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Daylight Design for Urban Residential Planning in Poland in Regulations and in A Practice. A Comparison Study of Daylight Conditions Observed in the Four Neighbouring Residential Areas

Natalia Sokol [1], Justyna Martyniuk-Peczek [1]

[1] Gdansk University of Technology, Faculty of Architecture, Department of Urban Design and Regional Planning, Narutowicza 11/12, 80-233 Gdansk, Poland

natalia.sokol@pg.edu.pl

Abstract. This paper reports on the partial results of the research aiming to illustrate how an integration of daylight design into an architectural planning process can help designers to create the residential buildings in respect to the environmental issues, solar and illuminance gains, as well as, the residents' needs and comfort. It describes how changing daylight recommendations affected the design of the block of flats regarding their orientation, the spacing, the forms, and the size of the windows in the four urban residential areas. The results of this study help to determine more precise characterization of daylight indicators useful in architectural planning.

1. Introduction

Daylight is named as an essential aspect of home [1] and an integrated part of the architectural planning. The design of daylight is crucial in the residential architecture and it influences the residents' visual performance, comfort and health. The perception of daylight variability and contrast contributes to an aesthetic appreciation of the spaces [2]. The quality and quantity of daylight within residential interiors depend on the several internal and external factors (figure 1). A control of daylight within the residential environment can be done in many ways but the major ones are through a control of the build form and through a control of the daylight performance inside the buildings [3]. The questions often asked during the building design process are: how much light is sufficient for humans for the optimal visual, biophysical and psychological performance and how to provide the optimal quantity of a superior quality daylight within the residential environment [4].

The sets of rules that specify the recommended design solutions and the target values of daylight performance through the different daylight indicators are partly explained in the national building and lighting standards. These documents should provide guidelines for the designers to the questions mentioned above. However, the latest Polish building daylight standard PN-71/B-02380 was withdrawn in 2005 [5]. The current Polish daylight recommendations, referring to the sunlight provision, spacing, overshadowing and the window-to-floor area ratio (WFR), included in the national building standards, seems to be very limited (Table 1). To illustrate an impact of the changing daylight recommendations on the design of the residential dwellings, an excerpt from the comparison study of the daylight conditions in the four neighbouring residential areas built in different time periods is presented in this paper.

