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International Journal of Human Capital in Urban Management (IJHCUM) aims to offer an outlook on the utilization of human capital in urban management based on existing urban and metropolitan problems. The journal expects to eventually turn into a convergence point as a reference available to professionals, managers and researchers in the field of urban management. Topics of interest include but are not limited to the following disciplines: Human Capital in Urban Management; Urban architecture, design, development and planning; Urban communications and services; Urban civil engineering and related management issues; Urban economics, administrative and financial management; Urban transportation systems and traffic management; Urban social and cultural welfare; Urban ecology and related; environmental concerns; Urban Health, Safety and Environment; Sustainable urban infrastructure.

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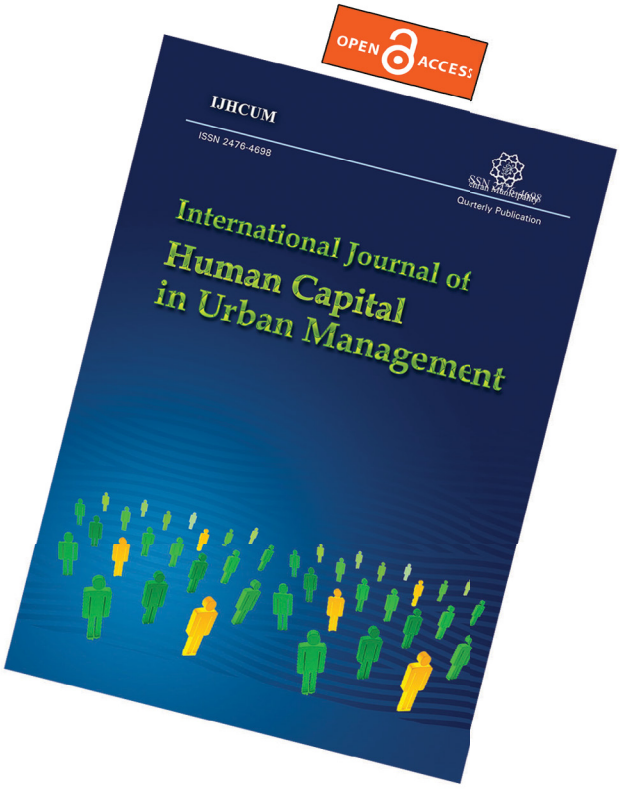
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ORIGINAL RESEARCH PAPER

Carbon footprint: A study of key components of pro-environmental

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ABSTRACT

BACKGROUND AND OBJECTIVES: Carbon emissions from the daily activities of urban populations are a primary contributor to climate change. The city of Surakarta, characterized by high mobility and significant emissions, necessitates an approach that emphasizes individual participation in efforts to reduce carbon footprints. This research aims to assess the community's willingness to reduce their carbon footprint based on five key indicators: housing, food, waste and water management, energy use, and transportation. Additionally, an analysis is conducted to identify the dominant factors influencing the community's preferences for environmentally friendly behavior.

METHODS: This study was conducted across five sub-districts in Surakarta City: Mojosongo, Sumber, Jayengan, Serengan, and Sondakan, selected for their high levels of urban activity and environmental relevance. The analytical method employed was Principal Component Analysis, a multivariate statistical technique used to reduce the dimensions of data and identify latent structures within a set of correlated variables. Principal Component Analysis enabled the researchers to extract principal components that represent key behavioral dimensions related to the willingness to decrease carbon footprint. The analysis was performed using STATA-13 and Minitab software for statistical computation and data visualization.

FINDINGS: The research findings indicate that the primary factors influencing WDC are community preferences regarding energy efficiency, waste management, and food consumption, which collectively account for 49.7% of the variability. The preference for sustainable living spaces and environmentally friendly transportation emerges as the second major factor, explaining 21.7% of the variability. The overall willingness of the community to reduce its carbon footprint is categorized as moderate. Among the five sub-districts, Jayengan exhibits the highest WDC index at 1.30, followed by Sumber (1.19), Semanggi (1.14), and both Sondakan and Mojosongo, which have the lowest indices of 1.10 each.

CONCLUSION: Research shows that residents in Surakarta City's five sub-districts have a moderate desire to lower their carbon footprint. Although awareness and concern, particularly about housing and transportation, are increasing, this has not yet translated into strong actions across all behaviors.

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INTRODUCTION

Climate change has emerged as one of the most significant global challenges today, driven by the rising concentrations of greenhouse gases in the atmosphere, including carbon dioxide (CO_2), methane (CH4), and nitrous oxide (N2O), which result from human activities. The Intergovernmental Panel on Climate Change (IPCC) forecasts that the average global temperature will rise by more than 1.5°C in the coming decades (IPCC, 2022). The current increase in global temperatures has rendered the environment more susceptible to natural disaster risks, including flooding due to rising sea levels, wildfires caused by prolonged droughts, extreme weather events, and heatwaves, as well as the threat of extinction for various plant and animal species (Klingelhöfer et al., 2020). This climate change is expected to trigger widespread hunger, climate crises, massive economic losses (Callahan & Mankin, 2022), damage to human physical and mental health, and mortality rates (Yang et al., 2021). Although extensive research has explored the causes and consequences of global warming, a limited understanding remains of how urban communities, especially in developing countries, can effectively participate in mitigating climate change through household-level behavioral changes. Addressing these escalating threats requires a comprehensive approach that reconfigures energy, transportation, and resource flows to enhance resilience, particularly in developing countries (Rauf et al., 2023). However, existing studies tend to focus predominantly on macro-level or technological interventions, often overlooking micro-level behavioral determinants that shape household carbon emissions. This creates a knowledge gap regarding the socio-economic and cultural factors influencing individuals' willingness to engage in sustainable practices. Therefore, this study seeks to bridge this gap by examining behavioral dimensions of carbon footprint reduction in urban Indonesia. These growing risks underscore the urgent need for timely and coordinated responses at the urban level. Strengthening urban governance is particularly crucial for enhancing climate resilience in rapidly urbanizing contexts, such as Indonesia. In recent years, cities have increasingly adopted localized climate governance strategies that prioritize adaptability and foster cross-sectoral collaboration (Abdillah et al., 2023). Within this context, the Sustainable Development Goals (SDGs) provide a comprehensive framework for integrating climate adaptation into urban development, offering opportunities to align local initiatives with broader sustainability targets in a synergistic manner. Yet, while mitigation and adaptation are both central to achieving the SDGs, local actions to reduce emissions remain underexplored. Understanding how urban households perceive and act toward reducing carbon emissions is therefore crucial for effective urban sustainability policies. Moreover, recognizing the synergies and trade-offs between mitigation, adaptation, and the SDGs is essential. While mitigation strategies often generate co-benefits across multiple goals, adaptation measures, particularly those focused on urban resilience, remain comparatively underexplored, despite their crucial role in achieving balanced and inclusive progress toward the 2030 Agenda (Kuipers, 2024). The industrial sector, transportation, and human activities contribute to rising carbon emissions. This situation poses a threat to sustainable development, particularly for developing countries that often face greater challenges in mitigating and adapting to climate change (United Nations Environment Programme, 2020). Indonesia is among the countries that contribute significantly to global CO2 emissions, primarily due to extensive use of fossil fuels, industrial activities, and transportation. The trend in carbon dioxide (CO2) emissions in Indonesia has increased over the past decade. This rise may be triggered by rapid economic growth accompanied by a rising population.CO2 emissions in Indonesia exhibit a fluctuating pattern, with notable spikes observed over the last five years. In 2013, Indonesia's emissions were recorded at 489.055 million tons, increasing to 594.101 million tons by 2018. After peaking in 2019 at 653.792 million tons, carbon emissions in Indonesia declined to 608.223 million tons in 2020 (Worldometers, 2025). This decrease may be attributed to the impacts of the COVID-19 pandemic, which led to restrictions on human activities and mobility. The COVID-19 pandemic, which began in late 2019, has had a widespread global impact on human activities, leading to a reduction in carbon emissions worldwide (Shamsi et al., 2022). This unanticipated reduction highlights the impact of behavioral change on climate mitigation efforts. Accordingly, the application of rigorous feasibility assessments is critical to evaluating the socio-political and technological preparedness of mitigation strategies, thereby

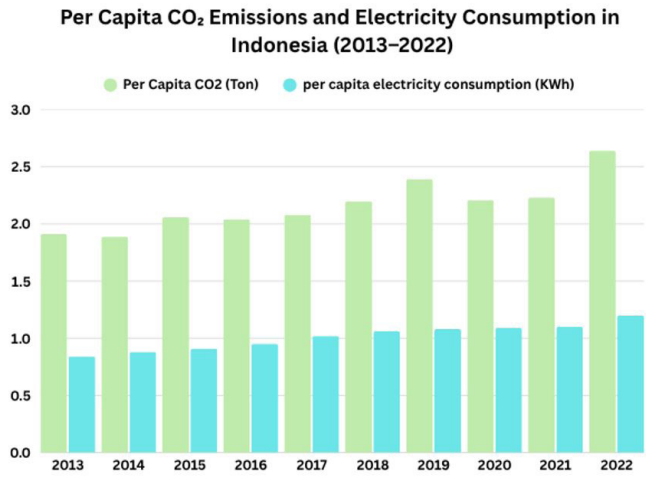


Fig. 1: Per capita CO_2 emissions and electricity consumption in Indonesia (2013–2022)

facilitating the integration of behavior-oriented approaches within broader climate policy frameworks (Nielsen et al., 2020). Recent evidence suggests that coal-based electricity generation and motorized transportation continue to be the primary sources of carbon emissions in Indonesia. Additionally, urban concentration and ongoing industrial expansion have been identified as key drivers of emission increases, particularly in densely populated regions (Zhang, 2019). The rapid growth of the transport sector, compounded by inadequate public infrastructure, further intensifies these emission challenges (Samad et al., 2022). Notably, during the COVID-19 pandemic, global CO_2 emissions temporarily declined by up to 17% due to widespread mobility restrictions and reduced economic activity, demonstrating the significant impact that behavioral and systemic shifts can have on emission trajectories (Le Quéré et al., 2020). Within this context, there is an increasing recognition of the value of incorporating behavioral strategies into climate mitigation efforts, particularly in low- and middle-income countries, where structural limitations often hinder the implementation of large-scale technological solutions (Nelms et al., 2022). Individual activities within households contribute directly and indirectly to 72% of greenhouse gas (Liu & Wang, 2024). On both individual and household levels, the accumulation of carbon emissions is referred to as the carbon footprint. The household carbon footprint is shaped by the lifestyle choices of each individual within the household, which generate emissions from energy consumption, transportation, and dietary patterns (Huang et al., 2024). In densely populated areas, energy consumption is estimated to account for approximately 70% to 80% of CO_2 emissions (Lin & Li, 2020).

Fig. 1 presents a comparative trend of per capita CO_2 emissions and electricity consumption in Indonesia between 2013 and 2022. Both variables exhibit a generally increasing trend, with CO_2 emissions peaking at 2.64 tons per capita in 2022 (International Energy Agency, 2022). This increase occurred gradually, although there were years, such as 2020–2021, when the growth slowed before sharply rising again in 2022. The rise was from 2.23 tons in 2021 to 2.64 tons in 2022. This increase is largely attributed to economic activities and energy consumption following the pandemic. The rise in per capita carbon emissions correlates with the increase in per capita electricity consumption, which also experienced a notable uptick during the same period, particularly from 2017 to 2019. The increase in electricity consumption has the potential to elevate CO_2 emissions, as a significant portion of Indonesia's electricity is still generated from the combustion of fossil fuels, such as coal and natural gas (Ministry of Energy and Mineral Resources, 2023). Nevertheless, promoting sustainable behavior in urban areas continues to face significant challenges (Rauf et al., 2023). It is emphasized that advancing urban sustainability requires a strong focus on resource efficiency, inclusive governance, and transformative behavioral changes as essential

components for achieving long-term resilience and meeting climate goals. In line with these global challenges and priorities, the Indonesian government is actively engaged in efforts to reduce carbon emissions as part of its climate change mitigation strategy. This is outlined in Law Number 16 of 2016 regarding the Ratification of the Paris Agreement to the United Nations Framework Convention on Climate Change. Through the Nationally Determined Contribution (NDC), Indonesia has committed to reducing Greenhouse Gas (GHG) emissions by 31.9% by 2030 through its efforts and by 43.2% with international support (Institute for Essential Services Reform, 2023). Achieving these targets requires coordinated action not only at the national level but also within local governments. Assessing local carbon reduction initiatives within the framework of the SDGs enables policymakers to monitor progress more efficiently. Research has shown that incorporating carbon neutrality indicators into local SDGs tracking systems can strengthen policy alignment and improve accountability at the municipal scale (Bilsky, E., Moreno, A. C., & Fernández Tortosa, 2021; Ciambra & Stamos, 2023). One of the measures implemented by the Indonesian government to decrease carbon emissions is the establishment of a carbon tax. The carbon tax is a fee imposed on taxpayers, whether individuals or entities, who purchase goods containing carbon or engage in activities that produce carbon emissions. The primary objective of this tax is to fulfil commitments under the Paris Agreement and to accelerate the development and utilization of new renewable energy sources. The tax rate is regulated in Article 13, paragraphs 8 and 9 of the Tax Regulation Harmonization Law, with a minimum carbon tax rate set at Rp 30 per kilogram of CO2e or an equivalent unit. Reducing carbon emissions can begin with minimizing the carbon footprint generated by individual activities. Although the changes made may be small, their impact can be significant when implemented gradually. Daily lifestyle choices play a crucial role in determining the success of these efforts. Key factors include the type of housing, energy consumption patterns, dietary habits, waste management, and transportation choices. Additionally, urban life transformation, household consumption patterns, and social practices are also key elements that support sustainable efforts to reduce carbon footprints (Lombardi et al., 2017). Specifically, this study aims to identify the factors that drive urban residents' willingness to engage in pro-environmental actions and to determine the most influential behavioral domains that can effectively reduce carbon emissions. These findings are expected to enhance understanding of the role of individual and collective behaviors in supporting sustainable urban systems and to provide insights that can inform policy strategies for behavior-based mitigation. To achieve these objectives, this paper employs an empirical approach that combines socio-economic analysis and behavioral assessment. The study was conducted in Surakarta, a rapidly growing Indonesian city characterized by high energy consumption and mobility levels. The analysis focuses on five behavioral domains: housing, food consumption, waste and water management, energy use, and transportation, to explore how daily lifestyles affect the overall household carbon footprint. This methodological approach enables a contextual understanding of the interrelationship between individual choices and emission outcomes in developing urban areas.

MATERIALS AND METHODS

Survey design and data collection

This study employed a quantitative survey design to systematically capture behavioral, socio-demographic, and attitudinal factors influencing individuals' willingness to decrease their carbon footprint (WDCF) in Surakarta City. This research was conducted in five sub-districts of Surakarta City, namely Semanggi, Jayengan, Sondakan, Sumber, and Mojosongo. The purposive selection of these areas was guided by two key considerations. First, these five sub-districts are sites where passive sampler devices have been installed by the Environmental Agency of Surakarta City, which are utilized to monitor the concentration of carbon emissions, particularly the pollutants SO_2 and NO_2. Second, these areas are situated along the transit routes of the Batik Solo Trans public transportation system and exhibit a high level of mobility. These criteria ensure that the selected sites represent diverse urban characteristics, combining both environmental monitoring zones and high-activity corridors. Thus, the five areas are considered representative of the broader urban structure across 54 sub-districts in Surakarta City. A total of 204 respondents were surveyed across the five sub-districts. The sample size was determined to achieve statistical adequacy and reflect the demographic diversity of Surakarta's urban population,

including variations in age, income, education, and occupation. Respondents were selected using a stratified random sampling approach to ensure balanced representation across gender and neighborhood categories. Data were collected using a structured questionnaire divided into two main sections. The first section collected socio-demographic information, including gender, age, education, occupation, monthly household income, and residential location. The second section measured behavioral and psychological dimensions associated with carbon reduction. The questionnaire instrument was adapted from Khanam et al. (2022) with modifications to align with Indonesia's urban context. The instrument was designed to develop the Willingness to Decrease Carbon Footprint Index (WDCFI), which captures pro-environmental behavior across five key domains: housing, food consumption, waste and water management, energy use, and transportation. Each domain included 2 to 3 statements measuring behavioral tendencies, rated on a 5-point Likert scale (Strongly Agree = 2 to Strongly Disagree = 0). Certain items, such as renewable energy use or vehicle ownership, were measured dichotomously (Yes = 2; No = 0). The total scores were normalized to form the WDCF index values, allowing cross-domain comparisons of behavioral readiness. The design of the WDCFI is theoretically grounded in environmental behavior research, which emphasizes attitudes, values, and awareness as predictors of sustainable behavior (Batalla-bejerano et al., 2020). Therefore, this instrument not only measures stated preferences but also reflects the psychological and contextual determinants of behavioral change.

Analytical framework

The analytical framework of this study integrates multivariate statistical techniques to identify latent behavioral dimensions and the factors influencing WDCF. Data from 204 participants were analyzed using Stata 13. The main analytical tool employed is Principal Component Analysis (PCA), a method suitable for reducing complex behavioral data while preserving essential variance. PCA was selected because it enables the extraction of key behavioral dimensions (principal components) that explain the largest proportion of variance in WDCF indicators, while minimizing multicollinearity among correlated variables. This methodological choice aligns with recent studies for that have applied multivariate analysis to urban SDG monitoring and behavior-based sustainability assessments (Jia et al., 2024; Yin et al., 2023). PCA is a statistical technique utilized to transform a set of correlated original variables into a new set of uncorrelated variables (principal components), aiming to reduce data dimensions without losing significant information. This technique enables researchers to identify latent structures within the data and to avoid multicollinearity issues among independent variables in subsequent analysis models (Abdi, H., and Williams, 2010; Ongbali et al., 2024). The justification for employing PCA lies in its ability to identify underlying structures in behavioral data and reveal how different socio-economic and psychological factors cluster together to influence carbon-reducing behavior. All extracted principal components (PC1–PC5) were continuous variables that cumulatively explained 100% of the data variation, with the first few components contributing the majority of the explanatory power. These components were subsequently interpreted as distinct behavioral constructs reduce the carbon footprint in Surakarta City. Fig. 2 illustrates the conceptual framework of the study, highlighting five key components that represent dimensions of environmentally friendly behavior: housing, food consumption, waste and water management, energy use, and transportation. The steps for implementing PCA in this study include: (1) standardizing the data for each WDCF indicator to ensure comparable variance, (2) calculating the correlation matrix among variables, (3) extracting principal components based on eigenvalues, and (4) interpreting factor loadings to ascertain the contribution of each indicator to the components. Principal components with eigenvalues greater than one ($\lambda > 1$) are utilized for further analysis. The PCA results are then used to construct the total WDCI, which reflects the community's collective willingness to reduce carbon emissions in the study area.

RESULTS AND DISCUSSION

Descriptive statistics and factor analysis for variables entering the analysis

This research involved 204 individuals residing in five sub-districts of Surakarta City, namely Semanggi, Jayengan, Sondakan, Sumber, and Mojosongo. These locations were purposively selected due to their high levels of residential carbon emissions, primarily nitrogen dioxide (NO_2) and sulfur dioxide (SO_2), which are major air pollutants in urban areas. Individuals were

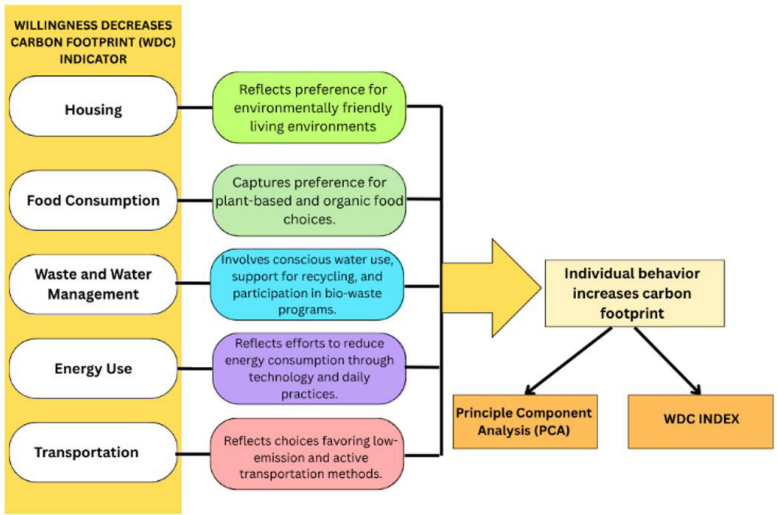


Fig. 2: Research concept

chosen as the unit of analysis because their daily activities, such as energy use, mobility, and consumption patterns, directly contribute to household-level carbon emissions. The research instrument consisted of 13 items representing five key behavioral indicators: housing (WDCF-H), food (WDCF-F), waste management (WDCF-W), energy (WDCF-E), and transportation (WDCF-T). Data collected from the 204 respondents were analyzed using Principal Component Analysis (PCA) to identify the dominant behavioral factors influencing the willingness to decrease carbon footprint (WDCF) among Surakarta residents. To evaluate the suitability of the data for factor analysis, the Kaiser-Meyer-Olkin (KMO) test was applied, yielding a KMO value of 0.727, which exceeds the minimum threshold of 0.50 (Verdian, 2019). This indicates that the data are appropriate for factor analysis.

Table 1 indicates that the KMO value obtained is 0.727, which exceeds the threshold of 0.05. Therefore, it can be concluded that the variables utilized in this study are suitable for further analysis through factor analysis. In addition to the KMO test, the anti-image matrix analysis is also employed to assess the partial correlations among the variables and to evaluate the appropriateness of each variable in the factor analysis process. This matrix produces the Measure of Sampling Adequacy (MSA) values for each variable, serving as an indicator of their suitability. According to Fatati and Puspitasari (2015), variables with MSA values above 0.05 are considered eligible for inclusion in the factor analysis, as they indicate that these variables possess adequate partial correlation levels with other variables in the model.

Table 2 presents the MSA values for each variable, specifically, the WDCF-H variable at 0.7748, WDCF-F at 0.6183, WDCF-W at 0.4626, WDCF-E at 0.3903, and WDCF-T at 0.9260. From these results, it is evident that the MSA values for all variables exceed 0.05. Con-

Table 1: KMO test

Variables	KMO
WDCF-H	0, 749
WDCF-F	0, 786
WDCF-W	0, 739
WDCF-E	0, 685
WDCF-T	0, 652
Total	0, 727

Table 2: Result of anti-image covariance

Variabel	WDCF-H	WDCF-F	WDCF-W	WDCF-E	WDCF-T
WDCF-H	0,7748				
WDCF-F	-0.0520	0,6183			
WDCF-W	0.1002	-0.0796	0,4626		
WDCF-E	0.1334	-0.1925	-0.2234	0,3903	
WDCF-T	-0.1532	-0.0618	-0.0648	-0.0334	0,9260

Table 3: Result of PCA

Variable	PC1	PC2	PC3	PC4	PC5
Eigenvalue	2,4844	1,0851	0,6767	0,4421	0,3117
Proportion of Variance	0,497	0,217	0,135	0,088	0,062
Cumulative Proportion	0,497	0,714	0,849	0,938	1,000

sequently, it can be concluded that all variables are suitable for further analysis. The eigenvalue measures the amount of data variance that can be explained by each principal component. A higher eigenvalue indicates that the component explains a greater variance in the data.

Table 3 displays the factors that have eigenvalues greater than one, highlighting two main components: PC1 with a value of 2.4844 and PC2 with a value of 1.0851. Collectively, these components explain 71.4% of the data's variation. The first principal component (PC1), accounting for 49.7% of total variance, is dominated by variables related to energy efficiency (WDCF-E), waste management (WDCF-W), and food consumption (WDCF-F). This dimension reflects internal household management and daily resource-use behavior, suggesting that residents' awareness of energy use, food choices, and waste practices collectively shape their pro-environmental attitudes. The second principal component (PC2), explaining 21.7% of the variance, is primarily influenced by housing (WDCF-H) and transportation (WDCF-T). This component represents external lifestyle choices that are more structural and infrastructural in nature, such as the design of housing units, proximity to transportation access, and reliance on private vehicles.

Fig. 3 illustrates the scree plot resulting from the PCA analysis, which displays the distribution of eigenvalues for each principal component. The X-axis shows the eigenvalues, or the variance explained by each component. The graph to PC5. It can be concluded that PC1 and PC2 sufficiently capture the primary information in the data's variation. The loading plot provides a visual interpretation of the two principal components, namely component 1 (PC1) and component 2 (PC2). The loading plot is utilized to depict the variables that exert the most influence on each component. In this study, the loading plot reveals the contribution of each variable in the principal component analysis related to Willingness to Decrease Carbon Footprint (WDCF). The identified variables include housing (WDCF-H), food (WDCF-F), waste management (WDCF-W), energy (WDCF-E), and transportation (WDCF-T).

Fig. 4 illustrates the spatial distribution of variables in the principal component analysis (PCA). The variables WDCF-H and WDCF-T are located far on the negative side of the X-axis (PC1) and have positive values on the Y-axis (PC2), suggesting that these behaviors are distinct from the others and may contribute more strongly to the second component. In contrast, WDCF-E, WDCF-W, and WDCF-F are clustered closer along the PC1 axis, indicating a stronger influence on the first principal component and highlighting their shared underlying patterns in environmentally conscious behavior. Figures 3 and 4 (Scree and Loading Plots) visualize the differentiation between the two components. Variables WDCF-H and WDCF-T cluster along PC2, while WDCF-E, WDCF-W, and WDCF-F cluster along PC1, confirming that internal consumption and external mobility are two distinct yet interconnected behavioral domains influencing WDCF.

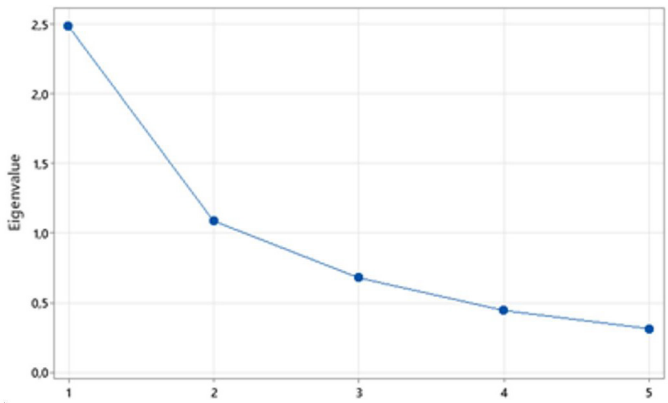


Fig. 3: Scree plot PCA

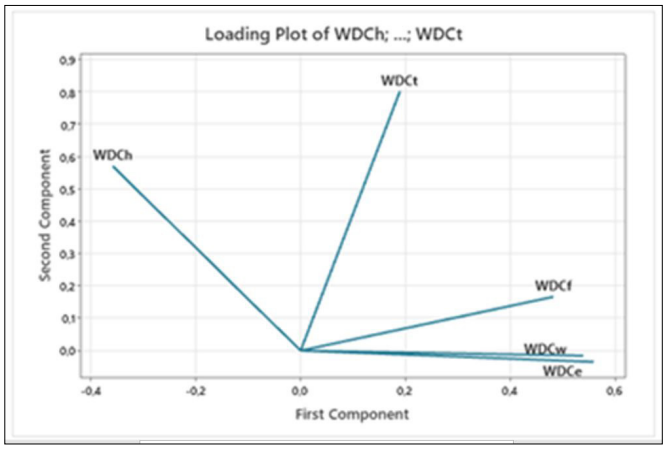


Fig. 4: Loading plot

Table 4 presents the results of the eigenvector values, which elucidate the relative contributions of each variable to the principal components. The eigenvector value for WDCF-H indicates a negative contribution to PC1, quantified at -0.358, while it shows a significantly large positive contribution to PC2, measured at 0.571. WDCF-T, positioned far on the positive side of the Y-axis, exhibits a dominant eigenvector value of 0.803 on PC2, signifying that this variable plays a substantial role in the second dimension. The variables WDCF-F, WDCF-W, and WDCF-E have eigenvector values of 0.482, 0.539, and 0.559, respectively, indicating high weights on PC1 and lower weights on PC2. From the principal component analysis with the loading plot, it can be concluded that the second principal component (PC2) is more influenced by the preferences of Surakarta City residents in reducing their carbon footprint through housing choices (WDCF-H) and transportation (WDCF-T). In contrast, the first principal component (PC1) is predominantly influenced by the community's preferences for energy efficiency (WDCF-E), waste management (WDCF-W), and food consumption (WDCF-F). These findings are consistent with Tajpour & Razavi 2023), who emphasized that collective team performance and entrepreneurial mediation enhance adaptability and innovation capacity within organizational systems, a mechanism that mirrors how household-level behavioral cooperation and collective awareness can foster greater climate resilience. Similarly, Arabiun et al., (2024) found that digital leadership strengthens organizational performance through the mediating role of entrepreneurship, reflecting how leadership and initiative at the community level can drive the diffusion of sustainable practices in urban environments.

Table 4: Eigenvector value

Variables	PC1	PC2	PC3	PC4	PC5
WDCF-H	-0,358	0,571	-0,610	0,403	0,104
WDCF-F	0,482	0,167	-0,564	-0,589	-0,273
WDCF-W	0,539	-0,016	0,017	0,661	-0,521
WDCF-E	0,559	-0,035	-0,107	0,178	0,802
WDCF-T	0,189	0,803	0,546	-0,144	0,008

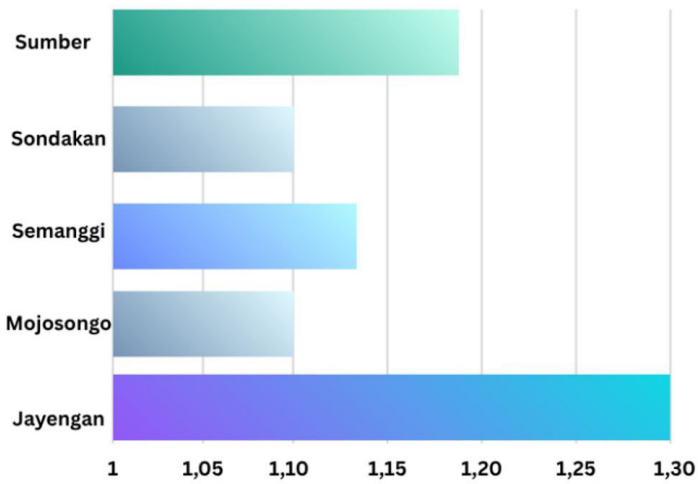


Fig. 5: Results of the WDC index by region

Estimation of the willingness to decrease the carbon footprint index

The index value reflecting the community's willingness to reduce its carbon footprint is based on five primary indicators: housing (WDCF-H), food (WDCF-F), waste management (WDCF-W), energy (WDCF-E), and transportation (WDCF-T). These five indicators are derived by summing the response codes for each section, dividing the sum by the number of questions in that section, and then dividing the result by the number of questions in that section. The resulting index is categorized as follows: 0–0.50 Low Willingness, 0.51–1.00 Moderate Willingness, 1.01–1.50 High Willingness, and 1.51–2.00 Highly Willingness. The results of these calculations are presented in Fig. 5.

Fig. 5 presents the results of the WDCI disaggregated by region. The figure highlights regional variations in community willingness to reduce carbon emissions across the five sub-districts studied. The willingness to decrease the carbon footprint index across the five sub-districts in Surakarta exhibits values within the same category, specifically indicating a moderate willingness. The sub-district of Jayengan records the highest index value at 1.30. The second-highest index is for the sub-district of Sumber, with a value of 1.19. Meanwhile, the fourth-highest index is held by the sub-district of Semanggi, with a value of 1.14. The sub-districts of Sondakan and Mojosongo show lower index values, both at 1.10. These results reveal that Surakarta residents demonstrate moderate but relatively consistent readiness to adopt low-carbon behaviors. Several contextual factors may explain this outcome: (1) Limited environmental literacy regarding the long-term benefits of individual behavioral change; (2) Economic constraints that prioritize affordability over ecological consideration; (3) Infrastructure limitations, such as inadequate public transport and access to renewable energy. This pattern aligns with Khanam et al., 2022), who note that even when awareness is present, habitual and financial barriers often limit be-

havioral transformation. Similarly, Ivanova et al. (2020) highlight that although households are responsible for over 70% of global emissions, willingness to change behavior does not always translate into action due to lifestyle lock-ins, infrastructure limitations, and the lack of strong behavioral incentives. By connecting household-level behaviors with broader sustainability strategies, this study contributes to the growing literature on urban human capital development and climate-responsive governance consistent with the integrative frameworks proposed by Tajpour and Razavi (2023) and Arabiun et al., (2024), who highlight the importance of entrepreneurial capability and leadership transformation in enhancing sustainable urban performance.

CONCLUSION

This research indicates that the level of community willingness in five sub-districts of Surakarta City to reduce carbon footprints is generally categorized as Moderate, based on calculations of the Willingness to Decrease Carbon Footprint index (WDCFI). This index value is derived from five behavioral indicators: housing (WDCF-H), food consumption (WDCF-F), waste and water management (WDCF-W), energy use (WDCF-E), and transportation (WDCF-T). The average index value across all sub-districts reflects a sufficient level of community participation, although it has not yet reached the high willingness category. The highest index value was recorded in Jayengan Sub-district (1.30), followed by Sumber (1.19) and Semanggi (1.14). Meanwhile, Sondakan and Mojosongo both had the lowest value of 1.10. All these values remain within the Moderate Willing classification, indicating that the community is beginning to show concern for the issue of carbon footprint reduction, yet has not been fully mobilized towards more concrete and comprehensive actions. The eigenvector values from the PCA illustrate the relative contributions of each indicator to the two main components. The WDCF-H variable exhibits a negative contribution to PC1 (−0.358) and a significantly positive contribution to PC2 (0.571), whereas WDCF-T has a dominant contribution to PC2 (0.803), indicating that the second dimension is heavily influenced by community preferences regarding environmentally friendly housing and transportation choices. Conversely, the variables WDCF-F (0.482), WDCF-W (0.539), and WDCF-E (0.559) exhibit high weights concerning PC1, indicating that the first dimension is predominantly influenced by energy efficiency behaviors, waste management, and sustainable food consumption. Therefore, it can be concluded that PC1 represents a dimension of household behavior oriented towards efficiency and consumption, while PC2 more accurately reflects environmental preferences in the context of spatiality and mobility. These findings can serve as a foundation for formulating more targeted intervention strategies, taking into account the behavioral aspects that most significantly affect the community's willingness to reduce its carbon footprint.

