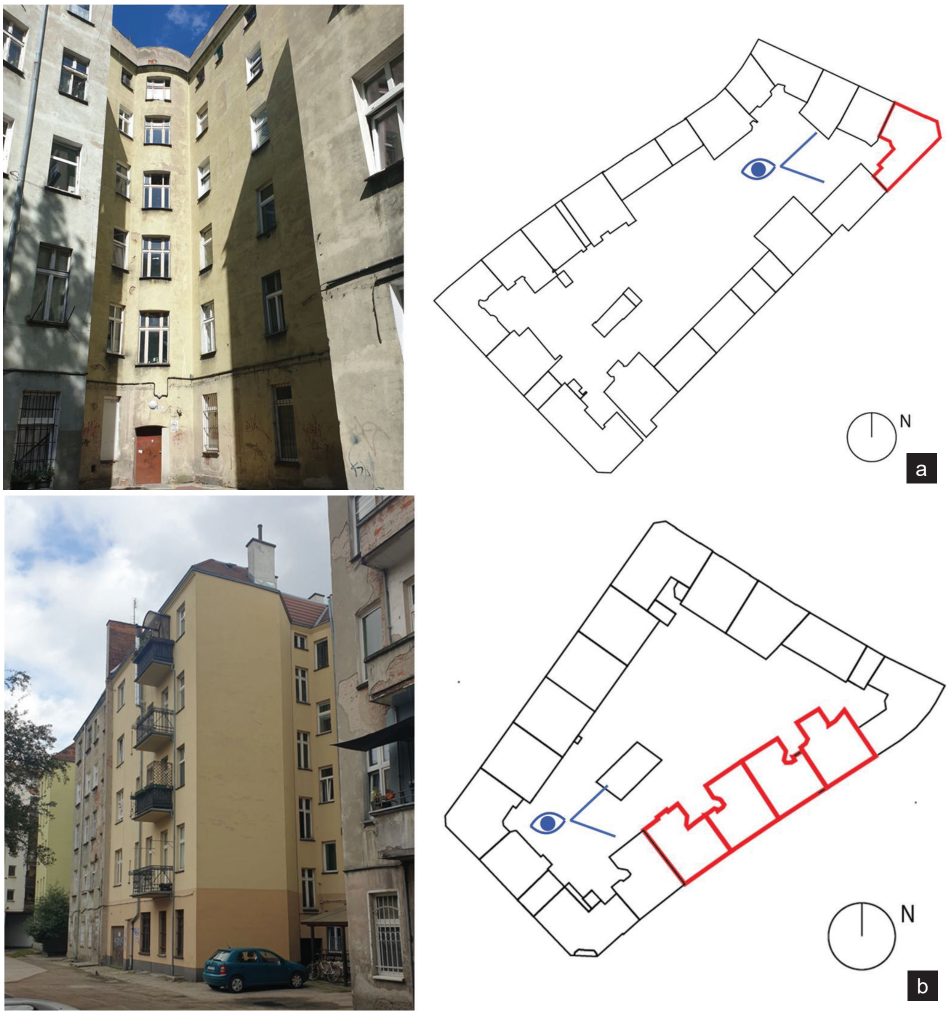


Fig. 3. Examples of Wrocław tenements quarters' interiors with an irregular building line: a) corners with adjacent buildings create an air shaft (E. Stein, Nowowiejska Street's corner) b) outbuildings' which create inner courtyard urban interior within all the quarter tenements' common courtyard (Barlickiego, Kluczborska, Nowowiejska, Żeromskiego Streets' quarter) (photos and plans by M. Smektała)

Il. 3. Przykłady wrocławskich wnętrz kwartałów kamienic z nieregularną linią zabudowy: a) narożnikowe i sąsiadujące kamienice tworzą wąskie studnie (narożnik ul. E. Stein i Nowowiejskiej), b) dobudowania, które tworzą małe wnętrza urbanistyczne na podwórku wspólnym dla wszystkich kamienic w kwartale (ul. Barlickiego, Kluczborska, Nowowiejska, Żeromskiego) (fot. i plany M. Smektała)

Desktop study

The relevant Polish legal requirements for building's obscuration, insolation and shading are defined within Technical conditions for buildings and their location [23]. These requirements also define the spatial conditions for new additions to existing buildings. Also, the relevant legal articles about indoor daylight measurement methods questioning the efficiency of Polish insolation requirements were reviewed. These articles served as an inspiration to introduce alternative daylight measurements, which fulfil the Polish requirements and assist in investigating how the balcony addition may impact indoor daylight.

Urban analysis

An urban analysis were prepared based on Wrocław geoportal urban plans, marking the irregularities in inner-courtyard building line of quarters containing the tenements from the turn of the 19th and 20th and 1st half of the 20th centuries from Nadodrze, Ołbin and Przedmieście Oławskie district (Fig. 7). The irregularities were grouped in order to find the similar patterns. Later the analysis was fulfilled with fieldwork observation of 39 quarters from Ołbin and Nadodrze districts visited in June–August 2022. Photographic survey and notes with schematic plan drawings were made with marks indicating the elevations with windows and without and building entrances from the inner courtyard. Based on these analyses, main irregularities' typologies were distinguished. Next, the typologies were used as a foundation for screening analysis. As follows, the average tenements' height was assumed as 22 m on the basis of Wrocław geoportal information and average first storey window sill height as 1.5 m from fieldwork data. These assumptions helped to define the average screening building height as 20.5 m. Next, the feasibility study of required space for balcony addition in relation to obscuring regulations was conducted.

