

IMPROVING ERGONOMIC COMFORT IN SMALL SPACES THROUGH ZONING

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Abstract: *This scientific study examines the issues of improving ergonomic comfort in organizing the interior space of small-scale apartments (30-45 m²) under conditions of modern urbanization. Due to population growth and limited land resources in urban areas, compact housing has become a global trend. The article analyzes the principles of maintaining human psychophysiological well-being, ensuring freedom of movement, and properly distributing functional zones in limited spaces. The research employs comparative analysis, grapho-analytical methods, voxel-based modeling, and international case study approaches. The results show that the effective use of transformable furniture, vertical zoning, and transparent partitions can increase the usable space of an apartment by 25-40%. The study also provides practical recommendations for applying ergonomic standards in the context of Uzbekistan, particularly based on examples of new residential complexes in the city of Tashkent. This work serves as both a theoretical and practical resource for architects, interior designers, and urban planning professionals.*

Keywords: *ergonomics, zoning, small-scale apartments, transformation, anthropometry, interior design, spatial efficiency, functional adaptability.*

INTRODUCTION

In the modern world, the unprecedented growth of urban populations and the acceleration of urbanization processes have led to the emergence of new housing typologies, such as small-scale apartments, studios, and micro-apartments (Thogersen K. 2017). Today, in rapidly developing metropolises like Tashkent, apartments ranging from 30 m² to 45 m² constitute a major segment of the real estate market (nur.namunadevelopment.uz). However, the reduction in space is often associated with decreased living quality, limited mobility, and the emergence of psychological discomfort, including feelings of confinement (claustrophobia) (Jahan I. Hossain S.H. Aayaz R. 2024). In addressing this issue, ergonomics-the science that optimizes the interaction between humans and their environment in terms of comfort, safety, and efficiency-plays a central role (Kizilkan G. 2021).

The relevance of this research lies in the fact that living in small-scale apartments is not only an economic necessity but has also become part of a modern lifestyle. However, many such apartments are still designed based on traditional planning standards, which do not allow for the efficient use of every square centimeter of space (Ospanov T. Prodanova N. Sarvut T. Matytsin A. 2024). The mismatch between human anthropometric characteristics and daily activity scenarios (cooking, working, resting, sleeping) leads to chronic fatigue, musculoskeletal disorders, and general dissatisfaction (Thogersen K. 2017).

Therefore, developing new flexible zoning methods and integrating them with ergonomic requirements is an urgent task.

The aim of this scientific article is to substantiate the principles of maximizing ergonomic comfort in small-scale apartments through functional zoning and to develop practical models.

The following objectives are set for the study:

1. To conduct a systematic analysis of international (Poland, Russia, Kazakhstan) and national (Uzbekistan) experiences in organizing small-scale residential spaces.
2. To determine minimal ergonomic parameters for small spaces based on human anthropometry and movement trajectories.
3. To systematize zoning methods that contribute to visual and physical space expansion (vertical zoning, transformable furniture, lighting scenarios).
4. To develop design proposals and models that ensure optimal ergonomic comfort in small apartments.

The object of the research is small-scale apartments and studios (30-45 m²) in modern multi-storey residential buildings in Tashkent. The subject of the research is zoning methods, transformable structures, and their relationship with the ergonomics of the living environment.

The scientific novelty lies in the development of a flexible zoning model based on the concept of “dynamic space” for small-scale apartments. This model, for the first time, integrates the climatic conditions of Uzbekistan (insolation, microclimate) and national lifestyle characteristics with modern transformation technologies (Osmanov T. Prodanova N. Sarvut T. Matytsin A. 2024).

The practical significance of the research lies in the fact that the proposed recommendations and design models can be used by architects and interior designers as methodological guidelines for designing small residential spaces. Furthermore, the proposed ergonomic parameters can serve as a basis for improving the building codes and regulations (KMK) of the Republic of Uzbekistan (Lex.uz. 2019).

