Thermal–Spatial Strategies for Rural Dwellings in Northern China

Chen Yang[1], Alamah Misni[2*], Mohamad Zulfadli Mohamad Zabidi [3]

[1] Studies for Postgraduate, Faculty of Built Environment, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia, [2] Studies of Landscape Architecture, Faculty of Built Environment, Universiti Teknologi MARA, 42300 Puncak Alam, Selangor, Malaysia, [3] King Salman Park, 11564 Riyadh, Kingdom of Saudi Arabia

2022445238@student.uitm.edu.my; alama884@uitm.edu.my; Lazulfadli88@gmail.com
Tel: +601117799029

Abstract

Rapid rural transformation in northern China presents challenges to thermal adaptation and residential satisfaction under changing climatic conditions. This study investigates relationships among spatial configuration, material characteristics, courtyard morphology, adaptive behaviours, thermal comfort, and residential satisfaction in rural dwellings. Survey data from 383 respondents were analysed using PLS-SEM Modelling. Findings indicate that housing typology significantly influences spatial organisation, courtyard performance, and perceived thermal comfort, while spatial configuration mediates residential satisfaction. The study highlights the importance of integrating climate-responsive spatial planning, passive environmental strategies, and occupant adaptive behaviours to develop resilient and context-sensitive rural housing strategies in northern China.

Keywords: Thermal adaptation; rural housing; courtyard; spatial planning

DOI: https://doi.org/10.21834/aje-bs.v11i32.491

1.0 Introduction
Rural revitalisation has become a significant development strategy in rapidly urbanising regions, particularly in northern China, where climatic variability strongly impacts residential environmental performance. Traditional rural settlements have evolved through long-term adaptations to local climate and socio-cultural conditions, resulting in vernacular courtyard dwellings that feature passive environmental regulation and spatial flexibility. These housing forms utilise thermal mass, shaded open spaces, and natural ventilation to moderate indoor thermal conditions while minimising energy consumption. Given buildings' substantial contribution to global energy use and carbon emissions, climate-responsive residential design has become increasingly vital for sustainable development (Aste et al., 2022).

However, contemporary rural reconstruction often replaces vernacular housing with standardised modern dwellings modelled on urban construction practices. Reinforced concrete structures and compact spatial layouts often prioritise construction efficiency over environmental adaptability, increasing cooling demand and reducing thermal resilience amid changing climatic conditions (Ren et al., 2022). Northern China's hot-summer and cold-winter transitional climate further accentuates the importance of adaptive strategies, as indoor comfort relies not only on building performance but also on occupants' behavioural responses. Residents often adjust their thermal environments by opening windows and utilising courtyards, which significantly influence their perceived comfort (Du & Chen, 2024).

From an environment-behaviour perspective, housing satisfaction arises from the interactions between spatial environments and human perception. Spatial configurations mediate the behavioural opportunities and environmental experiences within residential settings. Despite the growing research on adaptive comfort and vernacular sustainability, empirical studies that integrate spatial configuration, behavioural adaptation, and housing satisfaction using structural modelling approaches remain limited in rural northern China.

This study examines how environmental conditions and occupant behaviour interact in rural residential settings. Specifically, the study pursues three objectives: to compare the thermal performance of vernacular and contemporary rural dwellings, to assess the impact of courtyard morphology and material selection on indoor thermal conditions, and to establish structural relationships among spatial configuration, adaptive thermal comfort, and housing satisfaction.

2.0 Literature Review
Rising energy usage and climate change underscore the need for climate-responsive residential design that improves thermal comfort while reducing reliance on mechanical cooling. Vernacular architecture offers practical passive features, including courtyards, shade, natural ventilation, and thermal mass, while also supporting occupant behavioural adaptability. However, standardized home designs are gradually replacing these strategies. Therefore, this study examines the following relationships between dwelling features,

spatial design, adaptive thermal comfort, occupant behaviour, and housing satisfaction in order to address the limited usage of PLS-SEM in rural dwellings as follows:

2.1 Energy Transition and Thermal Performance in Residential Buildings

The building sector remains a primary contributor to global energy demand and associated carbon emissions, underscoring the urgency of improving residential thermal performance (Aste et al., 2022). Accelerated urbanisation, coupled with climate change, has intensified thermal stress in residential environments, particularly across rapidly developing regions in Asia (Ren et al., 2022). Inadequate building envelopes and construction methods that fail to account for climate factors increase cooling demand and operational energy use (Niza et al., 2022). Recent research highlights that combining spatial planning with passive design strategies can enhance thermal performance while promoting adaptive comfort in residential environments (Yang & Misni, 2026).