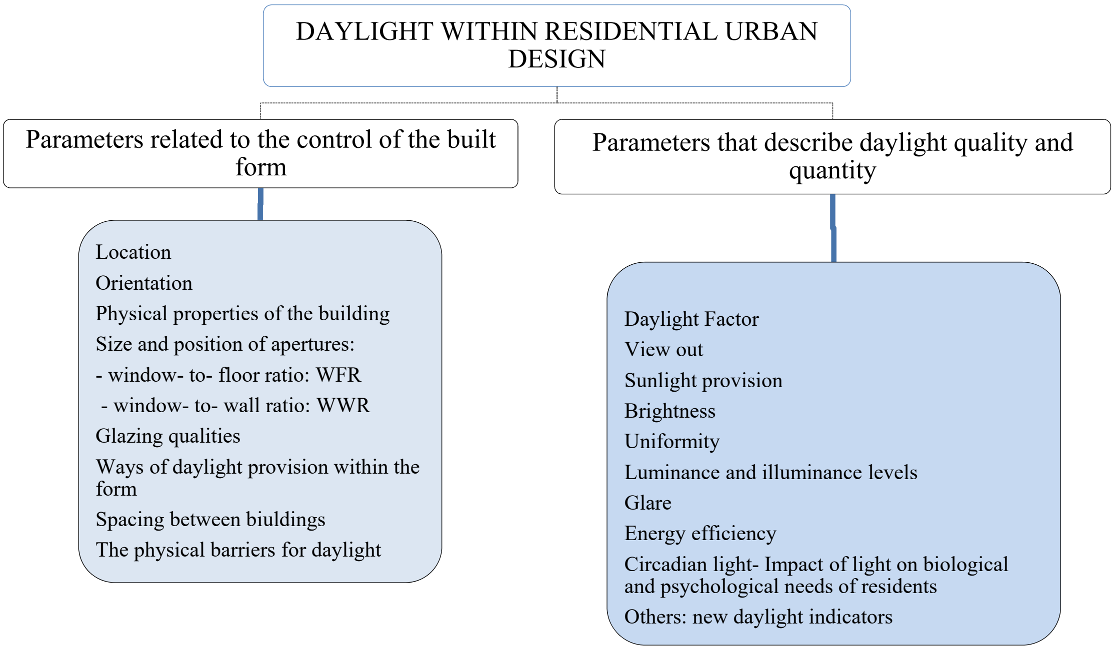

Figure 1. A set of aspects linked to daylight control in the residential design.

2. Background of the study

2.1. Daylight in the Polish recommendations

The national documents regulating daylight design in the buildings can be divided into four major categories: daylight and building standards, laws, guidance documents and a various kind of national or regional approved documents [3]. Due to a progress in photometry and the computer aided design tools, the ways and the parameters describing daylight performance keep changing, which is reflected in European daylight recommendations [6]–[9]. The Comité Européen de Normalisation (CEN) Technical Committee: CEN/TC 169/WG 11 is currently working on a revised version of the new European daylight standard EN 17037 *Daylight of buildings* [7], which contains recommendations for daylight and sunlight provision, target daylight factor values, recommendations for the view, glare protection and procedures of the suggested calculations of the chosen daylight indicators.

The new European standard is awaited in Poland, where it could replace the latest withdrawn building daylight standard PN-71/B-02380 *Natural Interior Daylighting Code of Practice* [10]. The old regulation detailed the general conditions of daylight distribution, daylight factor (D or DF) calculations and values, daylight coefficients, the glass transmittance and the reflectance values. Apart from the daylight standards, daylight design guidelines were and are mentioned in Polish building regulations. They usually focus on the distances between buildings, an orientation, the WFR and WWR values, and the insolation times. To illustrate the changes in daylight considerations, the review of daylight guidelines derived from historic and current Polish building regulations are presented below (Table 1).

The analysis of the data presented above show that while the recommendations regarding the orientation and the WFR values have not been changed, the regulations referring to the building spaces and overshadowing have been altered. The recommended distances between buildings are getting smaller which may influence the provision of daylight within the residential spaces.

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Table 1. Polish building regulations concerning daylight from 1928 until now

The summary of the historic approaches towards daylight in the Polish building recommendations and other influential regulatory documents in a context of the residential architecture

