Multi-Objective Optimization of Residential Building Design for Immigrant Resettlement in the Tibetan Plateau: A Case Study of Ankang Community

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Abstract

The Tibetan Plateau's extreme climate conditions pose unique challenges to residential building design, particularly for immigrant resettlement projects. This study focuses on the heating season energy efficiency, thermal comfort, and solar radiation acquisition potential of residential buildings in Ankang Community, exploring multi-objective optimization methods. Using the Multi-objective Grey Wolf Optimizer, a model was developed that integrates and simultaneously optimizes key building design parameters. The resulting Pareto-optimal solution set was then analyzed through multiple linear regression to reveal the underlying influence mechanisms. Findings highlight the south-facing window-to-wall ratio as a critical control parameter, while trade-offs are needed for variables like floor-to-floor height ratio due to conflicting goals.

Keywords: Tibetan Plateau, Multi-objective optimization, Energy efficiency, Thermal comfort, Solar radiation acquisition potential, Resettlement housing

1. Introduction

The Tibetan Plateau, with its extreme climate and high altitudes, presents unique challenges for residential building design, especially for immigrant resettlement projects. The harsh cold climate demands efficient heating solutions, and the high altitude exacerbates thermal discomfort, making sustainable building design essential. Current designs in this region often fail to fully address the energy efficiency, thermal comfort, and solar energy utilization in such extreme environments. Therefore, balancing housing provision with the improvement of residential environmental suitability and sustainability has become a pressing challenge in the field of architecture.

The performance of residential buildings constitutes a core concern in achieving energy efficiency, enhancing occupant comfort, and advancing sustainable development. In recent years, substantial progress has been made in this field, with research increasingly focusing on multiple aspects, including energy consumption, thermal comfort, daylighting, environmental adaptability, and performance evaluation methods. Wu et al. (2024) proposed an optimization framework integrating Bayesian Optimization with Extreme Gradient Boosting (BO-XGBoost) and the Non-dominated Sorting Genetic Algorithm II (NSGA-II) to address multi-objective optimization of residential building performance. The results demonstrated that the proposed approach effectively optimized the targeted performance objectives. Compared with the baseline Ídesign of the case building, energy consumption was reduced by 44.1%, the thermal comfort index decreased by 10.9%, and daylighting performance improved by 1.7%. Zhang et al. (2020) selected 27 design parameters related to residential spatial configurations and building envelope characteristics for optimization and analysis, aiming to establish the correlations between these parameters and building performance. This approach enables architects to readily identify design parameters based on their performance sensitivity. Shi et al. (2024) developed a Multi-Performance Collaborative Optimization framework (MPC_BPO) to analyze modern residential retrofit projects in extremely arid and hot climatic regions. Under the optimization scenario primarily driven by Energy Use Intensity (EUI), the Daylight Index (DLI) and Thermal Comfort Hours (TCH) increased by 12.32% and 6.67%, respectively, while the EUI was reduced by more than 8.47%. Alwetaishi (2022) found that, in hot climate regions, insulation measures and the window-to-wall ratio have a substantial influence on both energy consumption and thermal comfort. Kalaimathy et al. (2023) investigated the effects of visible light transmittance of glazing and the window-to-wall ratio on the daylighting performance of the ground floor in two-story residential buildings located in warm-humid climates. They found that a window-to-wall

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ratio of 16%, a visible light transmittance of 0.62, and a glare level of 0.52 can collectively satisfy daylighting requirements and standards. Shao et al. (2024) employed the Strength Pareto Evolutionary Algorithm 2 (SPEA-2) to conduct a multi-objective optimization of high-rise residential buildings in Xi ' an and Yulin, focusing on building energy consumption, thermal comfort, life-cycle cost, and carbon emissions.

In recent years, the performance of rural residential buildings has emerged as a key focus in the pursuit of building energy efficiency and sustainable development. Existing studies have primarily concentrated on energy consumption optimization, enhancement of thermal performance, application of green building materials, and low-carbon transition strategies. Zou et al. (2025) proposed an optimization approach for rural residential buildings in Inner Mongolia, aiming to reduce energy demand while enhancing indoor thermal comfort and daylighting performance. Comparative analysis indicated that, following optimization, energy consumption decreased by 22.56%, the percentage of people dissatisfied with the thermal environment (PPD) was reduced by 19.26%, and the user satisfaction index (UDI) increased by 25.44%. Wang et al. (2024a) proposed a more precise two-stage optimization design framework for rural residential buildings (RRBs) in hot-summer and cold-winter regions of China. Application of this framework to a typical three-bay RRB demonstrated that the optimized design achieved an annual reduction of 11% in total energy consumption for air conditioning and heating. Zhai et al. (2025) proposed a multi-objective optimization model based on the Chebyshev inequality. The optimization results indicated reductions of 29% in heating energy consumption and 6% in air-conditioning energy consumption. Shao et al. (2022) employed EnergyPlus coupled with a MOBO optimization approach to optimize building orientation, envelope design, and winter indoor temperatures for rural houses in western China, effectively reducing energy use and improving thermal comfort. Tahsildoost and Zomorodian (2020) analyzed energy retrofit strategies for rural residential buildings across different climatic zones in Iran using a multi-criteria decision support tool, reporting reductions of 46-55% in energy consumption and 40-51% in carbon emissions. Molake et al. (2023) proposed a courtyard-roof-based multi-objective optimization strategy for rural courtyard houses in cold regions, targeting daylight performance, thermal comfort, and energy efficiency.