2.2 Vernacular Architecture and Passive Climate Adaptation

Vernacular architecture showcases climate adaptation strategies that have evolved. It incorporates passive features such as courtyards, shading, and thermal mass to help regulate indoor environments (Yang & Misni, 2025). Courtyard designs are particularly effective in reducing heat gain and enhancing ventilation, with their geometric configurations significantly influencing airflow and thermal stability. However, in contemporary rural housing, these climate-responsive designs are often replaced by standardised layouts that lack passive strategies. This shift reduces environmental satisfaction (Zhang et al., 2022). These findings emphasise the need to reinterpret traditional spatial principles in modern sustainable housing design.

2.3 Occupant Behaviour and Adaptive Thermal Comfort

Thermal comfort is increasingly understood as an adaptive process influenced by occupants' behaviours, such as adjusting windows, changing clothing, and modifying activity patterns, rather than being solely determined by fixed environmental conditions. Research on naturally ventilated homes indicates that behavioural adaptation plays a crucial role in maintaining acceptable comfort levels across different climates (Du & Chen, 2024; Chen & Misni, 2025). The theory of adaptive comfort emphasises interaction between humans and their environment rather than reliance on mechanical conditioning. Vernacular courtyard designs also promote flexibility, environmental resilience, and user control (Muqoffa et al., 2025).

2.4 Spatial Configuration, Environment–Behaviour Interaction and Housing Satisfaction

Research on the relationship between environment and behaviour indicates that housing satisfaction results from the interaction between spatial configuration and residents' perceptions. These interactions influence environmental exposure, privacy, adaptive behaviour, comfort, and overall well-being. Post-occupancy studies further demonstrate that indoor environmental quality plays a significant role in satisfaction and psychological restoration, with courtyard designs promoting social interaction and enhancing perceived quality. Studies using Structural Equation Modelling (SEM) suggest that spatial and environmental factors indirectly affect housing satisfaction, primarily through mediators such as perceived thermal comfort and behavioural adaptation (Yang & Misni, 2026). However, a notable research gap remains in the empirical application of Partial Least Squares SEM (PLS-SEM) to rural dwellings, particularly in northern China's transitional climate.

3.0 Methodology

This study uses a quantitative approach that combines environmental assessment and a structured questionnaire to examine residential thermal performance, spatial configuration, occupant behaviour, and housing satisfaction. The collected data are analysed using PLS-SEM to determine the relationships among these factors and their influence on adaptive thermal comfort and residential satisfaction as follows:

3.1 Research Design Framework

A quantitative environment–behaviour framework is adopted to explore the interactions between spatial configuration, thermal conditions, and occupant adaptation in rural housing. The methodology combines physical environmental evaluation with human perception analysis to assess the residential experience within climate-responsive built environments (Figure 1). The researchers constructed a conceptual analytical model to examine the causal relationships among architectural variables and behavioural outcomes. This framework includes six latent constructs and eight hypotheses:

H1: Dwelling typology is associated with variations in spatial configuration.
H2: Dwelling type influences the selection and characteristics of building materials.
H3: Dwelling typology contributes to differences in courtyard configuration.
H4: Courtyard configuration affects the performance attributes of building materials.
H5: Spatial configuration plays a critical role in shaping material characteristics.
H6: Spatial configuration is expected to influence levels of housing satisfaction.
H7: Thermal comfort is hypothesised to affect the perception and utilisation of courtyard spaces.
H8: Thermal comfort is assumed to have a direct effect on housing satisfaction.