Computer simulations

For daylight computer simulations a simplified model of 6-storey (22 m height) tenement house was prepared based on review of tenements' floor and section plans found on an internet database with archived buildings photographs from Wrocław. Two rooms (5.8 m × 2.2 m and 5.8 m × 3.5 m), which represent a typical indoor space arrangement situated at backyard elevation were modelled at each storey with height of 3.2 m and 2.5 m at the last storey. The openings for windows equal 1 m × 2.1 m and for balcony doors 1 m × 2.7 m. Each opening is glazed with a triple glazed panel with *U*-value = 0.84,

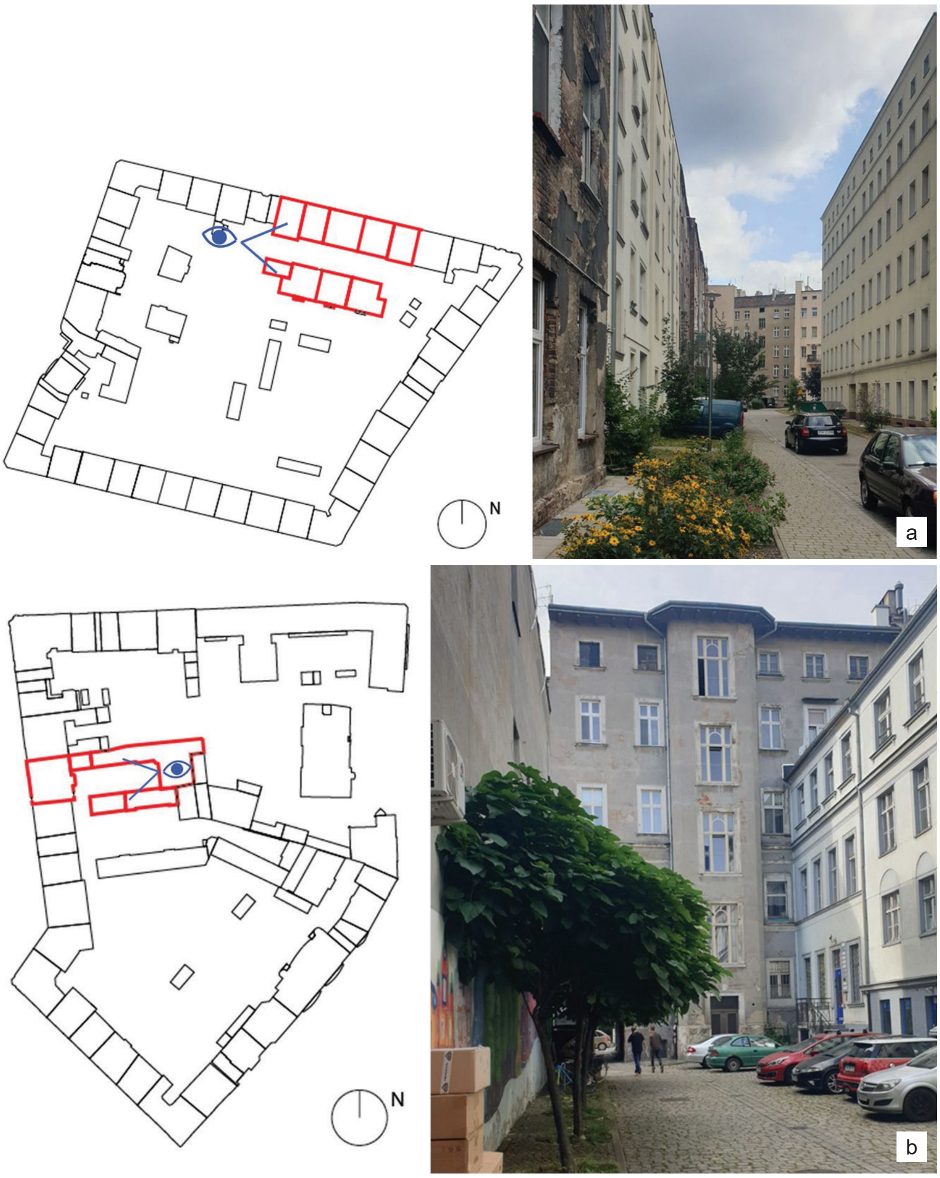


Fig. 4. Examples of Wrocław tenements quarters' interiors with an irregular building line: a) protruding elevations, which create irregular building line in the courtyard, (Jedności Narodowej, Kluczborska, Żeromskiego, Oleśnicka Streets' quarter) b) additional buildings within the courtyard situated in a close distance from inner-courtyard elevations, limited open space directly in front of the building (św. Maciej square and Henryka Pobożnego, Henryka Probusa Streets' quarter) (photos and plans by M. Smektała)

Il. 4. Przykłady wrocławskich wnętrz kwartałów kamienic z nieregularną linią zabudowy: a) wystające części elewacji, które tworzą nieregularną linię zabudowy wewnątrz kwartału (ul. Jedności Narodowej, Kluczborska, Żeromskiego, Oleśnicka), b) dodatkowe zabudowania na podwórku zlokalizowane w bliskiej odległości od wewnątrz kwartałowej elewacji; ograniczenie otwartej przestrzeni bezpośrednio przed budynkiem (kwartał przy pl. św. Macieja i ul. Henryka Pobożnego, Henryka Probusa) (fot. i plany M. Smektała)

which meet current energy efficiency requirements for new houses and assumed transmittance *TVIS* = 0.713 with 0.1 m frames and divided lites from 0.06 to 0.1 m. This assumption about the openings serves to investigate how the daylight would function after thermal modernization. The internal walls are spread with white paint with 83% reflectance and external walls with beige plaster of 78% reflectance. 3 balcony sizes were modelled (6 m × 1.5 m, 6 m × 2 m, 6 m × 2.5 m) with 3 options for balustrades (clear glass with *TVIS* = 0.88; opaque with 78% reflectance and with low transmittance glass *TVIS* = 0.158) and with option for screens placed from both sides of balcony 1.5 m wide. The simulations were conducted in Rhino architectural modelling software with Climate Studio plug for simulative analysis. The sensors were located every 0.3 m and 0.85 m above the floor surface (working plane) at the lowest storey, as the worst case scenario for daylighting. First, the Daylight Factor simulation was conducted for a tenement without balconies and with added balconies with different sizes and balustrades. Next, the illuminance simulation with option "Custom" considering Wrocław localization and different rooms' orientations (North, West, East, South) presenting the average daylight illuminance in lux was conducted to fulfil the information from Daylight Factor. The simulation served for indication of add-on balconies' impact on indoor daylighting.

