

Overheating and modernized buffer spaces: stationary modelling of typical block of flats

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Abstract. In the light of inevitable future renewal solutions towards outdated Soviet urban housing, the study suggests a strategy of buffer spaces rebuilding, minimizing the impact of the retrofit on the inhabitants and allowing one to reduce indoor thermal discomfort at the expense of normalizing overheating frequency. Three, gradually becoming more complicated, possible retrofit approaches to the buffer spaces (balconies, the attics and basement) of an equivalent building are assessed graphically and via simulations in Passive House Planning Package. The modelling focuses upon two outermost south-eastern-faced apartments, that in their initial state experience temperatures, exceeding 25°C - 26% of the annual occupied hours (while the temperatures exceeding 25°C – should be less than 10% of the time – a Passive House criterion). The last and most developed approach is happened to be the most effective as it reduces the frequency to 4% in the modelled apartments.

1. Introduction

Energy- and comfort-related renovation of multi-family mass housing is the issue of current importance in Russia with 31% of out of date housing erected for the 1946 – 70 period [1]. This building stock was primarily based on standard designs having set minimal housing conditions which are now steadily associated with uncomfortable microclimate. In particular, it has a typical set of predictors that are found to contribute to a critical rise in indoor air temperature during the warmest summer period: solely southern or eastern/western orientation without strict shading [2]; single-facing flats (approximately a one-third of the dwellings [3]) where passive cross-ventilation is difficult, coupled with absence of active cooling appliances [4]; the lack of comprehensive thermal protection along with poorly (and partially) insulated envelope which is characteristic of the current state [5]; small fully occupied apartments (occupancy density is quite high – 23 – 25 m² per an occupant [3], [1]) and hence large heat gains from people and appliances adding to the indoor temperature increase (there is a firm correlation between the occupancy level and values of internal heat gains [6]). Given the sum of the factors, there is a vital need of undertaking retrofit measures to prevent excessive heat in the dwellings.

This is clear that any refurbishment means discomfort for residents who have to change temporarily their dwellings because of the renovation works. An alternative of retrofitting without rehousing rises as a solution to minimize disturbances for the occupants. Focusing on the strategy of remaining them in their apartments during renewal processes one can detect effective concepts that are either based on limited terms of renovation (for example by implementing prefabrication retrofitting technologies [7])



or deal solely with subsidiary units (private exterior spaces [8]). This study sticks to the later one and is aimed, by means of steady-state modelling, to trace the impact of improved buffer spaces – balconies attics and basement – on incidence of overheating in a typical apartment building (that is a four-story house for 32 apartments with masonry external walls, concrete floor slabs and a pitched slate roof; the principal façade has oriented south).

2. Method

Excessive indoor temperatures are shown to occur irregularly within a building, some units may be critically warmer than others (for instance rooms on the top floor, kitchens [9]). In the context, segments of the building that is primarily prone to overheating and the adjoining buffer spaces, that are altered from approach to approach, – top- and ground floor corner apartments with south-eastern orientation – are modelled (Table 1).

Table 1. Specification of the modelled apartments ^a.

	Area (m ²)	U (W/(m ² K))	g-value	f _T (%) ^b
Treated floor area	40.0			
Exterior walls	31.8	1.22		
Southern windows	6.7	2.27	0.70	
Eastern window	1.7	2.31	0.70	
Walls and floor/ceiling slabs adjacent to neighbouring properties ^c	100.0	1.33		
Basement slab	61.0	0.92		27
Loft slab	61.0	1.01		39
Insulated roof	74.8	0.25		
Insulated basement slab	61.0	0.89		

^a Additional parameters of the apartments used in the simulation: a number of inhabitants – 3 people; the volume (measured outwardly) – 99 m³ (each); the ceiling height – 2.5 m.

^b Decreasing temperature factor – a ratio of the difference between internal (20°C) and buffer space air temperatures to the difference between internal and minimum external (-30.9°C) air temperatures.

^c There is no heat flow between the adjacent spaces with equal operative temperature.

The modelling is conducted using Passive House Planning Package (PHPP) – a stationary program that is found to be ‘a good predictor’ in terms of overheating risk [10] and is validated for assessment of existing buildings [11]. A standard procedure of PHPP calculations is undertaken [12], focusing on the factors that are linked with predicting of overheating events such as: openings sizes and the share of glazing, orientation and dimensions of shading components of the building envelope, the values of conductivity via passive ventilation and summer thermal conductivity through the envelope. The program forms an annual line of indoor temperatures in a semi-dynamic single-zone model of the apartments to determine a point where the line meets the threshold (25°C) the segment lying above this point denotes a period when indoor temperatures are variously uncomfortable, depending on the share the segment occupies within a year [12].