The proposed model indicates that dwelling typology influences environmental performance through the combined effects of spatial organisation and material characteristics, with thermal comfort acting as an intermediary factor shaping residential satisfaction.

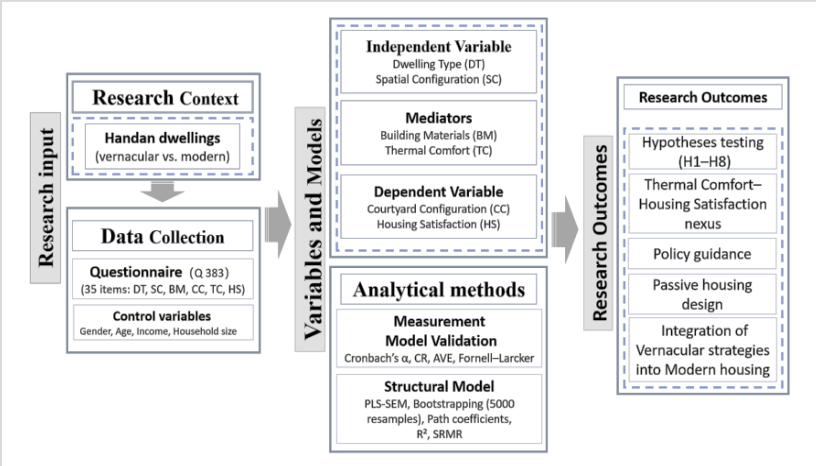

Figure 1: Conceptual framework for environment-behaviour relationships

3.2 Study Area

Figure 2: Study area location and the condition of houses in the surveyed village

The empirical investigation took place in Shatun Village, Handan City (Figure 2), in northern China, which experiences a hot-summer and cold-winter transitional climate. This area is characterised by high solar radiation intensity, significant diurnal temperature variations, and seasonal thermal stress, making it an ideal setting for evaluating climate adaptability in rural housing.

The study examined two primary types of residential buildings: Vernacular Courtyard Dwellings, built mainly before 2000 using brick masonry and designed with passive spatial layouts; and Modern Rural Dwellings, constructed after 2010, which use reinforced concrete systems and are influenced by urban housing models. The coexistence of these two housing types allows for a comparative assessment of their thermal and spatial performance under similar climatic conditions.

3.3 Data Collection and Survey Procedure

A structured questionnaire survey was conducted between July and August 2025, during peak summer conditions, to capture occupants' thermal perceptions and behavioural responses. Stratified household sampling yielded 383 valid responses. The questionnaire consisted of four sections, including: i. Demographic characteristics, ii. Spatial perception and dwelling characteristics, iii. Thermal sensation and adaptive behaviour, and iv. Housing satisfaction evaluation. The researchers measured thermal perception indicators using five-point Likert scales adapted from studies on adaptive thermal comfort. Behavioural adaptation variables included window-operation frequency, courtyard usage, ventilation practices, and activity-relocation patterns. Participation was voluntary, and the Universiti Teknologi MARA Research Ethics Committee approved the study.

The study uses six main latent variables to examine the relationship between residential design, thermal comfort, and housing satisfaction (Table 1). In simple terms, these variables work together to explain how residential design affects residents' comfort and satisfaction. The Dwelling Type (DT), Spatial Configuration (SC), Building Materials (BM), and Courtyard Configuration (CC) represent important characteristics of the physical dwelling. These characteristics can influence Thermal Comfort (TC), which may subsequently affect Housing Satisfaction (HS). Overall, the framework examines how dwelling characteristics and spatial design influence thermal comfort and, ultimately, housing satisfaction.

Table 1: The operational definition

Latent variable	Dimension	Content summary
DT	Dwelling Type	Classification of residential forms based on typology and construction characteristics.
SC	Spatial Configuration	Organization of spatial layout, including openings, circulation, and functional zoning.
BM	Building Materials	Main construction materials and envelope performance in insulation, acoustics, and durability.
CC	Courtyard Configuration	Physical composition and functional features of courtyard spaces, such as vegetation and shading.