The issue of ergonomics in small apartments is not limited solely to furniture arrangement. It encompasses a broader range of factors, including human spatial perception, indoor air circulation and lighting conditions, as well as the seamless transition between different types of activities (Ospanov T. Prodanova N. Sarvut T. Matytsin A. 2024).

International experience demonstrates that, through the application of “smart” design solutions, it is possible to achieve a fully functional living environment even within spaces

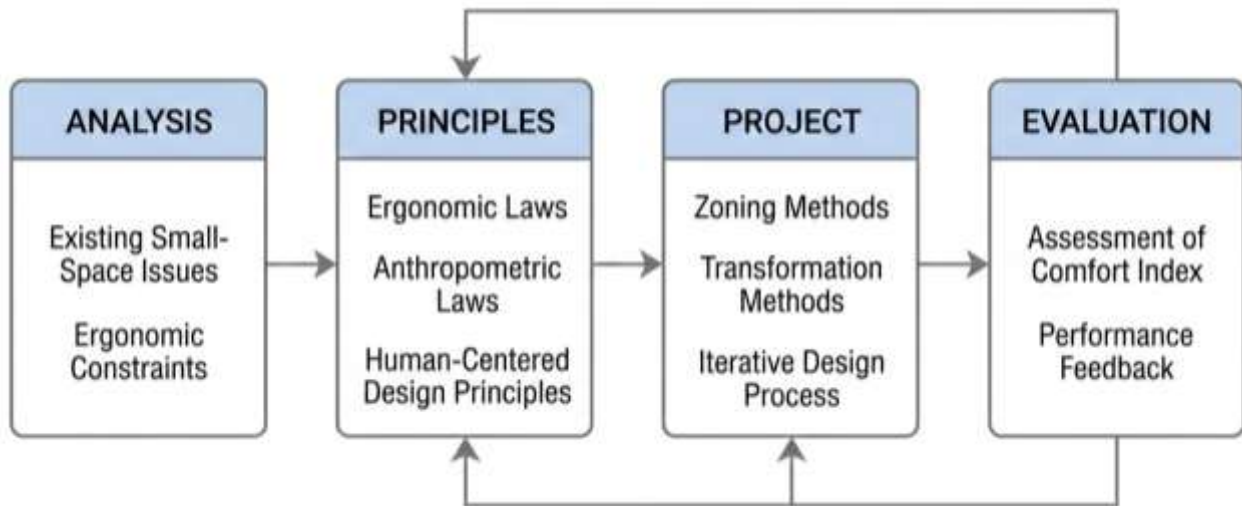


Figure 1. Conceptual framework of ergonomic planning optimization

as compact as 15-20 m². However, such outcomes require a high level of engineering precision and comprehensive design analysis (Thogersen K. 2017).

METHODS

The research methodology is based on a comprehensive approach that enables a multidimensional analysis of small-scale residential environments. The following key methods were employed in the study.

First, a **comparative analysis** was conducted to examine both international and local design practices. This included a comparison of optimized 27.3 m² apartment layouts in the “Za Żelazną Bramą” residential complex in Warsaw (Poland), compact studio apartments in the Russian and Kazakh markets, and contemporary projects in Tashkent such as “NUR” and “Tashkent City” (nur.namunadevelopment.uz). The analysis focused on indicators such as total apartment area, the proportion of functional zones, and the balance between open and enclosed spaces.

Second, a **grapho-analytical method** was applied. This method enabled the mapping of key human movement trajectories (“transit paths”) within small apartments. Movement radii for various daily activities-such as cooking, personal hygiene, sleeping, and working-were calculated based on anthropometric data. For instance, parameters such as the minimum width of kitchen work zones (110-120 cm) and circulation paths in living areas (80-90 cm) were evaluated against established standards.

Third, **voxel-based modeling and simulation methods** were used to assess both the visual and physical usability of space (Azadi Sh. Bai N. 2024). This technology allows for

the graphical representation of visibility and accessibility from every point (voxel) within the apartment. It proved particularly effective in identifying “dead zones”-areas that are underutilized or ergonomically inefficient.