Results

Desktop study

Polish technical regulations for building location and required sun exposure

According to the Polish building law, no part of a building should breach the space within the 60 degrees angle placed on a horizontal plane with the apex situated in the middle of the window axis starting from the internal wall plane (Fig. 8). The length of the arms of the angle depends on screening building height, which is counted from the bottom edge of the lowest situated windows on the elevation to the highest edge of the screening building. Nevertheless, in the inner city build-up area, it is allowed to

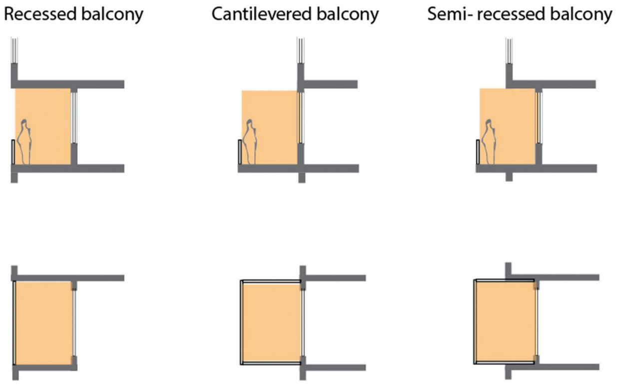


Fig. 5. Balcony's typologies (drawings by M. Smektała)

Il. 5. Typy balkonów (rys. M. Smektała)

Fig. 6. Map presenting the types of plots' ownership in Wrocław. The interiors of the quarters marked in yellow, orange and beige belong to Wrocław municipality (source: Wrocław Spatial Information System, [20])

Il. 6. Mapa własności gruntów we Wrocławiu. Wnętrza kwartałów oznaczone kolorem żółtym, pomarańczowym i beżowym należą do gminy Wrocław (źródło: System Informacji Przestrzennej Wrocławia, [20])

be shortened by half. Apart from it, placing an obscuring object at a distance of not less than 10 m from the window of the obscured room, such as a mast, chimney, tower or other building, without limiting its height, but with an obscuring width of not more than 3 m, measured parallel to the plane of the window is allowed [23] (Fig. 8).

Another rule requires direct insolation of at least one room in the dwelling for at least 3 h between 7 a.m. to 5 p.m. at the day of March and September equinox and the ratio of the plane passing the daylight within the window frame to floor area should be at least 1:8. However, the insolation time for dwellings situated in the inner city build-up area is only 1.5 h and in case of one room apartments the rule is not required [23].

Daylight Factor and illuminance calculation – missing themes in Polish regulations

The Polish regulations for indoor daylight consider the insolation only geometrically, disregarding other influencing factors' such as the window's glass transmittance, protruding elements shading the window. Apart from it, the regulations do not consider the fact that most of the room's daylight comes from reflection. The rules were defined when the low *U*-value factor of buildings' openings was not required and most of the windows were single glazed. Currently used triple or double glazed windows limit significantly the daylight transmittance. European countries regarding daylight regulation use the ratio of glazed area to floor area with duration of sunlight in rooms as in Poland or Slovakia or Daylight Factor. *DF* is described as a percent share of indoor to outdoor daylight, calculated with sky overcast (10 000 lx) on the 22th March at 0.85 m height from the floor surface.

$$DF = \frac{Ei}{Ee} \cdot 100\%,$$

where:

Ei – indoor light intensity at point of a working plane [lx],

Ee – outdoor light intensity at horizontal plane from the entire hemisphere.

According to Danish building requirements, the apartments' rooms intended for living and kitchens the *DF* should be equal or more than 2% at more than half of the room's floor area (200 lx). The *DF* presents the lowest possible daylight intensity in reality. Providing simulation with this method allows to indicate how balcony addition diminishes indoor daylight. However, it disregards the room's solar orientation and building's localization [24]. For this reason the *DF* calculation can be completed with average illuminance calculation expressed in lux. According to John Mardaljevic the most "desirable or at least tolerable" illuminance ranges from 300 to around 3000 lx, and significantly reduces the electric lighting usage [25], [26]. Since the daylight illuminance divers in rooms of different solar orientation, in case of north elevation the balcony addition may cause daylight underexposure (below 300 lx) or prevent from unwelcome glare effect at south orientation (over 3000 lx). Lack of considering described above daylight measurement methods in Polish regulations may cause the design to be inefficient and inhibit a more flexible approach to architectural solutions.

Urban analysis

The irregularities types in building line of tenements' backyard elevation. Spacious courtyards of Wrocław tenements provide a lot of potential possibilities for balcony addition. However, the irregular courtyard building line, especially in the corner wells, causes that there are spots in tenements' courtyards, where balconies cannot be added straightforwardly, due to lack of space and causing a risk of obscuration and overshadowing the neighbouring buildings. Based on urban plan analysis and fieldwork observation 4 types of irregularities, where balcony addition is limited were distinguished: corners creating air shaft, outbuildings creating inner courtyard urban interior, protruding elevations creating irregular building line in the courtyard and facing building in a close distance (Table 1).

The minimum space required for balcony addition.

For typologies described in previous paragraph the feasibility studies were conducted regarding the requirements about obscuring buildings to investigate the potentiality of

Fig. 7. An extract of urban analysis based on plans available to SIP – Wrocław Spatial Information System (source: [20])

Il. 7. Fragment analiz urbanistycznych na podstawie planów dostępnych w Systemie Informacji Przestrzennej Wrocławia (źródło: [20])

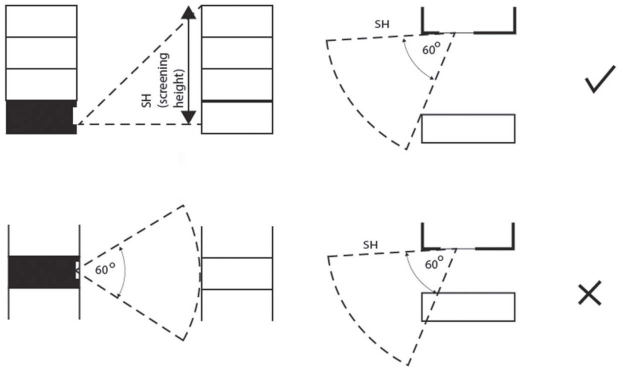


Fig. 8. Scheme explaining the regulation of building obscuration (drawing by M. Smektała)