AUTHOR CONTRIBUTIONS

E. Gravitiani conducted a literature review, designed the experiments, prepared the manuscript, and performed the final editing. N. W. Mulia conducted the experiments, performed the literature review, analyzed the data, and contributed to the preparation of the manuscript. A. Ratnadewati collaborated in developing the research idea and provided critical proofreading and feedback on the manuscript. D. T. Cahyaningsih translated the manuscript and conducted final editing

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CONFLICT OF INTEREST

The author asserts that there are no conflicts of interest in this research, whether financial, personal, or professional, that could influence the results or interpretations of the conducted study.

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ABBREVIATIONS (NOMENCLATURE)

CH_4	Methane
CO_2	Carbon dioxide
GHG	Greenhouse Gas
KMO	Kaiser-Meyer-Olkin
N_2O	Nitrous oxide
NDC	Nationally Determined Contribution
NO_2	Nitrogen dioxide
PC1	Principal Component 1
PC2	Principal Component 2
PC3	Principal Component 3
PC4	Principal Component 4
PC5	Principal Component 5
PCA	Principal Component Analysis
SDGs	Sustainable Development Goals
SO_2	Sulfur dioxide
WDCF-E	Willingness to Decrease Carbon Footprint for Energy
WDCF-F	Willingness to Decrease Carbon Footprint for Food
WDCF-H	Willingness to Decrease Carbon Footprint for Housing
WDCFI	Willingness to Decrease Carbon Footprint Index
WDCF-T	Willingness to Decrease Carbon Footprint for Transportation
WDCF-W	Willingness to Decrease Carbon Footprint for Waste

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ORIGINAL RESEARCH PAPER

Empowering performance: The impact of human resource development strategies on lecturer productivity

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ABSTRACT

BACKGROUND AND OBJECTIVES: Strategic Human Resource Development (HRD) is crucial for enhancing organizational performance and reputation within the competitive higher education sector. Lecturer productivity is a key indicator of institutional success; however, the efficiency of integrated HRD approaches in academic settings requires further empirical investigation. This study evaluates the impact of core human resource development practices, training, career development, and compensation on lecturer productivity at the National School of Administration in Muha Commune. It aims to identify gaps in HRD implementation and provide evidence-based recommendations for enhancement.

METHODS: A quantitative research design was employed. Using convenience sampling, 24 lecturers were selected from a population of 27. Primary data were collected via a structured, self-administered questionnaire using a five-point Likert scale. Data analysis was conducted with SPSS 25.0, utilizing descriptive statistics, Pearson's correlation, and multiple linear regression to identify relationships and predictive power.

RESULTS: The results revealed strong positive correlations among all Human Resource Development practices and lecturer productivity. Training demonstrated a strong correlation ($r = 0.714$, $p < 0.009$), career development a very strong correlation ($r = 0.851$, $p < 0.001$), and remuneration a moderate correlation ($r = 0.604$, $p < 0.002$). Regression analysis also confirmed that these three dimensions explain 76.2% of the variance in productivity ($R^2 = 0.762$, Adjusted $R^2 = 0.732$).

CONCLUSION: The study concludes that sustained, integrated investments in Human Resource Development are essential for enhancing lecturer productivity. It is recommended that the institution adopt a comprehensive strategy, including implementing a long-term training program based on a Training Needs Analysis (TNA), formalizing career feedback and goal-setting mechanisms, and reviewing the compensation structure to ensure equity and competitiveness.

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INTRODUCTION

The landscape of higher education is characterized by intense global competition, shifting demographics, and increasing demands for accountability and quality. In this challenging environment, the intellectual and pedagogical capabilities of academic staff are key drivers of institutional success, reputation, and sustainability. Consequently, the strategic management and development of human capital have evolved from a supportive administrative function into a pivotal strategic imperative for universities and colleges worldwide (Akfilni, 2025). Human Resource Development is particularly indispensable for building organizational credibility, fostering innovation, and enhancing overall institutional performance. Human Resource Development emerged from systematic efforts to improve workforce efficiency, notably during World War II's 'Training within Industry' program (Loewenstein, H., 1945). It has since matured into a comprehensive discipline focused on developing human potential through training, career development, and organizational learning (Swanson & Holton, 2010). In the context of higher education, the development of lecturers is widely recognized as a critical mechanism for enhancing the skills, efficiency, and creativity of academic staff, which directly translates to improved teaching quality, research output, and community engagement. Key Human Resource Development strategies, namely, targeted training, structured career development, and equitable remuneration, are theorized to be fundamental in motivating lecturers and unlocking their full productive potential, as explained by foundational theories such as Human Capital Theory (Becker, 1967) and Expectancy Theory (Vroom, 2005). Despite its established theoretical importance, the practical application and measurable impact of HRD within specific institutional contexts, particularly in developing regions, warrant further empirical investigation. Many institutions, including the National School of Administration (NSA) in the Muha Commune, may face challenges in implementing cohesive and effective Human Resource Development strategies due to resource constraints or a lack of strategic alignment. A clear understanding of which Human Resource Development strategies most significantly influence lecturer productivity at NSA is essential for informed decision-making and resource allocation. Currently, a gap exists in institution-specific evidence to guide the development of optimal Human Resource Development interventions for enhancing academic performance at the NSA. Located in Muha, a highly populated commune in Bujumbura Mairie, the National School of Administration is a crucial anchor for urban development. Being the main training institution for future civil servants and urban planners, its performance has a direct impact on the capacity of local governance, infrastructure, and social equity, making the productivity of lecturers a key factor in the progress of urban development. This study aims to address this gap by conducting a focused investigation into the impact of key Human Resource Development strategies on lecturer productivity at the National School of Administration. The findings of this research are expected to provide evidence-based insights that can guide the institution's management in refining its human capital policies. By doing so, this study contributes to the broader discourse on strategic human resource management in higher education institutions, particularly in urban and semi-urban settings facing similar developmental challenges. Specifically, this study seeks to achieve the following objectives:

- *To assess the extent to which training, career development, and remuneration influence lecturer productivity at the National School of Administration.*
- *To identify existing gaps in the current Human Resource Development practices at the institution.*
- *To provide actionable, evidence-based recommendations for enhancing Human Resource Development strategies to boost lecturer performance and institutional effectiveness.*

Literature review

Empirical review

The degree to which Human Resource Development (HRD) programs impact the productivity and performance of workers has been the topic of robust empirical investigation across several business industries. The collective inference derived from this body of literature is that investment in human capital is not merely desirable but essential for achieving long-term organizational success. This review synthesizes empirical studies across a range of industries, such as technology, retail, healthcare, manufacturing, and hospitality, to develop a broad foundation of knowledge regarding the effect of core HRD activities, such as training, career development, and compensation,

on productivity, thereby creating a benchmark for their application in the higher education sector. The core role of systematic training in developing individual capability and organizational performance is well documented. In the technology sector, where skills can become redundant within a few years, companies like Techsolutions Inc. have demonstrated the value of comprehensive training programs. These include technical and non-technical skill training, on-the-job training, and exposure to innovative platforms through real-time experience, all of which have gained widespread acceptance among employees. These programs keep employees informed about technological advancements, thereby enhancing their contribution to projects and, consequently, organizational achievement (Ismail, L.B. *et al*., 2021). The transformative power of training is also reflected in the case of General Electric Company, which achieved a 25% increase in output as a direct result of its leadership skills training (Ismail, L.B. *et al*., 2021). This is a classic example of how rational investment in employee development translates into actual productivity gains, supporting the view that training should be viewed not as a cost driver, but as a strategic investment. The service sectors yield strong testimony to the impact of training on performance measures. Ismail, L.B. *et al*., (2021) found that retail stores that invested more training hours per employee experienced a 15% increase in customer satisfaction scores. The improvement in service quality was a direct outcome of workers having higher morale and increased engagement, thereby increasing store-level productivity. Similarly, in the high-pressure environment of healthcare, tailored training initiatives centered on building clinical competency led to a 30% reduction in medical errors and a noticeable enhancement in patient care indicators among nurses at a major hospital system (Ismail, L.B. *et al.,* 2021). The manufacturing sector provides another concrete example in the form of Toyota's "On-the-System" training, which emphasizes hands-on practice and continuous improvement. This approach not only enhances employees' technical knowledge but also builds a deeply ingrained organizational culture of problem-solving and collaboration, significantly influencing overall productivity (Kramar, 2013). The success of such training approaches relies largely on the degree to which they are aligned with larger organizational goals as well as the specific needs of the employees. Research consistently demonstrates that organizations achieve better productivity when training programs are closely aligned with business objectives (Kramar, 2013). Besides formal training, the literature also places significant emphasis on motivational practices, which are normally integrated into career development and compensation structures. Tarigan *et al.,* (2022) research on retail highlights the complex dynamic between intrinsic and extrinsic motivation. Their study, which surveyed employees in various kinds of retail stores (i.e., fashion, electronics, and food), found that while external motivating factors like pay and recognition greatly improve performance and motivation, internal motivating factors are equally important. Employees who displayed a high degree of intrinsic motivation, which encompassed opportunities for self-development and a sense of autonomy in their work, had greater organizational commitment and more consistent gains in performance. Conversely, the performance of those whose motivational drive was largely based on extrinsic rewards was more inconsistent, fluctuating with the implementation of bonus or commission systems. This variation emphasizes that HRD strategies need to strike a balance between intrinsic and extrinsic motivators. Tarigan *et al.* (2022) argue that by employing HRM policies that value intrinsic motivation, such as skill development training and clear career progression channels, retail companies not only become more attractive employers but are also better positioned to retain their top talent, thus reducing the high staff turnover prevalent in the sector. The significance of a supportive working environment and organizational culture as part of career development is also emphasized in another professional study. Nafari and Rezaei (2022), within the healthcare context, posit that a positive organizational culture is necessary to foster professionalism. Health professionals' expectations extend far beyond technical expertise, requiring leadership, communication, and collaboration skills to manage rapid-paced, high-stakes situations. An organizational culture founded on values of cooperation, mutual respect, and a common vision gives workers a sense of purpose and belonging. This sense of purpose and belonging is crucial for enhancing productivity among professionals who are under high levels of stress. Leadership plays a most important role in the formation of this kind of culture. Alam (2022) defines transformational leadership as a key source of

motivation, encouraging employees to transcend their own self-interest for the benefit of the organization. Within this framework, "individualized consideration "where leaders identify and address the unique needs of each employee is particularly effective. Mentorship programs supported by transformational leaders, for instance, can provide personalized support for employees' professional growth, foster a sense of belonging, and prevent burnout and demotivation. This, in effect, promotes increased motivation and improves educational and organizational outcomes. A relevant case study in the manufacturing sector by Zamroni *et al.* (2024) presents the synergetic effect of integrating advanced training and a robust organizational culture. The company in question utilized a virtual reality training program, which exposed employees to virtual environment settings to hone their technical skills and awareness of complex machinery in a safe environment. Furthermore, the training material was tailored to meet the multi-faceted requirements of employees from different departments, and there were regular evaluations and feedback procedures to ensure the continued relevance and effectiveness of the training modules. This not only improved operational efficiency but also fostered an environment of ownership and responsibility among employees (Zamroni *et al.,* 2024). The study confirmed that a participative organizational culture, where employees were encouraged to have their voices heard and participate in decision-making, led to significant increases in motivation rates. Regular team-building activities and open communication for all fostered interpersonal bonds and feelings of "being at home," providing an essential foundation for enhanced productivity. Zamroni *et al.* (2024) ascertained that effective, innovative training programs, when supplemented with a supportive organizational climate, had direct positive impacts on productivity metrics. The hotel industry, also plagued by high labor turnover, provides additional proof of the effectiveness of motivational HRD interventions. Opang A. *et al.* (2022) document how innovative motivation strategies employed by large hotel chains considerably increased personnel retention. These interventions typically comprised formal recognition schemes, ongoing training, and performance-based incentives designed to satisfy the diverse needs of the employees. By routinely honoring employee achievement, organizations not only build morale but also develop a positive organizational culture that encourages long-term retention. The compensation aspect, while being a conventional extrinsic reward, is also evolving. Shah (2024) confirms that the implementation of recognition and reward frameworks is linked with high employee engagement and productivity. Furthermore, the advent of green human resource development introduces new incentive models. Yasin *et al.* (2022) discussed the example of Interface, a global carpet manufacturer that launched a reward scheme that rewarded employees for achieving environmental objectives and displaying collaboration. This approach positively affected the sustainable culture of the organization through increased participation in green activities while concurrently enhancing job satisfaction and decreasing turnover concerns that are directly tied to higher productivity levels. Finally, technological progress has created opportunities for more customized and efficient HRD processes. Shrestha, N. (2020) documents the rise of data-driven strategies in workforce development. For example, continuous learning platforms allow for customized on-demand training modules tailored to individual employees' needs, optimizing both cost and scheduling flexibility. This customization not only strengthens employee loyalty but also builds workforce capacity, thus increasing overall organizational productivity.

In short, the evidence gathered across a wide range of industries speaks with one voice: deliberate and disciplined HRD practices are powerful drivers of worker productivity. Targeted training builds essential skills; systematic career management and a positive culture foster intrinsic motivation and commitment; and equitable pay strengthens extrinsic motivation and retention. The most successful organizations are those that adopt an integrated approach, combining these elements into one coherent system that addresses the multifaceted needs of their human capital. The findings from such diverse settings provide a robust empirical base for investigating the impact of such HRD strategies on lecturer productivity in the specific context of higher learning institutions.

Theoretical framework

Human capital theory

This theory, largely attributed to economists like Becker (1967) and Ashley (1981), is based on the idea that individuals and organizations can invest in human capital (education, training, and health) to raise pro-

ductivity and economic return. Labor is regarded as an asset whose worth can be enhanced by investment. The core premise is that expenditures on education, training, and healthcare are investments, similar to physical capital, that yield future returns in the form of higher productivity and earnings (Blaug, 1976). The theory is relevant because it considers how lecturers' investment (the "human capital"), specifically through skill development (enhancing abilities), career development (enhancing future value and retention), and incentives (maintaining and motivating the asset), leads to a return on investment in the form of enhanced productivity and performance. From an organizational perspective, human capital theory posits that a firm's investment in its employees' knowledge and skills creates a valuable, firm-specific asset that is difficult for competitors to imitate, thus providing a sustainable competitive advantage (Barney, 1991; Wright *et al.,* 2001). The positive correlations found between these human development strategies and lecturer performance strongly support the theory's primary contention that investing in human beings has economic benefits to the firm.

Expectancy theory (Vroom's expectancy theory)

This theory of motivation was developed by Victor Vroom (2005) and argues that an individual's motivation to work hard is based on a rational process of calculation of three components: Expectancy: Belief that effort will lead to performance at the level desired by the person (e.g., "If I work harder, I can do better with my teaching."), Instrumentality: Belief that good performance will lead to a valued outcome or reward (e.g., "If I do better, I will get a promotion or bonus."), and Valence: Value assigned by the person to the reward (e.g., "I really want that promotion or bonus."). This theory provides a psychological explanation for how human resource development plans work, which is supported by this study's results. Training confirms Expectancy by giving lecturers the skills and confidence that their hard work can lead to improved performance. Career Development and Remuneration confirm Instrumentality by creating a tangible link between high performance and favorable outcomes like promotion, salary increase, and job satisfaction. The concept of Valence underscores the necessity for rewards to be personally meaningful to the lecturers, which can vary based on individual needs and career stages (Kuhl, 2021). The theory has been extensively applied in organizational and educational contexts to understand employee motivation and performance. For instance, a study by Mahmood *et al.,* (2022) found that expectancy theory constructs significantly predicted the job performance of academic staff, highlighting the importance of clear performance-reward linkages. Similarly, the theory explains why poorly designed incentive systems, where the link between effort and reward is weak or non-existent, often fail to motivate employees (Daouk, 2023).

MATERIALS AND METHODS

Design

The research employed a quantitative design for data collection. This enabled concurrent quantitative and qualitative data collection from a subset of the population at a specific moment (Weyant, E., 2022), allowing for statistical measures as well as contextual understanding.

Population and sampling

The study population consisted of all 27 lecturers at the National School of Administration. The sample size was calculated using Slovin's formula for finite populations with a 5% margin of error.

$n=\frac{N}{1+N\,(e)2}$, where: n = sample size, N = population size (27), e = margin of error (0.05 at a 95% confidence level). Applying the formula: $n=\frac{27}{1+27\,(0.05)2}=\ 24$. Therefore, the minimum required sample size was 24 lecturers. A non-probability, convenience sampling technique was used to select respondents based on their availability and willingness to participate. The entire population of 27 lecturers was invited, and 24 completed the questionnaire, yielding a response rate of 88.9%.

Although this sampling technique was selected based on its convenience, it is important to note that there are some methodological limitations to this technique. For instance, convenience sampling could result in biased sampling, as the sample may not be entirely representative of the whole population of lecturers. Therefore, generalization of the results to other settings or populations should be done with caution. Nevertheless, one of the advantages of this technique was that it had a very high response rate of 88.9%.

Data collection instrument and procedure

Primary data were collected using a structured

self-administered questionnaire. The instrument was divided into five sections:

- Section A: Collected demographic information of respondents (age, gender, educational qualification).
- Section B: Measured perceptions of training and its impact on productivity.
- Section C: Assessed career development practices and their influence.
- Section D: Evaluated remuneration structures and their contribution.
- Section E: Measured the dependent variable, lecturer productivity, and performance.

The questionnaire utilized a five-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), to capture respondents' levels of agreement with various statements.

Data analysis

The collected data were processed and analyzed using the Statistical Package for the Social Sciences (SPSS) version 25.0. The analysis was conducted in two stages:

Descriptive statistics: Frequencies, percentages, means, and standard deviations were computed to summarize the demographic profile of the respondents and their general perceptions of the study variables.

Inferential statistics: This was used to test the hypotheses and establish relationships between variables.

Pearson's Correlation Coefficient (r) was used to measure the strength and direction of the linear relationships between the independent variables (training, career development, remuneration) and the dependent variable (lecturer productivity).

Multiple Linear Regression Analysis was employed to determine the collective predictive power of the three independent variables on lecturer productivity. The model was specified as:

$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \varepsilon$

Where: Y = Lecturer Productivity and Performance, β_0 = Constant, X_1 = Training, X_2 = Career Development, X_3 = Remuneration, ε = Error term. The threshold for statistical significance was set at $*p* < 0.05$.

RESULT AND DISCUSSION

The respondents' demographic profile is crucial for contextualizing the human capital at the National School of Administration, an institution located in an urban commune. This result has significant implications not only for NSA managers but also for stakeholders in urban areas. Spending on faculty HRD is an indirect investment in the human capital of the city. Productive faculty members translate into quality graduates, who in turn improve the quality of the bureaucracy, private sector, and civil society in urban areas, leading to better city governance and development. Before delving into the results, it is important to again mention the sampling context. The data that will be discussed in the following paragraphs was collected using a convenience sampling technique. Although this technique was very effective and helped to obtain an excellent response rate, the fact that there is a possibility of selection bias means that the following descriptive and inferential statistics are a reflection of the perceptions of the lecturers who participated in the survey, and may not be universally representative of all academic staff. The results reveal that strategic HRD increases the efficiency of lecturers, thus directly improving the talent pool for urban governance. This highlights that the development of human capital in the public sector is of utmost importance for efficient urban governance. The improvement of educator performance will strengthen the basic workforce required for efficient urban development in Muha, which is a growing city.

As indicated in Table 1, half of the respondent population (50%, n=12) falls within the 30-40 years age bracket. The remaining respondents are equally distributed between the 40-50 and 50-60 age groups (25% each, n=6). This distribution reveals a workforce predominantly composed of early-career to mid-career professionals. From a human capital perspective, this demographic profile signifies a critical phase in the academic career trajectory. Lecturers in the 30-40 age range are typically beyond the initial probationary period and are actively building their teaching portfolios, engaging in research, and seeking career advancement (Ismail *et al*., 2021). This makes them a highly relevant cohort for studying the impact of Human Resource Development (HRD) interventions, as they are likely to be highly receptive to training, mentorship, and structured career development programs aimed at enhancing their productivity and long-term value to the institution (Shah *et al*., 2024). The concentration of early-career academics can be interpreted as a strategic asset for the institution. A

Table 1 : Distribution of respondents by age group

Items	Frequency	Percentage
30-40	12	50
40-50	6	25
50-60	6	25
Total	24	100,0

Source : Author (2025)

Table 2 : Gender Distribution of Respondents

Frequency		Percentage
Male	15	62,5
Female	9	37,5
Total	24	100,0

Source: Author (2025)

younger faculty may be more adaptable to technological innovations in pedagogy and more energetically engaged in community outreach and applied research activities that are central to the mission of urban higher education institutions (Yasin *et al*., 2022). However, this distribution also highlights a potential strategic consideration. The relatively smaller proportion of senior academics (50-60 years) may indicate a forthcoming succession challenge or a gap in experienced mentorship and research leadership, which are vital for sustaining institutional reputation and knowledge transfer (Becker, 1967). Therefore, targeted HRD strategies must not only cater to the development needs of this young, dynamic core but also implement mechanisms for capturing and transferring the knowledge of senior staff to ensure organizational sustainability. The gender composition of the academic faculty, i.e., the gender distribution, is a significant variable in understanding the organizational environment for Human Resource Development initiatives.

According to Table 2, the sample consisted of 24 lecturers, with a higher number of male lecturers (62.5%, n=15) compared to female lecturers (37.5%, n=9). This gender gap equates to a gender ratio of nearly 1.67 males per female lecturer. This documented gender imbalance reflects broader trends in academic staff composition within higher education institutions, particularly in certain geographic and disciplinary contexts (Ismail, L.B. *et al*., 2021). These disparities can be attributed to an interrelated collection of historical, socio-cultural, and institutional limitations that affect the recruitment, retention, and career progression of women academics (Abu Said *et al*., 2015). From a Human Resource Development point of view, this allocation is important. It is reported that gender diversity in an academic faculty can diversify pedagogical methods, stimulate research innovation, and improve the learning environment. The underrepresentation of either gender can lead to a homogenization of perspectives and may affect the perception and reception of institution-level Human Resource Development policies, such as training distribution, access to mentorship, and career advancement lines (Ujma *et al.,* 2020). Therefore, while addressing the impact of HRD interventions on productivity, consideration should be given to the perception with which these interventions are perceived and experienced by different demographic groups so that human capital formation can be made equitable and productive. Educational level of the instructors forms a crucial component of human capital, which has a direct influence on intellectual capital as well as pedagogical excellence of the institution (Becker, 1967). The highest education level of the respondents is represented in Table 3.

As indicated by Table 3, most of the staff consist of Master's degree holders, who constitute three-quarters of the sample (75.0%, n=18). This is consistent with the tertiary-level teaching requirement and suggests a robust knowledge base among staff. However, a relatively lower proportion possess terminal

Table 3: Educational qualifications of respondents

	Frequency	Percentage
Professor	2	8.3
PhD	4	16,7
Master	18	75,0
Total	24	100,0

Source: Author (2025)

degrees, with only 16.7% (n=4) of them possessing a Doctorate (PhD) and 8.3% (n=2) the rank of Professor. This allocation also highlights a potential strategic gap in the senior level of academic capital. Even though personnel are qualified to carry out the central role of teaching, proportionally low numbers of doctorate-level qualifications might influence the institution's research production, grant-winning potential, and institutional reputation (Shah, 2024). In the competitive landscape of higher education, a strong stock of PhD-level staff is often associated with enhanced institutional ranking and research productivity (Ismail, L.B. *et al.,* 2021). The young, mostly master 's-level faculty members are a crucial source of human capital for the urban management of Muha. Expenditure on their training and development directly benefits the National School of Administration's ability to produce competent civil servants and planners. This enhances local administrative capacity, infrastructure management, and social equity, proving that strategic HRD is a key prerequisite for sustainable urban development. The profile, therefore, identifies a significant opportunity for goal-congruent human resource development interventions. Strategic investment in career development programs, such as sponsoring doctoral research and developing a research culture, is essential to enhance the academic qualifications of the faculty and thereby raise the human capital stock of the institution for long-term urban and institutional management. In summary, the typical respondent in this study is a male lecturer aged 30-40 holding a Master's degree. This kind of profile suggests a qualified, experienced, and likely-to-be-at-that-stage-of-career sample concerned with training, clear career advancement, and competitive pay. It should be remembered that it is against this demographic background that the observations on the Human Resource Development approaches and lecturers' productivity are considered. Descriptive statistics, including means (M) and Standard Deviation (SD), were computed to provide the respondents' comprehension of the key Human Resource Development constructs and their associations with lecturer productivity. Table 4 presents the findings.

Note: Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree. The results indicate that the feedback given by the participants was positive overall, as all mean scores were above the neutral level of 3.0. The highest level of agreement was achieved under items concerning professional development, with participants strongly agreeing that it improves lecturer performance (M=4.38, SD=0.609 and M=4.63, SD=0.492). This is in harmony with past research that presumes that concentrated training constitutes the foundation of gaining necessary competencies as well as improving organizational performance (Ismail, L.B. *et al*., 2021). Moreover, the respondents agreed that compensation is also an important factor. They emphatically agreed that poor standards of living can adversely affect the psychological logic of a lecturer (M=4.25, SD=0.672) and that high-paid lecturers are more efficient (M=4.03, SD=0.897). This points toward the crucial role of equitable pay as a spur and a root of psychological well-being, a notion supported by fundamental theories of motivation (Vroom, 2005). In terms of career development, the respondents agreed that career planning enhances job satisfaction (M=4.03, SD=0.822) and facilitates work performance (M=3.94, SD=0.759). This implies that lecturers are motivated by clear channels of advancement and promotion, as espoused in the provisions of Expectancy Theory (Vroom, 2005). The overall high mean score on all the constructs (Grand Mean M=4.07, SD=0.78) indicates a deep consensus of the academic personnel in the National School of Administration that these HRD strategies are significant enablers of their productivity. These descriptive results provide a baseline awareness that the primary independent variables not only exist but are also perceived to have an effect, laying the groundwork

Table 4: Mean and Standard Deviation

Items	Moyenne	Écart-type	N
The practice of training reduces the wastage of materials	3,78	1,070	24
Professional development improves a lecturer's performance	4,38	,609	24
Good career planning helps in the working performance of lecturers	3,94	,759	24
Career planning provides job satisfaction	4,03	,822	24
With the help of career planning, work decisions are easier to make	3,84	,808	24
There should be fairness when compensation is being given to the lecturers	3,91	,893	24
A low standard of living can affect the psychological reasoning of a lecturer	4,25	,672	24
Lecturers with adequate salaries perform better than underpaid lecturers	4,03	,897	24
Good career planning helps in the working performance of lecturers	4,00	,880	24
Lecturers' performance and productivity are enhanced with the use of good compensation	4,00	,718	24
Professional development improves a lecturer's performance	4,63	,492	24
Overall Grand Mean	4.07	0.78	24

Source: Author (2025)

for the subsequent inferential analysis of determining the strength and significance of these relationships. The direction and strength of the linear correlations were examined through a Pearson correlation test between the most significant Human Resource Development strategies, training, career development, and remuneration, and lecturer productivity. The results, as in Table 5, show statistically significant positive correlations for all three independent variables. The evidence indicated a significant and statistically strong positive correlation between training and lecturer productivity ($r = 0.714$, $p = 0.009$). This finding underscores the critical role of targeted training in enhancing academic performance. It is in line with Ismail, L.B. *et al.* (2021), whose evidence provided showed that systematic training interventions improve individual abilities directly, thus resulting in quantifiable improvements in organizational output. This relationship supports the fundamental nature that investing in lecturers with adequate pedagogic and technical skills is an elementary driving force of productivity, an aspect explained amply by Human Capital Theory (Becker, 1993). Furthermore, a very strong positive relation was demonstrated between career development and lecturer productivity ($r = 0.851$, $p < 0.001$). This result underscores the powerful motivational impact of well-structured career development pathways. The outcome is consistent with Expectancy Theory principles (Vroom, 2005), whereby employees are driven as long as they perceive there is a causal relationship between effort, performance, and reward results, like promotion and growth. Empirical support is presented by Tarigan *et al.* (2022), who determined that intrinsic drivers, including professional growth prospects and autonomy, are critical to help promote organizational commitment and enhance performance levels in academic employees. Finally, a strong and significant positive correlation was found between compensation and lecturer productivity ($r = 0.604$, $p = 0.002$). This finding highlights the significance of equitable compensation as a fundamental extrinsic motivator. The discovery confirms the instrumental part of Expectancy Theory, whereby compensation is an attractive reward that justifies effort (Vroom, 2005). Previous research in the education sector has further indicated that reward for performance and reward schemes are effective in enhancing lecturer retention and engagement, positively impacting productivity (Shah, 2024). This implies that equitable remuneration is not merely a transactional necessity but a strategic investment that is crucial to job performance and satisfaction. In conclusion, the correlation analysis provides robust empirical evidence that all three of the Human Resource Development strategies, training, career growth, and compensation, are strongly and positively correlated with lecturer productivity at the National School of Administration. This

Table 5: Correlation

Items		Lecturer's productivity and performance
Training	Pearson Correlation	,714
	Sig. (Bilateral)	,009
	N	24
Career planning and development	Pearson Correlation	,851
	Sig. (Bilateral)	,000
	N	24
Remuneration	Pearson Correlation	,604
	Sig. (Bilateral)	,002
	N	24
Lecturer's productivity and performance	Pearson Correlation	1
	Sig. (Bilateral)	
	N	24

Source: Author (2025)

forcefully confirms the study's not explicitly stated hypotheses and highlights the multi-dimensional nature of motivating and maximizing academic performance. However, the results of the study should be considered in light of the limitations of the study. Although the sample represents 88.9% of the target population, the absolute number of the sample is small, which is 24. This has limited the study to a small statistical power in the regression analysis.

To determine the aggregate predictive value of the independent variables Training (X_1), Career Development (X_2), and Remuneration (X_3) for the dependent variable, Lecturer Productivity (Y), a multiple linear regression analysis was performed. Goodness-of-fit of the model and significance of individual predictors were assessed. The results, as presented in Table 6, indicate that the model is statistically significant ($F(3, 20)$ = [Note: F-value should be inserted here], $p < 0.001$). The combination of the three HRD strategies explains a high 76.2% of the variation in lecturer productivity ($R^2 = 0.762$, Adjusted $R^2 = 0.732$). This is a high explanatory power that is consistent with the basic assumption of Human Capital Theory, which states that collective investments in human capital are major drivers of performance achievements (Shah, 2024). The regression equation derived is given as follows: $Y = 4.451 + 0.172X_1 + 0.062X_2 + 0.167X_3$, where: Y = Lecturer's Productivity and Performance, X_1 = Training, X_2 = Career Development, X_3 = Remuneration, Model Summary: $R = 0.873$, $R^2 = 0.762$, Adjusted $R^2 = 0.732$. Dependent Variable: Lecturer's productivity and performance (Y).

Yet, when comparing the specific contribution of each predictor after adjusting for the others, none of the single coefficients were statistically significant at the 5% level (Training: $\beta = 0.185$, $p = 0.323$; Career Development: $\beta = 0.061$, $p = 0.743$; Remuneration: $\beta = 0.193$, $p = 0.306$). This is a typical phenomenon in regression analysis when predictors are highly correlated, a condition known as multicollinearity. (Gunst, R. F, *et al.*, 1975). The high correlations between the independent variables (see Table 5) mean that they share a considerable amount of variance in accounting for productivity, making it difficult for the model to distinguish their individual effects. Crucially, this statistical limitation does not diminish the substantive findings; rather, it reinforces them. The fact that the model cannot separate the unique contribution of each variable actually provides compelling evidence that training, career development, and remuneration operate not as isolated initiatives but as an integrated and mutually reinforcing system. Their power lies in their synergy when implemented together; they create a coherent HRD ecosystem where each component amplifies the effectiveness of the others. This synergistic effect means that focusing on any single strategy in isolation would likely yield diminishing returns, whereas a comprehensive

Table 6: Results of multiple linear regression analysis for predictors of lecturer productivity.

Coefficients[a]						
Model		Non-standardised Coefficients		Standardised Coefficients	T	Sig.
		B	Standard Error	Bêta		
1	(Constant)	4,451	1,391		3,199	,003
	Training	,172	,171	,185	1,005	,323
	Career planning and development	,062	,188	,061	,331	,743
	Remuneration	,167	,160	,193	1,043	,306
a. Dependent Variable: Lecturer's productivity and performance						

Source: Author (2025)

Table 7 : Analysis of Variance

Model	Sum of Squares	Df	Mean Square	F-stat	Sig.
1	Regression	124.567	3	21.34	.000
	Residual	38.912	20		
	Total	163.479	23		

approach addressing all three dimensions simultaneously produces optimal results. The high explanatory power of the combined model (R^2 = 0.762) confirms that lecturer productivity is best understood as the product of this interconnected system rather than the sum of independent effects. While individual significance is absent, the direction of the relationships is theoretically informative. With positive coefficients for the three variables, it implies that increased Training goes hand in hand with better productivity, which has implications for the observation that skill development plays a critical role in competency and performance (Zhang and Chen, 2024). An improvement in Career Development practices is linked with higher performance, reinforcing evidence that clearly formulated development paths are strong drivers (Tarigan *et al.,* 2022). A more competitive Remuneration system is linked with higher productivity, reinforcing its status as a central extrinsic motivator as formulated in Expectancy Theory (Vroom, 2005). Cumulatively, the regression analysis confirms that the Human Resource Development strategies are most effective as an integrated whole, where the combined effect is greater than the sum of individual effects. Lastly, regression analysis validates that Human Resource Development strategies function optimally as an integrated system. For the National School of Administration, it implies that a comprehensive approach, enhancing training, career advancement, and compensation simultaneously, is crucial to realizing optimal lecturer productivity, rather than addressing any single initiative in isolation. The implication here is that piecemeal investments in HRD are likely to be less effective, and what is needed is a holistic approach to developing human capital on all three fronts simultaneously.

Regression Sum of Squares (124.567) represents the variation in lecturer productivity that is explained by the three HRD strategies included in the model. Residual Sum of Squares (38.912) is the variation in lecturer productivity that is not explained by the model, i.e., it is due to other factors not included in the study. Total Sum of Squares (163.479): This is the total variation in lecturer productivity. F-statistic (21.34) is the ratio of the mean regression sum of squares to the mean residual sum of squares. A higher F-value indicates that the model explains a significant amount of variance in the dependent variable. Significance (Sig. = 0.000) or p-value is less than 0.05, which means the regression model is statistically significant.