Fourth, a **case study method** was employed to analyze real residential projects in Tashkent. Studio apartments of 35-40 m² in the “NUR” residential complex were selected for detailed examination (nur.namunadevelopment.uz). These layouts were evaluated in terms of real user needs, furniture arrangement, and ergonomic limitations.

Fifth, a **design modeling approach** was used to develop spatial reconfiguration scenarios through transformable furniture and mobile partitions (Saied A. Abdullah R. Sabah Ali J. 2024). Various spatial scenarios-such as daytime and nighttime configurations-were illustrated through graphical models. Additionally, vertical zoning possibilities were explored by analyzing room volume and ceiling height coefficients (nur.namunadevelopment.uz).

The study also incorporated **engineering analysis** to evaluate microclimate and lighting conditions. Air exchange rates and the penetration of natural light into the deepest parts of small spaces were considered fundamental factors of ergonomic comfort (Osmanov T. Prodanova N. Sarvut T. Matytsin A. 2024).

RESULTS

The study identified a set of patterns and technical parameters that contribute to improving ergonomic comfort in small-scale apartments. The findings indicate that spatial efficiency depends not only on the total area but also on the geometric arrangement of functional elements.

The first identified pattern relates to the proportion of furniture and equipment within the apartment. In small units (up to 30 m²), furniture and large household appliances occupy approximately 45-50% of the total area (Thogersen K. 2017), leaving minimal space for free movement. However, the use of transformable furniture-such as Murphy beds, folding tables, and expandable sofas-can reduce this ratio to 20-25% during daytime use (nur.namunadevelopment.uz).

The second key outcome is the development of a table of **ergonomic parameters for small spaces**, derived from the integration of anthropometric data and modern lifestyle requirements (Table 1).

The research also compared the effectiveness of three primary zoning strategies:

1. **Static zoning:** Partitioning spaces using brick or aerated concrete walls. In small apartments (under 40 m²), this approach visually reduces space and decreases natural light distribution by 30-40%.

2. **Visual and transparent zoning:** The use of glass partitions, shelving units, color differentiation, and varied flooring materials. This method preserves visual openness and allows light to flow freely throughout the space.

3. **Dynamic (transformational) zoning:** The use of sliding partitions, rotating modules, and foldable furniture. This approach proved to be the most effective for small apartments, enabling a single space to function simultaneously as a bedroom, living room, and workspace (Saied A. Abdullah R. Sabah Ali J. 2024).

Table 1 Comparative ergonomic parameters for small apartments

Zone Name	Minimum Width (cm)	Optimal Width (cm)	Standards Source of Ergonomic
Kitchen Zone Single-user passage (between)	90	1010	Neufert Architects' Data (Illustrative)
Passage with appliance use (e.g., oven/dishwasher open)	110	120	ISO 9241 (Illustrative)
Living Area Zone Main circulation path	90	110	Architectural Graphic Standards (Illustrative)
Passage between sofa and coffee table	40	50	General Ergonomic Texts (Illustrative)
Sleeping Area Zone Access to one side of double bed	60	70	Standard Housing Design Guides (Illustrative)
Access to wardrobe (sliding doors)	80	90	Neufert Architects' Data (Illustrative)
Workspace Zone Circulation behind desk chair	80	100	ISO 9241-5 (Illustrative)
Standard single-desk width	80	100	EN 527-1 (Illustrative)

The third key finding highlights the advantages of **vertical zoning**. In apartments with ceiling heights of 3 meters or more (for example, in newly built premium residential buildings in Tashkent), it is possible to create a “second level” (mezzanine), where the sleeping area is elevated, thereby freeing up the lower level for full-fledged living functions (nur.namunadevelopment.uz). This approach can increase the functional efficiency of a 30 m² studio to the equivalent of 42-45 m² of usable space.