Il. 8. Schemat wyjaśniający przepis dotyczący przesłaniania budynku (rys. M. Smektała)

Table 1. A schedule of irregular building line in tenements' courtayrds (elaborated by M. Smektała)
Tabela 1. Zestawienie typologii nieregularnej linii zabudowy wewnątrz kwartałów kamienic (oprac. M. Smektała)

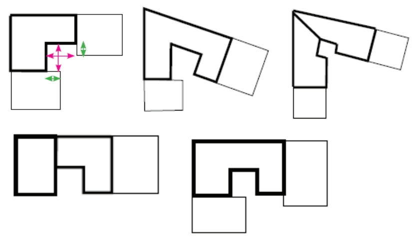
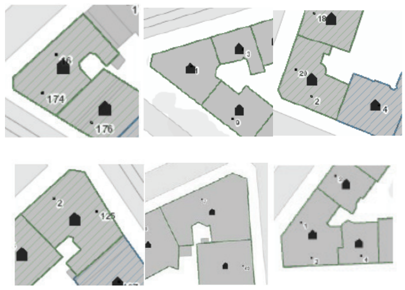
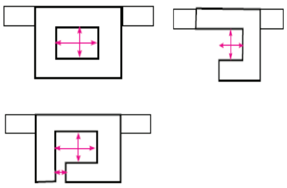
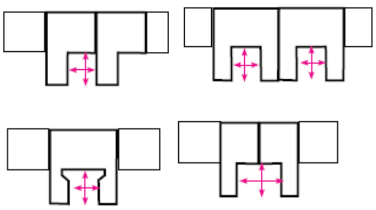
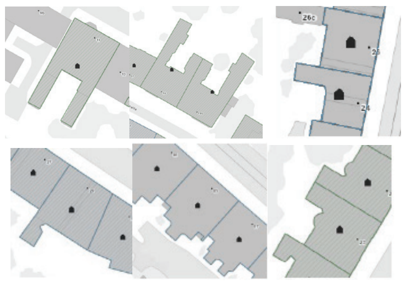
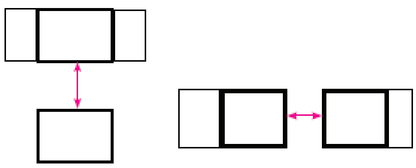
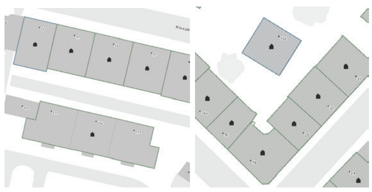
Typology name	Typology's schemes	Typology's examples from urban plan [geoportal Wrocław]
Corners creating air shaft		
Outbuildings elevations creating inner courtyard urban interior		
Protruding elevations creating irregular building line in the courtyard		
Facing building in a close distance		

Table 2. A schedule presenting minimal distances between the buildings to add balconies, depending on irregularity's typology (elaborated by M. Smektała)
Tabela 2. Zestawienie minimalnych odległości między budynkami do spełnienia w przypadku dodania balkonów w zależności od typologii nieregularności (oprac. M. Smektała)

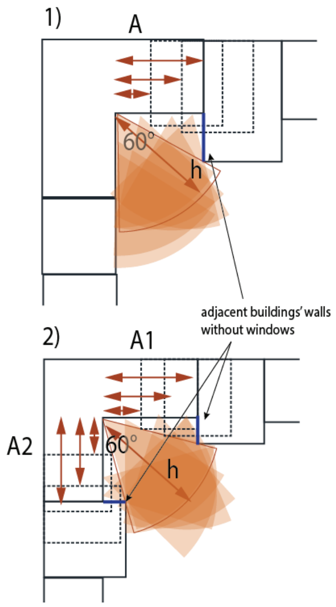
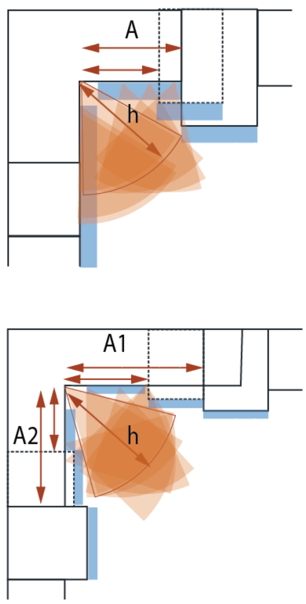
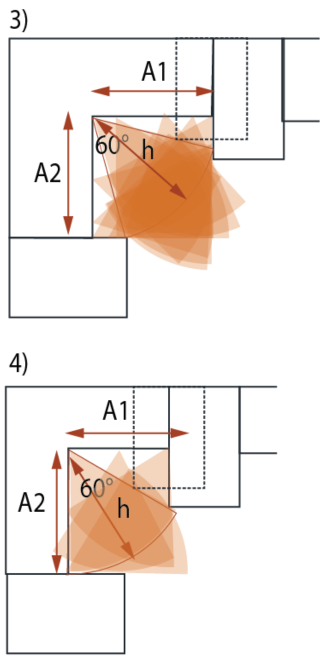
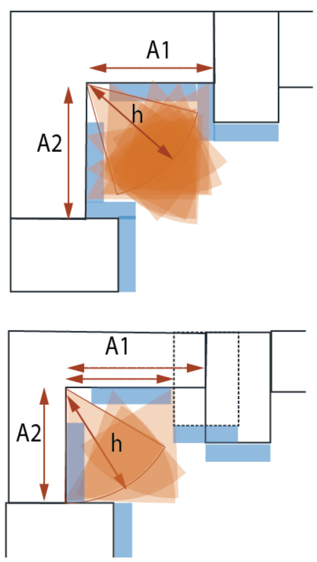
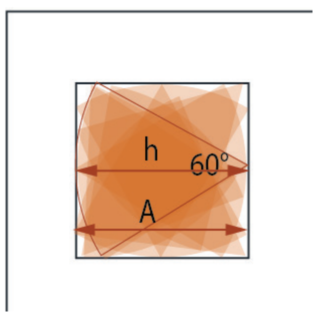
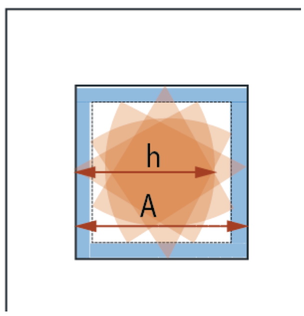
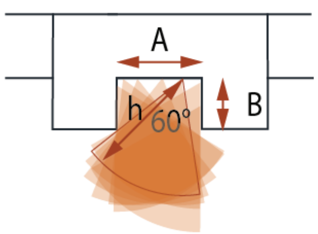
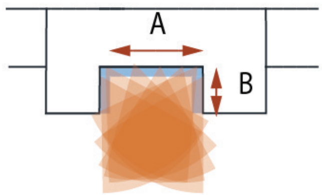
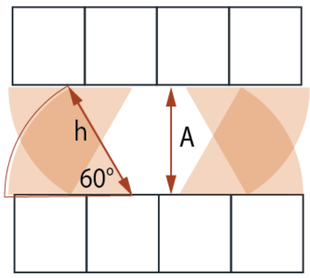
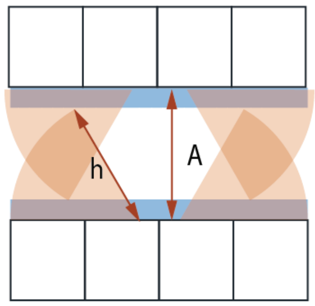
Typology name	Scheme without balconies	Scheme with balconies	Minimimun required distance between the elevations (A)
Corners creating air shaft Adjacent buildings' walls without windows (prevalent case)			There are many variables influencing the distance e.g. windows' positions, if there are protruding elevations from both (2, 3, 4) or one side (1), if adjacent building walls of protruding building have windows (1, 2) or do not (3, 4). The safest assumption is maintaining distance between the elevations of screening building height (*h* = 20.5 m) + balcony depth. However, if one of the protruding elevations is situated in this minimum required distance of screening building height (4), the second one can be in a closer distance, but it cannot breach the space of the plane of 60 degrees angle with apex situated in the corner and one of the angles' arms places along the elevation (1, 4, marked with dotted lines). If both adjacent buildings have protruding elevations situated in a closer distance than screening building height (2, 3, marked with dotted lines), then the both adjacent buildings cannot breach the space of an angle 60 degree
Corners creating air shaft Adjacent buildings' walls with windows			
Outbuildings creating inner courtyard urban interior			*A* = screening building height (*h* = 20.5 m) + the sum of 2 balconies' depths if balcony perimeters the elevation