The unique high-altitude, cold, and high-radiation climate of the Tibetan Plateau imposes elevated demands on residential building performance. In recent years, most related studies have focused on energy efficiency optimization and the thermal design of building envelopes. Xiao et al. (2024) investigated the impact of early-stage design parameters on the energy performance of low-energy solar rural houses integrated with building-integrated photovoltaic (BIPV) roof systems. Yang et al. (2024) investigated three typical residential buildings in Litang County and Ngari Prefecture during the winter and transitional seasons, revealing the dynamic behavior of south-facing exterior walls in terms of heat collection, storage, and insulation under the local climate. Wang et al. (2024b) proposed a Global Energy Calculation Method (GECM) to evaluate the impact of exterior windows on building energy consumption. Using a residential building as a case study, the results demonstrated that appropriate selection of window types and the design of suitable envelope ventilation rates can effectively reduce overall energy use.

Although previous studies have applied widely used multi-objective optimization algorithms such as NSGA-II and SPEA-2 to improve residential building performance in cold regions, most of these studies focus on general climatic zones in northern or northwestern China. Research specifically targeting immigrant resettlement housing in the Tibetan Plateau remains limited. Compared with conventional cold-region residential buildings, resettlement housing in high-altitude plateau areas exhibits distinct climatic constraints, solar radiation characteristics, and spatial typologies, which require tailored optimization strategies.

To address these research gaps, this study makes three main contributions. First, it focuses on immigrant resettlement housing in the Tibetan Plateau, a building typology that has received limited attention in previous building performance optimization studies despite its unique climatic and socio-spatial characteristics. Second, a Multi-objective Grey Wolf Optimizer (MOGWO) is integrated with post-optimization statistical analysis. Compared with commonly used algorithms such as NSGA-II and SPEA-2, MOGWO requires fewer tuning parameters and exhibits strong global search capability, making it suitable for solving continuous and nonlinear multi-objective optimization problems in building design. This framework not only generates Pareto-optimal solutions but also reveals the influence mechanisms of key design parameters through multiple linear regression, thereby improving methodological transparency compared with studies that report only optimal solutions. Third, the reliability of the optimization results is strengthened through baseline comparison and statistical analysis, providing more robust design insights for residential buildings in high-altitude regions.

By integrating parametric modeling, simulation-based optimization, and regression-based mechanism analysis, this study aims to clarify how architectural design parameters jointly influence heating season energy efficiency, thermal comfort, and solar radiation acquisition potential in plateau resettlement housing, thereby providing actionable guidance for climate-responsive residential design in high-altitude regions.

2. Research Method

This study integrates parametric modeling, performance simulation, and multi-objective optimization to explore the influence of key design parameters on residential building performance in the Ankang Community of the Tibetan Plateau. The research process includes three major steps: (1) identifying key design parameters based on the analysis of typical local building forms and envelope characteristics; (2) performing multi-objective optimization; and (3) analyzing the influence mechanisms of these parameters through regression analysis. Various tools were employed to support these stages, including Rhinoceros and Grasshopper for parametric modeling, Ladybug and Honeybee for performance simulations, and MATLAB for optimization and statistical analyses.The overall methodological workflow is illustrated in Figure 1.

2.1. Identification of Key Design Parameters

Typical building forms from Ankang Community were analyzed to identify key parameters. These parameters reflect the design features most relevant to the region's high-altitude climate and solar conditions. The parameter set and their value ranges were then defined as input variables for subsequent optimization.

2.2. Multi-Objective Optimization with MOGWO

A multi-objective optimization model was developed using the Multi-objective Grey Wolf Optimizer (MOGWO) proposed by Mirjalili et al. (2016). The model evaluated heating season energy efficiency, thermal comfort, and solar radiation acquisition. MOGWO iteratively balances these objectives, generating a set of Pareto-optimal solutions. By comparing this set of optimal solutions with the baseline model, the simulation results are validated, ensuring the effectiveness of the optimization process.

2.3. Analysis of Influence Mechanism

To further interpret the optimization results, a single-variable control method was applied to assess the impact of each design parameter. Based on the baseline building model, simulation experiments were conducted by varying one parameter at a time to evaluate changes in energy efficiency, thermal comfort, and solar radiation acquisition potential. Subsequently, multiple linear regression (MLR) was employed to quantitatively analyze the influence of each parameter. Standardized regression coefficients and t-statistics were used to determine both the relative importance and statistical significance of design variables. This analysis clarifies how specific design choices affect overall building performance in high-altitude cold regions, providing a deeper understanding of the underlying influence mechanisms.