The fourth finding relates to the **optimization of human movement trajectories**. Grapho-analytical studies indicate that the main “transit path” in a small apartment (from the entrance to the window, and from the bathroom to the kitchen) should be linear, with a minimum width of no less than 85 cm. Any angular or complex circulation paths tend to negatively affect the psychological perception of confined spaces.

The diagram below illustrates a comparison of spatial distribution between conventionally planned apartments and ergonomically optimized layouts.

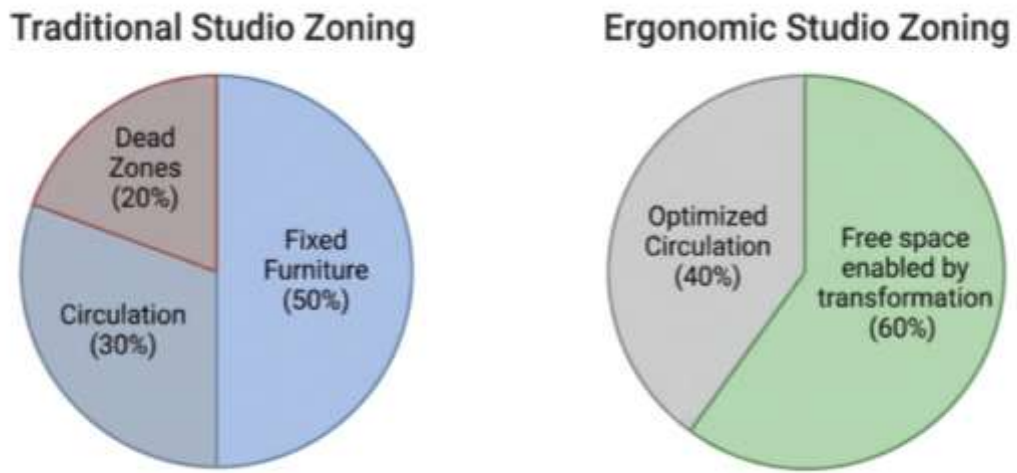


Diagram 1. Comparative analysis of floor space efficiency



Figure 2. 3D visualization of an ergonomic studio layout (30 m²)

The design conclusions derived from the study confirm that achieving ergonomic comfort in small apartments requires furniture to function not merely as movable equipment, but as an integral part of the architectural structure (e.g., built-in wall systems). Additionally, the use of window sills as workstations or kitchen surfaces, the implementation of sliding door systems, and the transformation of corner “dead zones” into storage solutions are

identified as some of the most effective strategies for spatial optimization (nur.namunadevelopment.uz).



Figure 3. Transformable furniture unit: Night vs Day scenarios

DISCUSSION

The interpretation of the research findings indicates that the level of ergonomic comfort in small-scale apartments is directly dependent on the architect’s **spatial thinking** and the integration of technological solutions. A comparison of the obtained results with international studies reveals several important aspects.

A study conducted by Polish researcher A. Dudek (2023), based on simulations of 27.3 m² apartments in Warsaw, demonstrates that even in extremely limited spaces, the careful selection of functional elements-such as folding beds and TV cabinets with angled mechanisms-can significantly improve the quality of living (Tokajuk A. 2023). Our research confirms this conclusion; however, in the context of Uzbekistan, it also highlights the importance of integrating the **kitchen and living area**. According to national traditions, the dining space serves not only a functional purpose but also acts as a central hub for social interaction (nur.namunadevelopment.uz).

The experience of compact housing markets in Russia and Kazakhstan (2024) shows that the primary focus there is placed on safety and optimal microclimate conditions (Osmanov T. Prodanova N. Sarvut T. Matytsin A. 2024). Similarly, our study identifies

safety (ergonomic distances) and **microclimate (air circulation)** as critical factors. In small apartments, limited air volume (cubic capacity) leads to a rapid increase in carbon dioxide concentration, which necessitates the integration of ventilation systems within the zoning design (Cirovic I. Dimitrijevic A. Vasiljevic J. 2023).