Table 2 cont. A schedule presenting minimal distances between the buildings to add balconies, depending on irregularity's typology (elaborated by M. Smektała)
Tabela 2 cd. Zestawienie minimalnych odległości między budynkami do spełnienia w przypadku dodania balkonów w zależności od typologii nieregularności (oprac. M. Smektała)

Protruding elevation creating irregular building line in the courtyard			In cases were A < screening building height (h = 20.5 m), the ratio A + balcony depth to B should be more than 2 (A + balcony depth)/$B \geq 2$
Facing building in a close distance			A = screening building height (h = 20.5 m) × ($\sqrt{3}$)/2 + balcony depth A = 17.75 m + balcony depth

adding balcony in these precarious spots. The Table 2 presents the results of the study, indicating the minimal distances for buildings situated in these irregular spots outlining an overall space requirement. The guidance is simplified since there are many variables influencing the distance such as: windows' positions, if there are windows in adjacent buildings. Especially in cases of the corners creating an air shaft, it is difficult to propose a straightforward assumption, and in reality each case requires an individual proceeding. The guideline was considering the full screening building height as a minimum distance instead of half of this height, as it is allowed for inner-city areas. Thus in reality the distance can be twice smaller, however this assumption was refused because of underexposure of rooms. Many tenements' courtyard corners create very narrow air shafts, which without adding balconies, do not meet current requirements about the building localization. Nevertheless, apart from courtyards' corners, there are many spots in Wrocław tenements courtyards, which have a distance of screening height (in this study assumed as 20.5 m plus balcony depth), where balconies can be easily added.

Daylight simulations

The Daylight Factor

Besides the feasibility studies, the daylight simulation analysis was conducted to investigate how the balcony may potentially shade the interior of the tenement. The Table 3 presents the simulation results for 3 balcony sizes (6 m × 1.5 m, 6 m × 2 m, 6 m × 2.5 m) with different balustrade types: clear glass, reflecting glass with law transmittance and opaque panel, and with option of adding screens at both sides of opaque and reflecting glass balustrades. First of all, the Daylight Factor simulation for a current state without a balcony with triple glazed windows, presents a significant daylight difference between the rooms. In the smaller room the proportions of windows' opening to floor area equal approx. 1:6.25, whereas in the bigger 1:5. In this case almost half of a bigger room has $DF \geq 2\%$, which is in accordance with Danish indoor daylight requirements for living spaces, whereas the smaller room has approximately 1/3 floor area with $DF \geq 2\%$. Added balconies consequently diminishes this area. It is especially noticed in bigger rooms, where the area above 2% DF shrinks from 1/2 to 1/3 or 1/4 of the room surface. Balcony depth and screens impact more significantly the daylight than balustrade materials. However, high ceilings and windows cause that the daylight still reaches the back wall of the rooms (Table 4).