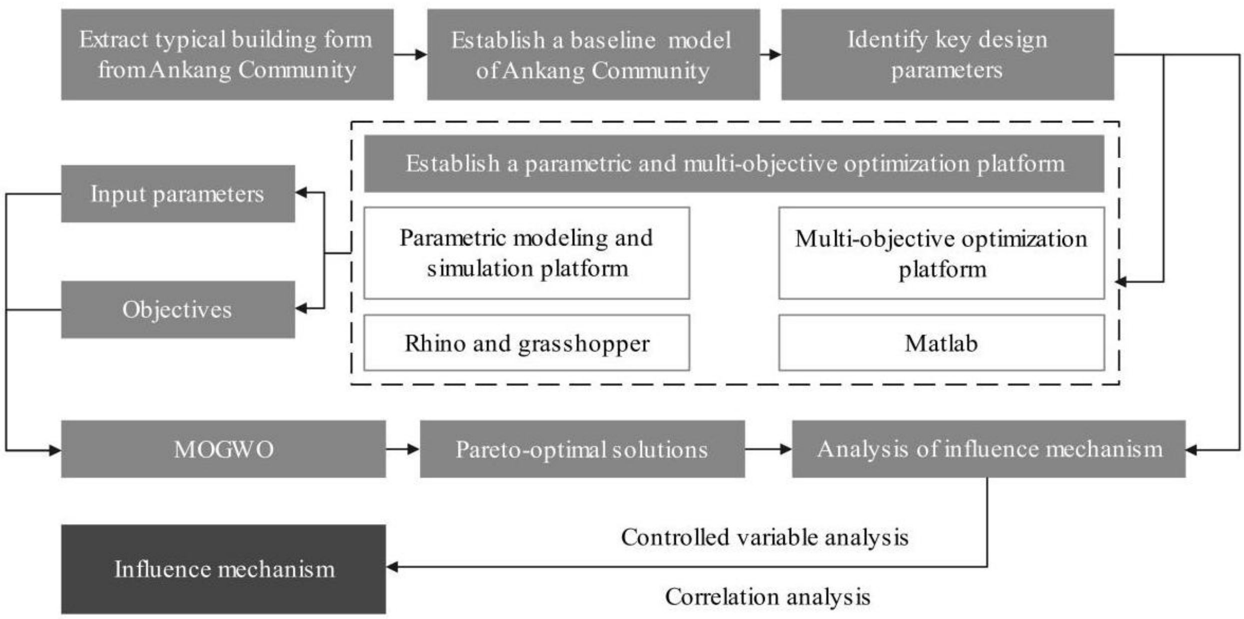

Figure 1: Methodological flowchart

3. Case Study

This study focuses on Ankang Community, a representative resettlement community located in Xinghai County, Qinghai Province, on the eastern Qinghai-Tibet Plateau. The area is characterized by a typical high-altitude climate with low temperatures and strong solar radiation. As a government-led resettlement project, the Ankang Community reflects typical design responses to harsh plateau conditions. Buildings are mostly two-story and compactly arranged, with adaptive strategies in form, material, and energy systems that are representative of similar communities in the region.

A commonly found two-story terraced residential unit was selected as the case building（show in Figure 2）. The building envelope features 240 mm thick KP1-1 perforated brick walls insulated with graphite-expanded polystyrene, and windows are double-glazed. Details of insulation and glazing materials are listed in Table 1 and Table 2. A centralized heating system operates from October 15 to April 15. The building model was generated in Rhinoceros and simulated using Ladybug and Honeybee coupled with EnergyPlus. The climate data used in the simulation was the typical meteorological year (TMY) weather file of Xinghai County, Qinghai Province. Occupant-related input data follow standard residential settings: metabolic rate of 1.0 met, clothing insulation of 1.0 clo, and air velocity of 0.1 m/s.

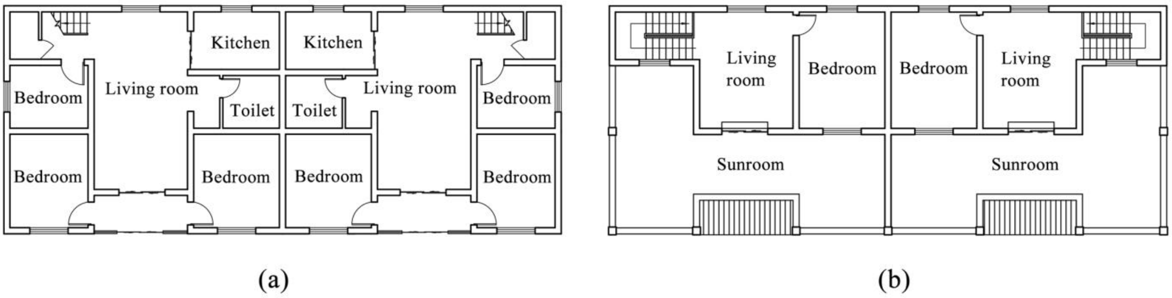

Figure 2: 2D plan:(a)ground floor,(b)second floor

Table 1: Insulation material and and their specifications for the Case Building

Material name	Thickness（mm）	Density（kg m^{-3}）	Specific heat（J kg^{-1} K^{-1}）	Conductivity（W m^{-1} K^{-1}）
GEPS	100	25	1000	0.032