International studies on ergonomic comfort indices (Lee et al., 2024) tend to focus primarily on **thermal comfort** (PMV index) (Lee Junsoo, Koo Chongwan, 2024). In contrast, our research prioritizes **psychological comfort** and **visual openness**, which are essential for preventing claustrophobic sensations in small living environments (Jahan I. Hossain S.H. Aayaz R. 2024). Therefore, transparent partitions and multi-level lighting systems should be regarded not merely as aesthetic features, but as ergonomic necessities (nur.namunadevelopment.uz).

Regarding the application of **smart furniture technologies**, it should be noted that such solutions may increase the initial cost of housing; however, they prove economically efficient over time by maximizing spatial usability (Saied A. Abdullah R. Sabah Ali J. 2024). The “multi-functional blocks” examined in this study-combining sleeping, storage, and workspace functions within a single module-are shown to be among the most innovative approaches to spatial management in compact apartments.

Furthermore, the research findings reveal partial inconsistencies with the current building regulations of Uzbekistan (KMK 2.08.01-19) (Lex.uz. 2019). While existing standards strictly define minimum room sizes and their separation, they lack sufficient ergonomic guidelines for transformable spaces and studio-type apartments. This highlights the need for future amendments to regulatory frameworks.

The final interpretation is that ergonomics in small-scale apartments represents the art of maximizing limited resources-primarily space. In this process, every element (windows, doors, furniture, lighting) must be harmoniously aligned with the human body and its movement patterns (Thogersen K. 2017).

CONCLUSION

The comprehensive study on improving ergonomic comfort through zoning in small-scale apartments leads to the following fundamental conclusions:

First, the key to creating a comfortable living environment in apartments ranging from 30-45 m² lies in **functional flexibility**. Replacing traditional static walls with transparent partitions, mobile structures, and transformable furniture allows the usable space to expand by 30% to 45% during daytime use. This significantly enhances the psychological perception of openness and comfort.

Second, **minimum spatial parameters based on human anthropometry** (transit paths of 85-90 cm and work zones of 110-120 cm) must form the foundation of small apartment design. Failure to comply with these standards leads not only to physical discomfort but also to long-term health issues, particularly affecting the musculoskeletal system. The parameter table proposed in this study provides an essential technical reference for designers.

Third, **vertical zoning and multi-functional modules** represent a promising direction in small-scale residential architecture. Efficient use of ceiling height (mezzanines, podiums)

increases spatial density and maximizes the functional performance of each square meter. This is especially relevant in cities like Tashkent, where land value is high and spatial efficiency has significant socio-economic benefits.

Fourth, ergonomic comfort is determined not only by physical dimensions but also by **microclimate and lighting conditions**. Maintaining proper insolation and natural ventilation within zoned spaces plays a crucial role in preserving human psychophysiological well-being. The proposed “Model of Ergonomic Zoning Principles” (Figure 4) integrates all these factors into a cohesive design framework.