Illuminance

Since the DF does not consider the building localization and solar orientation, the illuminance simulation was conducted. The simulation presenting the average lux levels on the areas allows to indicate the underexposed (below 300 lx) and overlit (above 3000 lx) spaces. In this simulation only one case of a balcony with screens and balustrades of high reflective glass was considered since the most influencing daylight elements are the sizes of balconies. This balustrade type presents the average daylight impact regarding the balcony materiality. The Table 4 demonstrates the simulation results for rooms exposed to North, South, West, East solar orientation with 3 balcony sizes and current state without a balcony. The average illuminance varies significantly depending on the solar

Table 3. Schedule with Daylight Factor simulation results (elaborated by M. Smektała in Climate Studio software)
Tabela 3. Zestawienie wyników symulacji Daylight Factor (oprac. M. Smektała przy wykorzystaniu Climate Studio software)

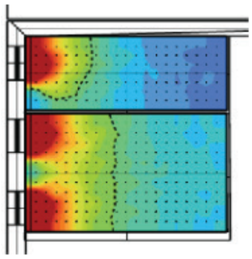
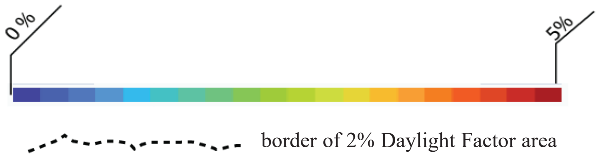
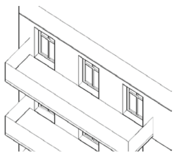
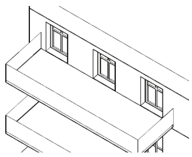
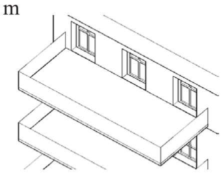
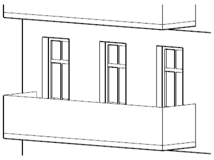
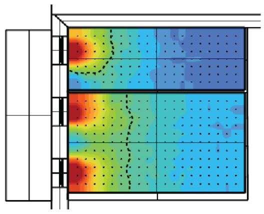
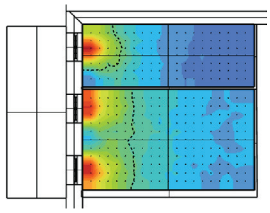
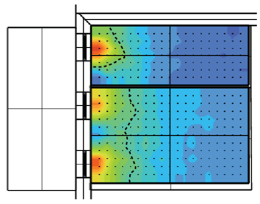
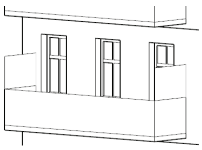
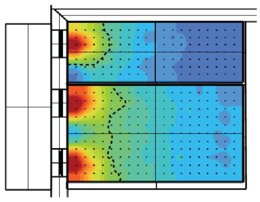
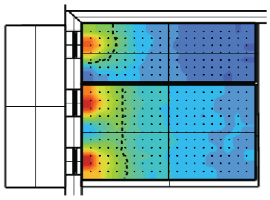
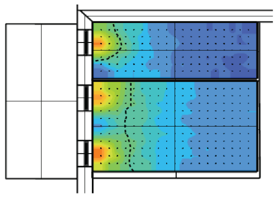
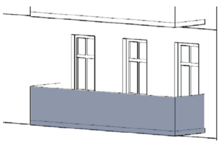
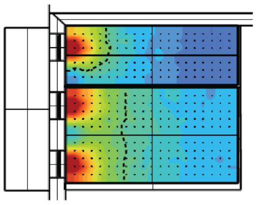
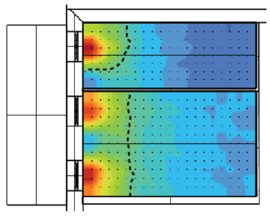
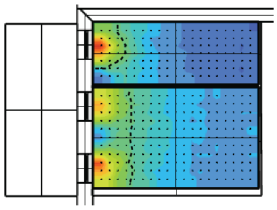
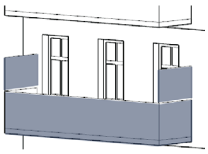
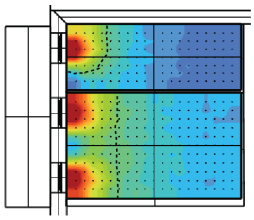
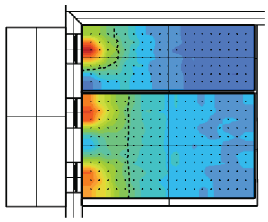
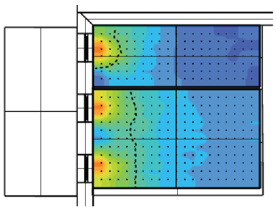
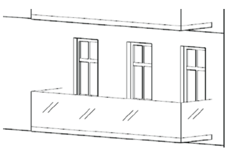
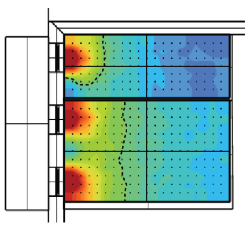
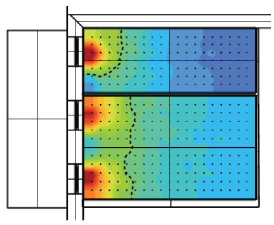
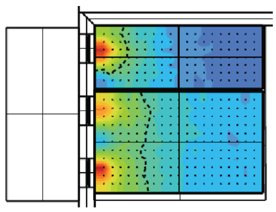
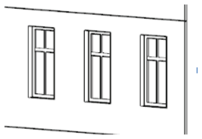
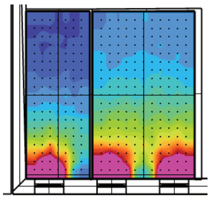
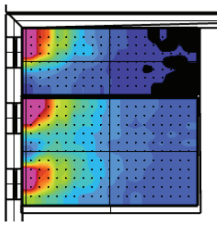
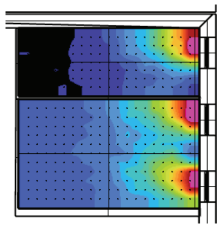
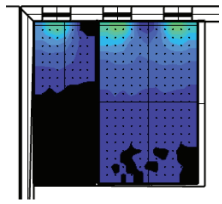
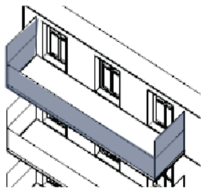
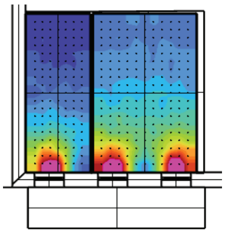
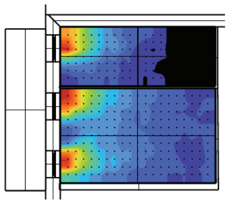
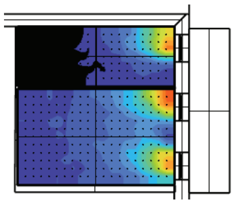
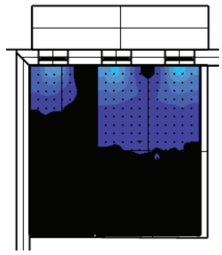
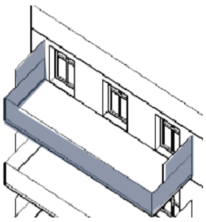
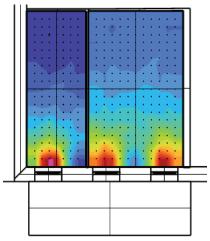
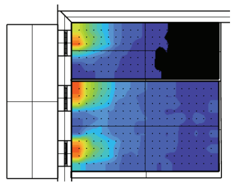
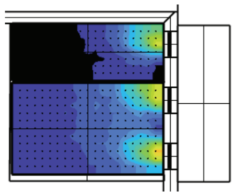
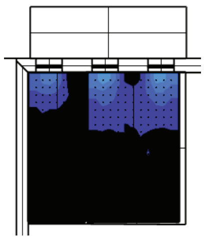
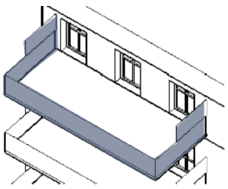
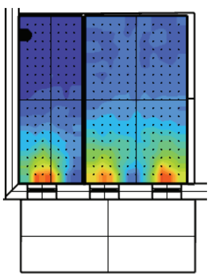
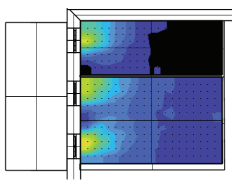
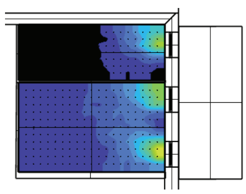
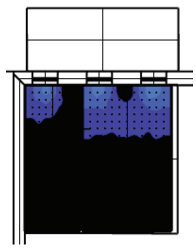
Current state without balcony, window openings equal 1 m × 2.1 m 		Legend: 	
Materials\Size door openings equal 1 m × 2.6 m	1.5 m × 6 m 	2.0 m × 6 m 	2.5 m × 6 m 
Opaque balustrade 			
Opaque balustrade with screens 			
Balustrade with reflective glass 			
Balustrade with reflective glass and screens 			
Clear glass balustrade 			