CONCLUSION

This study provides empirical evidence that strategic Human Resource Development (HRD) is a critical predictor of lecturer productivity at the National School of Administration in Muha Commune. The findings strongly indicate that key HRD strategies, namely, training, career development, and remuneration, form an interdependent system that significantly enhances academic performance. The study demonstrated that every Human Resource Development variable distinctly and importantly correlates with productivity. Training displayed a strong positive correlation ($r = 0.714$, $p = 0.009$), validating its role in empowering lecturers to gain the necessary skills for effective teaching and research, as hypothesized by human capital theory. Career development showed the strongest correlation ($r = 0.851$, $p < 0.001$), illustrating the strong motivational effect of well-established development paths and career advancement opportunities, consistent with Expectancy Theory tenets. Remuneration showed a moderate correlation ($r = 0.604$, $p = 0.002$), illustrating that equitable and competitive remuneration is an important extrinsic motivator that helps sustain performance and reduce counter-productive behaviors. The multiple regression formula ($R^2 = 0.762$) statistically confirms that the three variables combined explain a considerable 76.2% of the variance in lecturer productivity. This highlights the value of a holistic Human Resource Development approach, as the individual components are highly interconnected. The lack of a unique contribution for each variable in the regression model indicates that their power lies in collective implementation rather than in independent initiatives. The strategic HRD expenditure on the faculty will have an immediate positive impact on institutional capacity, ensuring sustainable urban management, infrastructure development, and social equity that is imperative in addressing the complex nature of urbanization. Strategic spending on lecturers by HRD will directly enhance urban management through the development of human resources for administration. A productive and well-trained faculty at NSA will produce qualified civil servants and planners required for infrastructure management and social equity in Muha. The development of lecturers is, therefore, not just an academic matter but a fundamental requirement for sustainable development. Training, career development, and compensation, therefore, represent an integrated and synergistic system, and not a series of distinct and separate activities. The cumulative impact of these areas has the potential to catalyze faculty productivity in a manner that is more effective than any single approach. For institutions of higher education, therefore, this integrated and holistic approach is the key to academic excellence. Therefore, for colleges and universities in urban and semi-urban regions aiming to improve institutional performance and reputation, the following evidence-based recommendations are proposed :

- *Institutionalize career development structures by implementing systematic feedback mechanisms, establishing clear promotion policies, and creating personalized career path plans to enhance motivation and retention.*
- *Develop a long-term, needs-based training approach based on a structured Training Needs Analysis (TNA) to make skill development programs relevant and effective.*

To conduct a comprehensive review of the remuneration system to ensure internal equity and external competitiveness, thereby appropriately rewarding and acknowledging performance. Ultimately, strategic investment within an integrated Human Resource Development framework is not solely an administrative responsibility but a paramount strategic imperative for bolstering the academic workforce and driving institutional success in the high-stakes landscape of urban higher education.

AUTHOR CONTRIBUTIONS

All authors have read and approved the final version of this manuscript. All authors made considerable contributions to the study. William RUMURI was responsible for designing, collecting, and analyzing data, and drafting the manuscript. Prof. NTAWIRATSA Rédempteur was the supervisor of this work and also helped in sourcing the funding and guiding the project. Nickolas Adjei Koffi, PhD, contributed considerably to the methodology, analysis, and conceptualization of this paper. Jean Petit SINAMENYE and KARENZO Jean were involved in the data collection, analysis, and interpretation.

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CONFLICT OF INTEREST

The authors confirm that there are no competing interests or personal relationships known that may have influenced the work described in this paper. This study was done independently without any funding or sponsorship from third parties which might have influenced the study design, data collection, analysis, interpretation or even the decision to publish the results. The authors confirm that their professional affiliations, including but not limited to the University of Burundi and the University of Liverpool, were not at all factors in this research and the results obtained therein.

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ABBREVIATIONS (NOMENCLATURE)

HRD	Human Resource Development
NSA	National School of Administration
PhD	Doctor of Philosophy
TNA	Training Needs Analysis

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ORIGINAL RESEARCH PAPER

A spatial multidimensional evaluation of TOD performance around urban rail stations for urban planning

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ABSTRACT

BACKGROUND AND OBJECTIVES: This study analyzes 114 operational electric train stations in Thailand's Bangkok Metropolitan Region, covering seven rail lines: Sukhumvit, Silom, Airport Rail Link, Krung Thonburi, Thani Ratthaya, Nakhonwithi, and Chat Chai. Although substantial investment in rail infrastructure has resulted in a total of 190 stations, a systematic evaluation of the effectiveness of Transit-Oriented Development is still lacking, causing station-area development planning to lack clear direction. This assessment applies the multidimensional "6Ds" framework—Density, Design, Diversity, Connectivity, Destination Accessibility, and Distance to Transit—examined within 500-meter and 1,000-meter station catchment areas. The research has three main objectives: (1) to analyze the strengths and weaknesses of electric train stations in Bangkok and its metropolitan area using Transit-Oriented Development SCORE, (2) to propose future station-area development guidelines to increase public demand for mass transit use, and (3) to develop a web application to support the development of areas around rail transit stations.

METHODS: This study uses the "6Ds" Transit-Oriented Development framework by viewing stations as transportation nodes, urban activity centers, and functional linkages at the same time. The geospatial data used in the study were obtained from the National Statistical Office, the Department of Public Works and Town & Country Planning, and OpenStreetMap. The Transit-Oriented Development indicators consist of population density, household density, and Floor Area Ratio (the ratio of total building floor area to land area) (Density dimension); sidewalk density, number of parking spaces, and road density (Design dimension); land-use diversity (Diversity dimension); number of bus stops and number of railway station entrances/exits (Connectivity dimension); number of Points of Interest (Destination Accessibility dimension); and the distance of Points of Interest to the station and the distance of park-and-ride facilities to the station (Distance to Transit dimension). The researcher used the Information Entropy Weight Method to determine indicator weights based on data variability rather than relying on expert judgment, thereby making the Transit-Oriented Development calculation more consistent with Thailand's context. The IEW method uses the input data to assign Transit-Oriented Development weights to each dimension, enabling calculation of Transit-Oriented Development scores for each dimension. In addition, the researcher developed a prototype web application to display the Transit-Oriented Development values of each station, which allows comparative analysis to identify each station's strengths or weaknesses in each dimension, in order to support stakeholder decision-making for planning the development of areas around electric train stations.

FINDINGS: Based on the research findings, the key factors affecting the choice to use mass transit are "population density" and "the number of Points of Interest" around stations. Therefore, if the goal is to increase the Transit-Oriented Development SCORE, it is necessary to increase population density and increase the number of Points of Interest around the stations where area development is desired. This study shows that Transit-Oriented Development differs from station to station across Bangkok's entire transit network. This research helps fill the gap in objective evaluation by applying the Information Entropy Weight technique to reduce bias in assigning weights to variables. It also complements the literature by providing a large-scale evaluation, assessing as many as 114 electric train stations in Thailand, which is a broader scale than many previous studies.

CONCLUSION: This research develops an approach for evaluating Transit-Oriented Development in Thailand by using the Transit-Oriented Development SCORE. The results indicate differences in Transit-Oriented Development across 114 stations and show that Density and Connectivity have a strong impact on Transit-Oriented Development value. To increase the Transit-Oriented Development value for stations, the first approach that should be implemented is to promote area development in the form of Mixed-use Development by allocating space to support housing, commerce, and public space. This includes creating housing projects such as condominiums, housing estates, and hotels, which increase the number of residents in areas near stations, along with promoting commercial development such as building shopping malls, office buildings, restaurants, and cafés so that the station area becomes lively and has activities throughout the day. Increasing various points of interest, such as schools, hospitals, entertainment venues, parks, or museums, will further encourage more regular trips into and out of the station area and for a wider variety of purposes.

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INTRODUCTION

In Thailand, the Ministry of Transport has developed a strategy to upgrade the country's transportation system, and this strategy is consistent with the 12th National Economic and Social Development Plan (2017–2021), the 20-Year National Strategy (2018–2037), and the Thailand 4.0 vision (Knight Frank Thailand, 2023). The main component of this strategic plan focuses on developing Transport Services. The goal of this plan is to increase mobility by providing transportation options that are accessible, safe, and punctual, in accordance with international standards (Barter, 2013; Institute for Transportation and Development Policy, 2017). The two-decade transportation infrastructure development strategy focuses on improving traffic flow in Bangkok and surrounding provinces through travel demand management, which includes restrictions on private vehicles in commercial zones, limited parking along transit corridors, and road access fees (Belzer & Autler, 2002a). The government has made a large investment in developing rail infrastructure projects. At present, Bangkok and its metropolitan area have a total of 190 electric rail stations in service, namely 60 BTS Skytrain stations (47 stations on the Sukhumvit Line, 14 stations on the Silom Line), 107 MRT stations on four lines, 8 Airport Rail Link stations, 3 Gold Line stations, and 13 Red Line commuter rail stations. Countries in Asia are facing rapid urban expansion, causing urban planning to shift toward the concept of "neoliberalism," which emphasizes global economic competitiveness, social welfare, environmental quality, and economic development (Kidokoro et al., 2022; Ravindran et al., 2024; Shojaeivand, 2019). Previous studies on urban transport in Chinese cities have also shown that alternative low-emission transport modes, such as electric bikes, can contribute to reducing environmental impacts in rapidly urbanizing areas (Cherry et al., 2007). Therefore, Transit-Oriented Development (TOD) has been designated as an important strategy to enable transportation and urban development to proceed simultaneously (Calthorpe, 1993, 2014; Belzer & Autler, 2002b). From previous research, the term "TOD" refers to an area development approach with high density, leading to mixed land use; this concept emphasizes pedestrians and creates urban activities around public transport centers (Calthorpe, 1993; Liang et al., 2020). For measuring TOD values, the

development started from three dimensions: Density, Diversity, and Design (Cervero & Kockelman, 1997), and additional dimensions have been added in studies because later research included dimensions such as Distance to Transit, Destination Accessibility, Demand Management, and socio-demographic characteristics, resulting in more diverse TOD dimensions (Ewing & Cervero, 2010; Yang et al., 2024). The Node–Place model, which views stations as transportation "nodes" and urban "places" (Bertolini, 1999), has been used to analyze TOD, and it was then developed into the Node–Functionality–Place model, which gives stations a role as links between rail systems and people's everyday urban life (Su et al., 2021a). As a result, this analysis has become an important foundation used to classify station types and evaluate the alignment of the city with TOD development. A good station is not judged by passenger numbers, but the quality of development in the area around a station depends on the TOD value. Good design of the station area creates more diverse activities, improves accessibility, and enables the station to connect more with society and the economy. TOD promotes multi-modal travel, increases urban vitality, and promotes social and cultural interaction. TOD environments create a vibrant street atmosphere, lead to longer business hours, and create diverse social interactions. Stations with high TOD values carefully arrange land uses for residential, commercial, recreational, and institutional purposes close to transport hubs (Xiao et al., 2021). Recent studies using Points of Interest (PoI) data have analyzed urban changes near stations, then categorized what functions the area emphasizes (food-and-entertainment districts, office districts, residential districts, etc.), and evaluated whether these changes make the area more attractive for tourism or livelier, and how much they make the city appear more vibrant (Ding *et al.,* 2025; Yu *et al.,* 2022). Some studies collected "real evidence" to examine how TOD (urban development around stations/public transport systems) affects the economy, especially housing and condominiums, such as whether prices rise or fall, how rents change, movements of people in and out, and how demand to buy/rent in that area changes. Research in major Chinese cities found that if an area has TOD-type development (convenient travel, near rail stations), it makes house–condo rents increase noticeably, and this is especially clear in areas where travel truly becomes more convenient (easy station access, good connections, convenient transfers) and where land use is well-balanced (housing, shops, workplaces, and amenities are located close together) (Su *et al.,* 2021b; Yang *et al.,* 2024). When a well-connected station becomes well-known, land prices, housing prices, and rents often rise, causing low-income people or vulnerable groups to be unable to stay and to move out, even though that area has more jobs, opportunities, and better services (Lai & Tran, 2025). Although TOD is a concept that most people see as "good," when it is implemented in practice, the outcomes and methods depend on the conditions of each city. This is especially the case in developing countries, because many cities still lack tools or methods to measure how well TOD has been achieved, and existing tools often do not fit the local context. Importantly, they do not clearly indicate locations on maps regarding which spots are good, which are bad, or where improvements should be made (Ali *et al.,* 2025; Goode, 2023). Many projects that claim to "do TOD" are actually only building something next to a station, which is called Transit-Adjacent Development (TAD) (developing "beside" transit, not developing "for" mobility and daily life). For true TOD, when you get off at the station, it should be easy to walk (good sidewalks, safe crossings), there should be a mix of shops–homes–workplaces–services nearby, and the area design should be connected as a system (walkways, connections, roads, lanes/sois not cut off). For TAD, it only has an area located near a station, but walking is difficult (there are no sidewalks, and you have to cross dangerous roads). The surrounding area has only one type of building (e.g., only condominiums or only malls), and the area is not connected. In the end, users cannot walk and must rely on private cars or taxis (Goode, 2023; Renne, 2009). As for the definition of the boundary of TOD catchment areas, various radius values have been set. Calthorpe (1993) set a radius of 2,000 feet (about 600 meters), but modern ideas suggest a range of 400–800 meters around rail stations, considering differences in people's walking behavior. In Japan, a distance of 800 meters is considered suitable for walking (Zhuang & Zhao, 2014). Thailand's 2013 City Planning Act states that if land is within no more than 500 meters of an urban rail station, the state will give "special privileges" to project developers, meaning they can build a larger/more intensive building on the same plot of land (called an FAR bonus). There is also an additional

proposal that for a normal station with a single line, the influence distance should be 500 meters as before, but if it is a large interchange station, the influence distance should be expanded to 800–1,000 meters, because this type of station can attract users from a farther distance, and development around it should be supported more. Research on TOD creates "composite indices" to measure how much the area around a station follows the TOD concept by looking at multiple aspects at the same time, including Density, Diversity, Design, Distance to Transit, Destination Accessibility, and Connectivity (Ogra & Ndebele, 2014; Renne, 2008; Salat & Ollivier, 2017). However, applying TOD in developing countries still has limitations. Those who apply TOD need to adjust the methods to fit local legal frameworks, travel patterns, and data availability (Ali et al., 2025; Goode, 2023). Despite considerable efforts to enhance Bangkok's urban rail network, the planning process lacks comprehensive, contextually relevant multidimensional criteria for evaluating the spatial advantages and disadvantages of station placements. The researcher achieved notable progress by computing TOD Scores for 53 stations on the Blue and Purple Lines, gathering data on population density, retail mall quantity, road density, land-use diversity, and bus routes per station. A thorough spatial and multidimensional assessment of the entire operational rail network is ongoing (Saensomboon & Thapthimhin, 2023). This study presents a multidimensional assessment of the effectiveness of TOD, in which the researcher calculated the TOD SCORE for 114 operational electric train stations in Bangkok and its metropolitan area in Thailand. For this calculation, the researcher computed TOD in six dimensions: Density, Design, Diversity, Connectivity, Destination Accessibility, and Distance to Transit (Ogra & Ndebele, 2014). The indicators used in this study include several items, such as population density, road density, land-use diversity, POI, and the level of public transportation services, including connections with bus services at each station. For this study, the researcher used the Information Entropy Weight Method (IEW) to determine the weights of the indicators and to calculate the TOD score for each station. This methodology helps reduce bias from assigning weights to each variable and increases the ability to calculate TOD. After calculating the TOD index value of each station, the researcher can rank the TOD score of each station, which makes it possible to identify the strengths and weaknesses of the station and to plan the development of the environment around the station area in line with changes in the city (Wu & Divigalpitiya, 2023). This research analyzed the TOD value of each station and presented the results on a prototype web application. The displayed TOD value is an accessible decision-support tool for government agencies, private-sector agencies, and stakeholders involved in area development (Xiao *et al.,* 2021). This tool can evaluate station-level performance, compare rail-line routes, and calculate investment opportunities related to transit-oriented development. Research findings will be communicated to key stakeholders, including the Mass Rapid Transit Authority of Thailand (MRTA), State Railway of Thailand (SRT), Bangkok Mass Transit System Public Company Limited (BTS), Bangkok Expressway and Metro Public Company Limited (BEM), and Asia Era One Company Limited, supplying crucial information for the strategic planning of developments near electric train stations efficiently and sustainably.

MATERIALS AND METHODS

Data collection

Data collection for evaluating TOD performance covers 114 rail transit stations across seven main networks in Bangkok and its metropolitan area, using the 6Ds framework to define variables, as detailed below. Catchment Areas: Data were collected within two station-area catchment radii: 500 meters, which aligns with the FAR Bonus incentive criteria under Thailand's urban planning regulations, and 1,000 meters to assess performance at a broader neighborhood scale in line with walkability and station-access network concepts. Density Variables include population density, household density, and the Floor Area Ratio (FAR). Data were obtained from the National Statistical Office, the Department of Provincial Administration, and online real estate databases (Ogra & Ndebele, 2014; Singh *et al.,* 2017). Design Variables include road density, the number of parking areas, and sidewalk density. Data were collected through field surveys around rail transit stations and geospatial data analysis (Cervero, 2004; Chen & Zegras, 2016). Diversity: The variable is land-use diversity, calculated from the diversity of POIs. POIs were categorized into six main types: residential areas, public services, commercial uses, offices, public parks, and other infrastructure, to compute the Mix Index. Data were collected through field surveys around stations

(Renne, 2009; Salat & Ollivier, 2017). Connectivity and Demand Management Variables include the number of bus routes and the number of station entrances/exits. Data were collected through field surveys around stations and from mass transit system databases (Kuby, Barranda, & Upchurch, 2004; Zegras *et al.,* 2016). Destination Accessibility Variables include the number of POI—such as employment locations, schools, and shopping malls—within the study radius, to assess a station's capacity to function as a center of urban activity. Data were collected through field surveys around stations (Cascetta & Pagliara, 2016; Chen & Zegras, 2016). Distance to Transit Variables include the distance from Park-and-Ride facilities to the station and the average walking distance from POI to the station center, to measure the convenience of access to the transit system at a human scale. Data were collected through field surveys around stations (Fard, 2013; Singh *et al.,* 2017). Data Sources and Processing: All data were obtained from field surveys around rail transit stations, and additional information was received from private companies such as BTS and BEM, as well as government agencies including the National Statistical Office, the Ministry of Transport, MRTA, SRT, and the Bangkok Metropolitan Administration (Knight Frank Thailand, 2023; Ministry of Interior Regulation, 2013). All data will be normalized prior to weighting using the IEW method to construct the TOD Score in the next step. Details of data collection for each dimension are presented in Table 1.

Fig. 1 illustrates the calculation of POI within a 500-meter radius around a mass transit station. The colored dots surrounding the station represent different types of places, such as schools, hospitals, markets, convenience stores, transport services, warehouses, workplaces, and villages. The purpose of collecting this data is to survey what kinds of key facilities are located around the station, how many there are, and how far each one is from the station. This information makes it possible to evaluate the station's potential to attract people and is also useful for urban development planning—for example, if there are many schools or workplaces near the station, it is likely to increase ridership. Ultimately, all of this data will be used to calculate the TOD Score (Transit-Oriented Development Score), which serves as an indicator of the efficiency and suitability of development in the station area.

Analytical framework

This study employs a multidimensional analytical framework grounded in the Node–Place Model (Bertolini, 1999), which explains the relationship between mass transit stations and the surrounding urban areas. The framework is further extended through the Node–Functionality–Place (NFP) model (Su *et al.,* 2021) to emphasize "functionality" as a linking dimension between the rail transit system and land use. In addition, the Land-use Transport Feedback Cycle concept (Wegener, 1999) is applied to explain how accessibility and station-area activities influence one another. The researcher collected data on six key dimensions of rail transit stations based on the 6Ds principle developed by Cervero and Kockelman (1997) and Ewing and Cervero (2010), in order to calculate the TOD SCORE. Density measures the number of population, households, and FAR around stations to examine how intensively the area is used (Ogra & Ndebele, 2014). Design assesses the quality of the station-area environment—including sidewalks, streets, and parking—in terms of walkability and comfort (Calthorpe, 1993; Cervero & Murakami, 2010). Diversity measures the variety of activities and land uses using a Mix Index derived from the distribution of POI, covering residential uses, retail, and various services (Belzer & Autler, 2002; CTOD, 2009). Connectivity evaluates how well stations connect to other transport systems, based on the number of bus routes and station entrances/exits (Cervero, 2004; Zegras *et al.,* 2016). Destination Accessibility counts key destinations that can be reached from the station, such as schools, workplaces, and shopping malls (Jiang *et al.,* 2017; Singh *et al.,* 2017). Distance to Transit measures the distance from park-and-ride facilities and the average walking distance to destinations to assess how easily the station can be accessed (Kuby et al., 2004; Chen & Zegras, 2016). To ensure neutral weighting that does not depend on subjective judgment, this study applies IEW (Shannon, 1948), a statistical approach that analyzes data variability across 114 stations to identify which indicators contribute most to differences in TOD performance in Bangkok. The weighted indicators are then combined to compute the TOD SCORE for comparing and clustering stations by their level of development (Fard, 2013; Renne, 2016). The resulting scores are used to develop a prototype web application serving as a Spatial Decision Support System (SDSS). This tool

Table 1: Explain the details of the variables in each dimension

Dimension	Basic Indicator	Impact on TOD	Operational Definition	Data Source
Density	Population Density (people/sq·km)	+	The number of people in a subdistrict per area of the	National Statistical Office / Department of Provincial
	Household Density (households/sq·km)	+	The number of households in a subdistrict per area of the subdistrict (for Bangkok, districts are used instead of subdistricts	
Design	FAR	+	Floor Area Ratio	www·feasyonline·com
	Sidewalk Density	+	Length of sidewalks near the streets around the station	Field surveys / Online maps
	Number of Parking Spaces	-	Number of parking spaces (POI) around the station	
	Road Density	+	Length of roads within the TOD radius around the station	extract·bbbike·org and GIS software analysis
Diversity	Land Use Diversity	+	Calculated based on the number of different types of POI using a Mix Index formula	Field surveys / Online maps and calculation formulas
Connectivity and demand management indicator	Number of Bus Routes	+	Number of bus routes that pass the station (counted by distinct route numbers)	Internet search on “List of train stations in Bangkok and metropolitan area”
	Number of Entrances/ Exits	+	Number of Railway Station Entrances/Exits	Internet search on “List of train stations in Bangkok and metropolitan area”
Destination accessibility indicator	Number of POI	+	Number of POI such as schools, condos, villages, clinics, hospitals, companies, delivery points, department stores, and hotels	Field surveys / Online maps
Distance to transit	Distance Between Park-and-Ride and Station	-	Distance between park-and-ride facilities and the station	Online maps
	Average Distance from POI to Station Center	-	Sum of distances from POI to the station divided by the total number of POI	Online maps

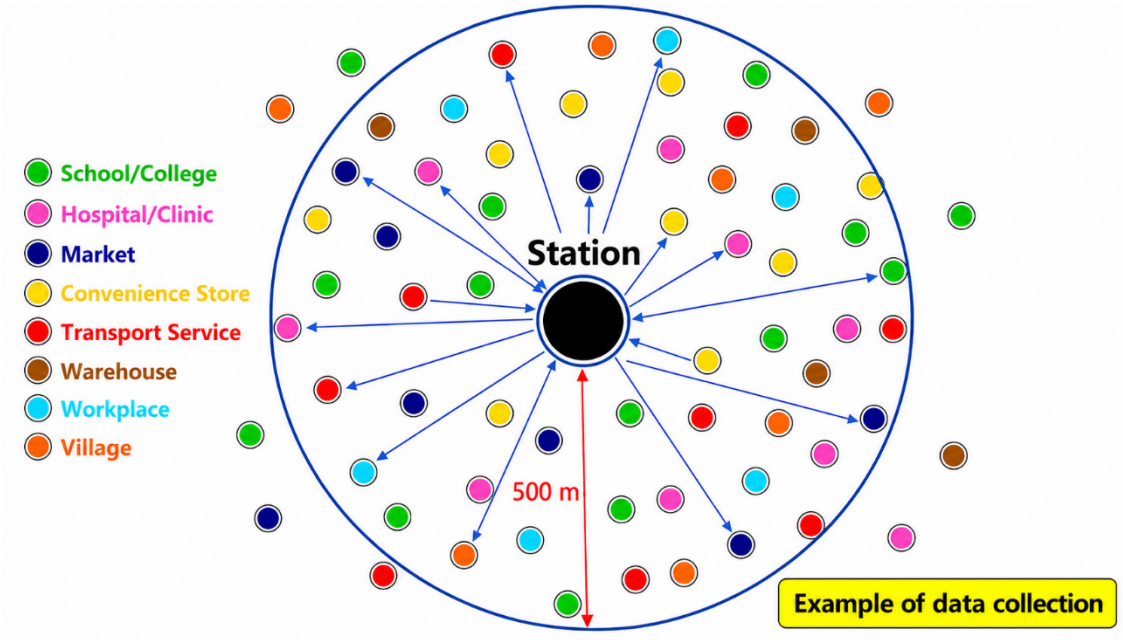


Fig. 1: Calculation of POIs within a 500-meter radius

enables agencies such as MRTA or SRT to analyze the strengths and weaknesses of each station and to formulate policies—for example, promoting mixed-use development or applying tax measures to encourage sustainable land use around stations (CTOD, 2011; Urban Redevelopment Authority, 2024), as shown in Fig. 2.

Fig. 2 shows the several factors that affect the TOD SCORE, as well as the ways the study collected data and the sources of that data. TOD is a concept that aims to make cities better places to live by making it easier to get to and utilize public transportation, which in turn encourages people to use public transportation instead of their own cars. TOD aims to reduce traffic congestion, especially from private cars; improve the development of station areas to get the most out of the land; build infrastructure that makes it easy to get around; mix land uses to make it easier to do important daily tasks like living, going to school, working, shopping, and getting medical care; and cut down on fuel use to protect the environment (Belzer & Autler, 2002; Mehndiratta & Salzberg, 2012; Calthorpe, 2014). More people and families living close together make public transportation more popular. The Floor Area Ratio (FAR) shows that land is being used more efficiently, as seen in high-rise or high-density constructions (Ogra & Ndebele, 2014; Cervero & Murakami, 2010). The density of sidewalks makes it safe and easy for people to walk (Calthorpe, 1993). But too many parking spaces can make people want to drive more (Belzer & Autler, 2002). Road density means that there are many ways to get to transportation centers (Cascetta & Pagliara, 2016). Mixed land use makes it easier for people to use public transportation for school, work, and living (CTOD, 2011; Singh *et al*., 2017). More bus lines that stop at a station make it easier to get around (Zegras *et al*., 2016). The abundance of entrances and exits at the station makes it easier to go to and from the station and eases traffic (Chen & Zegras, 2016). Adding more POIs around the station makes public transportation more appealing and useful (Jiang *et al*., 2017). On the other hand, increasing the distance between park-and-ride facilities and the station makes it less likely that people will use public transportation. In the same way, ridership goes down when attractions are far away from stations since people have to go a long way to get there (Kuby *et al*., 2004; Chen & Zegras, 2016). The research utilized both primary and secondary data sources. We used field observations and online mapping tools to collect primary data by surveying POIs within 500-meter and 1000-meter radii

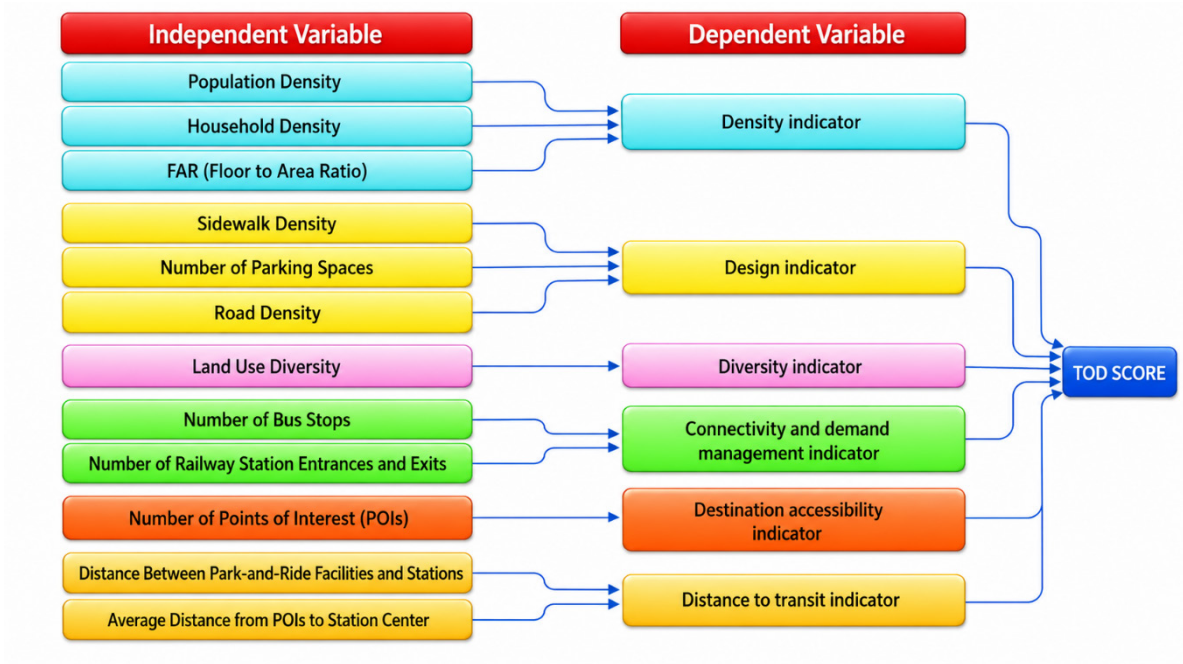


Fig. 2: Conceptual framework of the research

around electric train stations (Fard, 2013). Secondary data were obtained from governmental institutions and online platforms, such as the National Statistical Office, the Department of Provincial Administration, the Ministry of Interior, www.feasyonline.com, and extract.bbbike.org. Table 1 shows the different factors that determine the TOD SCORE, as well as the ways the researchers collected data and the sources of information they used. TOD is «a concept designed to create urban environments that make it easy to get to and use public transportation, which encourages people to use public transportation instead of their own cars» (CTOD, 2009). TOD has several main goals: to reduce traffic congestion, especially that caused by private cars; to make the most of station areas to increase land value; to build infrastructure that makes it easy and convenient to get around; to mix different types of land use so that important daily activities like living, going to school, working, shopping, and getting medical care can happen in the same area; and to use less fuel to protect the environment (Belzer & Autler, 2002; CTOD, 2011; Mehndiratta & Salzberg, 2012).

Density indicator

In this research, density refers to population density, employment density, and development within the area surrounding a railway station. Higher population and employment density indicate a higher level of TOD (Cervero & Murakami, 2010). The density gradient can be calculated from the ratio of total building floor area to land area (FAR) around the station. A higher FAR value also indicates a higher level of TOD (Fard, 2013).

Design indicator

This refers to smooth and safe access to transit stations, such as the construction of sidewalks, bicycle lanes, and street lighting, as well as the arrangement of facilities like benches, parks, landscaping, and libraries. A well-designed area emphasizes walkability and bikeability, which enhance the convenience of using public transport and increase ridership (Calthorpe, 1993; Ogra & Ndebele, 2014). The design indicator measures urban structure design with a focus on promoting walking and the attractiveness of the built environment. For this research, road density, number of parking spaces, and sidewalk density were used as proxies for the design indicator.

Diversity indicator

This study utilized POIs as a surrogate for mixed land use (Xie, 2017). The POIs were categorized into six classifications: 1) Residential zones, 2) Public services

(e.g., governmental institutions, educational facilities, healthcare services), 3) Commercial establishments (e.g., retail outlets, entertainment venues), 4) Corporations, 5) Parks, and 6) Miscellaneous (e.g., transportation-related infrastructures, storage facilities). The extent of mixed land use was subsequently determined using a specified formula.

$$Mix = -\frac{1}{\ln n}\sum_{i=1}^{n} p_i \ln p_i \quad (1)$$

Where Mix = degree of mixing (Level of Mixed-Use Integration), p_i = percentage share of each type of POI, i = type of POI, n = number of POI categories

Destination accessibility indicator

This indicator demonstrates the various types of locations accessible via public transportation, including your workplace, service centers, parks, and other destinations. It examines factors such as travel duration, service frequency, and the number of required transfers to assess the accessibility of these vital locations (Verduzco Torres, 2024). Destination accessibility is crucial as it exemplifies the fundamental purpose of transportation: to facilitate individuals' access to desired activities and essential services (Victoria Transport Policy Institute, 2024). Accessible locations foster a sense of welcome, generate employment opportunities, and enhance urban living by facilitating mobility and connecting individuals with essential destinations.

Distance to transit indicator

The distance to transit denotes the physical space an individual must traverse to reach a transit station or stop. The shorter the distance to transit, the more it enhances the efficiency and appeal of public transportation, as reduced distances promote walking as the primary means of access. Acceptable walking distances vary among cities due to variations in urban design, climate, and socio-cultural influences. For example, although a walking distance of 400 to 800 meters (approximately a 5 -10-minute walk) is frequently referenced in numerous studies, recent research indicates that individuals may be inclined to walk significantly greater distances based on the quality of the walking environment and personal attributes (Ewing & Cervero, 2010; Naess, 2015; Smith *et al.*, 2015). A study of transit users revealed that those located two miles from a transit stop had approximately a 50% likelihood of walking instead of utilizing motorized transport to access the station, indicating significant variability in walking behaviors (Durand *et al.*, 2015).

Composite TOD index

Calculation of TOD Score. The researcher applied IEW to determine the weight of each variable, following the approaches of Jiang *et al.*, (2016) and Y. Xie *et al.*, (2017), which were originally developed by Shannon and Weaver (1948). The calculation steps are as follows:

1) Decision matrix construction. A data matrix is constructed as: $X=(X_{ij})_{m\,x\,n}$, where m = number of stations, n = number of TOD indicators, X_{ij} = the value of indicator j for station i. 2) Normalization of the decision matrix. This step eliminates the effect of different measurement units of each variable to obtain standardized quantitative index values for comparison. These standardized values are denoted as X'_{ij}. For variables that have a positive effect on TOD, the normalized value can be calculated using Eqs. 2-4 as follows:

$$X'_{ij} = \frac{X_{ij} - X_{j\,min}}{X_{j\,max} - X_{j\,min}} \quad (2)$$

For variables that hurt TOD

$$X'_{ij} = \frac{X_{j\,max} - X_{ij}}{X_{j\,max} - X_{j\,min}} \quad (3)$$

X'_{ij} = the standardized quantitative index value of indicator j at station i, after normalization. X_{ij} = the original value of indicator j at station i. $X_{j\,min}$ = the minimum value of indicator j among all stations considered. $X_{j\,max}$ = the maximum value of indicator j among all stations considered.