TC	Thermal Comfort	Integrated assessment of indoor environmental conditions and occupants' thermal perception.
HS	Housing Satisfaction	Overall residential evaluation covering comfort, privacy, lighting, ventilation, and energy aspects.

3.4 Measurement Model Development

Multiple indicators from environmental-behaviour research frameworks and post-occupancy assessments operationalized each latent dimension. Cronbach's Alpha, Composite Reliability (CR), and Average Variance Extracted (AVE) were used to evaluate the measurement model's validity and reliability. An AVE of 0.50 confirmed sufficient convergent validity, while Alpha and CR values above 0.70 indicated appropriate reliability. To ensure each construct differed from the others, the study evaluated discriminant validity using the Fornell–Larcker criterion. These steps ensure construct validity and internal consistency before structural analysis.

3.5 Structural Equation Modelling (PLS-SEM)

Because it works well for predictive modelling with complex latent relationships and limited sample sizes, partial least squares structural equation modelling (PLS-SEM) was employed using SmartPLS 4.0. Because it enables simultaneous evaluation of measurement reliability and causal links across architectural and behavioural variables, PLS-SEM is widely used in research on environment-behaviour interactions and the built environment. We used bootstrapping with 5,000 resamples to assess the statistical significance of the path coefficients.

The researchers used path coefficients (β), R^2, Q^2, and SRMR to assess the PLS-SEM model. These metrics evaluated overall model fit, explanatory power, predictive relevance, and relationship strength. An SRMR value below 0.08 indicated satisfactory model fit, supporting the model's predictive performance and dependability.

3.6 Research Validity and Analytical Procedure

To ensure methodological rigour in line with standards, we conducted multicollinearity diagnostics using Variance Inflation Factors (VIFs) and ensured they were below 5.0. We also assessed predictive capability through blindfolding procedures. The analytical process consisted of five sequential stages: developing the questionnaire, implementing the field survey, validating the measurement model, testing the structural model, and interpreting the relationships between the environment and behaviour.

4.0 Results

The results present the findings on the relationships between dwelling type, spatial configuration, adaptive thermal comfort, occupant behaviour, and housing satisfaction. The analysis highlights the influence of architectural and environmental characteristics on residential performance and examines how behavioural adaptation contributes to the effectiveness of passive design strategies as follows:

4.1 Respondent Profile and Dwelling Characteristics

The researchers analysed 383 valid questionnaires to investigate thermal perception and residential satisfaction among rural occupants. Respondents were divided into two main dwelling types: vernacular courtyard houses (51.7%) and modern rural homes (48.3%). Most participants had lived in their current homes for over ten years, providing a reliable basis for evaluating environmental performance after occupancy. Vernacular dwellings were primarily single-storey courtyard houses with brick masonry walls, high thermal mass, and semi-open transitional spaces. In contrast, modern houses are mainly reinforced concrete structures, characterised by larger window openings and compact internal layouts. Preliminary observations suggested that residents in vernacular dwellings reported better natural ventilation and lower perceived summer overheating, while occupants of modern houses reported greater reliance on mechanical cooling systems.

4.2 Evaluation of the Measurement Model

The validity and reliability of the measurement model were evaluated before conducting hypothesis testing (Table 2). All constructs showed internal consistency, with Cronbach's Alpha and Composite Reliability (CR) values above the recommended cut-off of 0.70. This indicates that the measurement items exhibited sufficient internal consistency and that the concepts were dependable for further exploration. Therefore, the measurement model was deemed reliable enough to proceed with evaluating and testing the subsequent structural model.

Table 2: Measurement model reliability and validity results

Construct	Cronbach's α	Composite Reliability (CR)	AVE
BM	0.900	0.929	0.649
CC	0.714	0.901	0.623
DT	0.886	0.901	0.695
HS	0.777	0.873	0.402
SC	0.793	0.838	0.477
TC	0.806	0.891	0.527

Convergent validity was evaluated using Average Variance Extracted (AVE), as shown in Table 2, and most constructs met the suggested criterion of 0.50. However, the Housing Satisfaction Average Variance Extracted (AVE) score is 0.402, which is slightly below the suggested threshold of 0.50. However, because this architecture's Composite Reliability is higher than 0.70, we will continue to use it. According to earlier research, AVE values below 0.50 may still be acceptable if composite reliability is sufficient (Fornell & Larcker, 1981; Hair et al., 2022).