Table 4. Schedule with illuminance simulation results (elaborated by M. Smektała in Climate Studio software)
Tabela 4. Zestawienie wyników symulacji natężenia światła (oprac. M. Smektała przy wykorzystaniu Climate Studio software)

Legend				
	South	West	East	North
Current state without balcony 				
1.5 m × 6 m, balustrade with reflective glass and screens 				
2.0 m × 6 m, balustrade with reflective glass and screens 				
2.5 m × 6 m, balustrade with reflective glass and screens 				

orientation. The smaller room at the North elevation even without a balcony is underexposed on the half of the working plane area, whereas adding a balcony makes 1/4 of the smaller and 1/2 of a big room underexposed (black area on the graphs). There are also underexposed areas in a small room without a balcony on the West and East elevation, which reveals that the ratio window opening to floor area 1:8 is insufficient. In other cases balcony can be added without a fear of overshadowing the interior. What's more, it may limit the glare effect (pink area on the graphs) (Table 4).

Discussion

The aim of building codes is to ensure the safety, functionality, and sustainability of constructed buildings. The requirements regarding insolation and building obscuration are part of the rules which preserve dwellers' right for living in a healthy house with proper ventilation and lighting. The impact of an access to a private outdoors space such as balcony, loggia, terrace, private garden on dwellers' wellbeing and housing condition has been proved scientifically [9], [10]. Nevertheless, equipping an apartment with a balcony is not required within building regulations [23]. The need of adding a balcony to existing housing buildings is recognized and practised during retrofitting modernization in particular countries such as Germany, Denmark, Austria [15]. However, regarding the heritage housing there is a fear that balcony addition is not compatible with historical urban tissue, or may destroy façade ornaments. Besides, the balcony may deteriorate the living condition by lowering the interior daylight [27]. Polish building codes for buildings in the inner-city build-up area allows twice shorter distance between the buildings, and insolation time than in other areas [23]. Many historical houses facing the backyard were built disregarding the need for proper daylight. Low technical requirements and strict preservation guidelines may cause tenements to be doomed to poor daylight conditions [24], [28]. The study reveals that there are many tenements' backyards elevations, where balconies can be straightforwardly added. Nevertheless, the courtyard inner-corners remain questionable to this idea and require individual proceeding whether the balcony addition is possible and what measures should be taken to upgrade these apartments.

The daylight simulation may contribute to guidelines, considering the factors, which lack in Polish requirements. The study reveals that Polish regulations about insolation, shading and obscuring the buildings do not sufficiently preserve the indoor from overshadowing [27]. The rooms exposed to North elevation and the smaller rooms exposed to West and East are underexposed, even without adding a balcony. However, in such a case widening a window opening could improve the indoor daylight. In other cases the balcony addition may prevent the indoor from overheating and glare effect. Thus, the balcony can enhance the housing adaptability to changing seasons [7], [9]. Nevertheless, the illuminance analysis shows only an average amount, which fluctuates during the seasons. Thus, it is worthy to reflect on how the balcony design and elevation in tenements can respond to different demands depending on seasons. The feasibility study and simulation confirms that it is difficult to provide unambiguous rules in challenging spatial situations such as tenements' courtyards' inner corners. Such places require an individual approach.