Entropy calculation for each indicator

The entropy of indicator j is:

$$H_j = -\frac{1}{\ln m}\sum_{i=1}^{m} p_{ij} \ln p_{ij} \quad (4)$$

H_{ij} = the entropy value of each indicator j. m = the number of stations. p_{ij} = the proportion of the standardized quantitative value of indicator j at station i to the sum across all stations.

$$p_{ij} = \frac{X'_{ij}}{\sum_{k=1}^{m} X'_{kj}} \quad (5)$$

i=1,2,3,…,m and j=1,2,3,…,n → where m is the number of stations and n is the number of indicators, respectively. If $p_{ij} = 0$, assume $\ln p_{ij} = 0$. In general, if the

Table 2: TOD indicators and weight calculation using the IEW method

Dimension	Basic Indicator	Impact on TOD	Weight	
			500 m	1000 m
Density	Population Density (people/sq.km)	+	0.12	0.08
	Household Density (households/sq km)	+	0.14	0.12
	FAR (the ratio of total building floor area to land area)	+	0.06	0.07
Design	Sidewalk Density	+	0.13	0.14
	Number of Parking Spaces	-	0.15	0.08
	Road Density	+	0.03	0.05
Diversity	Land Use Diversity	+	0.03	0
Connectivity and demand management	Number of Bus Routes	+	0.1	0.11
	Number of Railway Station Entrances/Exits	+	0.07	0.08
Destination accessibility	Number of POIs	+	0.11	0.19
Distance to transit	Distance Between Park-and-Ride and Station	-	0.01	0.01
	Average Distance from POI to Station Center	-	0.04	0.08

entropy value is low, it indicates a higher degree of variation and greater information content. This leads to a larger weight being assigned to that indicator in the TOD calculation. Calculate the imbalance coefficient of each indicator.

$$G_j = 1 - H_j \quad (6)$$

G_j =the degree of divergence (or information utility) of indicator j. H_j =the entropy value of each indicator.

Weight calculation of each indicator

$$W_j = \frac{G_j}{\sum_1^n G_j} \quad (7)$$

W_j =the weight of indicator j. G_j =the degree of divergence of indicator j.

Compute the TOD SCORE for each station

$$V_i = \sum_{j=1}^{n} W_j X'_{ij} \times 100 \quad (8)$$

V_i is the TOD score of the station; n is the number of indicators that affect TOD. W_j is the weight of indicator j. X'_{ij} is the standardized quantitative index value of indicator j affecting TOD at station i.

RESULTS AND DISCUSSION

For the calculation of the weights of each factor influencing the TOD SCORE using the IEW method, the results are as follows:

From Table 2, the researcher calculated the weights of 12 indicators, divided into six dimensions: 1) density, 2) diversity, 3) design, 4) diversity, 5) connectivity and demand management, and 6) distance to public transit. The weights were calculated in two forms: 1) within a 500-meter radius of the station and 2) within a 1,000-meter radius of the station. The results of the weight calculation are as follows. In the density dimension, the weights of population density and household density within a 500-meter radius are higher than within a 1,000-meter radius, while the FAR weights are similar in both radii. In the design dimension, sidewalk density weights are similar in both 500 and 1,000 meters, parking facility weights are higher within 500 meters than 1,000 meters, and road density weights are lower at 500 meters compared to 1,000 meters. In the diversity dimension, the weight of land-use diversity within a 500-meter radius is higher than within a 1,000-meter radius, because the number of POIs at 500 and 1,000 meters varies significantly, leading to different results when calculating diversity. In the

connectivity and demand management dimension, the weights of bus routes and the number of station entrances and exits are similar in both 500 and 1,000 meters. In the destination accessibility dimension, the weight of POI at 500 meters is lower than at 1,000 meters, because the number of POI within 1,000 meters is considerably greater than within 500 meters. In the distance to transit dimension, the weight of park-and-ride distance is similar in both 500 and 1,000 meters, while the average distance of POIs to the station center is lower at 500 meters compared to 1,000 meters.

From Table 3, it is found that within a 500-meter radius, each transit line has the following average TOD scores: Sukhumvit Line (Light Green) – Average TOD Score: 34.94, Silom Line Dark Green) – Average TOD Score: 45.48 Airport Rail Link – Average TOD Score: 36.92 Krung Thonburi Line (Gold) – Average TOD Score: 43.23 Thani Ratthaya Line (Dark Red) – Average TOD Score: 26.55 Nakhon Withi Line (Light Red) – Average TOD Score: 23.73 Chat Chai Line (Pink) – Average TOD Score: 29.93. From these values, it can be explained that lines with stations located within densely populated areas of Bangkok tend to have higher TOD scores than those with stations outside Bangkok. For the density dimension, the Krung Thonburi and Silom Lines have higher average TOD scores than other lines, while the Thani Ratthaya and Nakhon Withi Lines have lower averages. For the design dimension, the Thani Ratthaya and Silom Lines score higher than others, while the Krung Thonburi and Nakhon Withi Lines score lower. For the diversity dimension, the Chat Chai and Krung Thonburi Lines score higher, while the Nakhon Withi and Thani Ratthaya Lines score lower. For the connectivity and demand management dimension, the Sukhumvit and Silom Lines score higher, while the Nakhon Withi and Thani Ratthaya Lines score lower. For the destination accessibility dimension, the Krung Thonburi Line, Airport Rail Link, and Silom Line score higher, while the Thani Ratthaya and Chat Chai Lines score lower. For the distance to transit dimension, the Nakhon Withi and Thani Ratthaya Lines score higher than other lines, while the Krung Thonburi and Silom Lines score lower.

Table 4 shows that each transit route has the following average TOD scores within a 1,000-meter radius: The average TOD score for the Light Green Sukhumvit Line is 36.36. The Silom Line (Dark Green) has an average TOD score of 40.00. Airport Rail Connection: Average TOD Score: 36.40. The average TOD score for the Gold Krung Thonburi Line is 45.09. The average TOD score for the Thani Ratthaya Line (Dark Red) is 29.52. There is an average TOD score of 25.01 for the Nakhon Withi Line (Light Red). Chat Chai Line (Pink) - Average TOD Score: 30.54. These numbers show that transit lines that serve Bangkok's most densely populated neighborhoods have higher TOD scores than those that serve areas outside the city, where the population density is lower. The Krung Thonburi and Silom Lines have higher average TOD scores for the density dimension, whereas the Thani Ratthaya and Chat Chai Lines have lower scores. The Thani Ratthaya and Sukhumvit Lines get higher design scores than the Nakhon Withi Line and Airport Rail Link, which get lower scores. In terms of diversity, all lines have almost the same average TOD scores. The Sukhumvit and Silom Lines are better at connecting and managing demand than the Nakhon Withi and Thani Ratthaya Lines. The Krung Thonburi Line and Airport Rail Link are better than the Silom and Chat Chai Lines at getting you to your destination. The Krung Thonburi Line and Airport Rail Link are rated higher for how far away they are from transportation, whereas the Nakhon Withi and Thani Ratthaya Lines are rated lower. Tables 4 and 5 support the same idea: the TOD score goes up when a transit route has stops in Bangkok, especially in areas with a lot of people. The number of people living in a square kilometer (persons/km^2), the number of dwelling units in a square kilometer (households/km^2), and the Floor Area Ratio (FAR) all affect the density dimension. When you do the maths for distances of 500 m and 1,000 m, you always get the same answer. The only differences are due to the different weights used. The number of pathways, parking spots, and highways affects the design dimensions. Calculating distances of 500 m and 1,000 m gives answers that are partly the same, but changes in the length of the pavements, parking spaces, and roads between the two radii cause problems. Land-use diversity determines the variety dimension. This is measured by the number of different sorts of POI, such as schools, condominiums, housing estates, clinics, hospitals, businesses, logistics centers, shopping malls, restaurants, and hotels. The 500 m and 1,000 m radii yield disparate outcomes owing to substantial variations in point of interest counts within categories. The connection and demand management

Table 3: The TOD scores of each studied urban rail transit line, calculated based on POIs within a 500-meter radius

Line	Statistical Value	Density	Design	Diversity	Connectivity and demand management	Destination accessibility	Distance to transit	TOD Score
Sukhumvit Line (Light Green Line)	Average	9.3	10.4	1.7	8.2	2.6	2.8	34.9
	Standard Deviation	3.5	3.5	0.6	3.3	1.4	0.8	8.2
	Minimum	2.1	4.3	0.1	1.3	0.7	1.4	19.1
	Maximum	19.1	16.3	2.6	14.5	6.0	5.5	49.6
Silom Line (Dark Green Line)	Average	19.6	10.7	1.8	6.7	4.1	2.5	45.5
	Standard Deviation	7.0	4.9	0.3	2.4	2.2	0.5	7.7
	Minimum	6.7	4.1	1.3	1.6	0.2	1.8	37.0
	Maximum	27.3	18.7	2.2	11.0	7.0	3.5	63.4
Airport Rail Link	Average	13.4	10.4	1.5	4.8	4.2	2.7	36.9
	Standard Deviation	9.0	3.2	0.6	2.9	3.9	0.9	12.3
	Minimum	0.4	6.6	0.6	1.2	0.5	1.4	22.5
	Maximum	28.2	16.0	2.1	8.7	11.2	4.0	57.5
Krung Thonburi Line (Gold Line)	Average	23.2	5.9	1.9	5.4	4.6	2.3	43.2
	Standard Deviation	0.1	2.9	0.1	1.9	0.3	0.5	5.1
	Minimum	23.0	2.1	1.7	3.0	4.3	1.6	40.0
	Maximum	23.3	9.1	2.1	7.7	5.0	2.9	49.1
Thani Ratthaya Line (Dark Red Line)	Average	6.6	10.8	1.5	3.2	1.6	2.9	26.6
	Standard Deviation	3.5	8.7	0.7	1.3	0.7	1.0	10.4
	Minimum	2.2	1.4	0.0	1.6	0.4	1.6	13.1
	Maximum	11.0	23.9	2.5	6.1	3.0	4.8	41.0
Nakhon Withi Line (Light Red Line)	Average	7.5	6.4	0.9	2.9	2.2	3.8	23.7
	Standard Deviation	5.5	2.7	0.3	0.8	1.4	0.7	6.3
	Minimum	4.0	4.7	0.6	2.2	0.7	3.0	16.9
	Maximum	13.9	9.6	1.3	3.7	3.2	4.5	29.2
Chatuchai Line (Pink Line)	Average	9.1	7.9	1.9	6.3	1.9	2.8	29.9
	Standard Deviation	4.3	3.6	0.4	2.2	1.6	0.7	6.4
	Minimum	4.0	3.0	1.0	1.2	0.0	0.9	18.2
	Maximum	18.4	18.7	2.5	11.1	5.3	4.5	44.8

Table 4: TOD scores of each studied urban rail transit line, calculated based on POI within a 1,000-meter radius

Line	Statistical Value	Density	Design	Diversity	Connectivity and demand management	Destination accessibility	Distance to transit	TOD Score
Sukhumvit Line (Light Green Line)	Average	10.7	11.4	0.2	8.8	2.3	2.9	36.4
	Standard Deviation	5.6	2.8	0.0	3.5	1.8	1.0	10.2
	Minimum	1.4	5.9	0.1	1.4	0.0	1.0	18.7
	Maximum	25.9	16.6	0.2	15.6	6.5	5.6	59.4
Silom Line (Dark Green Line)	Average	16.6	10.9	0.2	7.2	1.8	3.3	40.0
	Standard Deviation	4.0	2.3	0.0	2.6	1.1	1.1	5.2
	Minimum	7.9	6.8	0.2	1.7	0.5	1.9	30.0
	Maximum	21.1	14.6	0.2	11.9	4.8	5.6	49.0
Airport Rail Link	Average	10.6	9.5	0.2	5.2	7.5	3.4	36.4
	Standard Deviation	7.1	2.3	0.0	3.1	6.4	2.0	16.3
	Minimum	0.5	6.1	0.1	1.3	1.0	1.2	18.0
	Maximum	22.1	12.3	0.2	9.4	18.6	7.6	63.5
Krung Thonburi Line (Gold Line)	Average	16.9	9.7	0.2	5.9	9.0	3.5	45.1
	Standard Deviation	0.2	1.6	0.0	2.1	0.5	0.3	3.2
	Minimum	16.6	7.5	0.2	3.3	8.3	3.2	43.0
	Maximum	17.1	11.1	0.2	8.3	9.6	3.8	48.7
Thani Ratthaya Line (Dark Red Line)	Average	6.3	12.8	0.2	3.4	4.2	2.7	29.5
	Standard Deviation	1.4	7.8	0.0	1.4	0.9	0.7	8.9
	Minimum	3.6	4.7	0.2	1.7	2.9	2.0	16.8
	Maximum	8.0	24.4	0.2	6.6	5.3	4.1	42.1
Nakhon Withi Line (Light Red Line)	Average	8.4	7.2	0.2	3.1	3.8	2.3	25.0
	Standard Deviation	2.3	1.9	0.0	0.8	1.7	0.2	6.3
	Minimum	6.0	5.1	0.2	2.4	1.9	2.1	17.8
	Maximum	10.6	8.6	0.2	4.0	4.8	2.5	28.9
Chatuchai Line (Pink Line)	Average	7.9	9.5	0.2	6.8	2.7	3.4	30.5
	Standard Deviation	3.4	3.4	0.0	2.4	2.5	1.4	5.4
	Minimum	4.0	5.0	0.2	1.3	0.0	0.9	18.3
	Maximum	17.5	19.5	0.2	12.0	6.9	6.9	41.6

elements are based on how many bus lines there are and how many entrances and exits there are at each station. Because there are the same number of bus routes and entrances/exits for both distances, the calculations for lengths of 500 m and 1,000 m give the same results. The number of POIs affects how easy it is to go to the place. The computations for 500 m and 1,000 m are mostly the same, although there are some differences because there are more POI inside the 1,000 m radius. The distance of the transit distance is based on how close the station is to park-and-ride facilities and how far away attractions of interest are from the station center on average. The estimates for 500 m and 1,000 m are different because the distances between the park-and-ride and POI are very different for the two radii.

TOD score in each dimension of the station

The researcher calculated the TOD Score of each station using POIs within 500 meters and 1,000 meters around the transit stations. For the average TOD Score across all dimensions:

A TOD Score below 25.3 indicates that the level of development around the station area is very low.

A TOD Score between 25.3 and 31.0 indicates that the level of development around the station area is low. A TOD Score between 31.0 and 37.0 indicates that the level of development around the station area is moderate. A TOD Score between 37.0 and 41.8 indicates that the level of development around the station area is high. A TOD Score above 41.8 indicates that the level of development around the station area is very high.

Table 5 shows an example of the TOD Scores of Each Station, calculated based on POIs within a 500-Meter Radius, which presents the TOD assessment of selected stations. The TOD Score is derived from six key dimensions: Density, Design, Diversity, Connectivity and Demand Management, Destination Accessibility, and Distance to Transit. The combination of these dimensions provides an overall score that reflects the development potential of each station area. High-scoring stations include Saint Louis (63.44) and Phaya Thai (57.53). These stations demonstrate high density, strong accessibility, and favorable design characteristics, indicating very high TOD potential. Moderately scoring stations such as Bang Wa (36.98), Charoen Nakhon Iconsiam (40.03), Lak Si (40.95), Chaeng Watthana–Pak Kret 28 (44.84), and Wat Phra Sri Mahathat (43.33) fall within the medium-to-high development range. These stations exhibit balanced performance across the TOD dimensions. Low-scoring stations such as Srinagarindra (19.10), Taling Chan (16.91), and Chatuchak (13.12) show weak performance in most dimensions, particularly in density, connectivity, and accessibility, indicating low TOD potential. Suvarnabhumi (22.49) and Bang Son (29.21) are categorized as relatively low to moderate in TOD potential due to weak land-use diversity and accessibility, despite moderate design or connectivity scores. Overall, the table highlights that stations located in central urban areas (e.g., Saint Louis, Phaya Thai, Ha Yaek Lat Phrao) tend to achieve higher TOD Scores due to higher density and better accessibility, while peripheral or less-connected stations (e.g., Chatuchak, Taling Chan, Srinagarindra) score lower due to limited development intensity and connectivity challenges.

Table 6 shows how several transit stops performed on the TOD test: This shows the TOD scores for each station, which were based on sites of interest (POI) that were within 1,000 meters of the station. The six sections of the TOD Score—Density, Design, Diversity, Connectivity and Demand Management, Destination Accessibility, and Distance to Transit—are identical to the 500-meter research. The stations with the best TOD scores are Ratchathewi (59.38) and Phaya Thai (63.45). They may have done so well because they are densely populated and easy to get to, which means they are close to city activities and have a lot of connections. Sala Daeng (49.00) and Krung Thon Buri (48.73) are both in the midst of a huge city and have good connections to other places, which is why they are ranked so high. Wat Phra Sri Mahathat (41.62), Lak Si (42.06), and Charoen Nakhon Iconsiam (42.99) are all stations that get medium to high scores. These stations aren't as crowded as the ones in the Central Business District (CBD), but they have unique architecture and do well in all areas. Bang Son (28.94) and Bang Wa (30.02) are at the bottom of the moderate range, with scores that are not very high. They have good design and density, but they can't create transit-oriented neighborhoods since they don't have enough land-use diversity and are hard to get to. The stations with the lowest scores are Bearing (23.45), Ban Thap Chang (17.98), Taling Chan (17.75), Si Rat (18.34), and Lak Hok Rangsit University (16.76). These are largely peripheral stations that aren't ex-

Table 5: Example of the TOD scores of each Station, calculated based on POIs within a 500-meter radius

Station	Density	Design	Diversity	Connectivity and demand management	Destination accessibility	Distance to transit	TOD SCORE
Ha Yaek Lat Phrao	9.03	14.81	2.56	14.48	5.49	3.2	49.56
Srinagarindra	6.19	6.38	1.8	1.26	1.61	1.85	19.1
Saint Louis	27.19	18.74	1.75	6.69	7.03	2.05	63.44
Bang Wa	15.99	9.54	1.99	4.23	2.93	2.31	36.98
Suvarnabhumi	0.43	12.17	0.95	4.03	0.88	4.04	22.49
Phaya Thai	28.18	9.77	0.6	5.59	11.2	2.19	57.53
Krung Thon Buri	23.28	9.1	1.71	7.68	4.98	2.34	49.09
Charoen Nakhon Iconsiam	23.28	2.11	1.93	5.54	4.25	2.92	40.03
Lak Si	9.51	22.68	1.9	3.71	1.46	1.68	40.95
Chatuchak	3.05	1.37	1.25	3.08	1.68	2.68	13.12
Taling Chan	3.98	4.99	0.63	2.2	0.66	4.46	16.91
Bang Son	13.87	4.66	0.84	2.77	3.22	3.85	29.21
Chaeng Watthana–Pak Kret 28	18.42	8.64	2.4	6.74	5.04	3.6	44.84
Wat Phra Sri Mahathat	11.5	16	1.58	8	2.86	3.39	43.33

cellent for TOD since they don't have a lot of diverse forms of land use, aren't well-connected, and have lower urban density.

Fig. 3 illustrates the web application interface displaying the TOD Score of an individual station in relation to the average score of the entire transit line. It employs a table and a radar image to substantiate its argument. The green line represents the score of the selected station, while the blue line indicates the average score. The evaluation comprises six components: Density, Design, Diversity, Connectivity and Demand Management, Destination Accessibility, and Distance to Transit. The station performs above average in nearly all categories, particularly in Density, Design, Destination Accessibility, and Distance to Transit. However, it performs somewhat below average in diversity. This indicates that, despite the station's limited array of adjacent activities, it possesses significant potential for density, architectural development, and accessibility. The primary objective of enhancement should be to augment the diversity of interests surrounding the station.

Discussion

In this study, the researcher calculated the TOD SCORE of electric train stations in Bangkok by building on the previous study by Xie (2017), which analyzed Beijing and Singapore using IEW. The key strength

Table 6: Example of the TOD scores of each station, calculated based on POIs within a 1,000-meter radius

Station	Density	Design	Diversity	Connectivity and demand management	Destination accessibility	Distance to transit	TOD SCORE
Ratchathewi	25.78	14.3	0.18	9.31	6.46	3.34	59.38
Bearing	7.2	10.26	0.23	4.57	0.2	1	23.45
Sala Daeng	21.08	11.63	0.18	9.25	2.79	4.08	49
Bang Wa	12.37	10.18	0.23	4.57	0.54	2.14	30.02
Ban Thap Chang	3.09	10.06	0.24	1.3	2.11	1.18	17.98
Phaya Thai	22.06	12.3	0.14	6.04	18.56	4.35	63.45
Krung Thon Buri	17.06	11.07	0.21	8.29	8.29	3.81	48.73
Charoen Nakhon Iconsiam	17.06	7.46	0.21	5.98	9.04	3.24	42.99
Lak Hok Rangsit University	3.63	4.65	0.22	1.69	3.81	2.77	16.76
Lak Si	7.3	23.31	0.22	4	4.89	2.33	42.06
Taling Chan	5.97	5.12	0.19	2.37	1.9	2.2	17.75
Bang Son	10.58	8	0.2	2.99	4.69	2.48	28.94
Si Rat	3.97	5.09	0.21	1.3	3.32	4.45	18.34
Wat Phra Sri Mahathat	9.35	18.76	0.22	8.63	2.65	2.02	41.62

of this study that fills the literature is expanding the scope from four dimensions (Density, Diversity, Design, Connectivity) to six dimensions by adding Destination Accessibility and Distance to Transit, which is consistent with the expansion of TOD indicators from the "3Ds" to the "6Ds," and this fits the context of countries with rapid urban development such as China (Liang et al., 2020). In addition, the six-dimensional framework is linked to the Node-Functionality-Place Model, which emphasizes "Functionality," also called connectivity that facilitates walking and access, and this is considered the key to success in TOD projects (Su *et al.,* 2021a; Su *et al.,* 2022). Findings consistent with previous studies are that Population Density, the number of POIs, and the number of bus routes have high weights on the TOD SCORE. This is confirmed by research in Shenzhen showing that bus density and mixed-use land use are the main factors driving urban vibrancy around electric train stations (Xiao *et al.,* 2021), while road density and the number of station entrances/exits have lower impacts. However, this study found that parking facilities have increased importance weight compared with Xie (2017), reflecting Thailand's travel context, which still relies on private cars to access the rail system (feeder system), unlike Singapore or Beijing, which have denser feeder transport systems. In addition, the results also show clear spatial differences, where stations in the core area such as Saint Louis and Phaya Thai have higher performance than peripheral stations such as Lak Hok. This is consistent with phenomena in Tokyo and Chinese megacities showing that TOD sustainability decreases with distance from the city center (Su *et al.,* 2021a; Yang *et al.,* 2024). This issue reflects the problem of spatial inequality in Bangkok under neoliberal policies that emphasize commercial development in key economic areas, which may lead to "gentrification," or rising housing prices in areas with high TOD scores, making it difficult for low-income people to access (Kidokoro et al., 2022; Su *et al.,* 2021b). There-

TYPE	density score	design score	diversity score	connectivity and demand management score	destination accessibility score	distance to transit score
STATION	25.78	14.30	0.18	9.31	6.46	3.34
AVERAGE	10.65	11.40	0.21	8.83	2.34	2.93

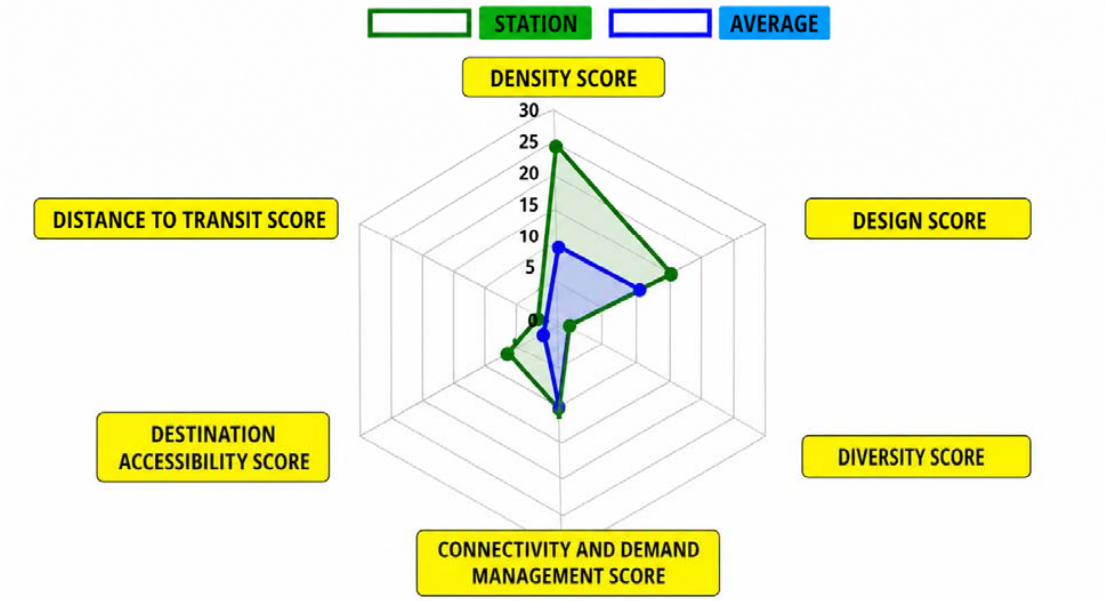


Fig. 3: Visualization of TOD score on the web application

fore, the development of the Web Application tool in this study is considered an innovation that helps policymakers evaluate station-level performance (micro-scale evaluation) and define area-specific strategies (typology-based strategy) to reduce development gaps and promote equity in sustainable access to mass transit (Li & Gu, 2025; Su *et al.,* 2022).

Recommendations

This study reveals substantial spatial differences in the efficiency of TOD across Bangkok's train network, necessitating tailored strategies for each station rather than uniform standards applicable to the entire system. Planning agencies should adopt typology-based strategies that prioritize investments according to station classifications: «Undersupplied TODs,» marked by considerable urban activity but inadequate connectivity, require immediate infrastructure improvements, while «Underdeveloped TODs» in suburban areas such as Lak Hok necessitate mixed-use zoning reforms and density incentives to enhance urban vitality (Su et al., 2021a; Wu & Divigalpitiya, 2023; Li & Gu, 2025; Ding et al., 2025). Secondly, considering that high-performing TOD areas generally incur rental premiums of 10-20% (Su et al., 2021b; Yang et al., 2024), governments must establish social equity measures, such as mandates for affordable housing and provisions for student accommodations, within the primary 500-meter catchments to avert economic displacement and spatial inequality (Kidokoro et al., 2022; Lai & Tran, 2025; Yang et al., 2024). Third, planners should adopt a Node-Place-Ecology (NPE) model that integrates environmental aspects, including the provision of green spaces and clean energy technologies, while also enhancing sidewalk density and human-scale design to diminish automobile reliance and bolster sustainable tourism vitality (Yang et al., 2024; Ding et al., 2025; Xiao et al., 2021). The web application must be improved by incorporating big data analytics that integrates social media and mobile positioning data for real-time assessments of urban vibrancy, supplemented by sophisticated spatial statistical models like Multiscale Geographically Weighted Regression (MGWR) to accurately analyze the spatial impact of TOD factors on property values (Xiao et al., 2021; Yu et al., 2022; Yang et al., 2024). Future

research should focus on cross-city comparative analyses in developing countries with emerging transit systems (Ali et al., 2025) and examine Land Value Capture (LVC) mechanisms and Rail+Property (R+P) models to generate sustainable financing streams for long-term transit infrastructure development (Wu & Divigalpitiya, 2023; Ravindran et al., 2024).

CONCLUSION

The main factors affecting TOD performance in Bangkok are density, design, and connectivity, which is consistent with the concept of "Functionality" that links transit accessibility together with urban place-making (Su et al., 2021a; Xiao et al., 2021). High TOD scores in this study reflect high population density and a high number of POIs around stations. The results of this study are consistent with the phenomenon of the "monopolization of central stations" observed in Tokyo and the "integrated" typology in Shanghai. In this study, Saint Louis and Phaya Thai stations ranked highest because they have strong urban amenities. In contrast, peripheral stations such as Chatuchak and Lak Hok have lower TOD SCORE, reflecting the "unsustained node" typology commonly found in Asian megacities under neoliberal urban planning, where infrastructure development often happens faster than land development. This study contributes to the literature by validating the multidimensional "6Ds" evaluation framework, which extends traditional models by adding destination accessibility and distance to transit, as a planning tool for the Global South (Liang et al., 2020; Ali et al., 2025). In practice, the findings suggest that policymakers should move beyond "one-size-fits-all" approaches and adopt typology-based interventions. Future development should not only promote mixed-use projects but should also implement Land Value Capture (LVC) or "Rail+Property (R+P)" strategies to secure funding for affordable social housing and student housing, reduce the risk of displacement caused by gentrification, and improve urban social welfare (Kidokoro et al., 2022; Lai & Tran, 2025; Wu & Divigalpitiya, 2023). In addition, the developed prototype web application is an innovative spatial planning support system that enables real-time benchmarking. To advance the field further, other researchers should integrate ecological indicators into this framework to transition toward a holistic Node-Place-Ecology (NPE) model and to ensure urban sustainability amid demographic changes and urban shrinkage (Yang et al., 2024; Ding et al., 2025).

AUTHOR CONTRIBUTIONS

Krisada Saensomboon, First Author, as the project leader, was responsible for securing research funding, conducting the literature review, collecting related documents, designing the experiment, carrying out field data collection, analyzing and interpreting the data, developing the Web Application, preparing the manuscript, and revising the manuscript. Rapee Udomsub, Corresponding Author, as the project researcher, was responsible for designing the experiment, conducting field data collection, sourcing the software used in the research, analyzing and interpreting the data, providing consultation to the project leader, and revising the manuscript

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the research, authorship, or publication of this article. All ethical principles in research, including informed consent, data integrity, and originality of the work, have been strictly adhered to.

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ABBREVIATIONS (NOMENCLATURE)

BEM	Bangkok Expressway and Metro Public Company Limited
BTS	Bangkok Mass Transit System Public Company Limited
eq.	Equation
FAR	Floor Area Ratio
Fig.	Figure
G_j	The degree of divergence (or information utility) of indicator j
H_{ij}	The entropy value of each indicator j
IEW	Information Entropy Weight Method
LVC	Land Value Capture
m	Number of stations
MGWR	Multiscale Geographically Weighted Regression
MRTA	Mass Rapid Transit Authority of Thailand
n	Number of TOD indicators
p_{ij}	The proportion of the standardized quantitative value of indicator j at station i to the sum across all stations.
POI	Points of Interest
SRT	State Railway of Thailand
TOD	Transit-Oriented Development
V_i	TOD score of the station
W_j	Weight of indicator j
X_{ij}	The original value of indicator j at station i
X'_{ij}	The standardized quantitative index value of indicator j at station i, after normalization
$X_{j\,max}$	The maximum value of indicator j among all stations considered
$X_{j\,min}$	The minimum value of indicator j among all stations considered

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ORIGINAL RESEARCH PAPER

Analysis of the factors influencing consumers' intention to purchase green food

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ABSTRACT

BACKGROUND AND OBJECTIVES: With sustained socio-economic development, problems such as resource constraints, ecological damage, and food safety have become increasingly prominent and have become important factors constraining sustainable development. To address these challenges, this study applies the stimulus–organism–response framework to examine key factors that shape consumers' green purchase intention in the food industry in China. Green advertising, environmental attitude, product attributes, and social media influence are conceptualized as external stimuli, while customer perceived value represents the internal psychological mechanism driving behavioural intention.
METHODS: A total of 371 valid survey responses were analysed using Statistical Package for Social Sciences software (version 27.0) and Analysis of Moment Structures (version 28.0) to conduct reliability testing, factor analysis, structural modelling, and mediation analysis.
FINDINGS: All four external variables significantly increase customer perceived value, which in turn strengthens green purchase intention. Mediation results show that customer perceived value partially mediates the effects of green advertising and product attributes, and fully mediates the effects of environmental attitude and social media influence.
CONCLUSION: The study demonstrates that customer perceived value plays a central role in transforming external green marketing stimuli into purchase intention. These findings provide theoretical insight for stimulus–organism–response-based green marketing research and practical guidance for food enterprises seeking to promote sustainable consumer behaviour.

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INTRODUCTION

Environmental concerns have become more prominent as socio-economic development intensifies issues such as resource depletion, ecological degradation, and food safety risks. Food production and consumption exert significant environmental impacts, which in turn influence human health and safety (Azzurra *et al.,* 2019). As a result, global attention to sustainable development has increased, and consumers are showing stronger preferences for food that is safe, eco-friendly, and healthy (Costa *et al.,* 2021). Despite these trends, a persistent gap remains between consumers' environmental awareness and their actual green purchasing behaviour. This gap slows the growth of green industries, weakens efforts to promote healthy consumption patterns, and limits progress toward sustainable food systems. China presents a particularly relevant context for examining this issue. Although food safety incidents continue to raise consumer concern, interest in green and eco-labeled products is increasing. Government initiatives have promoted green production and consumption, including a comprehensive green food certification system designed to improve food safety and reduce environmental harm (Ahmed *et al.,* 2021). The China Green Food Development Centre (CGFDC, 2021) reports substantial environmental and economic benefits from green food production, including reduced chemical inputs and increased ecosystem service value. These developments highlight China's commitment to sustainable food strategies but also underscore the need to understand why green food purchase intention remains inconsistent with consumer attitudes (Cheng *et al.,* 2024). Previous research has identified green advertising, environmental attitude, product attributes, and social media influence as important determinants of green purchase intention. However, most studies examine these factors independently and provide limited insight into how they operate within an integrated framework (Jiang *et al.,* 2025). For example, studies on green advertising mainly assess its direct effects on purchase intention, offering limited evidence about whether advertising increases intention by enhancing perceived value. Similarly, environmental attitude is widely recognized as a predictor of green behaviour, but it is often treated as a final determinant rather than a precursor. It may shape perceived value and indirectly influence intention, especially in the green food context, where empirical results remain limited. Research on product attributes shows that quality, safety, and functional performance are central to consumer evaluation, but how these attributes shape perceived value and later purchase intention remains unclear. Social media is also a major information source through reviews, influencers, and brand interactions, yet most studies examine its effects on brand image or loyalty rather than perceived value in green food consumption. These gaps limit understanding of how marketing cues jointly shape consumer decision-making. Customer perceived value is viewed as the bridge linking external stimuli to behaviour, but many studies treat it only as an outcome rather than a mediating process. This limits clarity on how consumers internalize environmental and product-related information before forming green purchase intention. Therefore, it is necessary to examine how green advertising, environmental attitude, product attributes, and social media shape perceived value and influence green purchase intention in one model. Although the Stimulus–Organism–Response (SOR) framework is widely used, most studies analyse only one or two stimuli at a time (Rivas *et al.,* 2022; Jiang *et al.,* 2025). Few integrate green advertising, environmental attitude, product attributes, and social media in a single framework. Perceived value is also often treated only as a direct predictor of intention rather than a mediating mechanism (Chen & Chang, 2012; Sweeney & Soutar, 2001). Evidence from China remains limited, despite its unique certification system and strong social media environment that may shape consumer perceptions differently (CGFDC, 2021; Cheng *et al.,* 2024). This study addresses these gaps by developing an integrated SOR model with four key stimuli and testing the mediating role of perceived value using data from China's certified green food market. Therefore, this study applies the SOR framework to explore the mediating role of customer perceived value in green food purchasing in China, May 2025.