This suggests the construct's internal coherence is acceptable. This suggests the construct's internal consistency remains sufficient. This outcome aligns with PLS-SEM criteria for exploratory behavioural and environmental research. The Fornell-Larcker criterion, which showed that each concept shared more variance with its indicators than with other concepts, further supported discriminant validity. Taken together, these results demonstrate that the measurement model's validity and reliability are sufficient for structural analysis.

4.3 Structural Model Evaluation

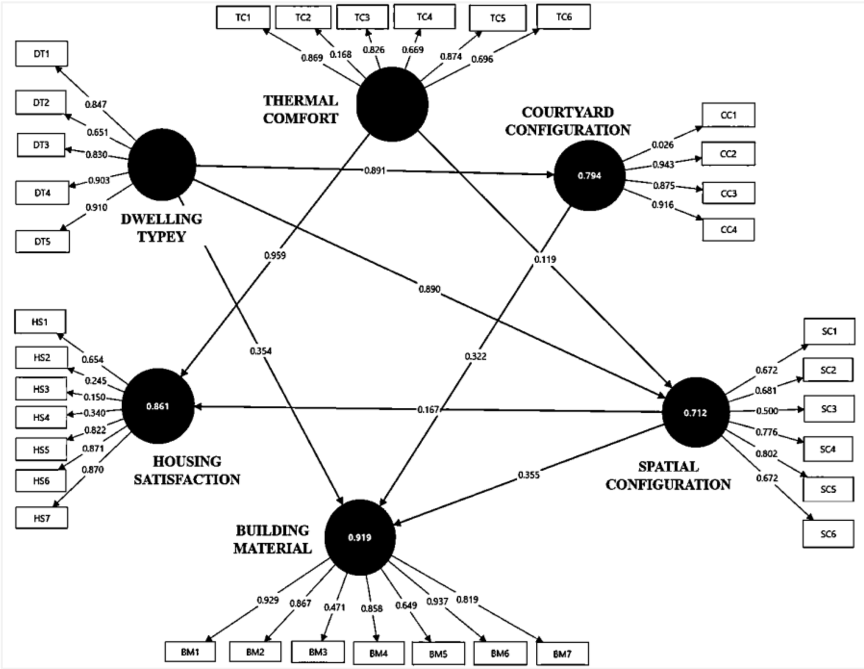

Figure 3: Structural equation model with path coefficients

After validating the measurement model, the structural model was analysed using bootstrapping with 5,000 resamples. Figure 3 shows a substantial causal relationship between architectural features, thermal comfort ratings, and home happiness. The most important factor in the model, Dwelling Type, had a substantial impact on Thermal Comfort ($\beta = 0.959$, $p < 0.001$), Courtyard Configuration ($\beta = 0.891$, $p < 0.001$), and Spatial Configuration ($\beta = 0.890$, $p < 0.001$). These results imply that house typology is a key factor in affecting spatial performance and environmental adaptability in rural residential contexts.

Furthermore, Building Materials significantly improved Spatial Configuration ($\beta = 0.355$), suggesting that the thermal-regulation capacity of building-envelope features affects spatial environmental behaviour. Additionally, Courtyard Configuration strongly influenced Spatial Configuration ($\beta = 0.322$), highlighting the importance of semi-open spatial systems for climate. Spatial Configuration also positively influenced Housing Satisfaction ($\beta = 0.167$, p

< 0.05), which suggests that the quality and arrangement of residential spaces contribute to occupants' overall satisfaction with their homes.

Overall, the structural model demonstrates that architectural characteristics affect housing satisfaction both directly and indirectly through spatial and environmental conditions. This underscores the importance of integrating dwelling typology, courtyard design, building materials, and spatial configuration in the design of climate-responsive rural housing.