Date	Type of document	Contents and practice
1928	Polish Building Regulation 1928 Decree-law of President of the Republic of Poland from 16 January 1928 on building law and housing estates (first one since Poland's independence in 1918) (*Dz.U. Nr 23, poz. 202., 1928*)	§15: need for sufficient supply of daylight for residential dwellings §177: 25% of the plot should be left free of buildings §181-189: Relation of building's height (H) to a distance to neighbouring building (D) **H ≤ 22 m; D (street side) ≥ H; D (courtyard) ≥ 1.5 H**. §241: a need for windows with a view in rooms of residential buildings, windows area to floor area ratio **(WFR)1/10** §277: smaller residential buildings with widows- distance from the boundaries of the plot 4 m, 3 meters without windows. Absence of proper definition of window area. Skylights for staircases are recommended in residential buildings.
1937 1939	Promulgation of Mister of Interior 28th February 1939 with regard to announcement of uniform text of Decree-law of President of the Republic of Poland on building law and housing estates [11]	§15 & §177: sufficient supply of daylight for residential dwellings §176: 25% of the plot should be left free of buildings. The rest similar to regulations from 1928. In 1937 Tolwinski proposed to introduce a maximum sunlight penetration to the dwelling, to orient residential buildings in NS direction and to position them at 11 or 13 o'clock. To keep a reasonable minimum distance between the buildings **D≥2/3H** even with NS orientation. The NS orientation of the building would give the east and west facades sunlight over 1.5 hour a day even of 21st of December, however the buildings could not be overshadowed on the south side by other buildings located closer than 3.5 H.
1954	*1954 - R-NTP-54 MBMO/5-00001*, Technical designing standard, General buildings, daylight, general directives of designing (project), Town Planning and Architecture Committee, Institute of Town Planning and Architecture Normative [12]	No changes
1961	Act Building Law, published on 31st of January 1961 in *DZ. U. Nr 7 pos. 46*. Decree-law of Chairman of Committee of Construction, Town Planning and Architecture, concerning technical conditions that should be fulfilled by common buildings, published on 21st of July 1961 in *Dz. U. Nr 38 pos. 196.*	§85: Wall or roof of opposite building cannot decrease the light incidence angle more than 27º, that means **D ≥ 2H**. If the light incidence angle was decreased more than 27º, it is necessary to proportionally increase the window area. **WFR≥ 1/8** (permanently occupied rooms) **WFR≥ 1/12** (temporary occupied rooms) Daylight shaft in residential only is special cases, buildings, apartments daylite only by windows orientated N, apartment for ≥4 people with one side daylighting, - necessary to use double-glazed windows on certain circumstances.
1980	Decree-law of Minister of Administration, Land Management and Environment, concerning technical conditions that should be fulfilled by common buildings, published on 3 July 1980 in *Dz. U. Nr 17 pos. 62.*	§ 7: **D ≥ H D ≥ 3 m** (H-height of the building); WFR**≥1:8, ≤1:5** (permanently occupied rooms) **≥1:12** (temporary occupied rooms) (window area = inside window frame). It is forbidden to construct apartments for ≥ 3 people with windows oriented N.
1994	Act Building Law, published on 7th of July 1994 in *Dz. U. Nr 89 poz. 414.* Decree-law of Minister of Spatial Development and Construction, concerning technical conditions that should be fulfilled by common buildings and their location, published on 14 December 1994 in *Dz. U. 1995 Nr 10 pos. 46.*	§ 13: D ≥ **H** – for obstructing objects not higher than 55 m, D≥ **55 m** – for obstructing objects higher than 55 m, D - decreased for a half in the down-town infill buildings (H-obstructing height - is counted from, a lower edge of the lowest windows in obstructed building till the level of the highest edge of obstructing object). **WFR≥1:8** (permanently occupied rooms in residential buildings) **≥1:12** (temporary occupied rooms) (window area = inside window frame). **Insolation time ≥ 3 h in equinox days (**21/03, 21/09) during 8 – 16 o'clock (permanently occupied rooms), multi-room apartments – delimit of insolation to at least 1 room, in town centre buildings - insolation ≥ 1,5 h, one room apartment – no insolation time required; the one-room apartments are allowed only with N exposition.