Literature review

The SOR model sets customer perceived value as the core variable in the organism, and complements each other in the external stimulus and internal cognitive paths. Providing solid theoretical support for this study to construct a model path with the main line of SOR. The SOR model explains how individuals

respond to external environmental stimuli through internal mental processes and consists of three core components: Stimulus, Organism, and Response (Mehrabian and Russell, 1974). This model is often used in consumer behavior research. It highlights that behavior is not directly caused by external factors, but is mediated by the individual's cognitive, emotional, or perceptual mechanisms (Jacoby, 2002). In green consumption research, the SOR model is commonly used to study how external marketing stimuli affect consumer intentions through psychological perception. Research has found that factors like green advertising and product attributes can increase consumers' perceived value, which then strengthens their willingness to purchase green food (Rivas *et al.,* 2022). This finding establishes the theoretical underpinning for constructing the research model, which forms the basis of the study's framework. Green advertising, product attributes, social media influence, and environmental attitude are viewed as external stimuli that may trigger consumers' value evaluations of green food. Customer perceived value acts as the internal psychological reaction, showing how consumers see the product's functional, emotional, and social benefits. Green purchase intention, as the response, reflects the motivation behind consumer behavior. The SOR model provides a logical framework for understanding how external factors influence purchase intention by engaging the internal role of perceived value.

Hypotheses development

Drawing on theoretical foundations and prior studies, this study formulates six core hypotheses, as shown in Fig. 1. These hypotheses are formed from how the literature explains and defines green advertising, environmental attitude, product attributes, social media influence, customer perceived value, and green purchase intention. Each hypothesis is developed step by step through the review of these key concepts. The model in this study includes four external stimulus variables that shape consumers' early perceptions of green food. Green advertising, environmental attitude, product attributes, and social media influence are common sources of information that consumers encounter before evaluating value. Prior studies show that these factors play a central role in shaping initial awareness and cognitive processing in green consumption settings (Rivas et al., 2022; Jiang *et al.,* 2025; Biswas & Roy, 2015). Other variables, such as trust, price sensitivity, or brand credibility, are also important. However, these variables often function as outcome-based evaluations that develop after consumers process the initial environmental and marketing cues (Chen & Chang, 2012; Aertsens *et al.,* 2009). Including these variables at the stimulus stage would weaken the conceptual clarity of the SOR structure. This study therefore focuses on four early-stage stimuli that have strong theoretical support and play a consistent role in shaping value formation in green purchase contexts (Sweeney & Soutar, 2001).

Green advertising

Advertising is seen as one of the most common promotional methods used by companies. It works as an indirect way of communication and is built on the idea of conveying a message emphasizing product superiority. This gives consumers a sense of enjoyment, which in turn influences their decision to purchase (Kusuma and Handayani, 2018). Green advertising is a more advanced form of traditional advertising. It allows companies to share messages with consumers by highlighting features such as the environmental safety of their products (Chang, 2011). When green advertising presents a company's environmental commitment or social responsibility, it enhances consumers' perception of the product's social value, such as its contribution to environmental protection or alignment with moral identity, thereby increasing green purchase intentions. When advertisements emphasize content such as the product's functional benefits, they help improve how consumers perceive the product's economic value. This, in turn, positively influences their intention to buy (Zhang *et al.,* 2024). These value perceptions, as consumers' subjective evaluations of products, are key psychological mechanisms in determining their green purchase intentions. They have a crucial mediating role in the pathways by which green advertising influences purchase intention.

H1. Green advertising has a positive impact on customer perceived value.

Environmental attitude

Environmental attitude refers to a mental tendency to judge the natural environment and the factors that affect its condition, showing either a positive or negative view (Milfont, 2012; Wittenberg

et al., 2023). It shows consumers' inner thoughts regarding the significance of environmental protection and is a fundamental driver of green consumer behaviour. Strong environmental attitude can encourage consumers to recognise the ecological, ethical, and functional values of green products, raise the perceived value of the good, and influence consumers' intention to buy (Sheikh *et al.,* 2025). Moreover, domestic scholars confirmed this relationship in the Chinese cultural context, where environmental attitudes influence green purchase intention indirectly by improving different aspects of customer perceived value, such as green awareness and positive emotions (Zhang *et al.,* 2024). Overall, these findings support the path that environmental attitude affects purchase intention through the mediating role of perceived value, which forms the theoretical basis for Hypothesis H2 in this study.

H2. Environmental attitude has a positive impact on customer perceived value.

Product attributes

Product attributes refer to the objective and factual characteristics of a product, which remain constant regardless of individual consumers' subjective preferences (Kalro and Joshipura, 2023). Against the backdrop of green food consumption, these attributes typically include indicators of eco-friendliness, health, safety, and sustainability. Studies have demonstrated that green product attributes significantly influence how customers perceive value. They fulfill both functional and moral expectations and enhance consumers' perceptions of ecological performance, product quality, and brand reputation, thereby positively influencing consumers' overall value assessment (Marcon *et al.,* 2022). Based on the SOR theory, this study treats product attributes as external stimuli that activate consumers' value perceptions of green food and, in turn, influence their purchase intentions.

H3. Product attributes have a positive impact on customer perceived value.

Social media influence

Social media influence denotes the persuasive power of social media platforms, content, and interactions on consumer perceptions, attitudes, and behaviours (Dananjoyo and Udin, 2025; Juniprianssa and Disastra, 2025). Studies suggest that social media exposure and peer interactions online can improve consumers' perceived value of green products by increasing their emotional, functional, social, and economic evaluations (Ng *et al.,* 2025; Nuamthong and Parnkam, 2024). Other studies have examined Key Opinion Leader (KOL) marketing on platforms like Xiaohongshu and found that a KOL's influence, expertise, and trustworthiness affect how consumers view social value, emotions, quality, and price (Li, 2023). These results support the use of the SOR model in this study and also highlight the mental processes behind perceived value, providing directions for future research.

H4. Social media influence has a positive impact on customer perceived value.

Green purchase intention

Green purchase intention is defined as a consumer's intention or plan to purchase environmentally sustainable food, often influenced by elements such as social norms, personal values, emotional attitudes, and perceived benefits associated with green products (Kim *et al.,* 2012). Understanding consumers' perspectives on green food purchase intention is important for marketers (Chan and Lau, 2002; Khasanah, 2024; Nuryakin *et al.,* 2023). Understanding the factors that influence consumers' green purchase intention is useful for making appropriate marketing strategies. It also contributes to removing obstacles that hinder green consumption (Welsch and Kühling, 2009). Studies show that consumers are motivated by value, and they usually consider the benefits and utility of the food before making a purchase. Consumers tend to have stronger purchase willingness when they perceive high value in green products, whether ecological, functional, or symbolic (Joshi *et al.,* 2018; Febriandika and Millatina, 2023; Sriviboon *et al.,* 2024). In summary, the research highlights that perceived value is a core psychological mechanism driving sustainable consumption intentions, providing strong theoretical support for the hypothesis.

H5. Customer perceived value has a positive impact on green purchase intention.

Customer perceived value

Customer perceived value denotes the consumer's subjective assessment of a product's overall benefit, derived from weighing the received utility against the cost incurred (Zeithaml, 1988). It has multiple

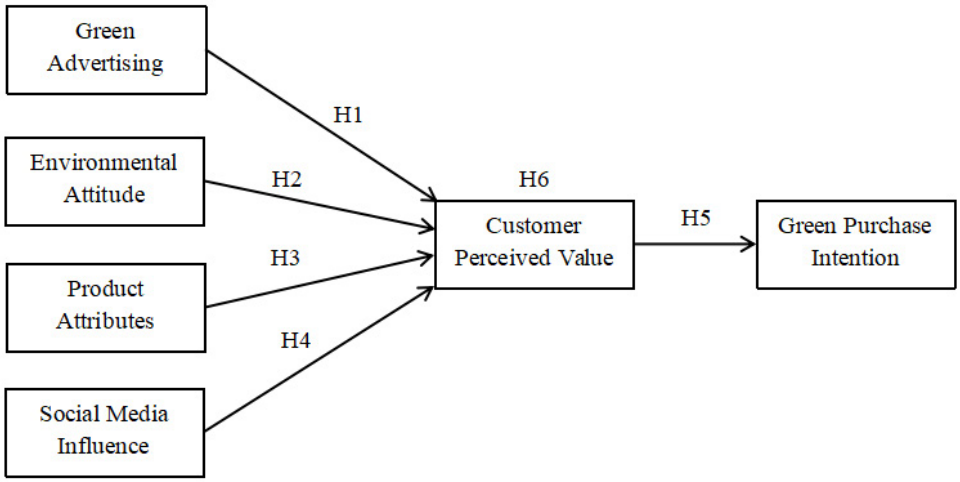


Fig. 1: Research model

dimensions, including functional, emotional, social, economic, and relational value, and serves as a key link between external elements and consumer behavior (Sweeney and Soutar, 2001). In terms of green food consumption, it reflects consumers' comprehensive judgement of whether green products are worthwhile (Chen and Chang, 2012; Fatmawati and Alikhwan, 2021; Qamari and Khairunnisa, 2024). A study on green agricultural products found that consumers show actual intention to purchase only when they personally perceive green products as valuable. In other words, customer perceived value acts as a key mental link between what consumers feel inside and how they behave outside (Chen *et al.*, 2025; Eldin, 2024). In this research, customer perceived value is a key psychological element that mediates the impact of green advertising, environmental attitude, product attributes, and social media influence on green purchase intention.

H6. Customer perceived value mediates the impact of green advertising, environmental attitude, product attributes, and social media influence on green purchase intention.

MATERIALS AND METHODS

Research design

This research adopts a positivist research paradigm. Positivism emphasizes the use of observable and measurable data to discover the laws behind social phenomena. It advocates that researchers should remain neutral and use systematic quantitative methods to collect and analyze data for identifying causal relationships among variables (Creswell, 2014). The study develops a theoretical path based on the SOR model to explore how external stimulus factors, such as green advertising, environmental attitude, product attributes, and social media influence, can further influence consumers' green purchasing intentions through the psychological mechanism of mediating variables, namely customer perceived value. A quantitative explanatory approach was employed to validate the proposed theoretical model. Data were collected through an online structured questionnaire using the Wenjuanxing platform in May 2025. The survey was disseminated via social media channels (e.g., WeChat, QQ, Weibo). Participants were required to have prior experience with or knowledge of green food consumption, enhancing data relevance and quality. To ensure instrument clarity and reliability, a pilot test was conducted with 20 participants representing diverse demographic backgrounds. The pilot study was used to assess face validity, internal consistency, and item clarity. Participants provided feedback on wording and comprehension, leading to minor revisions in phrasing and item sequencing. Preliminary Cronbach's alpha values from the pilot test indicated acceptable reliability for all constructs ($\alpha > 0.70$), supporting the suitability of the measurement items for the main study. No items were removed, but wording improvements enhanced semantic accuracy. A purposive–convenience sampling approach was used

to ensure that respondents had relevant experience with green food consumption. The inclusion criterion required participants to have purchased at least one certified green food product within the past 12 months. This ensured that respondents were capable of evaluating green food attributes and related psychological constructs.

Measures

The questionnaire consisted of two parts. The first collected demographic data (e.g., age, gender, income, education, residence); the second assessed core constructs using 7-point Likert scales. Each construct was measured by four items. Adapted items follow the wording and conceptual definitions of prior validated scales but were linguistically adjusted to fit the context of green food consumption in China, as shown in Table 1. To make sure the questionnaire is both reliable and valid, the measurement items of all variables are adapted from mature scales verified by previous researchers, and language localization and semantic adaptation are carried out in conjunction with the green food consumption background. Specifically, green advertising is designed according to Kim and Cha (2021) to assess consumers' perception of the genuineness, attractiveness, credibility and conveyed value of green advertising; environmental attitude is based on Gadeikiene and Svarcaite (2021) to evaluate consumers' environmental awareness and behavioral responsibility; product attributes are based on (Marcon *et al.,* 2022) to cover consumers' perception of green food, such as nutritional value, safety and environmental friendliness; Social media influence, as defined by Zhang *et al.,* (2024), reflects the role of social media in providing information, enabling interactive discussions, and shaping consumer perceptions. Customer perceived value is adapted from the study by Sweeney and Soutar (2001). It is used to measure how people view the value of green food in three aspects: economic, emotional, and environmental. Green purchase intention is adapted from Hudayah *et al.,* (2023) to measure consumers' intention to actively choose green food in the near future.

RESULTS AND DISCUSSION

Descriptive statistics

The survey subjects, as shown in Table 2, show a certain diversity in demographic characteristics. In terms of gender distribution, male respondents make up 52.0%, while female respondents account for 48.0%, and the proportion of males and females is nearly equal. The age distribution shows that people aged 18 to 30 account for the highest proportion at 38.8%, followed by 31-40 years old (30.7%), under 18 years old (18.9%), 41-50 years old (9.4%), and 51 years old and above account for the least, only 2.2%. Overall, most of the respondents belong to the young and middle-aged groups. Regarding educational qualifications, the proportion of undergraduate respondents is the highest, accounting for 69.0%, followed by high school (15.4%), master's (7.0%), PhD (3.8%), and other education (4.9%), indicating that the highly educated group dominated the sample. According to the income distribution, 38.5% fall within the 5001–10000-yuan monthly income range, 30.2% have a monthly income of 3001-5000 yuan, about 19.1% receive less than 3000 yuan in monthly earnings, and another 12.1% have an income of more than 10001 yuan. The overall sample is characterized by a medium income. About the distribution of occupations, the student group accounts for the highest proportion (27.2%), employees in a company and the self-employed each account for 24.8%; homemakers account for 3.0%, and other occupational categories account for 20.2%, reflecting that the sample occupation types are relatively rich. In terms of urban type distribution, tier 1 city respondents account for 31.3%, 25.9% of respondents are from new tier 1 cities, 24.5% from tier 2 cities, and 18.3% from tier 3 or lower tier cities. The sample covers cities of different levels. In addition, all respondents said that they had purchased green food (100%), and none said they had not purchased it, indicating that the samples of this study all have green food consumption experience.

Reliability and validity analysis

Table 3 shows that all constructs demonstrate strong reliability. Cronbach's alpha values range from 0.853 to 0.895, and all Composite Reliability (CR) scores exceed 0.85, surpassing recommended thresholds. These results confirm that the measurement scales exhibit high internal consistency and are suitable for subsequent analysis. The measurement validity was assessed through Kaiser-Meyer-Olkin (KMO), Bartlett's test, and Exploratory Factor Analysis (EFA). The KMO value of 0.911 and the significant

Table 1: Measurement Item

Construct	Operational Definition	Item Code	Measurement Item	Source
Green Advertising	Consumer awareness and influence from green advertising	GA1	I think green advertising expresses the true nature of green food.	Kim & Cha (2021)
		GA2	Green advertising is attractive and makes me pay more attention to green food.	
		GA3	I trust the information conveyed in green advertising.	
		GA4	Green advertising helps me recognize the unique value of green food.	
Environmental Attitude	Personal concern and beliefs about environmental protection	EA1	I care about how my food choices impact the environment.	Gadeikienė & Švarcaitė (2021)
		EA2	I believe purchasing green food is a good way to protect the environment.	
		EA3	I believe it is important to reduce environmental harm through my food choices.	
		EA4	I feel responsible for helping the environment through my purchases.	
Product Attributes	Consumer perception of green product safety, quality, and health benefits	PA1	I believe that green food has higher nutritional value than regular food.	Yoo *et al.* (2000) Zhao *et al.*, (2010)
		PA2	I trust the eco-labels and certifications on green food.	
		PA3	I believe green food is safer than regular food.	
		PA4	I believe green food is produced using environmentally friendly ways.	
Social Media Influence	Impact of social media on consumer awareness and decision-making	SM1	Social media provides me with useful and trustworthy green food information.	Jiang *et al.*, (2010) Zhang *et al.*, (2024)
		SM2	I enjoy discussing green food topics with others on social media platforms.	
		SM3	Feedback and opinions from social media increase my confidence in the value of green food.	
		SM4	Information shared on social media influences my evaluation of green food's quality.	
Customer Perceived Value	Consumer's evaluation of the overall benefit of purchasing green food	CPV1	I think green food provides good value for the money I spend.	Lin *et al.*, (2017) Danish *et al.*, (2019)
		CPV2	Purchasing green food benefits both my health and the environment.	
		CPV3	Purchasing green food makes me feel emotionally satisfied.	

		CPV4	Purchasing green food aligns with my environmental beliefs.	
Green Purchase Intention	Willingness to buy green food in the near future	GPI1	I am willing to purchase green food if they meet my expectations.	Hudayah *et al.*, (2023)
		GPI2	I prefer green food over regular food when making purchase decisions.	
		GPI3	I intend to purchase green food in the future.	
		GPI4	I am willing to frequently purchase green food.	

Table 2: Demographic description

Measure	Category	Frequency	Ratio (%)
Gender	Male	193	52.0%
	Female	178	48.0%
Age	<18	70	18.9%
	18-30	144	38.8%
	31-40	114	30.7%
	41-50	35	9.4%
	≥51	8	2.2%
Educational Qualifications	High school	57	15.4%
	Undergraduate	256	69.0%
	Master	26	7.0%
	PhD	14	3.8%
	Others	18	4.9%
Monthly Income	≤3000	71	19.1%
	3001-5000	112	30.2%
	5001-10000	143	38.5%
	≥10001	45	12.1%
Occupation	Student	101	27.2%
	An employee in a company	92	24.8%
	Self-employed	92	24.8%
	Homemaker	11	3.0%
	Others	75	20.2%
City Type	Tier 1 city	116	31.3%
	New Tier 1 city	96	25.9%
	Tier 2 city	91	24.5%
	Tier 3 or below	68	18.3%
Purchased Green Food	Yes	371	100.0%
	No	0	0.0%

Table 3: Reliability and convergent validity

Variable	Cronbach's alpha	AVE	CR
Green Advertising	0.882	0.65	0.881
Environmental Attitude	0.853	0.591	0.852
Product Attributes	0.877	0.642	0.877
Social Media Influence	0.863	0.613	0.863
Customer Perceived Value	0.895	0.681	0.895
Green Purchase Intention	0.885	0.658	0.885

Table 4: AVE square roots and correlation matrix

	GA	EA	PA	SM	CPV	GPI
Green Advertising	0.806	0.371	0.36	0.293	0.449	0.315
Environmental Attitude		0.769	0.356	0.338	0.423	0.286
Product Attributes			0.801	0.334	0.458	0.431
Social Media Influence				0.783	0.492	0.248
Customer Perceived Value					0.825	0.497
Green Purchase Intention						0.811

Bartlett's test ($p < 0.001$) indicate that the data are suitable for factor analysis. EFA extracted six factors with a cumulative variance of 74.60%, aligning with the theoretical structure of the model. All items loaded strongly on their intended factors (loadings > 0.70) with low cross-loadings, demonstrating good convergent and discriminant validity. Communalities exceeded the recommended 0.50 threshold. Overall, the results confirm that the measurement instrument exhibits sound structural validity and is appropriate for subsequent Confirmatory Factor Analysis (CFA).

Confirmatory factor analysis

CFA was conducted to assess convergent and discriminant validity. All constructs achieved AVE values above 0.50 and CR values exceeding 0.85, indicating strong convergent validity and internal consistency (Fornell and Larcker, 1981). Discriminant validity was assessed using the Fornell–Larcker criterion (see Table 4). The square root of the AVE for each construct (shown on the diagonal) exceeded its correlations with other constructs, indicating that each variable is empirically distinct. For example, Customer Perceived Value has an AVE square root of 0.825, higher than its correlations with Product Attributes (0.458) and Green Advertising (0.449). Likewise, Green Purchase Intention's AVE square root (0.811) is greater than its correlations with Customer Perceived Value (0.497) and Product Attributes (0.431). These results confirm satisfactory discriminant validity across all constructs To assess whether the measurement model demonstrates structural differentiation and to evaluate significant structural differences among latent variables, this study examines the model's goodness of fit. As illustrated in Table 5. The overall model demonstrates a strong structural fit across all measurement indicators, indicating that it accurately reflects the underlying data structure. The chi-square statistic (X^2) of the full model is 528.472 with 237 Degrees of Freedom (DF), resulting in a Chi-square divided by degrees of freedom (CMIN/DF) value of 2.230, which is below the recommended threshold of 3.00. This suggests low model residuals and good overall model fit. The incremental fit indices are also at an excellent level: the Comparative Fit Index (CFI) is 0.945, the Tucker–Lewis Index (TLI) is 0.936, the Incremental Fit Index (IFI) is 0.945, and the Normed Fit Index (NFI) is 0.905. All exceed the commonly accepted cutoff value of 0.90, demonstrating strong model performance. In addition, the Root Mean Square Error of Approximation (RMSEA) is 0.058, which falls within the acceptable range of 0.05–0.08, indicating adequate control of model error. The Standardized Root Mean Square Residual (SRMR) is

Table 5: Model fitting results

Model	X^2	DF	P	CMIN/DF	CFI	TLI	NFI	IFI	RMSEA	SRMR
Value	528.472	237	0.000	2.230	0.945	0.936	0.905	0.945	0.058	0.055

Table 6: Results of hypothesis testing

Path		Beta	t	p	Supported
H1	Green Advertising → Customer Perceived Value	0.222	4.923	0.000***	Yes
H2	Environmental Attitude → Customer Perceived Value	0.160	3.526	0.000***	Yes
H3	Product Attributes → Customer Perceived Value	0.222	4.901	0.000***	Yes
H4	Social Media Influence → Customer Perceived Value	0.299	6.760	0.000***	Yes
H5	Customer Perceived Value → Green Purchase Intention	0.497	11.005	0.000***	Yes

Note: All p-values are significant at the 0.001 level. D-W values are 1.905 and 1.897, respectively, indicating no severe autocorrelation.

0.055, which is below the recommended threshold of 0.08, further confirming low residual levels and an excellent overall model fit.

Regression analysis

This study conducts a multiple linear regression analysis in which Customer Perceived Value is the dependent variable and Green Advertising, Environmental Attitude, Product Attributes, and Social Media Influence are the independent variables. Table 6 presents the results. The model reports an R^2 value of 0.416, indicating that the four independent variables collectively explain 41.6% of the variance in Customer Perceived Value, reflecting a good model fit. The F-test result (F = 65.110, p = 0.000) confirms that the overall model is statistically significant. Specifically:

- Green Advertising → Customer Perceived Value: Green advertising exerts a significant positive effect on Customer Perceived Value (β = 0.222, p = 0.000), supporting H1.
- Environmental Attitude → Customer Perceived Value: Environmental attitude has a significant positive effect on Customer Perceived Value (β = 0.160, p = 0.000), supporting H2.
- Product Attributes → Customer Perceived Value: Product attributes show a significant positive effect on Customer Perceived Value (β = 0.222, p = 0.000), supporting H3.
- Social Media Influence → Customer Perceived Value: Social media influence demonstrates a significant positive impact on Customer Perceived Value (β = 0.299, p = 0.000), supporting H4.
- Customer Perceived Value → Green Purchase Intention: Customer Perceived Value demonstrates a significant positive impact on Green Purchase Intention (β = 0.497, p = 0.000), supporting H5.

To gain deeper insight into the mediating role of Customer Perceived Value in the influence of Green Advertising, Environmental Attitude, Product Attributes, and Social Media Influence on Green Purchase Intention, this study employs the PROCESS macro integrated in SPSS 27.0. Model 4 is selected to test mediation effects, and the Bootstrap method (5,000 resamples with a 95% confidence interval) is applied to evaluate the significance of indirect effects. A mediation effect is confirmed when the confidence interval for the indirect effect does not include zero. The mediation analysis treats Green Advertising, Environmental Attitude, Product Attributes, and Social Media Influence as independent variables, Customer Perceived Value as the mediating variable, and Green Purchase Intention as the dependent variable. Separate models are established to assess both the strength and the type of mediation (complete or partial). As shown in Table 7, Green Advertising exhibits a significant direct effect on Green Purchase Intention (β = 0.120, p = 0.023). The indirect effect through Customer Perceived Value is 0.209, and the Bootstrap confidence interval excludes zero, indicating a highly significant mediation effect (p < 0.001). This demonstrates that Customer Perceived Value plays a partial mediating role between Green Advertising and Green Purchase Intention, accounting

Table 7: Path test

Path		Meaning	Effect	95% CI		Standard Error (SE)	z / t	p	Conclusion
			Low-er	Upper					
	GA→CPV→GPI	Indirect effect	0.209	0.154	0.270	0.029	7.556	0.000	
	GA→CPV	X→M	0.477	0.382	0.572	0.048	9.640	0.000	
1	CPV→GPI	M→Y	0.438	0.343	0.525	0.046	8.866	0.000	Partial Mediation
	GA→GPI	Direct effect	0.120	0.017	0.224	0.053	2.287	0.023	
	GA→GPI	Total effect	0.329	0.228	0.431	0.052	6.370	0.000	
	EA→CPV→GPI	Indirect effect	0.210	0.147	0.278	0.033	7.060	0.000	
	EA→CPV	X→M	0.466	0.367	0.558	0.049	8.959	0.000	
2	CPV→GPI	M→Y	0.450	0.356	0.542	0.047	9.224	0.000	Full Mediation
	EA→GPI	Direct effect	0.100	-0.006	0.205	0.054	1.851	0.065	
	EA→GPI	Total effect	0.309	0.203	0.415	0.054	5.725	0.000	
	PA→CPV→GPI	Indirect effect	0.181	0.124	0.244	0.030	6.223	0.000	
	PA→CPV	X→M	0.485	0.392	0.577	0.047	9.906	0.000	
3	CPV→GPI	M→Y	0.373	0.274	0.469	0.049	7.725	0.000	Partial Mediation
	PA→GPI	Direct effect	0.267	0.167	0.368	0.051	5.237	0.000	
	PA→GPI	Total effect	0.448	0.352	0.544	0.049	9.173	0.000	
	SM→CPV→GPI	Indirect effect	0.262	0.198	0.328	0.034	8.653	0.000	
	SM→CPV	X→M	0.539	0.449	0.627	0.046	10.851	0.000	
4	CPV→GPI	M→Y	0.486	0.386	0.578	0.049	9.521	0.000	Full Mediation
	SM→GPI	Direct effect	0.006	-0.105	0.115	0.056	0.098	0.922	
	SM→GPI	Total effect	0.267	0.161	0.374	0.054	4.925	0.000	

for approximately 63.5% of the total effect. The direct path from Environmental Attitude to Green Purchase Intention is not significant ($p = 0.065$), whereas the indirect path through Customer Perceived Value is significant ($\beta = 0.210$, 95% CI: [0.147, 0.278]). This indicates that Customer Perceived Value exerts a full mediating effect in this relationship. In other words, environmental attitude influences consumers' green purchase intention primarily by enhancing their perceived value of the product. Product Attributes show a significant direct effect on Green Purchase Intention ($\beta = 0.267$, $p < 0.001$), as well as a significant indirect effect through Customer Perceived Value (0.181, 95% CI: [0.124, 0.244]). This suggests that Customer Perceived Value acts as a partial mediator, accounting for approximately 40% of the total effect. For Social Media Influence, the direct effect on Green Purchase Intention is not significant ($p = 0.922$), while the indirect effect through Customer Perceived Value is significant ($\beta = 0.262$, $p < 0.001$). This result indicates that Customer Perceived Value functions as a full mediator, meaning that social media influences green purchase behavior primarily by elevating consumers' perceived value. Taken together, the findings show that among the four predictor variables, Green Advertising and Product Attributes exhibit partial mediation, whereas Environmental Attitude and Social Media Influence exhibit full mediation through Customer Perceived Value. This highlights the central role of Customer Perceived Value in translating environmental and marketing stimuli into green purchase intention, particularly for Environmental Attitude and Social Media Influence. The results show that Social Media Influence affects Green Purchase Intention only through Customer Perceived Value. This suggests that social media serves mainly as a channel that shapes value perception rather than producing direct behavioural intention. Prior studies

report similar findings, where social media exposure increases awareness and interest but only leads to intention when consumers perceive clear functional or emotional benefits (Samaniego-Arias *et al.,* 2025). In China, consumers often use social platforms to evaluate authenticity, quality, and safety before making decisions. This behaviour shapes internal value judgments first and does not create intention without perceived benefit. This supports the SOR model, which states that external stimuli influence behaviour only after internal psychological processing. The full mediation of Environmental Attitude also shows that general pro-environmental values do not automatically lead to green purchases. Consumers may support environmental protection in principle. However, purchase intention increases only when they believe the product delivers value to them. This reflects the value–action gap observed in previous research, where environmental attitudes require translation into perceived personal benefit before behaviour occurs (Hoang *et al*., 2024). For green food marketers, this means environmental messages should link ecological benefits to concrete consumer value, such as safety, health, or quality. The full mediation of Environmental Attitude through perceived value highlights a culturally specific mechanism in the Chinese context. While Western studies often show that environmental attitudes directly predict green purchasing behavior (e.g., Gleim *et al.,* 2013; Joshi & Uniyal, 2021), Chinese consumers tend to prioritise personal benefits over abstract pro-environmental ideals. This pattern aligns with China's socio-cultural characteristics, including high uncertainty avoidance and longstanding concerns over food-safety scandals, which heighten reliance on perceived value as a risk-reduction mechanism. As a result, even strong environmental attitudes do not translate into purchase intention unless consumers believe the product provides concrete personal value. This cultural logic explains why environmental attitude exerts an indirect effect only through perceived value in this study. Green Advertising and Product Attributes show partial mediation. Both variables influence intention directly because consumers can respond immediately to persuasive advertising cues or salient product characteristics. Advertising may create an emotional connection or trust, while product attributes may convey quality or safety. Yet both variables also enhance perceived value, which strengthens their influence. Earlier studies confirm that product- and advertising-related cues can trigger both direct and value-driven pathways to green purchase (Li *et al.,* 2024; Li *et al.,* 2025). This dual effect indicates that marketers should use clear product information and persuasive messaging to reinforce both immediate reactions and deeper value evaluations. Overall, these findings extend the SOR framework by showing that external stimuli differ in how strongly they depend on the organism's stage. Social Media Influence and Environmental Attitude rely fully on Customer Perceived Value. Advertising and product cues have both direct and indirect effects. This distinction clarifies how Chinese consumers process green information and shows the central role of perceived value in the formation of green purchase intention. The findings also diverge in notable ways from global research. In many Western and Southeast Asian contexts, environmental attitude exerts a significant direct effect on green purchase intention, reflecting stronger internalization of ecological norms (Kim *et al.*, 2012; Aertsens *et al.*, 2009). In contrast, our results mirror studies in China showing that environmental concern is insufficient without perceived personal benefits (Ahmed *et al.,* 2021; Cheng *et al.,* 2024). Similarly, unlike social media studies in Western markets where influencer credibility and peer communication directly stimulate purchase intention (Samaniego-Arias *et al.,* 2025), our findings show full mediation through perceived value. This suggests that Chinese consumers interpret social media information more cautiously and rely on value judgment to validate authenticity. These cross-national differences emphasize that the SOR pathways may vary according to cultural, institutional, and market conditions rather than being universally standardized. Taken together, these contrasts with prior research demonstrate that the mechanisms driving green food consumption are not uniform across cultures. This study contributes to the global literature by showing that in emerging markets like China, perceived value functions as a pivotal psychological filter in shaping green purchase intention. This underscores the importance of contextualising SOR-based models within different cultural and institutional environments.

CONCLUSION

This study advances the understanding of green consumer behavior by developing and empirically

validating a theoretical model grounded in the SOR framework. Focusing on China's green food market, the study investigates how four external stimuli—Green Advertising, Environmental Attitude, Product Attributes, and Social Media Influence—shape Green Purchase Intention through the mediating role of Customer Perceived Value. Findings based on 371 valid responses indicate that all external stimuli significantly enhance Customer Perceived Value, which in turn positively influences Green Purchase Intention. Furthermore, Customer Perceived Value was found to function as a full or partial mediator depending on the stimulus, highlighting its central role in translating marketing and environmental cues into consumer intentions. The study contributes theoretically by extending the application of the Stimulus–Organism–Response framework to sustainable consumption and establishing Customer Perceived Value as a key psychological mechanism in green purchasing decisions. From a practical standpoint, the findings offer clear guidance for both green food companies and policymakers. Firms are encouraged to enhance the quality of Green Advertising, promote green identity through consumer engagement initiatives, improve product transparency, and leverage social media platforms to increase Customer Perceived Value. Meanwhile, policymakers should strengthen advertising regulations, environmental education, green product labeling systems, and financial incentives to foster a supportive environment for green consumption. The study also provides policy implications that align with China's national strategy for promoting green consumption. Strengthening the credibility and transparency of green certification and labeling can enhance consumer trust and increase perceived value. Clearer standards for green advertising and stricter oversight of environmental claims would help reduce misinformation and improve market confidence. Public environmental education programs that highlight the health and safety benefits of green food may also shift consumer perceptions in a positive direction. In addition, policy incentives for producers who adopt verifiable green practices could support the growth of a more sustainable and trustworthy green food industry. Despite its contributions, this study has several limitations. First, the use of purposive-convenience sampling limits representativeness, and the findings may not generalize to China's wider population. Because the survey was distributed through social media, participation depended on voluntary online access, which increases the risk of sampling bias. Although respondents were drawn from different city levels, the sample does not fully reflect China's demographic or regional diversity. Future studies should consider probability-based or stratified sampling to obtain a more nationally representative dataset. Second, because this study relies on self-reported perceptions, future research could incorporate behavioural data, scenario-based experiments, or mixed-method designs to reduce response bias and triangulate consumer intentions. Third, the cross-sectional design restricts the ability to infer causality. Longitudinal studies or experimental approaches would help clarify how attitudes and perceived value develop over time and how they influence actual purchasing behaviour. Fourth, the current model includes only selected predictors. Future studies may examine additional factors such as brand trust, price sensitivity, cultural values, and environmental knowledge to build a more comprehensive theoretical framework. Lastly, the digital marketing landscape is changing rapidly. Future research should explore how emerging media formats, including short video platforms, livestreaming, and social commerce, shape green consumer behaviour across different demographic and cultural groups.