A number of respective values are assumed by default according to the PHPP [13]: internal heat gains (2.1 W/m² – for residential buildings, occupied 24 hours), effective storage capacity (204 Wh/m²K – for buildings made of solid components), not perpendicular solar flux – 0.85, and glass pollution – 0.95. The local climatic input data are acquired from [14]. Along with the total shading coefficient for the openings the radiation balance of an opaque part of the envelope is determined as the product of its absorption (0.5 – walls, 0.8 – roof), emission (0.9), orientation (180°), horizontal deviation (90° – façades, 25° – roof), and reducing shading factors. The last are graph-analytically found for each retrofit approach as a share of surface shading by means of formation of solar flux

projections onto the façades at 9 a.m. on 21 December and at 12 on 21 June – respectively, the minimum and maximum heights of the sun [15] (see Figure 1). Ambient shading factors (other buildings, trees) are not taken into the calculation.

3. Results and conclusion

Various configurations of private outer spaces combined with the insulated roof and basement slab are consistently added to the model in order to differentiate the effect of every approach to the buffer space modernization on intensity of indoor overheating. Even the first approach consisting in converting balconies into loggias, deeper and with opaque screens on the short sides, appeared to be able to significantly reduce alarming overheating arising inside the apartments in their initial state. The further approaches enlarging the influence of shading elements – first of all balconies slabs and opaque screens – on the increase of the whole building sunshield (from 128 m² – for the initial state to 657 m² – for the last retrofit approach) notably strengthen the tendency (Table 2). The last approach can be considered as an optimal one since it allows both normalizing excess heat occurrence and inserting extra room for the inhabitants to use (the insulated attics, which may serve as utility area, and the spacious loggias, that may contain numerous kinds of the inhabitants' indoor activity [8]).

Table 2. Ranking of overheating frequency caused by different modelled approaches to the buffer spaces modernization, in accordance with PHPP criteria.

Retrofit approach	Overheating (percentage of annual occupied hours) in the <i>top</i> and ground floor apartments	The PHPP criteria [16]
Initial state	26; 22	harmful
I	15; 11	poor
II	10; 8	acceptable
III	4; 4	good

Placing the issue of thermal comfort into the context of mass housing renovation, the present study, by means of modelling, demonstrates that retrofitted buffer spaces (loggias primarily) on the one hand may be effective as a measure to reduce overheating risk under the local climate, on the other – become a small-scale strategy of the housing stock modernization without rehousing the inhabitants. Moreover, taking into account that this housing typology is of wide occurrence throughout the country, a unifying retrofit strategy for the standard housing buffer spaces turn out to be applicable to considerable quantity of a total urban housing stock.

Subsequent research on the subject might be focused on energy savings achieved with less reliance on active cooling due to additional shading produced by the improved buffer spaces.