4.4 The Model's Predictive Power

The explanatory power of the structural model was evaluated using coefficients of determination (R^2), as shown in Table 4. Both Thermal Comfort and Spatial Configuration showed strong predictive associations with dwelling qualities and environmental perception, with substantial explanatory power. The model has reasonable predictive capability for behavioural and satisfaction outcomes, as indicated by the predictive relevance evaluated using Q^2 values. Additionally, the Standardized Root Mean Square Residual (SRMR) was within the recommended level of 0.08, indicating sufficient model fit in line with PLS-SEM analytical requirements.

Table 3 shows how well the integrated thermal-spatial framework explains residents' environmental experience in rural dwellings. This work used PLS-SEM, which prioritizes predictive capability over stringent model-fit requirements, despite the SRMR value of 0.168 exceeding the generally advised threshold of 0.08. Other studies suggest interpreting SRMR carefully in PLS-SEM, particularly in exploratory research (Henseler et al., 2016). This study therefore highlights R^2 and Q^2 values, which show adequate explanatory and predictive capacity.

Table 3: Model Fit summary for PLS-SEM Analysis

Dimensions	Saturated model	Estimated model
SRMR	0.165	0.168
d_ULS	17.202	17.691
d_G	n/a	n/a
Chi-square	infinite	infinite
NFI	n/a	n/a

Table 4: Coefficient of determination (R^2) for endogenous constructs

Endogenous Variable	R^2	R^2 Adjusted
Building Materials (BM)	0.919	0.919
Courtyard Configuration (CC)	0.794	0.794
Housing Satisfaction (HS)	0.861	0.860
Spatial Configuration (SC)	0.712	0.711

4.5 Environment–Behaviour Mediation Effects

Further analysis reveals that Spatial Configuration serves as a vital link between dwelling characteristics and housing satisfaction. Rather than directly affecting satisfaction, architectural features shape behavioural opportunities that help occupants adapt to thermal conditions. Courtyard spaces, for instance, encourage adaptive behaviours such as spending time outdoors, adjusting ventilation, and shifting activities over time. These adaptations enhance perceived comfort without increasing energy consumption. This finding supports the Environment-Behaviour hypothesis, which posits that environmental quality arises from the interaction between spatial affordances and human adaptation processes. The results confirm that passive spatial design strategies improve both environmental performance and subjective well-being in rural residential settings.

5.0 Discussion

The discussion interprets the findings in relation to existing research on residential thermal performance, vernacular architecture, spatial configuration, and occupant behaviour. It highlights the significance of dwelling type, courtyard design, and behavioural adaptation in shaping thermal comfort and housing satisfaction, while considering their implications for climate-responsive and sustainable residential design as follows:

5.1 Thermal–Spatial Interaction in Rural Residential Environments

The findings suggest that the thermal performance of rural dwellings is mainly influenced by the interaction between spatial configuration and occupants' behavioural adaptations, rather than by building materials alone (Ibrahim et al., 2020). The notable impact of dwelling type on thermal comfort indicates that vernacular courtyard houses incorporate climate-responsive spatial strategies developed through long-term environmental adaptation.

In contrast to modern rural housing, vernacular dwellings manage indoor conditions through spatial buffering, shaded transitional areas, and natural ventilation mechanisms. Courtyard spaces act as microclimatic regulators by reducing solar heat gain while facilitating airflow and outdoor activities. These results indicate that sustainable rural housing should revisit and adapt vernacular spatial principles rather than rely on standardised construction models that undermine passive environmental regulation. From an Environment–Behaviour perspective, architectural space functions as an adaptive system that allows occupants to respond dynamically to thermal conditions through their daily use of space (Huang et al., 2015).

5.2 Behavioural Adaptation as a Mediating Mechanism

A key contribution of this study is identifying spatial configuration as a crucial link between environmental performance and housing satisfaction. The findings indicate that occupants actively adapt to thermal conditions by opening windows, using courtyards, and relocating activities. In line with adaptive thermal comfort theory, comfort arises from the interaction between humans and their environment rather than from fixed indoor temperature settings (De et al., 2020). Courtyard spaces enhance behavioural flexibility by providing semi-outdoor environments that support both seasonal and temporal adaptations. This mediation effect suggests that improving spatial adaptability can increase residential satisfaction while reducing reliance on mechanical cooling. Consequently, it offers a viable pathway to low-carbon rural living environments.