Table 2: Glazing type and and their properties for the Case Building

Glazing type	Thickness（mm）	U value(W m^{-2} K^{-1})	SHGC(%)
double-glazed (5mm/15mm air/5mm)	25	2.5	0.7

4. Parameters and Indexes Determination

In this study, eight design parameters closely related to building heating energy efficiency, thermal comfort, and solar radiation acquisition potential were selected. These parameters include building orientation (BO), building aspect ratio (BAR), floor-to-floor height (FFH), shared wall ratio (SWR), sunroom roof slope (SRS), east-facing window-to-wall ratio (EWWR), south-facing window-to-wall ratio (SWWR), west-facing window-to-wall ratio (WWWR), north-facing window-to-wall ratio (NWWR), thermal insulation material for exterior walls (IM), and glazing type (GT) (see Table 3). These parameters directly influence a building's energy performance, indoor thermal comfort, and capacity to harness solar radiation.

To further quantify the impact of these design parameters, three evaluation indicators were selected (see Table 6). The Energy Use Intensity (EUI) during the heating season serves as the key metric for assessing heating energy performance, reflecting the building's energy consumption and providing a quantitative basis for energy optimization (Yao et al., 2024). The Percentage of People Dissatisfied (PPD) measures the proportion of people predicted to feel too hot or too cold and thus uncomfortable. It is calculated based on the Predicted Mean Vote (PMV), which reflects the average thermal sensation of occupants. PPD is an effective metric for assessing thermal comfort (Broday et al., 2021, Du et al., 2022).

To assess solar radiation acquisition potential, two indicators are used: the annual solar radiation per unit of exterior surface area (ASU) and the heating season solar radiation per unit of exterior surface area (HSU). ASU reflects the total annual solar radiation received by the building envelope, while HSU specifically measures solar gains during the heating season (Song et al., 2024). Given that this study focuses on individual buildings, and in order to emphasize the importance of solar radiation gain during the heating season while taking into account the overall annual solar radiation, a comprehensive index was defined: solar radiation acquisition is assessed based on annual and heating season solar radiation (AHSR) per unit window area.

Table 3: Design parameters

Design parameters	Variable Name	Range	Deviation	Unit	Note
BO	X1	0-80	10	°	BO ranges from 40° west to 40° east of south, defined as 0° to 80° for analysis.
BAR	X2	1.5-3.5	0.5	-	Varies with constant footprint area.
FFH	X3	2.7-3.3	0.1	m	-
SWR	X4	0-100	10	%	-
SRS	X5	0-5	1	°	-
EWWR	X6	0-30	5	%	Ranges based on relevant design codes.
SWWR	X7	0-45	5	%	
WWWR	X8	0-30	5	%	
NWWR	X9	0-25	5	%	
IM	X10	Show in Table 4			
GT	X11	Show in Table 5			

Table 4: Insulation materials and their specifications

Material name	Thickness（mm）	Density（kg m^{-3}）	Specific heat（J kg^{-1} K^{-1}）	Conductivity（W m^{-1} K^{-1}）
Aerated concrete	100	550	1050	0.14
Glass wool	100	20	840	0.037
Rock wool	100	92	840	0.044
Cellulose	100	48	1381	0.04
Polyurethane	100	35	1470	0.024

Table 5: Glazing types and their properties

Glazing type	Thickness（mm）	U value(W m^{-2} K^{-1})	SHGC(%)
Glazing 1	25	5.8	0.81
Glazing 2	25	4	0.59
Glazing 3	25	2	0.604
Glazing 4	25	2.6	0.77
Glazing 5	25	1.4	0.6

Table 6: Evaluation indicators

Evaluation indicators	Calculation Method	Note
EUI	$EUI=\frac{EUI_{heat}}{A_{total}}$	EUI_{heat} is the total energy consumption during the heating season (unit: kWh). A_{total} is the total building floor area (unit: m²).
PPD	$PPD=100-95\cdot e^{-0.03353\cdot PMV^4-0.2179\cdot PMV^2}$	Unit: %

AHSR	$AHSR=\frac{WSR_{annual}+WSR_{heat}}{A_{window}}$	WSR_{annual} is the annual window solar radiation(unit: kWh). WSR_{heat} is the heating season window solar radiation(unit: kWh). A_{window} is the window area (unit: m²).