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2002	The Regulation of the Minister of Infrastructure dated 12 April 2002 on the technical conditions to be met by buildings and their location Journal of Laws 2002 No. 75, item. 690; *BPIE* [13] [a] *Dz. U. 2002 Nr 75 poz. 690*	§ 12.1: If the provisions of § 13, 60 and 271-273 or separate provisions defining the allowed distance of some structures of buildings otherwise requires, the buildings on the plot construction must be placed at a distance from the border to a neighbouring building plot of not less than: 1) **4 m** - in the case of a building facing a wall with window openings and door systems towards the border, 2), **3 m** - in case of a building facing the wall without openings window or door in the direction of the border. § 13: The condition of the daylight provision for rooms designed to accommodate people is fulfilled if between the arms of angle of 60 ° (set in the horizontal plane, with the apex located in the inner face of the wall on the axis of the window of the room obscured) there is no other object veiled in less than the amount of obscuration (for objects obscuration of up to 35 m). § 57. 1: The connection of premises used to accommodate people should be provided with daylight, tailored to its purpose, shape and size, subject to the conditions specified in § 13 and the general provisions of health and safety. § 57. 2: In a room designed to accommodate people of window area ratio, calculated in the light of the frames, the floor surface should be at least **(WFR) 1:8**, while in another room where daylight is required - at least **1:12**. § 58. 1: It is allowed to design rooms to accommodate people with artificial light only if: 1) The daylight is not necessary or it is not advisable for technological reasons, 2) it is justified by functional expediency locate the room in the underground facility or part of a building devoid of daylight. § 60: **Daylight should be provided at least one room in the apartment for three hours in the days of the equinoxes** (March 21 and 21 September), from 7.00 to 17.00. § 60. 1: Premises for the collective presence of children in the nursery, kindergarten and school, apart from chemical laboratory, PE rooms and art rooms, should be given a period of sunshine at least 3 hours in the days of the equinoxes (March 21 and September 21) hours 8oo- 16oo, while non-residential - in hours 7oo-17oo. § 60. 2: The multi bedrooms apartment allowed limiting the requirements referred to in paragraph. 1 to at least one room. While in the new urban buildings located in centre of cites there is allowed to limit the time of needed sunshine to 1.5 hours. For a one-bedroom apartment sun time is not specified.
2006 2008 2014	Changes in Legal Documents concerning the daylight recommendations *Dz. U. Nr 156, poz. 1118 2006* *Dz. U. Nr 201, poz. 1238 2008* *Dz. U. Nr 228, poz. 1514 2008* *Dz.U. Nr 56, poz. 461 2009* *Dz. U. poz. 926 2013*	Text as above, contemporary interpretations: *§ Art.13 of specifies the conditions for distances between buildings to guarantee access to daylight: **D ≥ H** for obstructing objects no higher than 35m; **D ≥ 35 m** for obstructing objects higher than 35m. For downtown infill buildings, the distance (D) can be decreased by half. Where: H is the obstructing height and is counted from: the lower edge of the lowest windows in the obstructed building to the level of the highest edge of the obstructing object.* *§ 57: In permanently occupied rooms, the ratio window area to the floor area (WFR) should be at least **1:8**, and in any other room, where daylight is required, the ratio should be at least **1:12**. The legislation foresees the exemptions when: 1. The daylight is not necessary or is not desirable due to applied technology 2. There is a need for functional spaces in the underground facility or part of a building with no access to daylight.* *§ 60: specifies the conditions for exposure to sunlight regarding room's function: In permanently occupied rooms, the provision of daylight should be at least for3 hours during equinox days (21/03 and 21/09) between 7am and 5pm. For multi-family apartments, the limit of daylight time in at least one room is set at 1.5 hours, while in single room apartments, no insolation time is required.*

2.2. The provision of daylight within the residential space

The basic daylight consideration in the residential environment include design decisions about a geographical location and orientation, a form of a building, an avoidance of external obstructions, the spacing between buildings, a position and a size of daylight apertures.

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There are many ways to introduce daylight into a residential building including:

- high-performance glazing
- daylight-optimized fenestration design,
- climate-responsive design of the glass openings
- window-to-wall area ratio WWR
- skylights
- tubular daylight devices
- solar shading devices
- daylight-responsive electric lighting controls
- daylight-optimized interior design
- design of shading systems
- surface reflectance of the used materials
- others.

The design of daylight within the residential environment is not only focused on a provision of a right amount of an excellent quality sunlight and skylight to ensure good visual conditions and to reduce the electricity demand, but also on ways how to do it without undesirable effects like glare, veiling reflections and thermal discomfort. It is important to mention, that the daylight availability varies in both: the amount and the spectrum, depending on many factors including a season of the year, a nature of the cloud cover and a predictability of the weather conditions.

The control and the appraisal of daylight within interiors is challenging due to the altering daylight conditions and its availability. It may also affect the moods of the occupant of a building. The costs of the daylighting solutions, usage, maintenance can be predicted. However, the non-visual impact of daylight on the residents' wellbeing and health are much more difficult to estimate.