AUTHOR CONTRIBUTIONS

W. C. Ng conducted the literature review, designed the experiments, and prepared the manuscript. Y. Gao performed the experiments, conducted the literature review, and compiled the data. U. Udin contributed to the literature review, assisted in manuscript preparation, and edited the manuscript. Z. Tan performed the remaining experiments and analyzed and interpreted the data.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundan-

cy, have been completely witnessed and addressed by the author.

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ABBREVIATIONS (NOMENCLATURE)

AVE	Average Variance Extracted
CFI	Comparative Fit Index
CGFDC	China Green Food Development Centre
CFA	Confirmatory Factor Analysis
CPV	Customer Perceived Value
CR	Composite Reliability
EA	Environmental Attitude
EFA	Exploratory Factor Analysis
GA	Green Advertising
GPI	Green Purchase Intention
KMO	Kaiser-Meyer-Olkin
KOL	Key Opinion Leader
PA	Product Attributes
PCA	Principal Component Analysis
RMSEA	Root Mean Square Error of Approximation
RQ	Research Question
SM	Social Media Influence
SOR	Stimulus-Organism-Response
SRMR	Standardized Root Mean Square Residual
TLI	Tucker-Lewis's Index

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ORIGINAL RESEARCH PAPER

Caged balconies and aesthetic governance: Informal space appropriation across formal and informal housing regimes

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ABSTRACT

BACKGROUND AND OBJECTIVES: This article examines the phenomenon of caged balconies in Da Lat, Vietnam, to explain how informal spatial extensions mediate tensions between residents' everyday survival needs and aesthetic governance in a heritage-linked tourist city. Rather than treating caged balconies as isolated architectural violations, the study conceptualizes them as socio-spatial responses to housing scarcity under tourism-oriented visual regulation. Building on debates on urban informality, everyday urbanism, spatial justice, and the politics of visibility, the research aims to: (i) identify the drivers behind caged-balcony construction; (ii) compare their morphologies and interfaces with shared space; (iii) analyze mechanisms of surveillance, regulation, and stigmatization; and (iv) advance an Urban Aesthetic Justice framework to interpret these practices as contested claims to spatial legitimacy.

METHODS: The study adopts a qualitative comparative case design focusing on two contrasting sites: Ngo Quyen Apartment (formal housing) and the To Ngoc Van canal-side settlement (informal housing). Data were triangulated through field observation and photographic documentation, 60 semi-structured interviews with residents, typological analysis of balcony extensions, and review of planning regulations and secondary documents. Materials were analyzed using thematic and content analysis across micro (household), meso (neighborhood), and macro (policy–market) scales.

FINDINGS: Clear contrasts emerge between the two sites. In the formal apartment compound, caged balconies are typically small, standardized, and used for auxiliary functions such as drying and storage. In the canal-side settlement, extensions are larger, built from salvaged materials, and essential for cooking, sleeping, or livelihood activities. These differences reflect interacting micro-level household pressures, meso-level infrastructural and management conditions, and macro-level shortages of affordable housing under image-conscious planning. Field evidence further reveals uneven enforcement and differentiated stigma, in which visually "orderly" extensions are tolerated while precarious yet life-sustaining structures are marginalized within the tourism-oriented urban landscape.

CONCLUSION: The study advances an Urban Aesthetic Justice framework, emphasizing that spatial legitimacy in tourist cities is shaped not only by legality and safety but also by aesthetic regimes and politics of visibility. Caged balconies thus emerge as material indicators of how tourism-driven governance produces uneven tolerance of informality and reinforces socio-spatial inequality. Policy implications include expanding affordable housing supply, strengthening participatory planning, adopting flexible, area-specific regulations that legalize small, safe extensions while removing hazardous ones, and upgrading infrastructure in canal-side neighborhoods. Although limited to two case sites and primarily qualitative evidence, the framework offers a transferable lens for analyzing informal spatial practices in other heritage- and tourism-oriented cities.

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INTRODUCTION

Rather than treating caged balconies primarily as an understudied architectural phenomenon, this paper advances a broader research problem by asking how aesthetic regimes in tourist-oriented cities actively produce and legitimize spatial injustice. In cities such as Da Lat, where urban governance prioritizes visual order, heritage imagery, and tourism branding, informal domestic extensions become sites through which everyday survival needs collide with aesthetic norms. The resulting tension is not simply regulatory but also distributive and symbolic, determining whose spatial practices are tolerated, whose are stigmatized, and whose are rendered invisible. Caged balconies thus serve as a strategic empirical lens for examining how aesthetic governance operates as a mechanism of spatial differentiation, rather than as a neutral tool of urban management. Over the past four decades, Vietnam has experienced one of the most rapid urbanization processes in Southeast Asia, driven by the Doi Moi reforms, internal migration, and accelerating land commodification (Tuan, 2022). These transformations have intensified housing shortages and exposed structural limitations in state-led planning systems, particularly in their capacity to accommodate diverse household needs (Waibel *et al.,* 2007). In response, urban residents have increasingly engaged in bottom-up spatial adaptations, producing informal extensions that blur the boundaries between legality, necessity, and everyday urban practice (Labbé, 2014). Recent studies published in the International Journal of Human Capital in Urban Management (IJHCUM) have similarly examined how informal housing adaptations and everyday spatial practices emerge in response to structural planning constraints, emphasizing their implications for urban livability, resilience, and governance. These works highlight that informal spatial modifications are not marginal anomalies but constitute integral components of how residents negotiate housing inadequacies and urban management regimes in rapidly changing cities. Situating the present study within this line of inquiry allows the Da Lat case to be read as part of a broader conversation on informal urban practices and their governance, while further extending this discussion toward questions of aesthetics and visibility in tourism-oriented contexts (Razmaramina *et al.*, 2025).

Among the most visible yet insufficiently theorized outcomes of this process is the proliferation of caged balconies, defined as metal-grill extensions projecting from balconies or windows to expand domestic space. While such structures have long been documented in megacities such as Hanoi and Ho Chi Minh City, their growing presence in mid-sized cities signals a diffusion of informal spatial strategies beyond high-density metropolitan cores (Harun & Kassim, 2025; Thinh *et al.,* 2023). This shift calls for closer examination, particularly in cities where urban development is shaped less by industrial concentration than by tourism, heritage conservation, and aesthetic regulation. Da Lat represents a critical yet underexplored case in this regard. Originally developed as a colonial resort town, the city has cultivated a distinctive urban identity grounded in landscape preservation, climatic exceptionalism, and architectural imagery. Urban governance in Da Lat is strongly oriented toward maintaining a curated visual and ecological character, positioning the city simultaneously as a tourist destination and a regulated aesthetic environment (Jones *et al.,* 2023; Tu *et al.,* 2021). Within this context, the emergence of caged balconies is not merely a functional response to housing scarcity; it constitutes a contested spatial practice through which everyday survival needs confront image-conscious planning re-

gimes. Existing scholarship on urban informality provides an essential foundation for understanding this phenomenon. Roy, (2005), reconceptualizes informality not as the absence of regulation but as a mode of governance characterized by selective tolerance and strategic enforcement, while Neuwirth (2016) frames informal structures as creative responses to systemic exclusion across the Global South (Roy, 2005). In Vietnam, studies have documented extensive household-level adaptations, particularly in tube houses, as residents respond to cost pressures, density, and regulatory constraints (Nguyen, 2025; Truong-Young, 2019). This body of work remains heavily concentrated on megacities, where informality is primarily explained through density, migration, and metropolitan land markets, leaving mid-sized cities analytically marginal (Tran Huynh Buu, 2022). Parallel research on everyday urbanism emphasizes how ordinary, incremental practices, such as extending balconies or appropriating semi-public space, actively produce urban form (Chase *et al.*, 1999). In Vietnam, caged balconies exemplify such practices, enabling multi-generational living, small-scale economic activities, and domestic flexibility. Yet, as Corey, (2021) argues, much of the everyday urbanism literature underplays the role of state-led imagery and tourism markets in shaping which everyday practices are tolerated and which are stigmatized. This concern connects directly to debates on spatial justice and the right to the city (Lefebvre, 2014), which foreground questions of who is entitled to shape, modify, and inhabit urban space. While informal extensions are often treated as regulatory violations, they can also be read as legitimate claims to housing and spatial use in contexts where formal provision fails (Nguyen, 2025). In cities governed through aesthetic control, these claims are filtered not only through legal frameworks but also through visual norms that privilege certain forms of space-making over others. Work on urban aesthetics and the politics of visibility further illuminates this dynamic. Zukin, (2008) demonstrates how aesthetic regimes operate as instruments of power, while Ghertner, (2015), shows how appearance becomes a criterion for sorting spaces and populations in "world-class" city-making. In tourist cities such as Da Lat, where visual branding is central to economic strategy, informal extensions are often targeted not primarily for safety reasons but because they disrupt curated urban imagery (Tran Huynh Buu, 2022). As a result, informality becomes unevenly governed. Compact, visually conforming adaptations may be tolerated, while precarious yet essential structures are stigmatized and rendered illegitimate. Despite these insights, a clear knowledge gap remains. Existing studies have not sufficiently examined how informality, spatial justice, and aesthetic governance intersect in mid-sized, heritage-linked tourist cities, which differ fundamentally from megacities in scale, governance priorities, and modes of visibility. In particular, little attention has been paid to how tourism-oriented aesthetic regimes actively shape the forms, regulation, and social meanings of informal domestic extensions. Addressing this gap, the present study advances three interrelated arguments. First, caged balconies in Da Lat function as essential socio-spatial adaptations to housing scarcity rather than incidental architectural violations. Second, their legitimacy is negotiated through aesthetic governance and visibility politics, producing differentiated tolerance and stigma across urban contexts. Third, these dynamics call for an Urban Aesthetic Justice perspective that links everyday survival practices to broader questions of spatial rights in tourism-driven cities. Accordingly, the paper pursues four objectives: (i) to identify the everyday drivers behind caged-balcony construction; (ii) to analyze their morphologies and interfaces with shared space in formal and informal settings; (iii) to examine mechanisms of surveillance, regulation, and stigmatization; and (iv) to propose an Urban Aesthetic Justice framework that contributes conceptually to debates on informality, planning, and spatial justice in heritage-oriented urban environments. This study argues that Da Lat's informal aesthetics differ fundamentally from those observed in Hanoi or Ho Chi Minh City, not merely in degree but in governance logic. In megacities, informal extensions are largely shaped by extreme density, migration flows, and metropolitan land markets, and they are often tolerated as functional responses to congestion. In contrast, Da Lat is a mid-sized, heritage-linked tourist city where informality is governed primarily through aesthetic visibility rather than spatial saturation. Here, urban regulation is closely tied to landscape imagery, colonial-era architectural references, and tourism branding, which together produce a regime in which spatial legitimacy is determined by visual conformity rather than by use-value or necessity. As a result, informal extensions such as caged balconies are not simply

regulated as technical violations but are instead evaluated as disruptions to a curated urban image. This aesthetic mode of governance generates differentiated tolerance, whereby visually "orderly" adaptations are tacitly accepted while precarious yet life-sustaining structures are stigmatized, thereby producing a distinctive form of spatial injustice. By foregrounding this dynamic, the paper contributes a mid-sized, tourism-oriented perspective that extends existing informality debates beyond the megacity focus that currently dominates Vietnamese urban scholarship.

The remainder of the paper is organized as follows. The next section introduces the theoretical framework, drawing on debates in urban informality, everyday urbanism, spatial justice, and aesthetic governance. This is followed by a section that describes the research design, case selection, data collection, and analytical approach. The subsequent section presents the empirical results, with a comparative focus on the form, function, regulation, and social meanings of caged balconies across formal and informal housing contexts in Đà Lạt. The paper then moves to a discussion that interprets these findings through the proposed Urban Aesthetic Justice framework and situates the case within broader regional and theoretical debates. The final section concludes by summarizing the key contributions, outlining policy implications, and identifying directions for future research.

Theoretical framework

Building on the above, this study uses a multi-layered framework with four pillars to analyze caged balconies in Dalat. (1) Urban informality (Neuwirth, 2016); (Roy, 2005) reads caged balconies not as exceptions to the urban system but as practices embedded in, and at times tolerated by, planning. This moves beyond a simple formal-informal binary. (2) Everyday urbanism (Chase *et al.,* 1999) understands caged balconies as products of everyday practice: residents reproduce living space from micro needs - housing, petty commerce, social connection. (3) Spatial justice (Lefebvre, 2014; Soja, 2009) frames the tension between community claims to habitation and the symbolic logic of planning. In this reading, caged balconies materialize claims for spatial justice where residents' needs meet aesthetic mandates and regulatory rules. (4) Urban aesthetics and the politics of visibility (Ghertner, 2015; Zukin, 2008) explain why caged balconies are labeled "ugly" or "inappropriate." The issue is not only construction technique; it is a mechanism of symbolic exclusion tied to urban branding in a tourism context. Together, these pillars read caged balconies as a calculated spatial strategy and as a site of contention among immediate needs, aesthetics, and governance Table 1.

Research questions and objectives

Based on the above context and framework, the study asks a central question: What do caged balconies in Dalat reveal about the relationship between residents' everyday needs and urban planning oriented to heritage-tourism agendas? To answer this, the paper sets three objectives. First, clarify the everyday drivers that lead residents to construct and maintain caged balconies as a strategy for adapting to urban living conditions. Second, analyze how caged balconies are defined, monitored, and stigmatized within an urban environment under strict controls over aesthetics and image. Third, contribute to debates on informal architecture in Vietnam by extending analysis to a distinctive mid-sized tourist city where tourism and selective heritage shape regulation and visual management. The study advances both academic and practical discussions. Academically, it adds to research on urban informality and vernacular adaptation in Vietnam by shifting attention beyond megacities such as Hanoi and Ho Chi Minh City to a mid-sized city framed by tourism and selective heritage. The Dalat case shows that informality is not confined to high-density contexts; it persists in tightly managed and staged environments geared to conservation and tourism. The study helps fill a gap in how everyday life, spatial justice, and aesthetic politics relate in cities that must both preserve and commodify their images. Practically, the paper offers a different lens for urban managers and policymakers in Dalat and other heritage-related cities in Vietnam. Rather than treating caged balconies simply as "architectural violations," it reads them as spatial adaptations that reflect real housing needs and residents' negotiations with the limits of formal planning. Recognizing and understanding these practices can support planning and conservation policies that are more flexible, inclusive, and equitable-balancing tourism development, visual preservation, and the dynamic needs

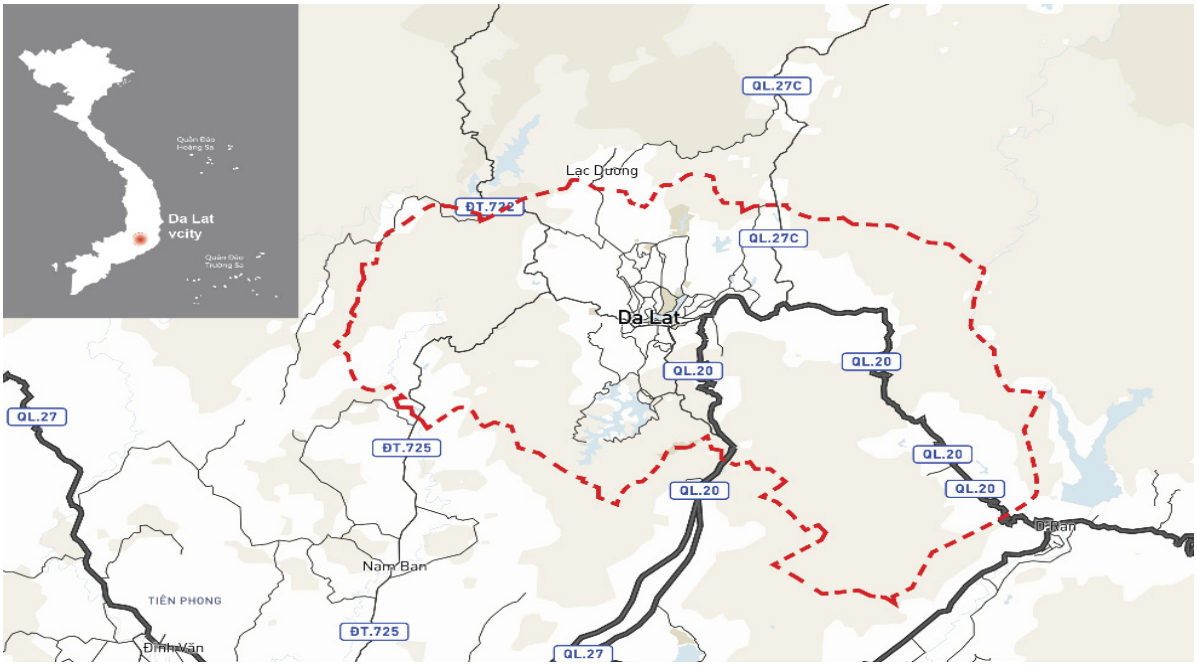


Fig. 1: Boundary of Da Lat City and research location.



Fig. 2: Characteristic Architecture of Da Lat.

Table 1: Comparison of the four theoretical approaches and the research approach for studying caged balconies

Theoretica	Main Content	Approach to Caged Balconies
Urban Informality (Neuwirth, 2016); (Roy, 2005)	Informality is not merely "outside" the system; it is a mode of urban operation at once selectively enabled by the state and creatively produced by residents.	Read caged balconies as outcomes of shortage and constraints in the formal housing system, and at the same time as flexible resident-made solutions for survival.
Everyday Urbanism (Chase *et al.*, 1999)	Everyday practice is central to urban production: people continually remake space through small, routine acts.	Read caged balconies as everyday creativity: ad-hoc extensions for additional living space, petty trade, or rental signs of adaptive flexibility.
Spatial Justice (Lefebvre, 2014) (Soja, 2009)	Spatial rights are at stake: who gets to use, alter, or produce space? Spatial justice entails a fair distribution of access and the ability to shape the city.	Read caged balconies as claims to the right to housing and the right to use space, especially for low-income households excluded from formal provision.
Urban Aesthetics (Ghertner, 2015); (Zukin, 2008)	Cities are governed not only by law but also by aesthetic norms and imagery; what counts as "beautiful/ugly" often decides what is deemed legitimate.	Read caged balconies as aesthetic controversies often labeled "ugly" or as "spoiling the image of a tourist city."

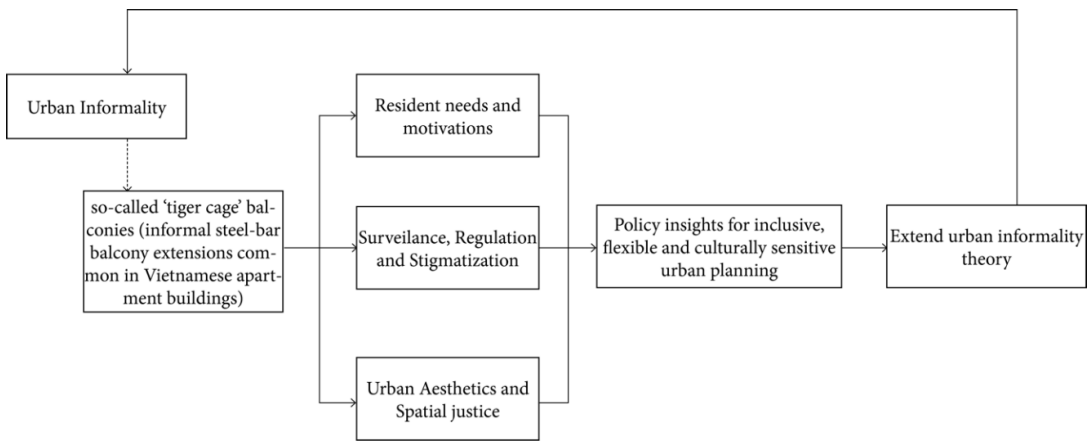


Fig.3: Research methods strategically applied to address specific research objectives

of local communities Fig. 3. Rather than treating caged balconies primarily as an understudied architectural phenomenon, this paper advances a broader research problem by asking how aesthetic regimes in tourist-oriented cities actively produce and legitimize spatial injustice. In cities such as Da Lat, where urban governance prioritizes visual order, heritage imagery, and tourism branding, informal domestic extensions become sites in which everyday survival needs collide with aesthetic norms. The resulting tension is not simply regulatory but also distributive and symbolic, determining whose spatial practices are tolerated, whose are stigmatized, and whose are rendered invisible. Caged balconies thus serve as a strategic empirical lens for examining how aesthetic governance operates as a mechanism of spatial differentiation, rather than as a neutral tool of urban management.

MATERIALS AND METHODS

This study adopts a qualitative approach to examine the formation, transformation, and social meanings of caged balconies in a tourist city such as Dalat. A qualitative design is particularly suited to the topic

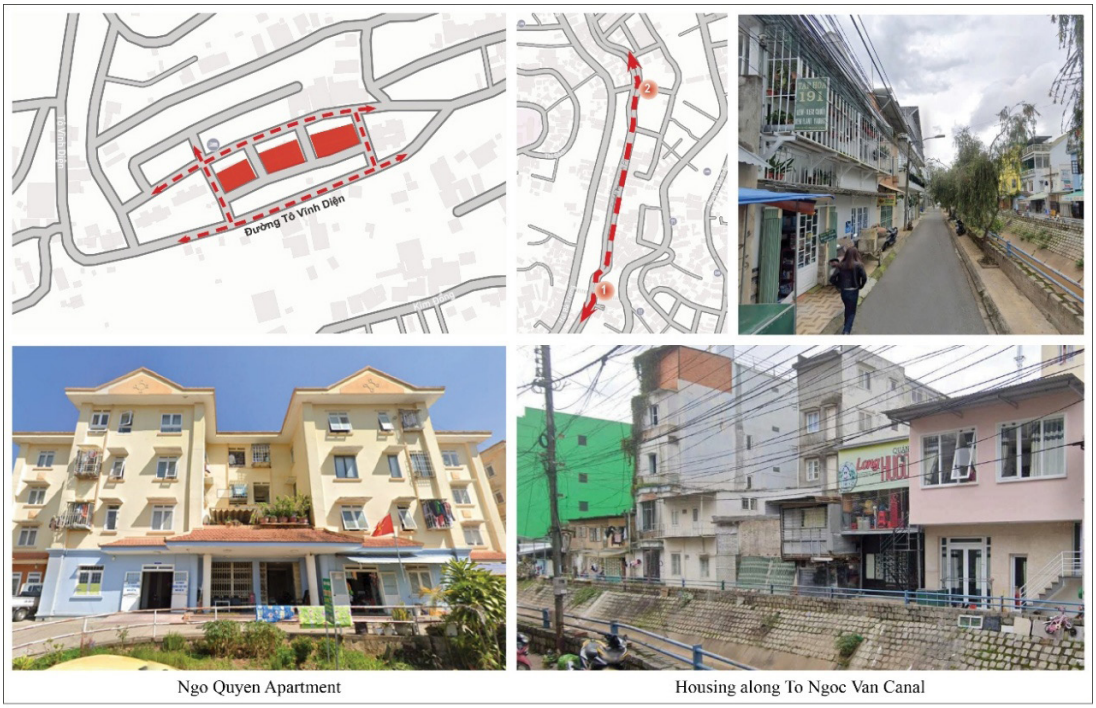


Fig. 4: Current status of caged balconies in Ngo Quyen Apartment and along To Ngọc Van Canal

because it captures the depth of everyday experience, residents' spatial strategies, and the ways municipal authorities and wider communities interpret the phenomenon. Dalat is selected as the focal case because of its distinctive status as a tourist city. Perched at roughly 1,500 meters (about 4,900 feet) above sea level on the Lang Biang Plateau, Dalat is the most populous settlement in Vietnam's Central Highlands and one of the country's most prominent tourist destinations. Historically, Dalat has been a unique urban setting marked by the coexistence and development of diverse cultural influences. It is also a city where caged balconies are widespread yet remain under-examined in a systematic manner. A case study approach allows the analysis of the complex relations among formal urban planning, everyday practices of living, and the politics of aesthetics within a specific context, thereby generating insights with broader relevance for comparable cities in Vietnam and Southeast Asia.

Research design

This study adopts a comparative case design to clarify how caged balconies emerge and function across contrasting urban contexts within the same city. By examining Ngo Quyen Apartment and the To Ngoc Van canal-side settlement Fig. 4, the analysis demonstrates that informal domestic extensions are shaped not only by household needs but also by differentiated socio-economic conditions, infrastructure provision, and governance regimes. Ngo Quyen Apartment represents a formal housing context characterized by standardized building typologies, defined property rights, and established management oversight, resulting in relatively regulated and compliance-oriented forms of informality. In contrast, the To Ngoc Van canal-side settlement exemplifies an informal housing regime marked by self-built dwellings, insecure tenure, limited infrastructure, and minimal regulatory presence, where caged balconies function as necessity-driven and precarious spatial adaptations. Locating both sites within the same city allows the study to isolate the effects of governance context and planning control, rather than broader citywide economic conditions, on the form, regulation, and social meaning of caged balconies. The paired comparison reveals how differences in infrastructure stability, income levels, and aesthetic expectations produce distinct modes of informal space-making. This contrast strengthens the analytical linkage between

able 2: Demographic characteristics of study participants.

Demographic Characteristics Investigation Groups	Locals	Key Informants		Total
In-depth interview	Ngo Quyen Habitats	To Ngoc Van Habitats		
	26(12M,14F)	31(16M, 15F)	3 (3M,0F)	60(31M,29F)

T(F = Female, M = Male)

spatial inequality and urban informality, showing that variations in caged-balcony construction reflect systematic urban conditions rather than isolated local idiosyncrasies.

Data collection

The study adopts a qualitative design and triangulates multiple sources to build a comprehensive understanding of the phenomenon. Fieldwork was conducted over 12 months between March 2024 and February 2025. Initial site reconnaissance and observational mapping were carried out between March and May 2024, followed by in-depth interviews and detailed photographic documentation from June to October 2024. Supplementary observations, follow-up conversations, and document review were completed between November 2024 and February 2025. This extended engagement enabled iterative refinement of interview themes and triangulation between observational and interview-based evidence.

Field observation

At both sites, we conducted on-site surveys and kept detailed notes on the physical environment, housing typologies, and in-situ caged-balcony extensions. Observations included photography, basic measurements of added structures, and documentation of the surrounding urban context. Direct observation clarified the architectural morphology of caged balconies and their interactions with adjacent public and semi-public spaces.

Semi-structured interviews with residents

Semi-structured interviews were conducted with a total of 60 residents living in Ngo Quyen Apartment and along the To Ngoc Van canal-side settlement, including 26 participants from the formal apartment compound, 31 from the canal-side area, and three local key informants familiar with housing management and neighborhood conditions. Interviews were carried out in participants' homes and focused on residents' motives, experiences, and perceptions regarding the construction and use of caged balconies Table 2. A purposeful, site-based sampling strategy was adopted to capture diversity in household structure, tenure status, and spatial practices rather than to achieve statistical representativeness. Inclusion criteria required participants to be adult residents aged 18 years or older who either owned or rented dwellings with caged balconies or had direct experience living adjacent to such extensions. Efforts were made to ensure gender balance, with 31 men and 29 women, and to include a range of age groups and livelihood conditions. The interview guide covered key themes, including reasons for extending domestic space, construction processes and costs, interactions with regulatory authorities, and perceived impacts on household life and the surrounding community. Together, these interviews provide rich qualitative evidence on the social drivers and lived implications of caged-balcony construction across both formal and informal urban contexts.

Housing and balcony typology analysis

In parallel with interviews, we classified and analyzed the forms of caged balconies at each site. Based on observation and collected measurements, extension modules were grouped by size, material, and position. Comparing the typologies of caged balconies between the apartment compound and the canal-side settlement helps assess whether differences in spatial configuration and urban management lead to distinct forms and scales of extension. We also reviewed the underlying housing structures (e.g.,

apartment layouts versus self-built canal-side houses) to situate the need for expansion.

Secondary documents

We analyzed secondary sources to contextualize the field data: (1) Dalat's urban planning files and building regulations (to assess the legal framework for extensions and housing construction); (2) population statistics and local government reports on the two study areas (to understand demographics, income, and settlement histories); and (3) prior studies and academic literature on informal housing and caged balconies in Vietnam. This document analysis cross-checks field findings against policy and theory and situates results within broader scholarship on Vietnamese urban planning and development.

Analytic strategy

All qualitative materials, including interview transcripts, observation notes, documents, and photographic annotations, were analyzed using a combined thematic and content analysis approach. Interviews were fully transcribed and coded manually through iterative reading and the systematic organization of data into thematic clusters, rather than through automated software. This manual process enabled close engagement with residents' narratives and attention to the contextual specificity of spatial practices. The analysis followed three interrelated stages. (i) Open coding was conducted to identify recurring themes related to residents' motives and purposes for constructing caged balconies, as well as their physical forms and materials, interactions with authorities and legality, and perceived social and spatial consequences. (ii) Axial coding was used to link these themes across micro (household), meso (neighborhood), and macro (policy and market) scales, allowing patterns to be situated within broader urban conditions. (iii) Interpretive synthesis was undertaken to connect the empirical themes to the theoretical constructs of urban informality, spatial justice, and aesthetic governance. Following within-site analysis, a systematic cross-case comparison was undertaken between Ngo Quyen Apartment and the To Ngoc Van canal-side settlement. This comparative step foregrounded similarities and differences in rationales, construction pathways, and regulatory experiences, thereby clarifying how governance context, infrastructure conditions, and socio-economic inequality shape the production and interpretation of caged balconies. The resulting core patterns and themes form the empirical foundation for interpretation presented in the Results and Discussion sections.

Ethical considerations

The research adheres to established ethical principles in urban social research, especially when working with vulnerable communities in informal settings. Informed consent was obtained before each interview after participants were briefed on the study's aims. Personally identifiable information is protected; participant names and precise addresses are not reported, ensuring anonymity. Fieldwork was conducted with respect and attentiveness, avoiding judgment of living conditions or decisions to build caged balconies. The study is context-sensitive: recognizing that caged-balcony extensions are tied to livelihoods and urgent needs, interviews were conducted in a friendly manner and avoided questions that might raise concern. Findings are presented in aggregate, emphasizing the phenomenon rather than attributing responsibility to individuals to protect informants and avoid negative impacts on the communities studied. Complementing these ethical safeguards, the study also reflects critically on researcher positionality as an integral part of ethical practice. The researcher's training in urban planning and architecture, together with prior professional engagement in Vietnamese planning and design discourse, enables sensitivity to aesthetic regulations and planning logics shaping residents' environments. At the same time, this background carries the risk of privileging formal design norms over everyday spatial practices. To address this concern, the analysis consistently foregrounds residents' narratives and lived experiences, rather than applying normative judgments of form or appearance. Throughout fieldwork and interpretation, reflexive attention was paid to how concepts such as "ugliness," "order," and "visual disruption" are socially constructed and institutionally embedded, rather than treated as neutral descriptors. Interpretations of aesthetic governance were therefore grounded in participants' accounts and triangulated with observed regulatory practices, strengthening ethical integrity and reducing the risk of imposing external evaluative frameworks on residents' spatial adaptations.

RESULTS AND DISCUSSION

Form, function, and spatial effects of caged balconies

The survey and field observations reveal clear differences in caged balconies between Ngo Quyen Apartment and the canal-side settlement along To Ngoc Van. In this study, "caged balconies" refer to metal-grill enclosures attached outside balconies or windows, commonly used to expand usable floor area. Their scale, materials, placement, and everyday functions vary markedly across the two sites.

At Ngo Quyen Apartment, most caged balconies are small, typically about 1–2 m², projecting roughly 1 m from the facade. These additions are mainly used for drying clothes, potted plants, or small storage (Fig. 5). The extension has no independent floor support; the frame is drilled and anchored into the building's structural elements. By contrast, in the To Ngoc Van canal-side area, extensions are substantially larger. Many structures reach 4-6 m² and are used for functions such as a cooking corner or auxiliary sleeping area. This necessity is reflected in residents' own accounts. As one canal-side resident explained: "The house is too small for five people. If we don't extend outward, there is nowhere to cook or sleep. We know it looks messy, but we have no other choice." (Fig. 6). In some Vietnamese urban housing estates, similar extensions have been reported to add up to 12 m² of usable space. Construction characteristics also differ. At Ngo Quyen, caged balconies are comparatively uniform and sturdy, typically built with welded steel frames anchored to the structure, anti-rust coating, and metal mesh; some households add glass or acrylic panels for rain protection. Styles and colors are relatively consistent. In To Ngoc Van, caged balconies frequently use makeshift and salvaged materials, including corrugated sheets, timber boards, wire mesh, and recycled plastics. Craft quality varies and structures often appear fragile. Comparable conditions in canal-side settlements include patched shelters using rusted metal or cardboard, propped on limited supports over weak ground. Placement and encroachment patterns likewise diverge. At Ngo Quyen, caged balconies generally remain within the original balcony footprint, rarely extending beyond the building line. They cluster on mid and upper floors and have limited impacts on shared space. In To Ngoc Van, many additions protrude into alleys or shared passageways, narrowing circulation. In some cases, residents stack additions onto neighboring roofs, producing patchwork agglomerations above street level. Similar conditions have been observed where inter-block voids are filled and stacked cages reduce space quality and emergency egress. The housing context reported for each site also differs. Ngo Quyen is a state-built apartment compound with standardized layouts; unit sizes of roughly 50-65 m² generally cover basic family needs. Extensions, when present, serve auxiliary functions. By contrast, the canal-side settlement comprises self-built, space-constrained houses, often only a few tens of square meters, hosting larger households and lacking enclosed amenities.