5. Results and Discussion

5.1 Pareto-Optimal Solutions

The multi-objective optimization using MOGWO yielded a Pareto front of design solutions that balanced three key performance indicators: EUI, PPD, AHSR. As shown in Figure 3, each point represents an optimized design solution successfully identified by MOGWO. Compared to the baseline, the optimized solution significantly reduced both EUI and PPD, with EUI decreasing by 20% to 30% and PPD decreasing by 30%. Meanwhile, AHSR was also significantly improved, increasing by 20% to 40% (see Table 7). These results demonstrate the significant optimization effect of the combination of strategic design parameters on building performance.

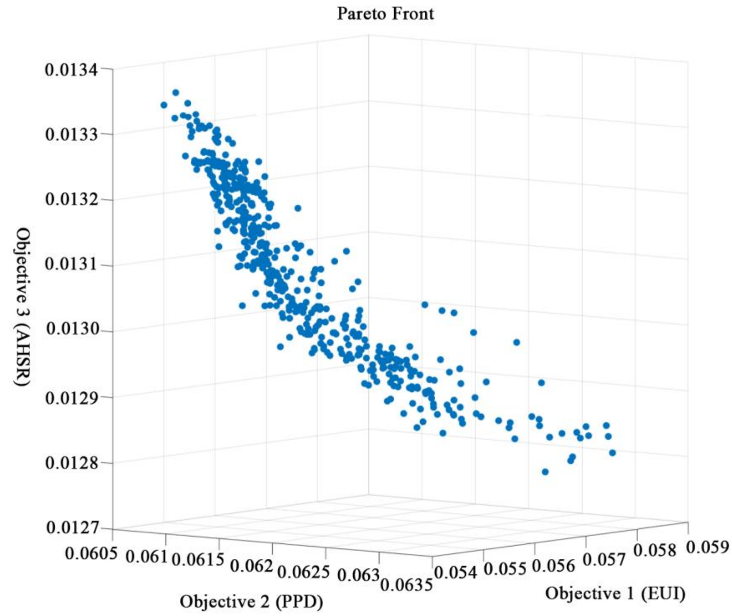

Figure 3: Tri-objective Pareto solutions during optimization

Table 7: Performance comparison between the Top 10 optimized solutions and the case building

EUI	PPD	AHSR
-28.95%	-33.77%	39.84%
-19.87%	-32.62%	22.87%
-23.21%	-31.40%	24.78%
-20.47%	-31.79%	31.84%
-23.50%	-30.02%	27.52%
-26.64%	-31.93%	28.12%
-18.48%	-31.77%	17.34%
-22.42%	-29.50%	21.45%
-23.07%	-31.79%	25.34%
-24.10%	-32.31%	27.73%

5.2 Influence Mechanism

To investigate the influence of individual design parameters on building performance, eleven line charts were generated to illustrate the variation of the three optimization objectives under different input conditions (see Figure 4). The plots show the percentage changes in EUI, PPD, and AHSR relative to the baseline model of a typical residential unit. For each parameter, the x-axis represents the parameter value, and the y-axis represents the corresponding percentage change in each performance indicator compared to the baseline. Overall, most variables demonstrated clear and monotonic trends.

Regarding BO, an orientation of 10° east of due south resulted in the lowest EUI and PPD, along with the highest AHSR. Deviations from this optimal orientation increased EUI and PPD while reducing AHSR. Performance deterioration was less pronounced for rotations toward the southeast compared with those toward the southwest, which may be attributed to the asymmetrical distribution of solar radiation under the local climatic conditions.

For BAR, smaller ratios (1-2) substantially degraded EUI and PPD, while larger ratios (>2.5) slightly improved AHSR (about 1% per 0.5-unit increase) but also raised EUI (about 0.4% per 0.5-unit decrease) .

FFH and SWR exhibited similar linear trends: increases in FFH and reductions in SWR led to higher EUI and PPD, accompanied by lower AHSR. For FFH, each 0.1 m increase raised EUI by approximately 0.6% and PPD by about 0.1%, while reducing AHSR by roughly 0.6%. For SWR, the deterioration rates of EUI, PPD, and AHSR accelerated as the ratio decreased.

SRS exhibited a stable and linear trend. As the SRS increased, both EUI and PPD improved markedly, while AHSR rose steadily, indicating that roof slope adjustment can enhance multiple aspects of building performance simultaneously. On average, each 1° increase in SRS improved performance indicators by approximately 0.7%.

Regarding the WWR, the impact of different façades WWRs on EUI, PPD, and AHSR varies from one another. Increases in EWWR, WWWR, and NWWR led to higher EUI and lower AHSR. Notably, NWWR shows the fastest decline in AHSR, with an approximate 6% reduction for every 5% increase in WWR.Increasing EWWR tended to reduce PPD, whereas PPD increased with higher NWWR; changes on WWWR had minimal impact on PPD.SWWR exhibited an almost linear trend: as WWR increased, EUI and PPD gradually decreased while AHSR increased.This effect was especially pronounced when SWWR was below 0.25, where each 5% increase in WWR reduced EUI by approximately 1%, reduced PPD by around 2%, and increased AHSR by about 2%.