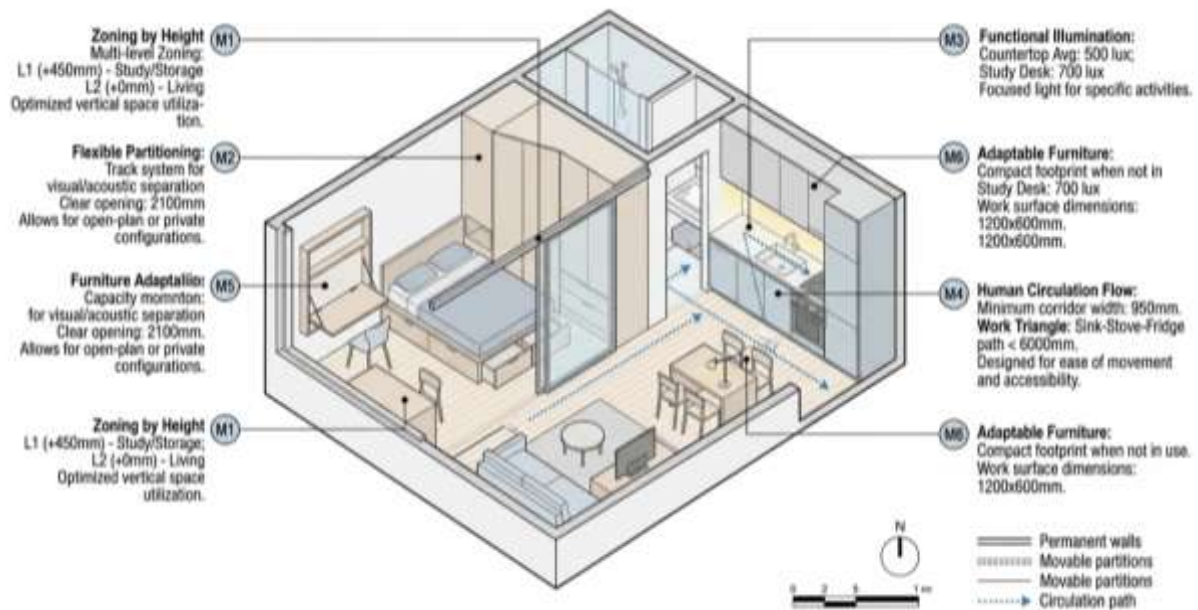


Figure 4. Final model: Integrated ergonomic zoning principles

The results of the study hold both theoretical and practical significance for the field of architecture and design in Uzbekistan, contributing to the improvement of compact housing design quality and enhancing living conditions for the population in the future.

REFERENCES:

- 1.Thogersen K. (2017). *Small spaces need smart solutions*. Norwegian University of Science and Technology. https://www.ntnu.edu/documents/139799/1279149990/31+Article+Final_krithog_fors%C3%B8k_2017-12-07-22-08-50_TPD4505+-+Design teori+-+Small+spaces+need+smart+solutions+-+Kristoffer+Th%C3%B8gersen.pdf/11a2f430-986b-4da8-9b44-14b204436e01 (PDF)
- 2.Namuna Development (2023) *100 ideas for the interior of a one-room apartment in Tashkent*. <https://nur.namunadevelopment.uz/en/100-idej-dlya-interera-odnokomnatnoj-kvartiry-v-tashkente/>