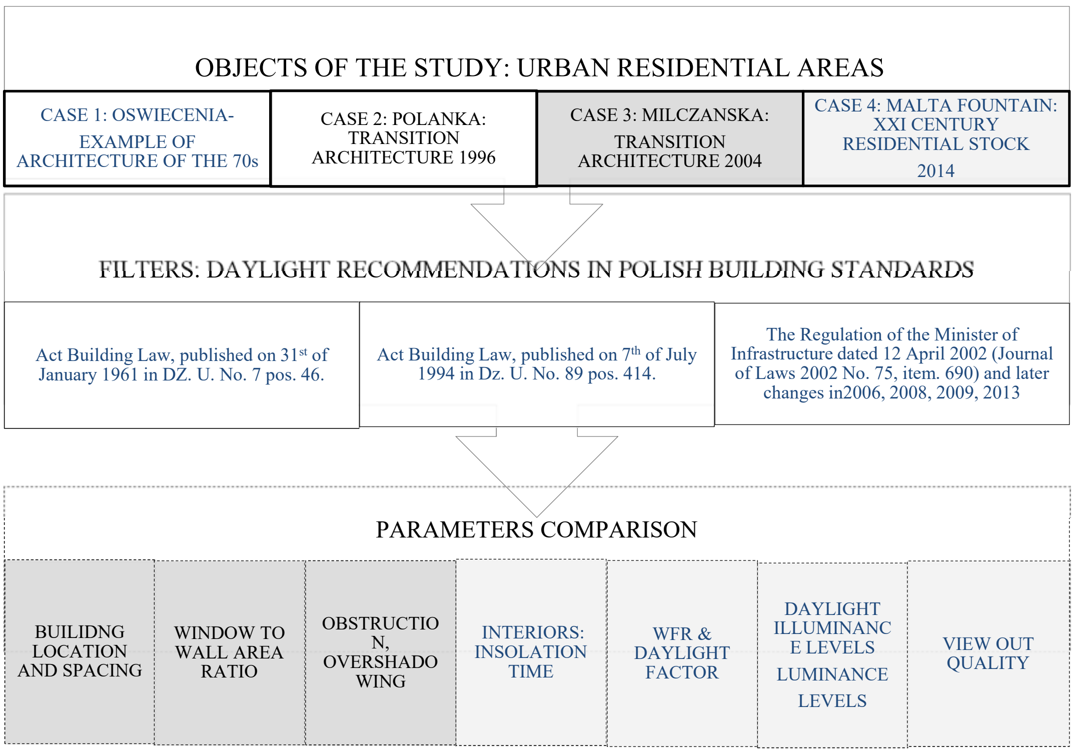

Figure 2. The simplified layout of the comparison method used for the analysis of the four residential areas cases in the first phase of the study.

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3. Method

The study of daylight conditions in the four neighbouring residential areas are done in two stages. During the first stage the urban, architectural and physical properties of the building forms significant for the each of the four residential areas are analysed and compared (Table 3). The comprehensive study of the external, physical parameters like a building orientation, spacing, and a size and position of the windows and rooftops is performed in relation to the daylight recommendations found in building standards (figure 2) along with a photographic documentation, and the sites measurements.

Table 2. The overview of the historic and contemporary approaches towards daylight in the Polish building standards applicable for the investigated areas in Poznan.