For IM and GT, Polyurethane and Glazing 5 were identified as the optimal choices.It is also evident that IM and GT have a considerably greater impact on EUI and PPD compared with other design parameters.

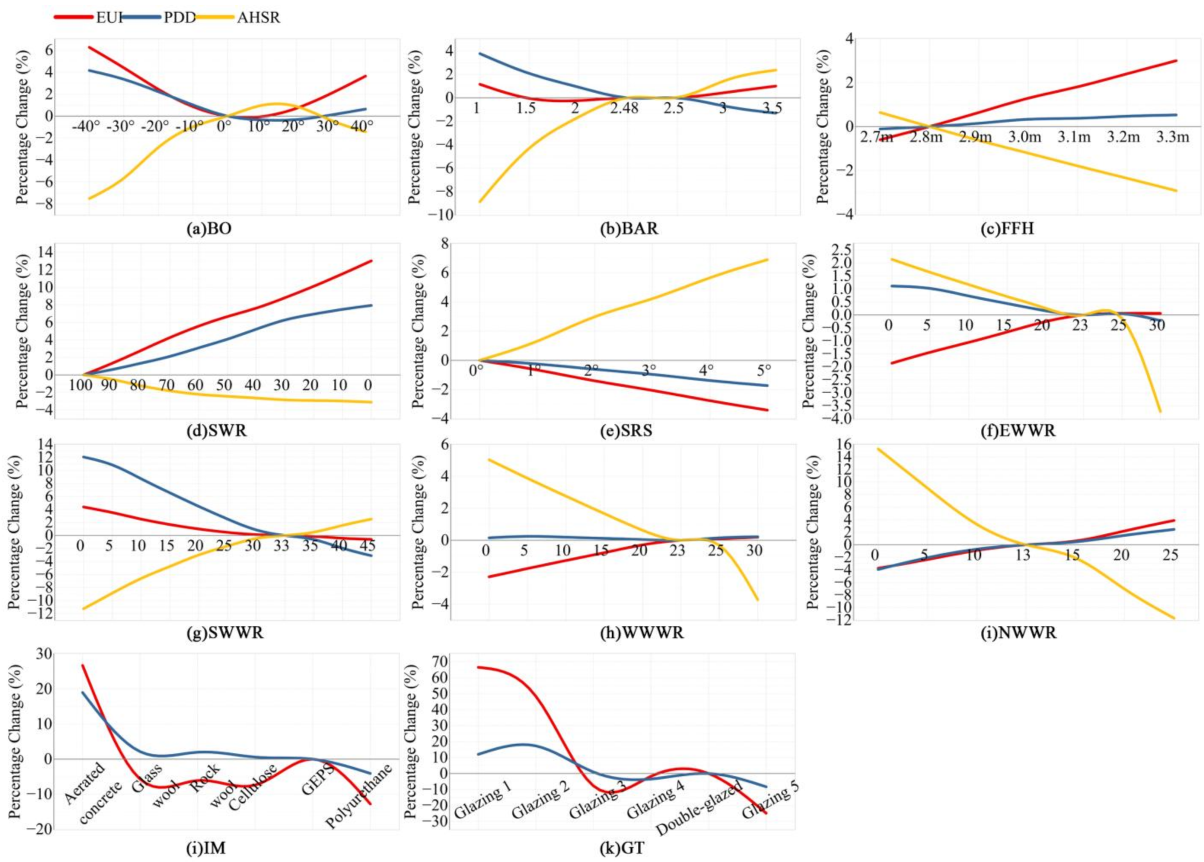

Figure 4: Influence of design parameters on building performance

To further explore the combined effects of the parameters, a MLR model was employed for evaluation (see Figure 5 and Figure 6). The regression models achieved R^2 values above 0.8, indicating strong explanatory power. The analysis reveals distinct patterns of influence across the three performance indicators. For EUI, parameters SWR (X4) and SRS (X5) exhibit strong negative effects, while WWWR (X8) and NWWR (X9) demonstrate strong positive effects, indicating that SWR (X4) and SRS (X5) play a dominant role in reducing energy consumption. This finding is reinforced by the t-statistics, as SWR (X4), SRS (X5), SWWR (X7), NWWR (X9), IM (X10), and GT (X11) all exceed the ±2 significance threshold, confirming the statistical relevance and robustness of their impacts on EUI.

In terms of PPD, SWWR (X7) emerges as the most influential parameter, exerting a strong negative effect, whereas NWWR (X9) and IM (X10) display comparatively strong positive effects. This underscores the critical role of SWWR (X7) in improving thermal comfort by mitigating user dissatisfaction. The corresponding t-statistics, all with absolute values greater than ±2, further validate the statistical significance of these relationships.