Regulation, oversight, stigma, and safety-related observations

Across both sites, residents link caged-balcony extensions to limited interior space and efforts to improve everyday living conditions. In the To Ngoc Van canal-side settlement, multi-member households extend space by adding lean-to attics, canopies, or steel-mesh frames for drying and storage. The choice of low-cost, easy-to-install materials reflects economic constraints. Motivation is also associated with tenure: owner-occupiers, about two-thirds of households, are more proactive in modifying their homes, while renters rarely invest in extensions. In Ngo Quyen Apartment, where unit layouts are standardized and living conditions are comparatively stable, motivations are mainly auxiliary rather than adding rooms. Oversight and enforcement are reported to differ by site. At Ngo Quyen, the presence of building management and peer attention is associated with self-limited extensions; several residents stated that oversized additions would prompt reminders or objections from neighbors. One resident shared: "Small cages are acceptable here, but if they protrude too much, neighbors will complain or the management will say that they undermine the building's image". At To Ngoc Van, the absence of centralized management and routine oversight is associated with more extensive and varied construction, including encroachment into alleys and common space. In regulatory terms, unauthorized extensions are classified as violations, but enforcement varies. Compact additions at Ngo Quyen are reported as more often tolerated when perceived as temporary or limited in structural impact. At To Ngoc Van, despite more serious violations, inspections and sanctions are reported as infrequent, and some households described small fines as a cost



Fig. 5: Current functional use of caged balconies at Ngo Quyen Apartment Building



Fig. 6: Current functional use of caged balconies at housing along To Ngoc Van Canal

Table 3: Micro-Meso-Macro drivers of caged balcony formation and governance

Analytical Level	Key Factors	Manifestation in Ngo Quyen Apartment	Manifestation in To Ngoc Van Canal-side Area
Micro (Household)	Household size, tenure, daily needs	Auxiliary use (drying, storage); small-scale cages	Essential use (cooking, sleeping); large extensions
Meso (Neighborhood)	Infrastructure, management, oversight	Stable infrastructure; informal peer regulation	Narrow alleys; weak oversight; spatial encroachment
Macro (Policy/Market)	Housing supply, planning priorities, aesthetics	Partial tolerance under image control	Informality normalized under neglect and stigma

of doing construction. Socially, caged balconies are frequently described as "ugly" and "damaging to urban image," particularly in a tourist city like Dalat. Along the canal, extensions are also linked to stereotypes of poverty and non-modernity. One local official stated: "Caged balconies along the canal look messy, both hazardous and harmful to the image of a tourist city like Dalat." Safety-related concerns are also noted for improvised canal-side extensions, including risks of structural failure, electrical fires from ad hoc wiring, and reduced emergency access in narrowed circulation spaces.

Discussion

Interpreting divergence: housing constraints and multi-level drivers

The divergence between Ngo Quyen and To Ngoc Van can be interpreted through differences in housing constraints and governance conditions. In Ngo Quyen, the state-built apartment typology and standardized unit sizes (roughly 50 to 65 m^2) support extensions that remain supplementary rather than essential. In the canal-side settlement, more severe space constraints and limited enclosed amenities correspond to larger and more intensive extensions that function as necessary living space. In low-income urban contexts where per-capita dwelling space can be extremely limited, incremental additions often become an everyday survival strategy rather than an optional improvement (Neuwirth, 2016). The drivers of extension can be synthesized across three levels. At the household level, limited floor area, multi-generational composition, tenure status, and functional needs shape extension practices. At the community or estate level, local infrastructure and oversight conditions influence whether extensions remain contained or become spatially intrusive. At the institutional level, broader market and policy conditions affect residents' capacity to access formal housing options and thereby increase reliance on self-provisioned enlargement. This multi-scalar reading aligns with the argument that informality is structured by planning and state power, rather than existing outside it (Roy, 2005). To clarify this synthesis, the following table summarizes the key drivers of caged-balcony formation at the household, neighborhood, and policy - market levels, and compares how these factors manifest differently in Ngo Quyen Apartment and the To Ngoc Van canal-side settlement. The table provides a structured overview of how housing constraints and governance conditions jointly shape divergent extension practices across the two sites.

Urban Aesthetic Justice (UAJ) as an interpretive framework

UAJ is proposed as an interpretive framework to explain how everyday housing adaptations are evaluated and governed in heritage-linked tourist cities Fig. 7. The framework integrates four components: everyday spatial practice, aesthetic governance, politics of visibility, and spatial legitimacy Fig. 8. Everyday spatial practice highlights routine, small-scale adaptations through which residents secure livability under constraint, consistent with everyday urbanism's attention to ordinary practices as constitutive of urban life (Chase *et al.,* 1999). Aesthetic governance captures regulatory regimes in which visual order, heritage imagery, and tourism branding shape the evaluation of space alongside legality, consistent with arguments on rule through aesthetic norms and image-making (Ghertner, 2015). Politics of visibility specifies how tolerance, enforcement, and stigma vary according to visual prominence and symbolic meaning, producing differentiated treatment of similar practices across urban space (Ghertner, 2015). Spatial legitimacy refers to the socially and institutionally mediated recognition of residents' rights to occupy, modify, and represent space, extending spatial justice discussions

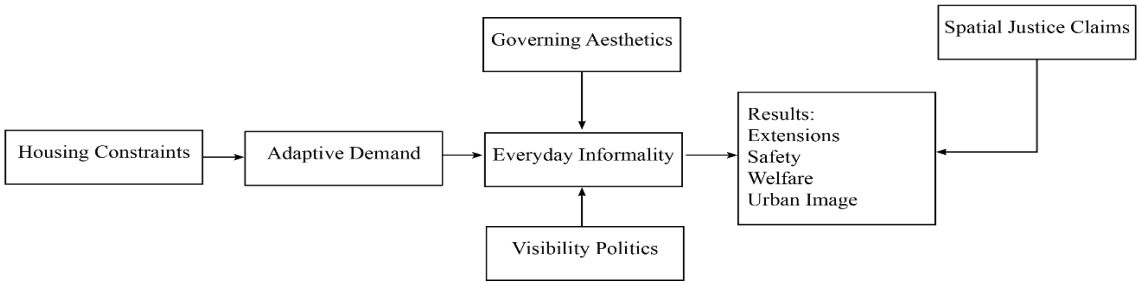


Fig. 7: Urban visual justice framework

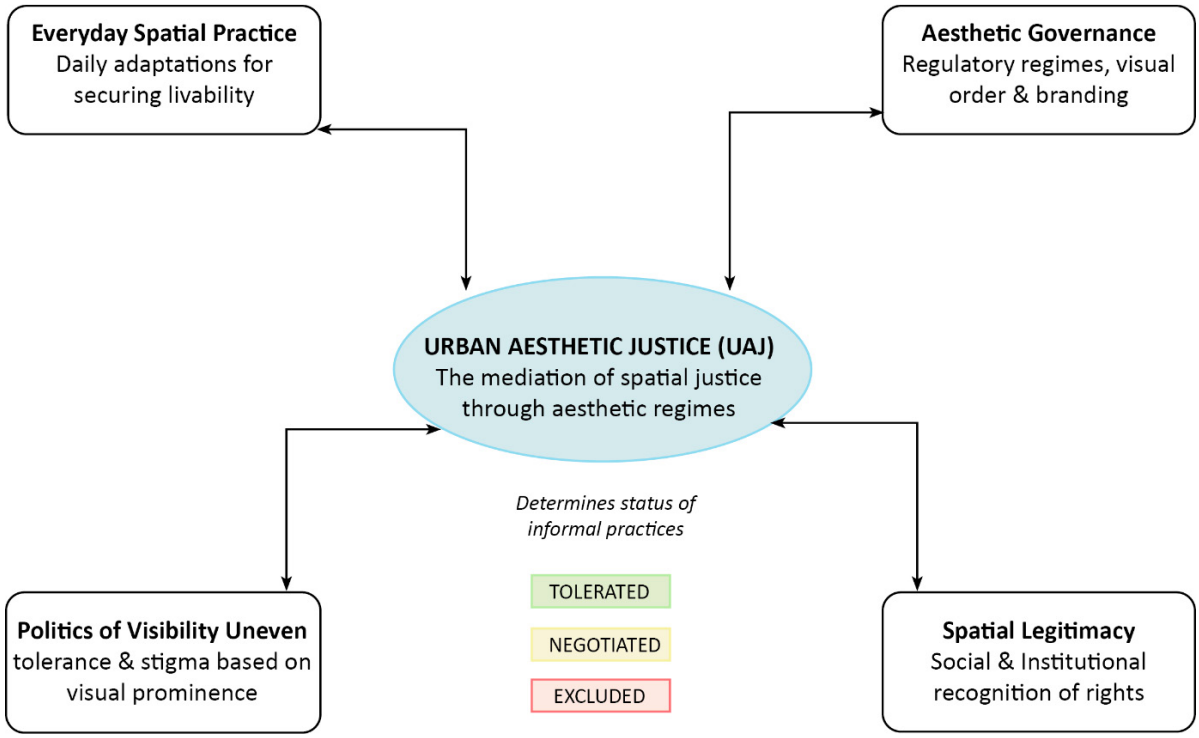


Fig. 8: UAJ components: practice, aesthetic governance, visibility, legitimacy

that emphasize rights to produce and use space (Soja, 2009). UAJ also clarifies how representational order becomes part of the justice question in tourism-oriented heritage settings. In this sense, the framework is compatible with Lefebvre's emphasis on the right to difference as a claim to lived heterogeneity against homogenizing spatial orders (Lefebvre, 2014), and with Jacobs' emphasis on everyday urban life as the basis of how cities function and remain legitimate in practice (Jacobs, 1961). Within this framing, caged balconies can be read not only as functional extensions but also as resident-produced differences that conflict with curated facade regimes in branded tourist cities.

UAJ differs from existing frameworks such as Urban Visuality and Aesthetic Citizenship in both analytical focus and normative orientation. Studies of urban visuality primarily examine how cities are seen, represented, and governed through visual regimes, emphasizing spectacle, imagery, and perception as instruments of power. Aesthetic citizenship, in turn, focuses on how residents gain recognition or belonging through conformity to dominant aesthetic norms, often highlighting inclusion through visual participa-

tion or performance. By contrast, UAJ foregrounds questions of justice rather than representation, emphasizing how aesthetic regimes actively distribute spatial legitimacy, risk, and material opportunity. Rather than asking who is visible or recognized, UAJ asks whose everyday spatial practices are tolerated, negotiated, or excluded under aesthetic governance, particularly in contexts of housing scarcity. In this sense, UAJ reframes aesthetics not merely as a symbolic or cultural register, but as a governing mechanism that produces spatial inequality, especially in tourism-oriented and heritage-linked cities.

Policy contradictions, regional parallels, and broader applicability

The Da Lat case can be situated within broader contradictions between policy aspirations, heritage branding, and everyday housing needs. Vietnam's urban policy promotes modern and sustainable development goals, yet reports and commentaries indicate persistent constraints in affordable housing supply, contributing to households' reliance on self-provisioned space-making (Hùng, 2021; Xuan, 2024). In Da Lat, strict place branding narratives and aesthetic regulation are widely discussed as shaping planning priorities, while integrated social housing solutions remain limited (Nguyen & Vo, 2025). This tension is particularly notable given that the national programme has formally assigned provincial completion targets for social housing for 2025 and subsequent years through 2030 (Decision No. 444/QĐ TTg, 2025). At the provincial level, Lam Dong established a Social Housing Development Steering Committee and set an implementation goal of more than 2,000 social housing units for 2025 to 2030, while also reporting multiple planned land sites for social housing but a still limited number of approved projects at the time of reporting (Nguyen & Vo, 2025). Uneven implementation further blurs the boundary between legal and illegal practices, echoing findings that enforcement can be selective and exceptionalized under pressure from low-income and migrant housing demand (Seo *et al.,* 2022; Thinh & Kamalipour, 2024). These interlocking contradictions are summarized in Figure 9. This pattern aligns with Roy's conceptualization of informality as a mode of regulation, where rules are selectively applied, suspended, or reworked to allocate legitimacy (Roy, 2005). In tourism-oriented contexts, this selectivity often intersects with aesthetic governance, where visual conformity becomes a practical criterion shaping what is tolerated in public view (Ghertner, 2015). Comparable dynamics are documented across Southeast Asian cities where informality is managed through negotiated tolerance, image-led priorities, and uneven clearance or resettlement interventions. In Bangkok, street vending has been regulated through periodic clearance campaigns and negotiated rules justified through order and streetscape concerns (Batréau & Bonnet, 2016). In Metro Manila, eviction and resettlement along waterways have been framed through risk and safety governance that restructures legitimacy and displacement (Alvarez & Cardenas, 2019). In Jakarta, river normalization and flood control agendas have intersected with global city aspirations, contributing to differentiated legitimacy and displacement along riverscapes (Dovey *et al.,* 2019). Beyond caged balconies, UAJ is intended to apply to other informal practices governed through aesthetic regimes, including rooftop extensions, street vending, and facade greening. Across these cases, spatial legitimacy is often shaped through aesthetic judgment and visibility, not only through uniformly applied legal criteria (Ghertner, 2015; Roy, 2005). Building on these regional precedents, Da Lat can draw practical lessons from community upgrading and incremental formalization approaches. Bangkok's Baan Mankong programme demonstrates how city-supported, community-led upgrading can improve infrastructure and housing conditions while reducing displacement through collective organization and tenure-related arrangements (Boonyabancha, 2005). Jakarta's long-running kampung improvement and more recent kampung-oriented initiatives similarly illustrate incremental service upgrading and negotiated recognition as alternatives to clearance, particularly in river-adjacent settlements (Bank, 1995; CODI, 2020). These experiences suggest that, for canal-side areas in Da Lat, pairing minimum safety and infrastructure standards with mechanisms that enable in situ upgrading and community participation may be more effective than purely aesthetic restriction or episodic enforcement.

CONCLUSION

This study has examined the phenomenon of caged balconies in Da Lat to illuminate how informal spatial extensions articulate the tension between residents' everyday survival needs and the

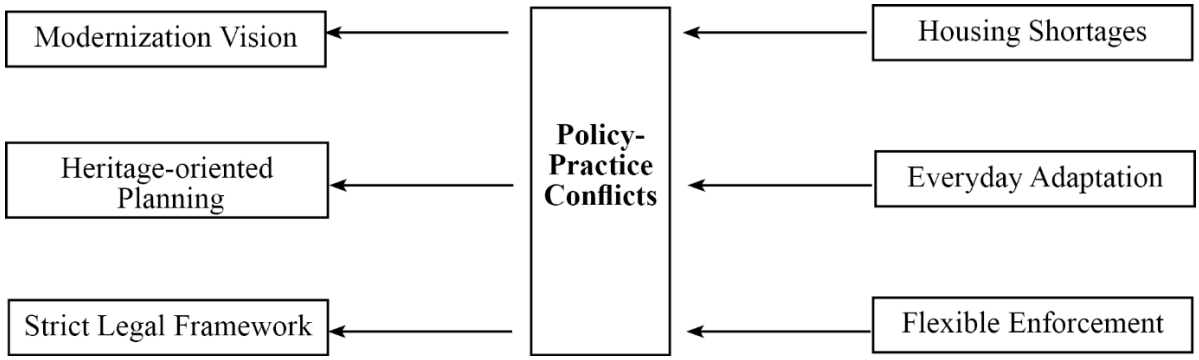


Fig. 9: Conflicts in housing policy and urban planning in Da Lat

aesthetic governance of a heritage-linked tourist city. Through a comparative analysis of Ngo Quyen Apartment and the To Ngoc Van canal-side settlement, the research demonstrates that caged balconies are not ad hoc architectural fixes but socio-spatial indicators of urban inequality, housing policy limitations, and uneven planning inclusion. The contrast between a formally managed residential environment and a precarious canal-side settlement reveals how household economics, infrastructure provision, and governance regimes shape both the form and persistence of informal extensions. More broadly, the findings expose a two-tier urban condition in which a carefully staged city for visitors coexists with an everyday city where residents improvise to secure livability. Empirically, the study provides systematic evidence of differentiated informality. In formal housing compounds, caged balconies tend to be compact and auxiliary in function, while in canal-side settlements they are larger, multifunctional, and integral to daily survival. This contrast offers an evidence-based benchmark for reinterpreting what is often labeled as visual disorder as an unevenly distributed necessity rather than individual noncompliance. These findings challenge dominant regulatory approaches that frame informality primarily as a technical or aesthetic violation. Conceptually, the paper advances the Urban Aesthetic Justice framework, which extends spatial justice debates by demonstrating that legality alone cannot explain spatial legitimacy in tourism-oriented cities. Instead, visibility and aesthetic conformity operate as de facto regulatory criteria through which tolerance, enforcement, and stigma are selectively applied. By foregrounding the politics of visibility, the framework deepens understandings of informality and everyday urbanism, emphasizing unequal rights to difference, recognition, and spatial presence. While developed through the case of caged balconies, the framework is transferable to other informal practices such as rooftop extensions, street vending, and facade interventions that are governed through image-making in heritage contexts. From a policy perspective, the study underscores the need for differentiated responses that combine immediate risk reduction with long-term structural reform. Short-term actions should focus on tiered regulations, minimum safety standards, participatory mediation, and targeted infrastructure upgrades, particularly in high-risk informal areas. Long-term strategies must expand affordable housing supply, integrate livelihood protection into upgrading programs, institutionalize participatory planning, and adopt urban design codes that balance heritage conservation with the right to everyday inhabitation. The study is not without limitations. Its empirical scope is confined to two illustrative sites and relies primarily on qualitative evidence. Future research should expand spatial coverage, incorporate quantitative and environmental analyses, and further test the applicability of Urban Aesthetic Justice across diverse heritage-linked cities.

AUTHOR CONTRIBUTIONS

D. T. Do developed the conceptual framework and research methodology for the study. T.T. Truong, X.M. Ho, and Q.P. Phan performed the formal analysis. T. T. Truong and X. M. Ho prepared the original draft of

the manuscript. T.T. Truong, Q. P. Phan, and D.T. Do reviewed, revised, and edited the manuscript, and also contributed to the visualization of the research findings. All authors read and approved the final version of the manuscript.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the research, authorship, or publication of this article. All ethical principles in research, including informed consent, data integrity, and originality of the work, have been strictly adhered to.

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ABBREVIATIONS (NOMENCLATURE)

m^2	Square meter
UAJ	Urban Aesthetic Justice

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ORIGINAL RESEARCH PAPER

From likes to public spaces: the impact of social media on gender-based spatial behaviors in urban public spaces

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ABSTRACT

BACKGROUND AND OBJECTIVES: The rapid expansion of social media has introduced a digital layer into the production and experience of urban public spaces, particularly influencing gendered patterns of movement, visibility, and access. This study investigates how social media platforms mediate and reshape gendered behaviors on Ferdowsi Street in Sanandaj, Iran, examining the interaction between physical design, cultural norms, and digital representations in producing spatial inequalities.

METHODS: A mixed-methods approach was employed using a triangulation strategy to ensure validity. Behavioral mapping was conducted to identify spatial behavior patterns. Additionally, semi-structured walk-along interviews were conducted with 46 participants (24 males and 22 females), and thematic analysis was carried out, incorporating both deductive coding based on the Monitoring Cycle of Gender Behavior Differences in Public Space and inductive coding to identify emerging digital-behavioral themes.

FINDINGS: Results show clear gendered spatial segmentation: adolescent and young men predominantly clustered at peripheral, high-visibility nodes, while women concentrated in central and safer segments of the street. Social media played a significant mediating role in producing these patterns. Adolescent boys were highly sensitive to viral, geotagged, and event-driven content, translating online visibility into rapid physical presence. Young women selectively responded to cultural and commercial posts, shaping their spatial use more cautiously. Across all age groups, social media amplified specific nodes along the street, effectively branding certain areas and transforming them into digitally driven hubs of activity. These patterns reflect a hybrid physical-digital public space in which digital representations contribute to the reproduction of gender norms and influence the distribution of agency, comfort, and access.

CONCLUSION: The study concludes that spatial behaviors in contemporary urban environments cannot be understood solely through physical design or socio-cultural norms; digital representations now function as an active component in the production of space. Social media platforms mediate gendered access and reinforce spatial inequalities by commercializing visibility and shaping collective perceptions of safety, desirability, and social value. As a result, designing inclusive and gender-sensitive public spaces requires coordinated interventions in both the physical environment and the digital sphere.

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68	9	2

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INTRODUCTION

Over the past two decades, social media platforms have rapidly expanded, becoming interactive spaces that shape social behavior and public life. Social media, especially social networking sites (SNSs), is a response to the challenges of an ever-evolving and interconnected world - a world that requires increased learning and collaboration to solve today's complex problems (Coman & Grigore, 2018). The influence of these networks on all aspects of daily life and the modern world is now undeniable (Allcott *et al.,* 2020), and they have become an integral part of our lives (Akram and Kumar, 2017). Social media platforms are fast, accessible, and affordable, so a wide range of people can use them. Communication strategies have taken a new form in this new interactive space, and the management of this space, including words, gestures, looks, expressions, trends, and biases, can influence decisions and social behaviors (Hermosilla *et al.,* 2018). Beyond their digital domain, social media increasingly intervene in the production, perception, and everyday use of urban public spaces. Experiences such as the 15M movement in Spain, the Arab Spring, and Occupy Wall Street demonstrate that social media can act as a catalyst, creating unprecedented mechanisms for collective action in urban public spaces and leading to a rethinking of the role of these spaces in the community-building process (de Vicente, 2021). However, these transformations do not affect all social groups equally and often exhibit distinct patterns, profoundly influenced by gender (Yuan, Wei, and Lu, 2018). Many activities once confined to urban public spaces, such as social interaction and leisure, are increasingly facilitated through virtual platforms. These include shopping (Yu *et al.,* 2018) and socializing (Hafez and Wang, 2018), as well as non-present virtual pursuits (Romm-Livermore, 2012). Moreover, the undeniable role of social networks in shaping social norms and biases (Eismann *et al.,* 2018; Fischer and Reuber, 2011; Derek Ruths and Juergen Pfeffer, 2014) has become evident in contemporary life. Social media has diverse impacts on individuals (Hafez and Wang, 2018), producing both positive and negative social and cognitive effects. Interactions on these platforms can stimulate social engagement and shape individual behavior (Bayer *et al*., 2020; Kaya & Alhajj, 2019). Even a simple post on social media can have a significant impact on individuals, especially if it elicits emotional responses from the audience (Eismann *et al.,* 2018). Social media act as mediators between private and public spaces, creating dynamic interactions that continuously reshape urban public life (Van Dijck and Poell, 2015). Social networks are increasingly conceptualized as hybrid public spaces, closely interconnected with physical public spaces through a fusion of human interaction, media platforms, and communication technologies. Social media is transforming public space in complex ways. This condition reflects a socio-spatial transition in which digital and non-digital realms increasingly overlap (Tierney, 2013). Such hybridization suggests that digitally shaped perceptions and norms may translate into observable behavioral patterns in physical public spaces. This raises the question of whether such digitally shaped cognitive differences affect behavioral patterns in physical public spaces and how these effects differ across gender groups. Social media platforms influence behavioral patterns in public spaces and can trigger different types of social behaviors, both positive and negative (Allcott *et al.,* 2020). From the available sources, it can be inferred that social media can influence the perception, design, and use of public spaces, sometimes blurring the lines between virtual and physical environments. Although some studies have recently been conducted using social media data (Bernabeu-Bautista *et al.,* 2023; Yang and Liu, 2022; Nguyen *et al.,* 2019), It appears that less attention has been paid in the discourse of social media studies to the impact on actual urban spaces and the behavior of individuals in those spaces, as well as how this mediating force affects social biases and behaviors in those real spaces. As the boundaries between the digital and physical worlds become increasingly blurred, understanding this relationship is critical to grasping the evolving landscape of public space. However, how these digitally mediated influences operate within non-Western socio-cultural contexts, particularly in relation to gendered spatial behavior, remains largely underexplored. Since its inauguration in 2020, Ferdowsi Pedestrian Street has become one of the most active public spaces in Sanandaj, Iran. As a major pedestrian corridor connecting central commercial areas and traditional markets, the street has developed into a focal point of everyday urban life and, simultaneously, one of the most frequently represented spaces on social media platforms through geotagged posts and online visibility. This

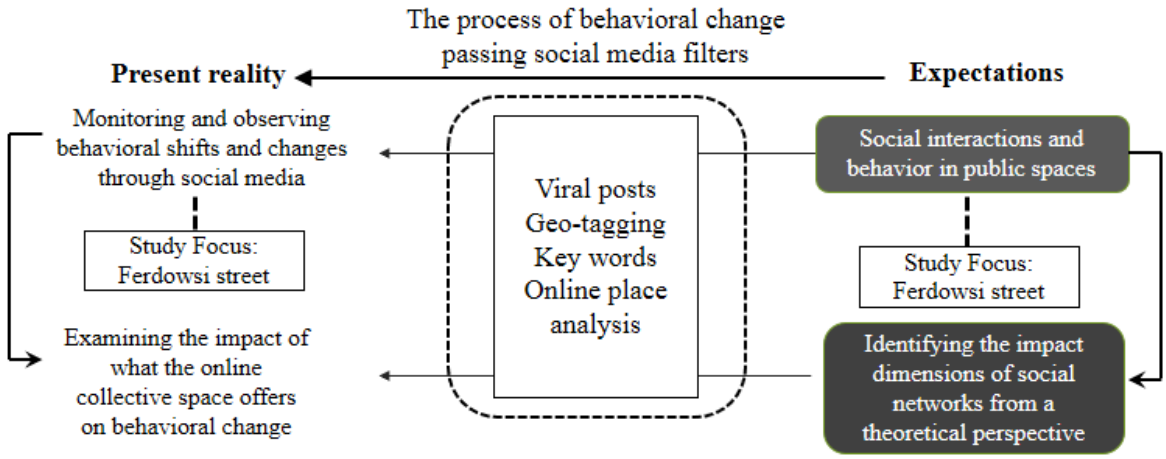


Fig. 1: The logical development of the study

dual physical-digital presence makes Ferdowsi Street an appropriate case for examining how social media intervenes in real spatial behaviors. Investigating these dynamics within the socio-cultural context of Iran, where norms of gendered visibility and public presence differ significantly from Western settings, offers a critical and underexplored perspective on digitally mediated public space. The main objective of this study is to explore how social media shapes gender-based behavioral patterns in urban public spaces, with particular attention to Ferdowsi Pedestrian Street. Specifically, the study seeks to identify gendered differences in spatial presence, public interaction, and perceived positive and negative impacts of social media on everyday urban life. Methodologically, the study adopts a mixed-method approach based on triangulation, combining behavioral mapping, systematic observation, and walk-along interviews over three months. The collected qualitative data were thematically analyzed to reveal the complex interplay between digital representation and physical behavior in everyday public life (Fig. 1).

Social media as a driver of behavioral change in public spaces

The topic of reciprocal influence between social media and human behavior has attracted considerable attention from researchers over the past two decades (Allcott et al., 2020; Bayer *et al.,* 2020; Carrier, 2018; Fischer and Reuber, 2011; Huang *et al.,* 2021; Kaya and Bicen, 2016; Mano, 2014; Meiselwitz, 2018; Pan *et al.,* 2017; Derek Ruths and Jürgen Pfeffer, 2014; Scopelliti *et al.,* 2021; Swingle, 2016; Valenzuela *et al.,* 2012; Van Dijck and Poell, 2015). Undoubtedly, the increasing prevalence of virtual social media networks and their impact on human behavior represent one of the empirical challenges of contemporary cities (Centola, 2013). However, limited research has examined how these digital interactions shape behavior in urban public spaces within non-Western contexts such as Iran. This section of the research focuses on the latest theoretical perspectives and empirical studies that examine the intersection of social media and public behavior. The goal is to clarify the impact of social media on behavior change in public spaces and provide a theoretical foundation for our study in Ferdowsi Street in Sanandaj. Hiraishi *et al.,* (2018) show that information shared on social media can influence pedestrian behavior in urban areas, guiding movement and attention. Despite all the concerns and criticisms expressed about social networks (Beckmann *et al.,* 2018; Meinert *et al.,* 2018). These networks have driven large-scale social movements and influenced emotional and behavioral responses on platforms such as Twitter, Facebook, and YouTube (Mano, 2014; Carrier, 2018; Swingle, 2016; Kaya & Alhajj, 2019). Tierney (2013) introduces social networks as a new public space, emphasizing their interconnectedness with physical public space and their lack of competition with each other. He argues that social media platforms promote new social, cultural, and political agendas and defines social media as "*counterpublics*" that serve as alternatives for marginalized populations to express their collective

opinions and interests that are often overlooked. Nonetheless, the divisions and boundaries between digital and non-digital public spaces are becoming less obvious, creating complex interactions across time and space. Preliminary observations in Iranian urban contexts suggest that similar digital-physical interplay may shape local social behaviors. Social networks have dual effects on communities, shaping young people's social behavior while also presenting risks such as cyberbullying and reputational harm. These platforms provide opportunities for communication, learning, and professional networking, but can simultaneously facilitate negative outcomes (Akram and Kumar, 2017). Individuals actively choose communication channels based on goals and motivations, with social media complementing, rather than replacing, face-to-face interactions. Online engagement allows for impression management, social coordination, and regulation of proximity and emotions, shaping the way people interact in everyday life (Carrier, 2018). Virtual spaces have become primary tools for exploring social relationships, influencing how social boundaries and norms are learned, especially among youth (Swingle, 2016). Evidence from the COVID-19 pandemic further demonstrates that social networks can redefine social norms and behavior in public spaces, including hygiene practices, spatial distancing, and adherence to collective rules (Scopelliti *et al.,* 2021; Fischer and Reuber, 2011). Social media platforms reshape public spaces within the framework of a networked society, influenced by the commercial mechanisms of communication. The analysis by Van Dijck and Poell (2015), including the shift of social networks toward "light news" in Sweden, demonstrates how platform-based curation can distort public interests and reshape civic engagement. Based on this perspective, Bayer et al. (Bayer *et al.,* 2020)conceptualize social media as socio-technical ecosystems composed of four pairs of key elements and features: profiles and self-presentation, networks and social mobilization, streams and social comparison, and messaging and social connectedness. By providing new ways to discover, observe, and meaningfully interact with others across time and space, social media extend possibilities for interpersonal engagement, yet also create psychological vulnerabilities such as loneliness or heightened comparison pressures. Their notion of virtual streams mirrors dynamics like physical presence in an urban square, where evaluative signals such as likes or comments become quantified, measurable cues that shape social comparisons over time. Mass media can serve as a valuable resource for studying behavioral change on a large scale. Online personal and social data constitute a rich source of information for studying human behavior; however, many predictions and analyses conducted in the digital space may present a distorted representation of the real world, as biases—particularly in user populations—exist across all social platforms, which can influence individual behavior (Ruths and Pfeffer, 2014). A study investigating the effects of social media on student behavior yielded interesting results, indicating that students are aware of protecting their social identity and that social media fulfills their need for respect, which positively impacts their social and mental health (Kaya and Bicen, 2016). Therefore, these networks have significant potential to influence behavior and modes of interaction in urban public spaces (Humphreys, 2010). Research has also shown that these networks can influence different individuals' perceptions of various urban spaces through images of those spaces created in the digital realm. For example, the frequency of mentions of a location's name on Twitter was significantly associated with its perceived beauty and role in the daily life of the local community. Similarly, the frequency of mentions of registered locations on Instagram (Instagrammability _ was linked to the perception of a place as an architectural landmark and tourist attraction. Furthermore, the frequency of references to a location on Twitter, Twitterability, correlated with the perception of its beauty and its connection to the daily lives of communities (Huang *et al.,* 2021). While the existing theoretical literature offers valuable insights into the influential role of social media in shaping collective movements and behaviors of individuals, as well as its intricacies in guiding people's decisions and choices, a theoretical framework has been developed at this stage through the integration of these theoretical perspectives and empirical research to understand the opportunities and threats of social networks in relation to public behavior in urban spaces (Fig. 2). The virtual space should not be viewed as a flat and equal realm; rather, much like the physical world, it is fragmented by social stratification, wealth, education, and gender (Faris and Rahimi, 2015). Although a literature review indicates that

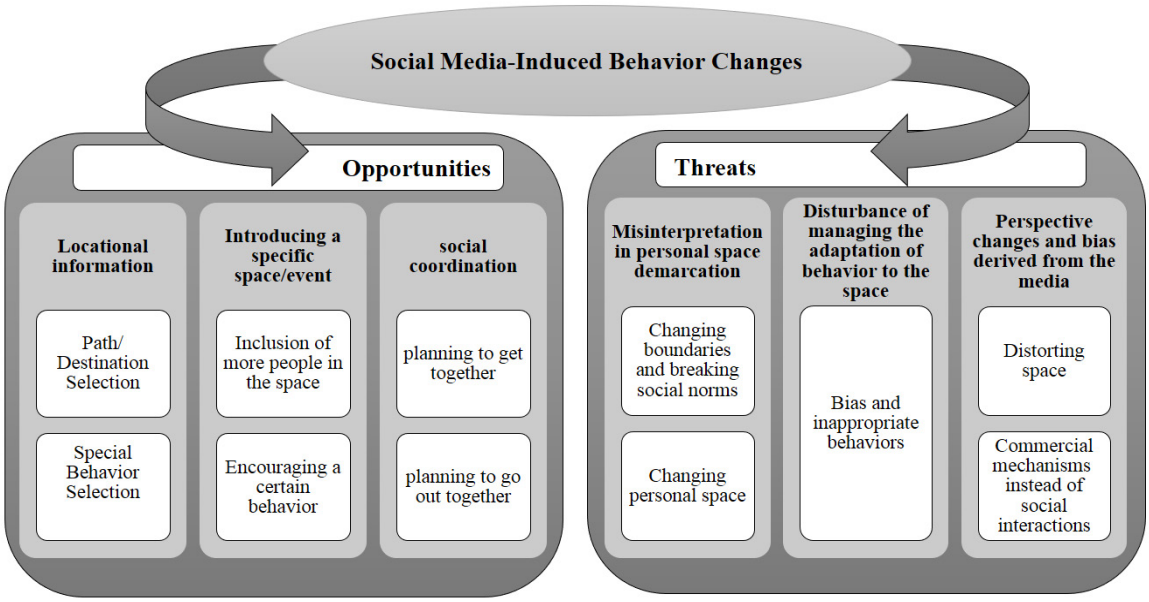


Fig. 2: A framework of how social media shapes public behavior.

social networks can influence emotional responses, identity construction, mobilization, and place perception across various contexts, the mechanisms through which online representations, norms, and biases shape everyday spatial practices have not been sufficiently theorized or empirically examined. This conceptual gap is particularly evident in Middle Eastern countries, where socio-cultural norms, gender visibility, and patterns of public presence differ significantly from those in Western urban settings—yet are largely absent in existing research on social media and urban space. Therefore, the aim of proposing this framework in the present study is to provide a basis for assessing the influence of social networks on individuals' spatial behavior in Iran's urban public spaces, with a focus on the city of Sanandaj. This framework will be developed and subsequently evaluated and analyzed through walk-along interviews with individuals and the creation of behavioral maps in later stages of the research.