DATE & NAME OF THE DOC.	BUILDING ORIENTATION & SPACING	OBSTRUCTION	WINDOWS WFR	INNSOLATION TIME	DAYLIGHT FACTOR	ENERGY	AREA
1961 Act building Law 1971 PN-EN 15193:2010 *Energy requirements for lighting*	Forbidden to construct apartments daylight only by windows orientated N Apartments for ≥4 people should be at least 2wo aspects Introduction of the double glazing in the rooms to protect them against excessive heat losses.	§85: Wall or roof of opposite building cannot decrease the light incidence angle more than 27º, that means **D ≥ 2H**. If the light incidence angle was decreased more than 27º, it is necessary to proportionally increase the window area.	**WFR≥ 1/8** (permanently occupied rooms) **WFR≥ 1/12** (temporary occupied rooms) Daylight shaft in residential only is exceptional cases.		Calculation method and target values 2% for rooms with skylights and windows, 0,5-0,8% for side widows +Reflectance values		*OSWIECENIA*
1994 Act Building Law .	N exposition is allowed for the one aspect one-room apartments	§ 13: D ≥ **H** – for obstructing objects not higher than 55 m, D≥ **55 m** – for obstructing objects higher than 55 m, D - decreased for a half in the down-town infill buildings (H-obstructing height - is counted from, a lower edge of the lowest windows in obstructed building till the level of the highest edge of obstructing object).	**WFR≥1:8** (permanently occupied rooms in residential buildings) **≥1:12** (temporary occupied rooms) (window area = inside window frame).	**Insolation time ≥ 3 h in equinox days (**21/03, 21/09) during 8 – 16 o'clock (permanently occupied rooms), multi-room apartments – delimit of insolation to **at least 1 room, in town centre** buildings - **insolation ≥ 1,5 h, one room apartment – no insolation time required**	Calculation method and target values 2% for rooms with skylights and windows, 0.5-0.8% for side widows +Reflectance values		*POLANKA*
2002 The Regulation of the Minister of Infrastructure 2010 PN-EN 15193:2010 *Energy requirements for lighting*		*Art.13 of specifies the conditions for distances between buildings in order to guarantee access to daylight: **D ≥ H** for obstructing objects no higher than 35m; **D ≥ 35 m** for obstructing objects higher than 35m. For downtown infill buildings, the distance (D) can be decreased by half. Where: H is the obstructing height and is counted from: the lower edge of the lowest windows in the obstructed building to the level of the highest edge of the obstructing object.*	*§ 57: In permanently occupied rooms, the ratio window area to the floor area (WFR) should be at least **1:8**, and in any other room, where daylight is required, the ratio should be at least **1:12**.*	*60: specifies the conditions for exposure to sunlight in regard to room's function: In permanently occupied rooms, the provision of daylight should be at least for3 hours during equinox days (21/03 and 21/09) between 7am and 5pm. For multi-family apartments, the limit of daylight time in **at least one room is set at 1.5 hours, while in single room apartments, no insolation time is required.***		Daylight assessment methods and calculation methodology to be used for the evaluation of the amount of energy used for lighting in buildings (lighting energy numerical indicator) LENI	*MILCZANSKA & MALTA FOUNTAIN*

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During the second stage of the study, the daylight conditions in 0 carefully chosen flats are apprised by a sequence of in-situ measurements, the computer simulations and the direct questionnaires with the residents who occupy them. The daylight performance indicators, which are also included in the daylight recommendation for the Polish building standards, like: insolation time, daylight factor, the WFR, are defined.

4. Results and discussion

The investigated, neighbouring residential areas were created from 1973 till 2013 in Poznan, Poland (Table 3). The daylight recommendations considered while the areas had been designed could be obtained from different Polish building standards and the approved documents. For the first stage of this study, only the daylight references found in the building regulations and the PN-71/B-02380 *Natural Interior Daylighting Code of Practice* [10] were taken into account (Table 2).