For AHSR, the standardized regression coefficients indicate that BAR (X2) and SWWR (X7) exert significant positive influences, while NWWR (X9) demonstrates the strongest negative effect. The robustness of these effects is confirmed by t-statistics exceeding the ± 2 threshold. Conversely, the remaining design parameters show relatively small standardized coefficients and non-significant t-values, suggesting minimal or uncertain contributions to AHSR. Notably, the alignment between standardized coefficients and t-statistics, coupled with relatively small standard errors, suggests that the regression estimates are both stable and reliable.

From a design perspective, the results indicate that, in high-altitude cold regions, optimizing SWR and SRS is critical for minimizing building energy consumption, whereas an excessively large NWWR and inappropriate IM choices tend to increase energy demand. Optimizing SWWR plays a key role in enhancing indoor thermal comfort, while overly high values of NWWR and unsuitable IM are associated with greater thermal discomfort. In terms of solar energy utilization, optimizing BAR and SWWR can significantly improve solar gain, whereas an excessively large NWWR, unfavorable BO, and inappropriate IM substantially weaken the building's ability to harness solar radiation.

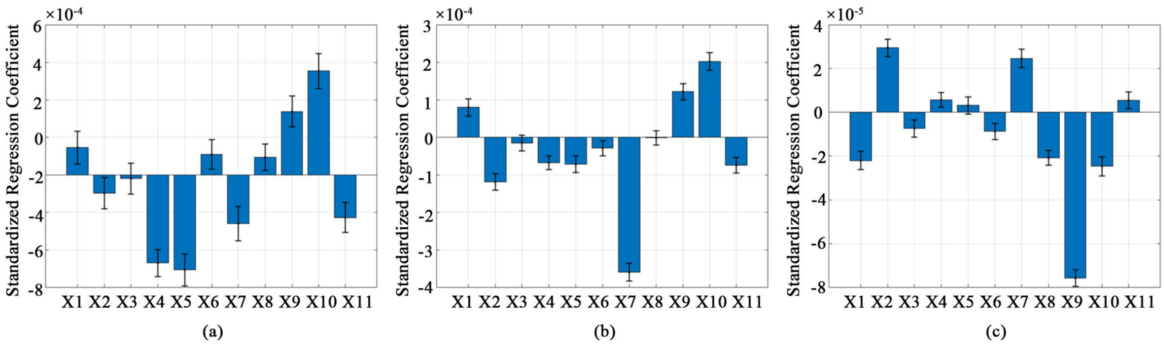

Figure 5: Standardized Regression Coefficient of each design parameter in relation to (a) EUI, (b) PPD and (c) AHSR

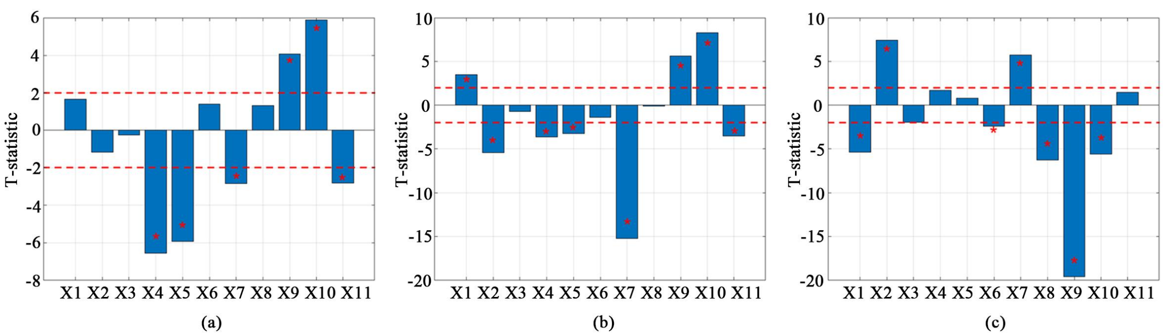

Figure 6: T-statistics of each design parameter in relation to (a) EUI, (b) PPD and (c) AHSR

5.3 Discussion

The above results were derived under specific constraints: a fixed building typology based on a typical Ankang Community unit and simulation settings tailored to the Tibetan Plateau context. While the optimized outcomes offer valuable guidance for similar high-altitude resettlement housing, caution is needed when applying them to other contexts. Limitations include the exclusion of construction cost constraints, which future studies should address to improve practical relevance.

6. Acknowledgments

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7. Conclusion

This research explored the influence mechanisms of various design parameters on building performance, providing design insights for climate-responsive and energy-efficient housing design in this extreme environments. The conclusion is summarized as follows:

- The south-facing window-to-wall ratio is the most influential variable, significantly reducing PPD and EUI while enhancing AHSR. It should be prioritized in design.
- Glazing type and insulation material effectively reduce EUI and PPD, making them important for passive energy-saving strategies.
- The floor-to-floor height significantly reduce AHSR, PPD and EUI, indicating goal conflicts and the need for trade-offs.
- The east-facing window-to-wall ratio and west-facing window-to-wall ratio show variable effects across objectives, requiring context-sensitive adjustments.

Although the control of design parameters such as window-to-wall ratio and building orientation in this study shows imilarities with studies in other cold regions, specific conclusions differ depending on optimization objectives.Future research could explore the applicability of this approach to other residential areas in this region.