5.3 Implications for Climate-Responsive Rural Housing Design

The shift towards modern rural housing has changed traditional environmental behaviour patterns by limiting spatial adaptability and the connection between indoor and outdoor spaces. The structural model shows that restricted adaptive spaces hinder occupants' ability to manage their thermal conditions naturally. The findings offer important design implications for climate-responsive architecture, particularly in warm-humid environments where spatial configuration, ventilation, shading, and occupant behaviour strongly influence thermal comfort. The study highlights the potential of traditional passive design principles to regulate the environment effectively without relying heavily on mechanical or technology-based solutions. One key implication is reintegrating courtyard systems as passive microclimate regulators. Courtyards can improve air movement, provide shaded areas, facilitate heat dissipation, and create a more comfortable transition between indoor and outdoor spaces. Appropriate orientation, vegetation, shading, and connections with surrounding rooms can further enhance their effectiveness.

The findings also emphasise the importance of shaded semi-open transitional spaces, such as verandas, covered terraces, and transitional corridors. These spaces give occupants greater flexibility to adjust their location and activities as thermal conditions change. Such spatial choices support behavioural adaptation and reduce dependence on air-conditioning. In addition, climate-responsive building envelopes should combine thermal mass with controlled ventilation to minimise heat gain while maintaining adequate air movement. Integrating appropriate materials, openings, shading devices, and ventilation pathways can improve buildings' overall thermal performance.

Overall, the study supports a human-centred approach to climate-responsive design that considers spatial interaction and occupant behaviour alongside environmental performance. Rather than depending primarily on advanced technologies, buildings can provide passive environmental conditions and flexible spaces that allow occupants to respond naturally to climatic variations. This approach contributes to sustainable architectural practice by promoting energy-efficient, adaptable, and context-sensitive design strategies that strengthen the relationship between building form, climate, and human behaviour. These strategies emphasise a human-centred approach to environmental design, moving beyond conventional energy-efficiency optimisation.

6.0 Conclusion

This study examined the thermal and spatial relationships in rural dwellings through an Environment-Behaviour framework using empirical modelling techniques. The study concludes that dwelling type is a major factor influencing environmental performance, as architectural form, spatial arrangement, materials, and ventilation strategies directly affect indoor thermal conditions and resident comfort. Spatial configuration also plays an important role in linking architectural design to resident satisfaction by enabling natural ventilation, shading, movement, and thermal adjustment.

In particular, the shape, proportion, and design of courtyards can enhance adaptive thermal comfort by improving airflow, reducing heat exposure, and providing flexible spaces for occupants. Furthermore, behavioural adaptation strengthens the effectiveness of passive design strategies, as residents actively adjust their activities and use of spaces in response to changing environmental conditions. Overall, the findings demonstrate that effective climate-responsive design should integrate architectural characteristics, spatial configuration, courtyard design, and human behaviour to achieve more comfortable and sustainable residential environments.

This study has several limitations. First, the cross-sectional design makes it harder to determine causal links between variables. Second, the results might not apply to other areas because the study is based on a single case-study town. Third, response bias may be introduced if the study used self-reported data. Additionally, data collection occurred during the summer, which may not fully reflect seasonal variations in thermal perception and adaptive behaviour. Finally, the relatively high SRMR value suggests that the structural model may have issues with overall fit, so these results should be interpreted with caution.

Future rural dwelling policies should focus on climate-responsive planning instead of standardised construction methods. Additionally, expanding research to include various climatic regions and seasonal conditions would enhance the generalizability of the findings. Integrating an understanding of human behaviour into architectural design offers a practical approach to creating resilient, sustainable rural environments across Asia.

Contribution of an Article to a Related Subject

The article advances the field by generating new knowledge, providing empirical evidence, and offering practical insights into thermal–spatial strategies for modern rural dwellings in northern China. Its findings enrich the existing body of knowledge by identifying key spatial and thermal components, their interrelationships, and effective strategies to improve residential environmental performance and support informed decision-making. The study also provides valuable guidance for researchers, practitioners, designers, and relevant stakeholders in developing more effective, sustainable, and evidence-based approaches to rural housing design.