- 3.Namuna Development. (n.d.). *Residential complex NUR | Apartments in Tashkent*
<https://nur.namunadevelopment.uz/en/e/>
- 4.Jahan I. Hossain SH. Aayaz R. (2024). *Optimizing small spaces: A comprehensive study on interior design challenges, perceptual experiences, and innovative solutions.*
https://www.researchgate.net/publication/378526360_OPTIMIZING_SMALL_SPACES_A_COMPREHENSIVE_STUDY_ON_INTERIOR_DESIGN_CHALLENGES_PERCEPTUAL_EXPERIENCES_AND_INNOVATIVE_SOLUTIONS
- 5.Saied A. Abdullah R. Sabah Ali J. (2024) *Impact of flexible furniture on small spaces in residential apartment with smart solutions.*
https://www.researchgate.net/publication/383039338_Impact_of_Flexible_Furniture_on_Small_Spaces_in_Residential_Apartment_with_Smart_Solutions
- 6.Kizilkan G. (2021). A study on examining the concept of ergonomics in preschool educational buildings designed with sustainable architectural approach through the sample of Bahriye Üçok Ecological Kindergarten.
<https://jag.journalagent.com/z4/vi.asp?pdir=megaron&plng=eng&un=MEGARON-03743>
- 7.Ospanov T. Prodanova N. Sarvut T. Matytsin A. (2024) *Developing architectural design solutions and the interior organization of compact apartments with a comfortable living environment: A case study of the real estate market in Russia and Kazakhstan.*
https://www.researchgate.net/publication/381873430_Developing_Architectural_Design_Solutions_and_the_Interior_Organization_of_Compact_Apartments_with_a_Comfortable_Living_Environment_A_Case_Study_of_the_Real_Estate_Market_in_Russia_and_Kazakhstan
- 8.Lex.uz. (2019). SHNQ 2.08.01-2019 “Turar joy binolari” shaharsozlik normalari va qoidalari [ШНК 2.08.01-2019 «Жилые здания» Градостроительные нормы и правила].
<https://lex.uz/uz/docs/-5894699>
9. Ispasoiu A. Milosan I. Gabor C. Pavalache-Ilie M. Oancea G. (2025). A risk assessment method for narrow spaces with low height. *Applied Sciences*, 15(21), 11625. MDPI. <https://www.mdpi.com/2076-3417/15/21/11625>
- 10.Ablyayeva A. Minachyeva A. Fatxuddinova L. (2024). Influence of ergonomics of schoolchildren's workplaces on the occurrence of musculoskeletal discomfort. *Hygiene and Sanitation.* <https://journals.eco-vector.com/0016-9900/article/view/638684/Gigiena%20i%20sanitariya>
- 11.Tokajuk A. (2023). *Optimization of the functional concept of the minimum apartment - a study on a selected example: The role of functional details.*
https://www.researchgate.net/publication/369961735_Optimization_of_the_functional_concept_of_the_minimum_apartment_-_a_study_on_a_selected_example_The_role_of_functional_details
- 12.Cirovic I. Dimitrijevic A. Vasiljevich J. (2023). *Ergonomic principles in designing space, furniture and equipment for preschool institutions.*
<https://sed.akademijazs.edu.rs/fajlovi/papers/proceedings/4-16.pdf>
- 13.Gajwani N. Rana D.P. (2024). *Optimizing residential spaces: The role of Multifunctional Furniture in Enhancing Functionality.* International Journal of Housing and

Human Settlement Planning.

[https://journalspub.com/wp-](https://journalspub.com/wp-content/uploads/2024/06/32-46-Optimizing-Residential-Spaces-.pdf)

[content/uploads/2024/06/32-46-Optimizing-Residential-Spaces-.pdf](https://journalspub.com/wp-content/uploads/2024/06/32-46-Optimizing-Residential-Spaces-.pdf)

15.Jain H. (2024). *Critical insights into thermal comfort optimization and heat resilience in indoor spaces.*

https://www.researchgate.net/publication/386734114_Critical_insights_into_thermal_comfort_optimization_and_heat_resilience_in_indoor_spaces

16.Azadi Sh. Bai N. (2024). *Ergonomics of spatial configurations: A voxel-based modelling framework for accessibility and visibility simulations.*

https://www.researchgate.net/publication/378714732_Ergonomics_of_spatial_configurations_a_voxel-based_modelling_framework_for_accessibility_and_visibility_simulations

17.Remizov A. Memon SH.A. Kim.J.R. (2023). *Climate zoning for buildings: From basic to advanced methods-A review of the scientific literature.* 13(3), 694. MDPI.

<https://doi.org/10.3390/buildings13030694>

18.Ahmed F. Hafijur Rahman S.M. (2024). *Evaluation of thermal comfort in residential buildings: A case study of Wari, Dhaka.* International Journal of Science and Research Archive. https://ijsra.net/sites/default/files/fulltext_pdf/IJSRA-2024-2576.pdf

19.Lee Junsoo, Koo Chongwan (2024). *Investigation of individual differences in thermal comfort of elderly residential spaces: Utilizing IoT-based physiological model.*

Korean Journal of Construction Engineering and Management. <https://koreascience.kr/article/JAKO202404357601173.do>

20. Huizenga Ch. Ouellet-Plamondon C. Schiavon S. Brager G. ... (2024). *Establishing maximum safe indoor temperatures for U.S. residential buildings.*

<https://espace2.etsmtl.ca/id/eprint/30466/1/Ouellet-Plamondon-C-2024-30466.pdf>