Conclusions

This study examined the spatial possibility for adding balcony to tenements' backyard elevation considering Polish requirements about obscuration of the buildings and balcony addition impact on indoor daylight. The spacious tenements' courtyards in Wrocław have an untapped potential for such an intervention. Nevertheless, there are spots, which require an insightful look, since irregular building lines complicates the balcony addition. The guidelines presented above indicate simplified patterns for minimum distance requirements depending on irregularity typology. Many inner-quarter elevations have enough space for balcony extension. However, there are spots in the tenements courtyards, especially in their corner's parts where adjacent buildings are in too close distance and do not meet current daylight requirements. The daylight simulation has revealed that regarding the south, west and east elevation, the balcony addition does not reduces the illuminance below recommendable level of 300 lux. Additionally, it can limit the glare effect in areas above 3000 lux, and consequently overheating. Rooms with North orientation are underexposed without balcony addition. In this case widening the window openings could be considered to improve the indoor daylight.

The Polish requirements about building obscuration, shadowing and insolation are not efficient in indoor daylight preservation. For this reason, it is recommended to assist the design with daylight simulation indicating the underexposed and overlit spaces. The irregularity of inner-courtyards building line, different solar exposure, cause that adding a balcony requires an individual approach, and simulation analysis may assist the design.

The importance of possessing an access to private space was a starting point for discussion of providing balcony extensions to inner-courtyard elevations. However, the study reveals that the balconies can play a role of an adaptive element to climate seasons, preventing overheating and glare. Nonetheless, to explore this potential of adaptability further research needs to be conducted about Polish insolation requirements and providing proper balconies design features regarding factors influencing indoor daylight in different seasons.

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Abstract

Exploring the potential for balcony addition to tenements' backyard elevation in Wrocław – spatial challenges related to shade and indoor daylight illumination

The expected intensification of thermal modernizations due to the European Union requirements related to the reduction of CO_2 emissions is a chance to reflect on potentiality of adaptation apartments in tenements to the current users' needs and expectations. One of the elements improving living quality is a properly designed access to private outdoor space such as balconies. Urban typology potentially allows extending tenements' backyard elevations with balconies. Nevertheless, these actions are not taken due to numerous limitations, i.a. because of an irregular elevations' building line inside the quarters. The research aims to indicate the spatial conditions that would allow adding balconies to backyard elevations within the context of Polish technical regulations. The article focuses on regulations regarding obscuring and overshadowing the building and the impact of balconies' additions on apartments' indoor daylight. The research was conducted based on following methods: the desktop study of relevant regulations about minimal distances regarding obscuring and overshadowing the buildings, urban analysis presenting the typologies of inner-quarter elevation building line and daylight simulations of Daylight Factor and illuminance unveiling the balcony addition's impact on interior daylight were conducted to reply these questions. The results are schedules of situations in tenements' courtyards, where an addition would be difficult or impossible indicating minimal distances requirements and of balconies' impact on indoor daylight depending on their forms and solar orientations. The study demonstrates that the Polish requirements are insufficient tool for indoor daylight preservation. The simulations conducted on the cases demonstrate that adding a balcony to the South, West and East elevations the illuminance does not lower the interior daylight below 300 lux, what is considered as a minimum level. What's more, balcony may reduce daylight illuminance, where it exceeds 3000 lux and may cause an unwelcome glare effect. However, further research is necessary to investigate the Polish insolation regulations and proper add-on balcony design as an element enhancing apartment adaptability to different climate seasons.

Key words: balcon, indoor daylight, heritage housing adaptation

Streszczenie

Badanie możliwości dodania balkonów do wewnątrz kwartałowej elewacji kamienic we Wrocławiu – wyzwania przestrzenne związane z przesłanianiem i doświetleniem wnętrza

Spodziewana intensyfikacja termomodernizacji wynikająca z wymogów Unii Europejskiej dotyczących ograniczenia emisji CO_2 jest okazją do podjęcia refleksji nad potencjałem dostosowania lokali mieszkalnych w kamienicach do aktualnych potrzeb i oczekiwań użytkowników. Jednym z elementów architektonicznych wpływających pozytywnie na jakość przestrzeni mieszkalnej jest dostęp do dobrze zaprojektowanej prywatnej przestrzeni zewnętrznej takiej jak np. balkon. Kwartałowa zabudowa kamienic potencjalnie umożliwia dostawienie zewnętrznych balkonów do tylnych elewacji. Niemniej działania takie nie są podejmowane ze względu na liczne ograniczenia m.in. przestrzenne związane z nieregularną linią zabudowy wnętrz kwartałów. Celem badania jest wskazanie, na przykładzie Wrocławia, jakie warunki przestrzenne muszą być spełnione, aby umożliwić dostawienie balkonów do podwórkowej elewacji kamienic w ramach polskich przepisów prawa budowlanego. W artykule skupiono się na przepisach dotyczących przesłaniania i zacieniania budynków oraz na wpływie dostawienia balkonów na doświetlenie mieszkań światłem dziennym. Badania przeprowadzono na podstawie analizy warunków technicznych pod względem minimalnych odległości wynikających z zacieniania i przesłaniania budynków, analiz urbanistycznych systematyzujących typologię linii zabudowy elewacji kamienic wewnątrz kwartału oraz komputerowych symulacji pomiaru Daylight Factor i natężenia światła dziennego pokazujących wpływ dostawienia balkonu na zacienianie mieszkania. Rezultatem jest zestawienie typologii sytuacji w kwartałach kamienic, gdzie dobudowanie byłoby utrudnione lub niemożliwe, ze wskazaniem wymaganych minimalnych odległości, oraz przedstawienie wpływu dostawienia balkonu na doświetlenie mieszkania w zależności od kierunków świata i formy balkonu. Badania potwierdzają, że polskie warunki techniczne nie są wystarczającym narzędziem do zapewnienia odpowiedniego poziomu światła dziennego. Symulacje przeprowadzone na przykładach wykazały, że dodanie balkonu do południowej, zachodniej i wschodniej elewacji nie zaniża średniego poziomu natężenia światła poniżej poziomu 300 luksów, który jest uważany za minimalny. Ponadto balkon może niwelować poziom natężenia światła powyżej 3000 luksów, który może wywołać niechciany efekt olśnienia. Wymagana jest dalsza analiza biorąca pod uwagę polskie wymogi nasłonecznienia oraz badania mające na celu określenie odpowiedniego projektu balkonów, który wspomoże adaptację mieszkań do pór roku.

Słowa kluczowe: balkon, światło dzienne, adaptacja zabytkowej architektury