Acknowledgement

The authors warmly thank the villagers of Shatun Village for their valuable Participation in the survey, and thank Universiti Teknologi MARA (UiTM) for supporting their research.

References

Aste, N., Del Pero, C., & Leonforte, F. (2022). Toward building sector energy transition. In Handbook of Energy Transitions (pp. 127–150). CRC Press. https://doi.org/10.1201/9781003315353-9

Chen, Y., & Misni, A. (2025). Comparative analysis of sustainable design strategies in Sanheyuan vernacular and modern dwellings: Effects on summer microclimate in Sha Tun village, Handan, Hebei Province, China. Journal of Asian Architecture and Building Engineering, 1–25. https://doi.org/10.1080/13467581.2025.2585698

Du, J., & Chen, B. (2024). Indoor thermal environment and adaptive behaviors in summer of urban households in northern China: Status and trend. Energy and Buildings, 324, 114916. https://doi.org/10.1016/j.enbuild.2024.114916

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. Journal of marketing research, 18(1), 39-50. https://doi.org/10.2307/3151312

Hair, J., & Alamer, A. (2022). Partial Least Squares Structural Equation Modeling (PLS-SEM) in second language and education research: Guidelines using an applied example. Research methods in applied linguistics, 1(3), 100027. https://doi.org/10.1016/j.rmal.2022.100027

Henseler, J., Hubona, G., & Ray, P. A. (2016). Using PLS path modeling in new technology research: updated guidelines. Industrial management & data systems, 116(1), 2-20. https://doi.org/10.1108/IMDS-09-2015-0382

Huang, K. T., Lin, T. P., & Lien, H. C. (2015). Investigating thermal comfort and user behaviors in outdoor spaces: A seasonal and spatial perspective. Advances in Meteorology, 2015(1), 423508. https://doi.org/10.1155/2015/423508

Ibrahim, A., Ali, H., Abuhendi, F., & Jaradat, S. (2020). Thermal seasonal variation and occupants' spatial behaviour in domestic spaces. Building Research & Information, 48(4), 364-378. https://doi.org/10.1080/09613218.2019.1681928

Muqoffa, M., Suyitno, Yaningsih, I., Rachmanto, R. A., Himawan, K., Caroko, N., & Basuki. (2025). Exploring natural ventilation strategies in Javanese vernacular houses for sustainable design. Journal of Asian Architecture and Building Engineering, 24(6), 4985–5004. https://doi.org/10.1080/13467581.2024.2439348.

Niza, I. L., Luz, I. M. D., Bueno, A. M., & Broday, E. E. (2022). Thermal comfort and energy efficiency: Challenges, barriers, and step towards sustainability. Smart Cities, 5, 1721–1741. https://doi.org/10.3390/smartcities5040086

Ren, Z., Fu, Y., Dong, Y., Zhang, P., & He, X. (2022). Rapid urbanization and climate change significantly contribute to worsening urban human thermal comfort: A national 183-city, 26-year study in China. Urban Climate, 43, 101154. https://doi.org/10.1016/j.uclim.2022.101154

Yang, C., & Misni, A. (2025). Analysis of thermal comfort in single-story courtyard vernacular dwellings in rural China: Passive design strategies for adapting to the climate. Buildings, 15(21), 3964. https://doi.org/10.3390/buildings15213964

Yang, C., & Misni, A. (2026). Exploring comfort and efficiency: Comparing vernacular and modern dwellings in rural Handan, Northern China. Sustainability, 18(3), 1575. https://doi.org/10.3390/su18031575

Zhang, X., Li, H., Jian, Y., Fu, H., Wang, Z., & Xu, M. (2022). Vernacular or modern: Transitional preferences of residents living in varied stages of urbanisation regarding rural landscape features. Journal of Rural Studies, 95, 95–108. https://doi.org/10.1016/j.jrurstud.2022.07.011