The study of the physical characteristic of the buildings and their arrangements in the context of daylight~~,~~ shows that they were designed according~~ly~~ to the daylight recommendations mandatory at the time of their creation. The preferred way for the provision of daylight to all of the investigated buildings were the side and roof windows. In Oswiecenia (C1) and Polanka (C2), cases 1 and 2, there are no apartments with all the widows facing north. The dominant orientation of the windows is NE and SW in C1 and EW in C2. According to the changes in the regulations, the distances between buildings are diminishing. The distances between C1 buildings are approximately 25 m, which is twice the amount of the distance between C2 buildings. The dominant form of the buildings for C1 and C2 are simple perpendicular forms. The Milczanska (C3) and Malta Fountain (C4) block of flats have the compound forms with the inner courtyards. Some of the buildings in C3 and C4 are connected on the ground level. Due to the diminishing distances between buildings, the provision of daylight is the best in C1 and the worst in C4, especially for the one-aspect apartments facing the courtyards. The first observations withdrawn from the physical characteristic comparison were evaluated in the second stage of this study during the in-situ measurements inside the 10 selected apartments and during the directed questionnaires. The number of received data is still analysed. However, in relation to the daylight recommendations described in this paper, the values of the widow-floor-ratio parameter are lower in the C2 and C3, although they have not been changed in standards since 1961.

The reviewed standards do not consider key issues for a residential daylit space like: quality of view, protection against glare, brightness uniformity or the non-visual effects of daylight on the residents, which were investigated in the second stage of this study.

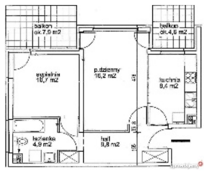
The key building parameters affecting daylighting designs and reflected in daylight recommendations in the Polish building standards, do not guarantee good provision of daylight (Table 2). They do not inform about daylight performance within the rooms. The levels of daylight in residential flats can be severely reduced by neighbouring buildings especially in C4 situation.

5. Conclusions

The responses to the following questions: how much light is sufficient for the residential rooms and how to provide the optimal quantity of a superior quality daylight within the residential environment, are not found in the daylight recommendations in Polish building standards. The quality and the quantity of daylight and its performance are not addressed in the current daylight regulations.

The preliminary results of the comprehensive analysis of the daylight recommendations and their applications in a context of the investigated buildings and interiors~~,~~ from the four chosen areas indicate that daylight regulations are fragmentary and focused more on a control of the built form than on an actual performance of daylight. The tendency expressed in the regulation to diminish distances between neighbouring buildings may aggravate a daylight provision to the buildings, an insolation time and a quality of the view, therefore the quality of daylight overall.

Table 3. The basic comparison of the 4 investigated residential areas in Poznan.

RESID. NAME	CASE 1: OSWIECENIA	CASE 2: POLANKA	CASE 3: MILCZANSKA	CASE 4: MALTA FOUNTAIN
Date	1973	1996	2004	2013
Map	 15 x 4 fl. block of flats, 1x 10 fl. long buildings, 3x 16 fl. tall buildings	 13 x 4 floors multifamily Buildings along Polanka St (various developers)		 2x 6 floors multifamily buildings between Katowicka & Milczanska St.
Aspects	1 or 2	1-3	1-3	1-2
Number of floors 0-4				
				
Localization	Rataje, Poznan	Nowe Miasto- Polanka, Poznan	Nowe Miasto- Milczanska, Poznan	Nowe Miasto- Malta Fountain, Poznań, Milczanska 1
Type of urban settlement	Nucleated, linear	Linear along Polanka street with inner courtyards	Nucleated with inner courtyards	Nucleated, with inner courtyard
Price for m² in PLN	3500-4000	5000-7000	5000- 7000	7000-10000
Types of windows	Windows, skylights for staircases	Windows, skylights, balcony doors	Side widnows, skylights, balony windows	Windows, balcony doors

The most popular WFR parameter, found in the Polish recommendations, does not indicate anything about a direct obstruction, an orientation or a type of glazing, which all affect daylight provision to the building. Apart from the daylight factor parameter, explained in the PN-71/B-02380 and in use until 2005, none of the others known daylight indicators addressing a quality or a quantity of daylight in the residential buildings, are recalled in Polish standards.

The limitations of the daylight recommendations in the building standards influence the design decisions and a creation process of living spaces. Constantly decreasing distances between the residential buildings and their new compound forms have an impact on daylight conditions which may have consequences for the residents' quality of life.

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