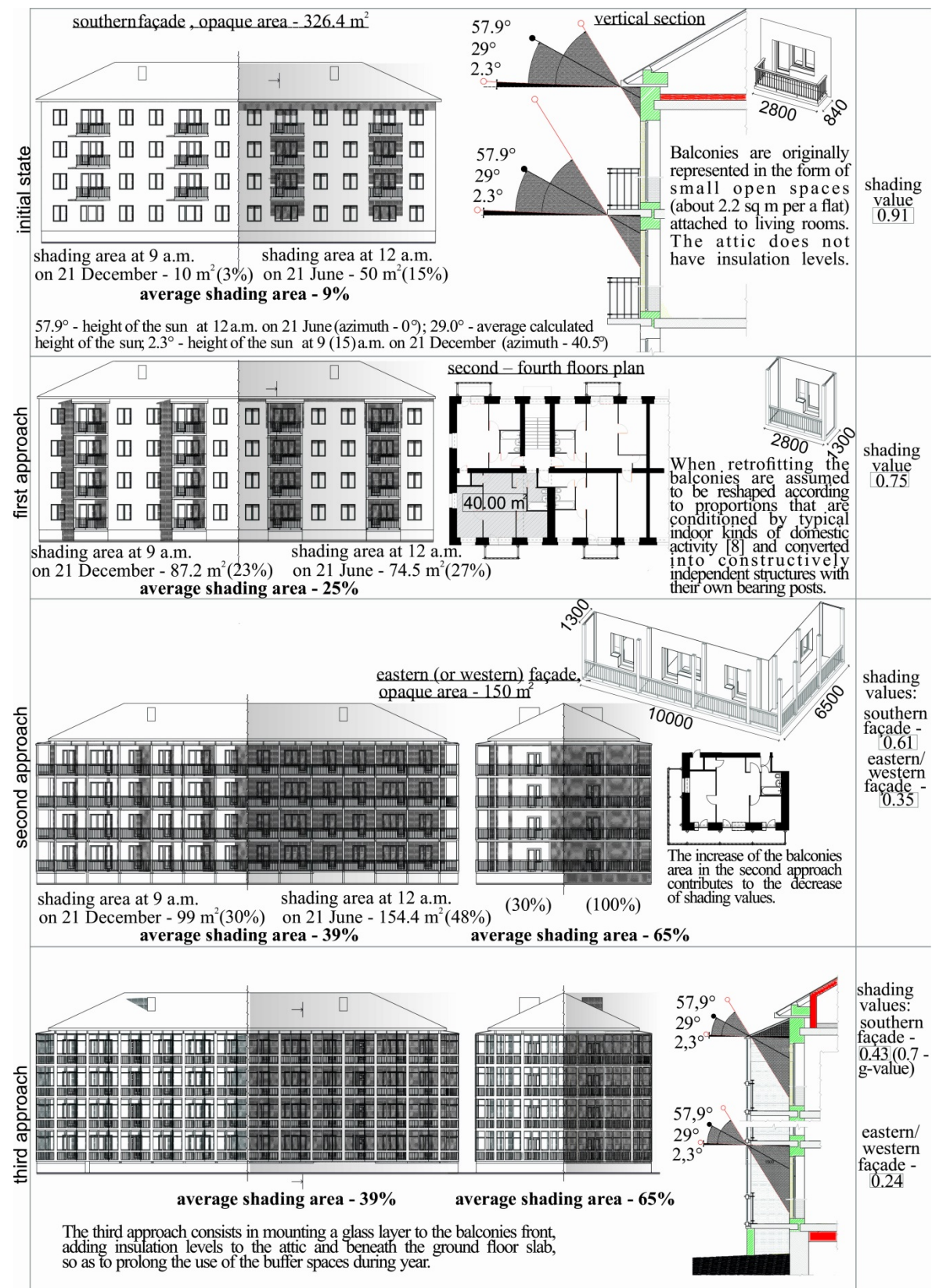


Figure 1. Building and shading characteristics of the retrofit approaches. Determination of shading values to calculate radiation balance of the opaque envelope.

References

- [1] Calabekov I G 2017 *Russian reforms in figures and facts* (Moscow: Rusaki) p.174 <http://refru.ru> (Ongoing)
- [2] Mlakar J and Štrancar J 2011 *Energy and Buildings* **43:6** pp 1443–1451
- [3] Local Agency of Federal State Statistics Service of the Chelyabinsk region 2013 *Housing stock of Chelyabinsk region: statistical bulletin* (Chelyabinsk: Chelyabinskstat)
- [4] Tillson A, Oreszczyn T and Palmer J 2013 *Building Research & Information* **41:6** pp 652–661 DOI:10.1080/09613218.2013.808864
- [5] Mavrogianni A, Wilkinson P, Davies M, Biddulph P and Oikonomou E 2012 *Building and Environment* **55** pp 117–130
- [6] Kildsgaard I, Jarnehammar A, Widheden A and Wall M 2013 *Buildings* **3** pp 258–277 DOI:10.3390/buildings3010258
- [7] IEA Programme for Energy Conservation in Buildings and Community Systems 2011 *Annex 50 Prefabricated Systems for Low Energy Renovation of Residential Buildings* (Duebendorf: Empa – Swiss Federal Laboratories for Materials Science and Technology)
- [8] Berezin D V 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **262** 012142
- [9] Vellei M, Ramallo-González A P, Coley D, Lee J, Gabe-Thomas E, Lovett T and Natarajan S 2016 *Building Research & Information* **45:1-2** pp 102–118 DOI: 10.1080/09613218.2016.1222190
- [10] Ridley I, Clarke A, Bere J, Altamirano-Medina H, Lewis S, Durdev M and Farr A 2013 *Energy and Buildings* **63** pp 67–78
- [11] Moran F, Blight T, Natarajan S, Shea A 2014 *Energy and Buildings* **75** pp 216–227
- [12] Feist W 1998 *Passive House Summer Climate Study* (Darmstadt: Passive House Institute)
- [13] Feist W, Pfluger R, Kaufmann B, Schnieders J and Kah O 2007 *Passive House Planning Package 2007* (Darmstadt: Passive House Institute)
- [14] *Surface Meteorology and Solar Energy Data Set* <https://eosweb.larc.nasa.gov>
- [15] Twarowski M 1970 *Slonce w architekturze* (Warszawa: Arkady) chapter 17
- [16] Lomas K J and Porritt S M 2017 *Building Research & Information* **45:1-2** pp 1–18 DOI:10.1080/09613218.2017.1256136

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