8. References

Alwetaishi, M., 2022. Energy performancein residential buildings: Evaluationof the potential of building design and environmental parameter. Ain Shams Engineering Journal, 13,101708.

Broday, E. E., Ruivo, C. R. & Gameiro da Silva, M., 2021. The use of Monte Carlo method to assess the uncertainty of thermal comfort indices PMV and PPD: Benefits of using a measuring set with an operative temperature probe. Journal of Building Engineering, 35,101961.

Du, H., Lian, Z., Lai, D., Duanmu, L., Zhai, Y., Cao, B., Zhang, Y., Zhou, X., Wang, Z., Zhang, X. & Hou, Z., 2022. Evaluation of the accuracy of PMV and its several revised models using the Chinese thermal comfort Database. Energy and Buildings, 271,112334.

Kalaimathy, K., Shanthi Priya, R., Rajagopal, P., Pradeepa, C. & Senthil, R., 2023. Daylight performance analysis of a residential building in a tropical climate. Energy Nexus, 11,100226.

Mirjalili, S., Saremi, S., Mirjalili, S. M. & Coelho, L. d. S., 2016. Multi-objective grey wolf optimizer: A novel algorithm for multi-criterion optimization. Expert Systems with Applications, 47,106-119.

Molake, A., Zhang, R. & Zhou, Y., 2023. Multi-Objective Optimization of Daylight Performance and Thermal Comfort of Enclosed-Courtyard Rural Residence in a Cold Climate Zone, China. Sustainability.

Shao, T., Wang, J., Wang, R., Chow, D., Nan, H., Zhang, K. & Fang, Y., 2024. Multi-Objective Optimization for the Energy, Economic, and Environmental Performance of High-Rise Residential Buildings in Areas of Northwestern China with Different Solar Radiation. Applied Sciences, 14,6719.

Shao, T., Zheng, W., Li, X., Yang, W. & Wang, R., 2022. Multi-objective optimization design for rural houses in western zones of China. Architectural Science Review, 65,260-277.

Shi, G., Yao, S., Song, J., Bi, W., Qin, G. & Ni, P., 2024. Multi-performance collaborative optimization of existing residential building retrofitting in extremely arid and hot climate zone: A case study in Turpan, China. Journal of Building Engineering, 89,109304.

Song, G., Liu, Y., Li, W., Tan, J. & Cho, S., 2024. Comprehensive Comparative Analysis of Morphology Indexes for Solar Radiation Acquisition Potential in Lhasa Urban Residential Area. Sustainability.

Tahsildoost, M. & Zomorodian, Z., 2020. Energy, carbon, and cost analysis of rural housing retrofit in different climates. Journal of Building Engineering, 30,101277.

Wang, M., Xu, Y., Shen, R. & Wu, Y., 2024a. Performance-Oriented Parametric Optimization Design for Energy Efficiency of Rural Residential Buildings: A Case Study from China's Hot Summer and Cold Winter Zone. Sustainability, 16,8330.

Wang, X., Wu, Y., Dong, X., Liu, M., Lei, B. & Mai, X., 2024b. Optimization of global energy consumption of buildings based on photothermal coupling effect of exterior windows in Qinghai-Tibet plateau. Journal of Building Engineering, 85,108710.

Wu, C., Pan, H., Luo, Z., Liu, C. & Huang, H., 2024. Multi-objective optimization of residential building energy consumption, daylighting, and thermal comfort based on BO-XGBoost-NSGA-II. Building and Environment, 254,111386.

Xiao, Q., Liu, Y., Cho, S. & He, Y., 2024. Early-Stage Design Parameters for Low-Energy Solar Rural Houses in Qinghai-Tibet Plateau. E3S Web of Conferences.
Yang, L., Ye, Y., Qiao, Y., Feng, H., Wang, J., Dou, M., Wu, Y., Cao, Q. & Liu, Y., 2024. Thermal performance of south-facing envelopes in solar enrichment zone of Qinghai–Tibet plateau: Field measurements of multiple dwellings in winter and transition seasons. Renewable Energy, 237,121869.
Yao, G., Chen, Y., Han, C. & Duan, Z., 2024. Research on the Decision-Making Method for the Passive Design Parameters of Zero Energy Houses in Severe Cold Regions Based on Decision Trees. Energies.
Zhai, X., He, Z., Wang, R., Lu, S. & Zhang, L., 2025. Multi-objective optimization of building envelope of rural housing in the severely cold region of China based on energy consumption, thermal comfort and cost-effectiveness. Indoor and Built Environment, 34,627-643.
Zhang, J., Liu, N. & Wang, S., 2020. A parametric approach for performance optimization of residential building design in Beijing. Building Simulation, 13,223-235.
Zou, D., Sun, C. & Gao, D., 2025. Multi-Objective Optimization-Driven Research on Rural Residential Building Design in Inner Mongolia Region. Energies, 18,1867.