Gender and urban public space as a heterogeneous behavioral context

Many studies have recognized gender differences in cities and highlighted gender inequalities in urban spaces (Day, 1999; Jalalkamali and Doratli, 2022; Jo *et al.,*2020; Listerborn, 2020; Peake, 2020; Polko and Kimic, 2022; Sági, 2022; Wu *et al.,* 2022). While we are familiar with the phenomenon of urban spaces being highly segregated by income, social class, and race, urban spaces are not consciously segregated by gender. Indeed, the aim has always been to make these spaces inclusive. But social norms and traditional definitions based on discussions of 'masculinity' and 'femininity' also inevitably have a profound impact on the urban experience and how urban spaces can be used, sometimes leading to inequalities in use that predominantly favor male dominance. Statements such as "He is really masculine" (strong, silent, authoritarian) or "She is a desirable girl" (beautiful, talkative, caring) (Jarvis *et al.,* 2009) indicate that there are significant differences between traditional and modern areas in terms of behavioral restrictions for women in public spaces (Jalalkamali & Doratli, 2022). In addition to social and cultural norms, the physical structure of public space itself influences the types and patterns of observable behavior, and human behavior and experiences in public space can be influenced by the physical and ecological characteristics of the built environment (Rasoulpour *et al.,* 2019). In addition, a high-quality urban environment leads to a greater diversity of behavioral patterns and cognitive relationships (Ahmed and Neima, 2020). Researchers believe that social behavior in public spaces tends to

be concentrated in centrally located and highly symbolic public places, and despite the increasing popularity of virtual public spaces, physical public spaces continue to provide a vibrant environment for public and private behavior (Liao *et al.,* 2012). On the other hand, social networks have the power to change the traditional ways people communicate in public spaces (Nguyen *et al.,* 2019). In relation to the urban environment, we consistently deal with a spectrum of possibilities. This is because the environment provides a wide range of opportunities for decision-making; environmental conditions make certain decisions and behaviors (and consequently their outcomes) more probable than others for individuals (Tigran *et al.,* 2020). For example, excessive traffic congestion affects people's perception of environmental safety (Mohamed and Stanek, 2019). Individuals can shape their environment in ways that enable various behaviors within urban spaces. It seems that in all of the above cases, the moderating role of social media (Pan *et al.,* 2017) in studying behavior change and moderating and reinforcing certain behaviors and activities in public spaces is worth exploring and evaluating. Accordingly, this research investigates how the influences of social media intersect with gender-specific experiences of public space and how these dynamics manifest in the study area.

Regional insights into public behavior and gendered urban experiences

Recent studies from Iran and neighboring countries provide evidence on how behavioral patterns in urban public spaces are shaped by gender (Haghighi *et al.,* 2021; Jalalkamali and Doratli, 2022), cultural norms (Rafatjah, 2012), and socio-political conditions (Askarizad, He and Dastoum, 2025). However, research directly examining the interplay between social media and behavior in public spaces within this region remains limited. The existing theoretical literature emphasizes the differences and gender inequalities in the use of and access to urban public spaces (Hashemi, Hosseinian and Moradi, 2021), as well as issues such as safety (Avar and Karimi, 2025), social surveillance (Arjmand, 2016), social expectations, and the unequal experiences women have in public space (Mohammadpour and Abbaszadeh, 2024). Parallel studies from countries with socio-cultural structures similar to Iran, such as Turkey, similarly emphasize the influence of social norms, gender stereotypes, and the socio-spatial construction of gender in the city on women's access to and mobility within urban spaces, as well as the gendered imbalance in the use of these spaces (e.g., Beyazit *et al.,* 2023; Cag and Ozkazanc, 2025; Kaya, 2023; Yazici, 2019). Similar to global trends, Iran has also witnessed a daily increase in users across various social networks. The influence and often indirect, yet observable, roles these platforms play in information dissemination and collective movements—as well as in shaping urban mobility and public perception—alongside their complex impact on the offline world, have been briefly discussed (e.g., Faris and Rahimi, 2015; Khiabany, 2015). However, studies have seldom considered behavioral changes in urban public spaces as a direct or indirect result of online interactions, particularly regarding the gendered consequences of social media content associated with specific urban locations. Therefore, this study aims to fill this research gap by integrating the proposed theoretical framework with a targeted empirical examination of a Middle Eastern context, specifically investigating the direct influence of location-related posts on social networks on gender-based behaviors in the public spaces of Sanandaj.

MATERIALS AND METHODS

Survey design and data collection

In this study, a combined method is used to identify gender-specific behavioral patterns in the selected public space, to understand the type of active users in each space, and to improve the validity of the research findings through the triangulation method (Bans-Akutey and Tiimub, 2021), as well as to gain deeper insights and a better understanding of the phenomenon. In the first phase, the behavioral mapping technique is used to observe behaviors and identify recurring patterns. Based on environmental observations on five different days over three months, the highest number of individuals present in the space during the busiest hour, i.e., just before sunset, will be determined. The density measurements were carried out from March 11, 2023, to May 5, 2023. The highest concentration points, perching areas, and movement paths of individuals were recorded and displayed in behavioral maps using AutoCAD and GIS software. In the second phase, the walk-along interview technique is used for an in-depth investigation of the nature of individuals and groups in the selected public space. This technique is preferred

Table 1: The total number of participants in the walk-along interviews conducted in Ferdowsi, categorized by age and gender.

Gender of space users	50 and above Elderly	30 -49 Middle-aged	20 -30 Young	10 - 20 adolescent	3 -10 Child	Walk-along groups	Duration of companionship
Male	4	10	7	24	1	28	1064 Minutes
Female	3	10	5	2	1		
Total	7	20	12	26	2		
Total of 66 individuals							

for capturing behavioral outcomes due to its dynamic question-and-answer format (Barron *et al.,* 2021; Skov *et al.,* 2019). To ensure diversity, individuals of all ages, both genders, and different social groups were relatively evenly represented in the selection process. To achieve repetitive and saturated research results, walk-along interviews were conducted with different groups. In total, 66 people participated in Ferdowsi Street in winter and spring 2023, forming 28 different groups. For example, there were groups consisting of young people, children, and older people (Table 1). Participants for the walk-along interviews were selected through purposive sampling, ensuring representation across gender, age range, and general social background (including students, various socio-economic groups, families, youth groups, and older visitors). The accompanying duration for each group varied, ranging from a minimum of 10 minutes to a maximum of 1 hour and 15 minutes, depending on the willingness of participants and the saturation of responses for each thematic component. These accompanying sessions continued until sufficient answers were obtained for the research components, varying for each group. In the final phase, to conduct thematic analysis, the walk-along interview transcripts for each group were converted into text files for use in NVIVO software. The coding process followed a hybrid deductive-inductive strategy: First, deductive codes were derived from the adapted behavioral observation framework (which will be explained in detail in the following section) (Gehl and Svarre, 2013; Whyte, 1980). Subsequently, inductive codes emerged from recurring themes in the participants' narratives. Additionally, the correlation between certain significant components was discussed and examined and was reported in the findings of the research.

Monitoring cycle for analyzing social media-induced behavior changes in Ferdowsi Street

In examining walk-along interviews, this study adopts a behavior surveillance cycle (Fig. 3) derived from a combination of behavior typologies in urban space by Gehl and Svarre (Gehl and Svarre, 2013) previously introduced by Whyte (1980), with slight modifications and the addition of indicators on the manner of behavior in space and the influential factors of virtual space on behavior. Ultimately, it uses behavioral map analysis. In this cycle, each indicator is used to investigate in walk-along interviews and includes the following aspects:

(1) Behavioral Identification in Urban Space, including: Who? (identifying space user groups, gender, and specific groups), What? (necessary, optional, and mandatory activities in the space), How? (the manner of behavior in space and personal spaces), When? (timing and duration of activities), and where? (tracking specific behavior points and behavioral locations).
(2) Identification of social media contributions regarding the selected public space, including popular posts on the most widely used social networks in the city, geo-tagging and specific points mentioned on social media platforms, and keywords related to Ferdowsi Street, such as buildings, surroundings, and specific events in the space.
(3) Geographic Information System (GIS) analysis and behavior mapping, including: spatial distribution of users by gender and age during peak hours, density analysis, and identification of high-activity behavioral nodes.

Ferdowsi Street: Setting the scene

Ferdowsi Street in Sanandaj plays a crucial role in the center of the city due to its historical and social importance to the central fabric of the city (Fig. 4), its commercial and arterial centrality between the old and new squares of the city (Enghelab and Azadi squares), and its high pedestrian traffic (Rezaee

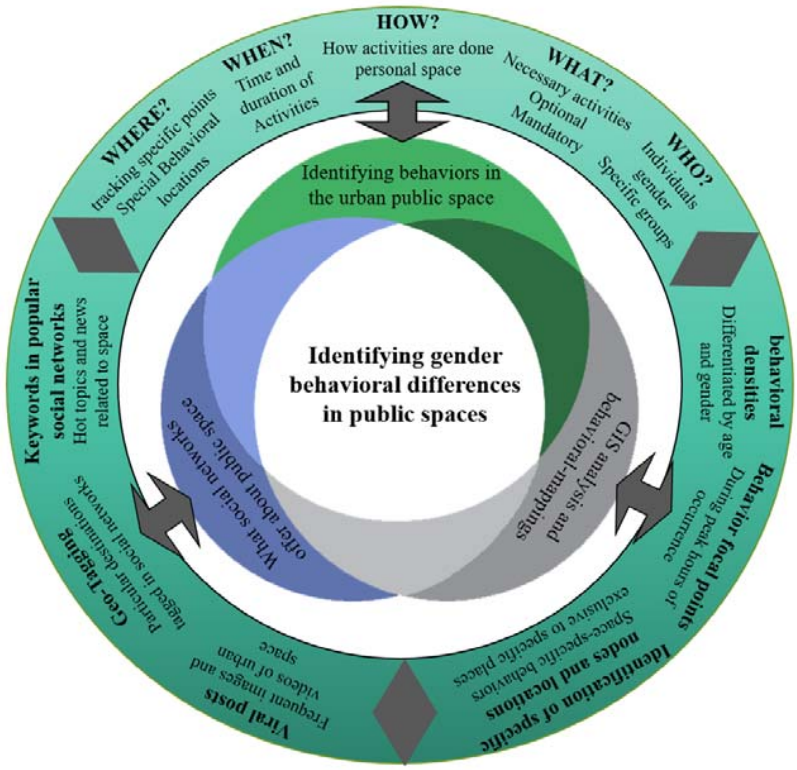


Fig. 3: Monitoring cycle of gender behavior differences in public space based on the social media effects

and Nasiri Ardali, 2019). In 2020, this street was redesigned and transformed into a pedestrian zone. The new design banned car traffic while formalizing the street vendors, who previously operated informally, and acknowledging their presence in this space. This street, which is an important access to the main centers of the city, the historic market, and the commercial districts, is always very busy. Due to the presence of street vendors, the movement and vibrancy of the square continue until late in the evening (around 22:30) (Fig. 5). Its continuous social presence and symbolic centrality make it an ideal site for examining gendered patterns of public behavior.

Ethical considerations

In conducting this research, ethical considerations were given paramount importance to ensure a responsible and respectful examination of gender-specific behavioral differences. Accordingly, the ethical frameworks and standards of the *Helsinki Declaration* were followed. In line with this declaration, informed consent was obtained, confidentiality and anonymity were ensured, and the general welfare of participants was safeguarded throughout all interviews and data collection processes. Furthermore, measures were taken to protect the privacy of participants, ensuring that all information obtained during the study remained confidential and was used exclusively for this research.

RESULTS AND DISCUSSION

Gendered behaviors and social media influence in Ferdowsi Street

Overview of thematic analysis

Walk-along interviews were analyzed using NVivo with both deductive coding based on the "Monitoring Cycle of Gender Behavior Differences in Public Space" and inductive coding for emerging themes. A total of 28 groups (66 participants) of diverse ages, genders, and social backgrounds were included to ensure representativeness (Table 2). Coding focused on five key indicators: Who, What, How, When, and Where, as well as the influence of social media on behaviors.

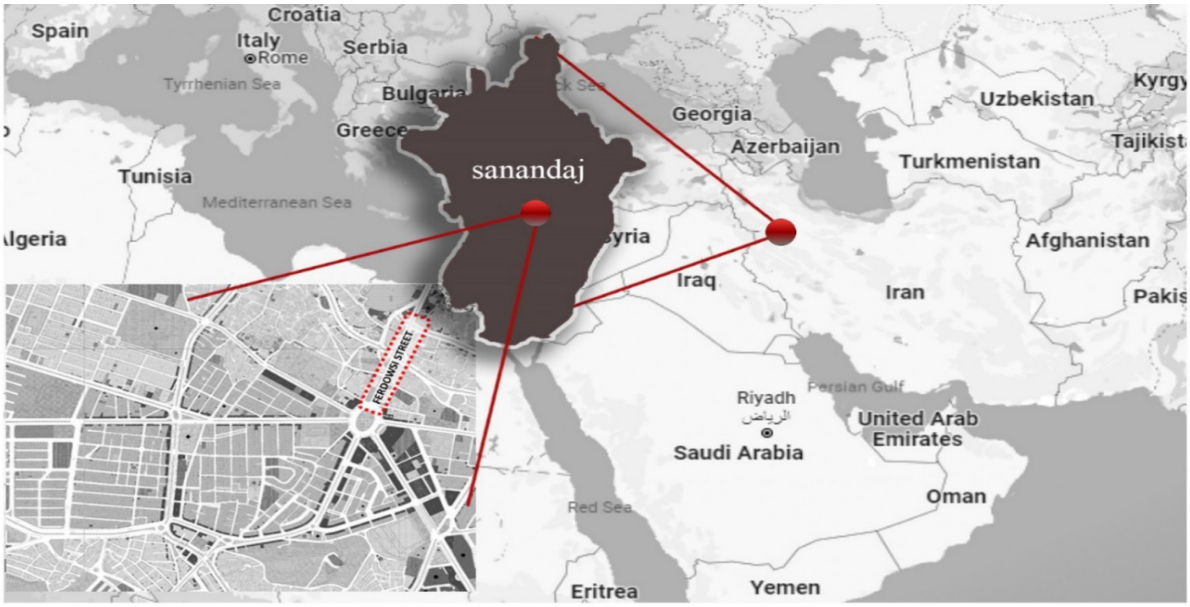


Fig. 4: Geographic location of the study area, Ferdowsi Street in Sanandaj, Iran.



Fig. 5: A Glimpse into Daily Life and Interactions on Ferdowsi Street, Sanandaj

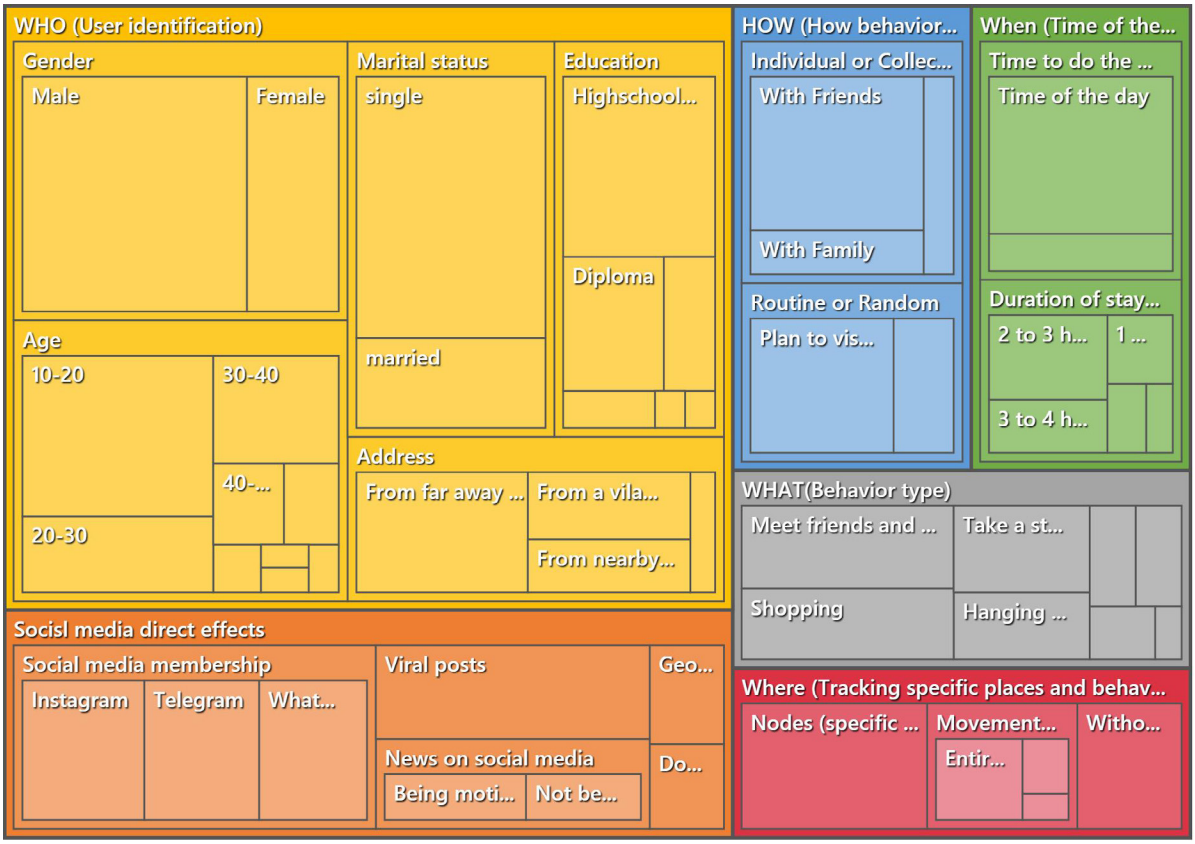


Fig. 6: Thematic Hierarchy of User Behaviors on Ferdowsi Street (Thematic Coding Results).

Additionally, the chord diagram (Fig. 7) illustrates the correlation between demographic groups and engagement with location-based viral posts on social media. The strongest interactions belong to two clusters: young women (20–30) and adolescent boys (10–20), revealing a gendered polarization in social-media-driven presence.

Spatial distribution of gendered behavior

Behavior mapping and GIS analysis show a clear gendered spatial pattern (Fig. 8). Women, especially younger women, concentrate in the central part of Ferdowsi Street, whereas men dominate peripheral nodes such as the Naser-Khosrow entrance and the Namaki Bus Station. Young men more frequently occupy one linear movement corridor leading to the BaanBashgah market, indicating a strong directional pattern in male mobility. The spatial segregation reflects gendered comfort zones and perceived safety, revealing masculine clustering in transitional or high-visibility nodes and more distributed female presence along commercial fronts. The density maps also revealed that social media exposure amplifies these patterns: locations frequently tagged or advertised online drew adolescents and young adults, creating digitally mediated nodes of activity.

Key behavioral patterns

The analysis reveals key user demographics and behavioral patterns for Ferdowsi Street (Table 2). A significant portion of users are young males who often visit with friends, primarily for socializing. Furthermore, social media plays a substantial role in attracting visitors and influencing their movements within the space. The street functions as a citywide informal social hub, attracting male youth and facilitating peer-group clustering. Women's use remains more functional and spatially cautious.

Social media influenced patterns

A gendered pattern of social media influence on spatial behavior was observed. Teenage boys demon-

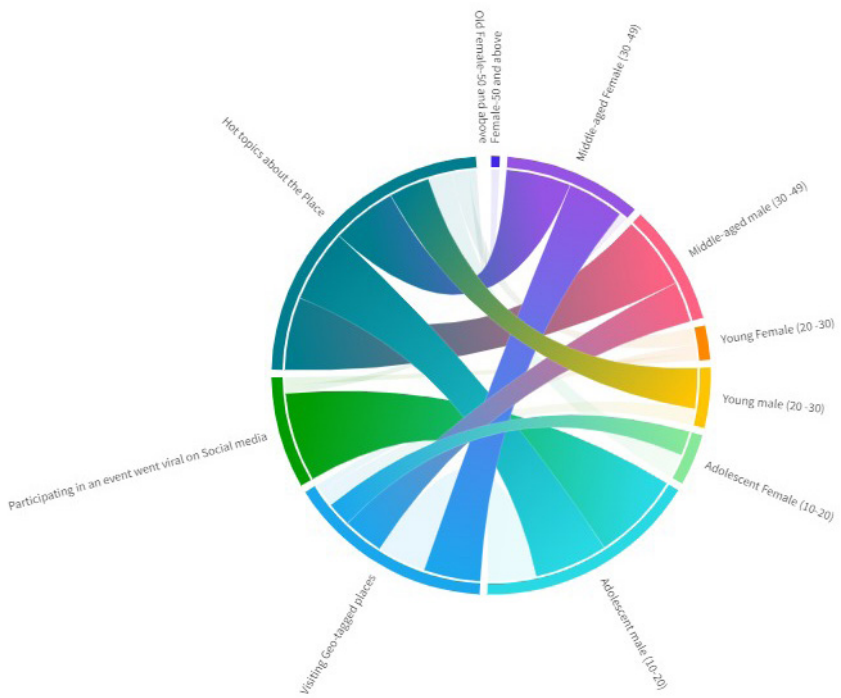


Fig. 7: Correlation between demographic groups and location-oriented social media posts, 2024 (Walk-along interviews).

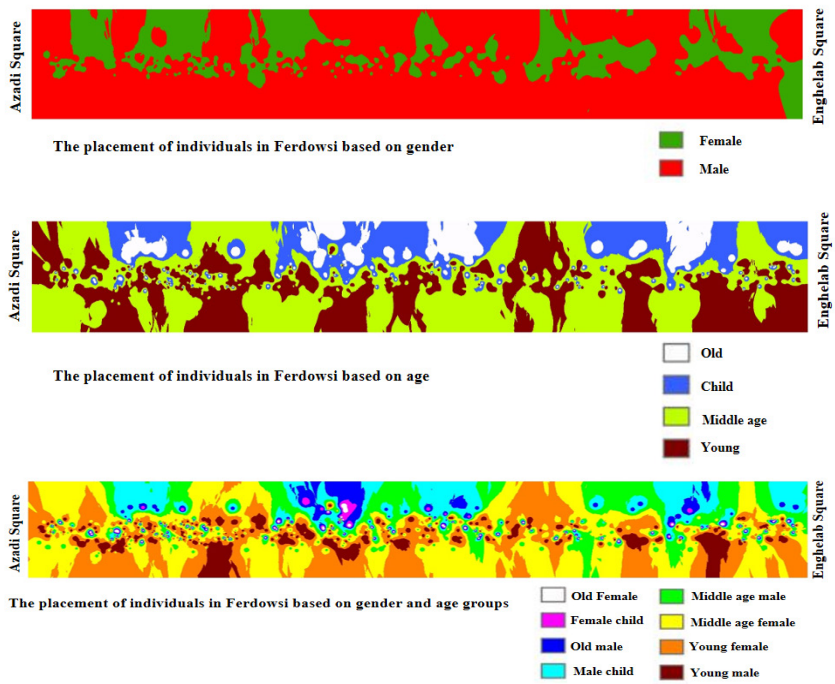


Fig. 8: Spatial distribution of gender and age groups along Ferdowsi Street, based on behavior mapping, 2024.

Table 2: Summary of key behavioral patterns on Ferdowsi Street

Behavioral Indicator	Dominant Finding	Notable Gender Trend
WHO (Users)	• 34% are adolescent/young males (15-25). • 36% have a high school education or are students. • 31% come from distant city neighborhoods; 18% commute from suburbs/villages 2-3 times/week.	High male overrepresentation
HOW (Behavior & Activities)	• 41% of visits are with friends; 12% are with family. • 31% coordinate visits in advance for planned activities (e.g., walking, shopping). • 13% of visits are unplanned (e.g., passersby, aimless wandering).	Strong male clustering in peer groups
WHAT (Activity Type)	• 22% meet friends (average 2-3 hours). • 13% shop (in three distinct patterns). • Other activities: aimless wandering (15%), socializing/hanging out (12%), business (6%), people-watching (6%).	Women engage more in shopping/errands; men in hanging out
WHEN (Timing & Duration)	• 51% are frequent users (daily or 2+ days/week). • Preferred time: evening/sunset (34%), then morning (10%). • Longest stays (2-4 hours) are common among young boys and those from distant areas.	Teenage boys show the longest presence
WHERE (Location)	• Highest concentration (31%) of young boys/adolescents at specific hangout spots. • Elderly men (14.4%) and middle-aged women (4.7%) use market entrances. • 18% occupy space without a specific purpose; most (64%) traverse the entire street.	Women favor commercial areas and mid-street
SOCIAL MEDIA INFLUENCE	• Top platforms: Instagram (28.8%), Telegram (27.3%), WhatsApp (25.8%). • 55% of social media users report that posts changed their movement/destination. • Teenage boys are most influenced by viral/location-tagged posts (56.7% of the affected group). • Young women are uniquely influenced by cultural event posts (39%). • Middle-aged users are influenced differently: men by news, women by commercial ads.	Social media influences men (teen and middle-aged) through trends, news, and peer-based content, while it influences women (young and middle-aged) through experiential, cultural, and commercial content.



Fig. 9: Word cloud generated from walk-along interviews.

strated the strongest behavioral response, particularly to Instagram advertising, geotagged posts, and viral content. Notably, 41% of this group were directly influenced by or aware of protest-related posts during September–October 2022, indicating a heightened sensitivity to event-driven content. In contrast, young women were primarily influenced by posts concerning cultural events, while middle-aged users exhibited divergent motivators: men responded mostly to news content, and women to commercial posts. Overall, the influence of these platforms on movement was significant, with 55% of social media users reporting that they had altered their route or destination based on location-triggered content. A clear gendered digital-to-physical transfer is evident. Adolescent boys translate online content into spatial presence more rapidly, while women respond selectively to specific content types such as cultural or commercial posts. The word cloud (Fig. 9) visualizes prominent interview terms such as friends, evenings, Instagram, and hanging out, reflecting the social nature of the street and the centrality of peer-group presence.

Gendered spatial dynamics and digital mediation

The findings of this study reveal that Ferdowsi Street operates as a heterogeneous behavioral context in which physical design, cultural norms, and digital infrastructures jointly shape gendered patterns of presence. Social media functions as a mediator of gendered access, enhancing or constraining who moves where, when, and for what purpose. The findings indicated the congregation of adolescent boys at entry/marginal points; the movement and lingering of women in the central section; friendly group behaviors; and the immediate influence of location-based posts on adolescents' destinations. Lefebvre's concept of the "social production of space" emphasizes that space is not merely a backdrop for human activity but an active element in shaping social relations (Pradeep, Jisha, Paul, and Benziker,

2024). Space is produced by social relations; people's material behaviors (movement, stopping, direction of movement) are symbolic of social structure. When adolescents cluster in marginal hubs, this everyday practice reveals a picture of social power distribution and agency. Social networks perform the work of distributing spatial information (geotags, viral posts), and this information is rapidly translated into "where I should go." Thus, spatial practice transforms: digitally prominent locations become physical hubs. On Ferdowsi Street, adolescent and young men are directly influenced by location-based posts and viral content, whereas young women primarily respond to cultural or advertising-related content. Given that social networks can influence individual behavior in urban space—even reinforcing or altering informal social constraints and norms (Carrier, 2018; Swingle, 2016; Van Dijck and Poell, 2015)—social media thus plays a mediating or reinforcing role in gendered access to space. The impact of location-based posts on young and adolescent boys demonstrates that digital visibility directly shapes patterns of movement and pause in space. Social media streams and networks guide behavior, with the digital environment functioning as a "social space" that enables social comparison and valuation (Bayer *et al.,* 2020). Both physical and digital spaces simultaneously contribute to the reproduction of gender norms and roles, and the commodification of public space through social networks becomes tangible. Commercial posts and digital advertisements highlight specific sections of Ferdowsi Street; middle-aged individuals, in particular, respond to advertising-related posts; parts of the street effectively become branded. In the digital age, corporations, business pages, and algorithms have assumed the roles of "designer" and "arbiter of meaning": they construct the "visual framework" of space and suggest which places hold economic and social value. Drawing on what Lefebvre terms the representational or abstract space—referring to homogenized, commodified spaces under capitalist logic (Lefebvre, 1991)—this logic is now measured by "likes, reach, and views"; digital quantitative data transforms into capital and a metric of a place's value. In other words, space becomes designated by the logic of platforms and the market. Young women often target specific cultural events on Ferdowsi Street and are drawn there through social media posts; the presence of men at entrances has, in a way, become a "display of power/visibility"; certain spaces are felt to be "off-limits" for women. This is precisely where Lefebvre's *represented space* transforms into *lived space* (Schmid, 2022). These are places imbued with symbolic and emotional weight, where everyday experience gains meaning. Instagram posts construct a desirable image of a place (the space of representation), and this image translates into lived experience: for instance, when a spot is labeled as "youthful and masculine," women's presence there becomes conditional and constrained. Digital representation on social networks shifts a place from a local memory/experience into a "comparable image"; people decide whether to be present based on that image—meaning representational spaces are shaped through digital content, which in turn reproduces or alters the lived experience. Therefore, it can be argued that the representation of a place on social media unfolds in the following manner: First, 1) Posts, advertisements, and platform-generated narratives construct the concept of a place (defining it as "marketable" or "youthful," for example). 2) People then act based on these images—they either visit the place or avoid it. 3) A collective experience of the place emerges, which in turn reinforces new representations. Consequently, a cycle of spatial production arises, intertwining the digital and the physical objective space, and either reinforcing or reproducing gender inequalities. In line with our findings, prominent locations are valued based on quantitative metrics (tags, likes), and this valuation determines physical presence. The result is a reduction in differential spaces—places for diverse, non-homogeneous experiences. For women, this risk is twofold. Either a space becomes commodified and appealing only to culturally sanctioned users (e.g., young men), or networks create performative and temporary spaces (such as events) for women, which lack social sustainability. The findings of this research confirm that the production of space today incorporates a digital layer. This demonstrates that in contemporary discussions on urban spaces, relying solely on Lefebvre's triadic interpretation is insufficient; one must also acknowledge the "blurring and dissolution of boundaries between digital spatial representation and physical spatial production." Social media accelerates the performative production of place, and these representations rapidly translate into spatial practices. Consequently, gender inequalities are either reinforced or, at times, reconfigured. For

studying spatial justice and gender-sensitive design, "digital representations" must be considered as one of the influential factors in the production of space. Urban planning must move beyond "purely physical design" and incorporate digitally oriented policies into its agenda. Examples include regulations on local advertising on social media, planning for "equitable performative spaces," and supporting local events to enhance women's presence in urban public spaces. To change this condition, intervention is required at both the level of physical design and digital governance to transform space from a commodity-driven state back to an inclusive and accessible one. In conclusion, the hybrid physical-digital nature of public space underscores the necessity for *social media-informed urban design*. This approach acknowledges how online content shapes offline spatial behavior. Similar research in contexts comparable to Iran and other Middle Eastern countries—where socio-cultural norms profoundly influence spatial movement and accessibility—can contribute to a better understanding of the interplay between digital platforms and physical space, ultimately advancing the goals of spatial inclusion and justice.

Theoretical contributions

The results of this study advance the understanding of gendered public space by demonstrating that Lefebvre's triadic framework for interpreting urban space must, in the contemporary context, be understood through a broader lens that incorporates digital representation as an active layer in spatial production. Social media platforms shape representational space by framing places as desirable, masculine, commercial, or culturally coded. These representations, in turn, rapidly translate into lived spatial practices. The findings point to the emergence of a *socially mediated cycle of spatial production*, where online visibility, tags, and algorithmic reinforcement determine physical presence, comfort, and access in real-world space. This contributes a new conceptual framework for public space research, articulated here as *social media-informed urban design*.

Policy and urban design implications

From a policy and design perspective, the results indicate that promoting inclusion in public spaces cannot rely solely on physical and structural interventions. Urban management must address the digital and virtual dimensions of spatial inequality. Consequently, designing equitable and gender-sensitive public spaces requires coordinated interventions across both virtual and real spheres, such as regulating the commercial branding of places on social media; supporting cultural events centered on women in urban spaces; diversifying performative spaces to reduce gender-based clustering; and enhancing safety and visibility in peripheral nodes dominated by male presence. Urban planners and municipalities must recognize and integrate the impact of digital placemaking as part of spatial management strategies, especially in socio-cultural contexts like Iran, where informal norms strongly shape spatial movement and access.

Limitations

The present study acknowledges several limitations. First, the research focuses on a single urban site in Sanandaj, Iran, which limits the generalizability of the findings. Second, observational data and in-person interviews were collected during specific time periods; seasonal variations or long-term behavioral shifts were not captured, which could influence the long-term effects of social networks. Third, the study relies on participants' self-reported interactions with social media, which may not fully reflect the nuanced impacts of social platforms and the algorithms shaping them.

Directions for future research

Future studies could usefully complement the results of this research by conducting multi-location comparisons across cities in the Middle East with similar socio-cultural structures. This would help identify what other behavioral patterns dominate urban public spaces under the influence of social networks and test this study's findings in different contexts. Further research should also investigate algorithmic placemaking, longitudinal shifts in gendered spatial behavior, and the role of platforms beyond Instagram. Integrating digital ethnography, sentiment analysis of location-based posts, and real-time mobility tracking could provide deeper insights into how digital representations evolve into real-world spatial practices. Expanding this line of inquiry can contribute to developing a comprehensive framework for social media-informed urban design capable of advancing spatial justice and gender equality.

CONCLUSION

This study examined Ferdowsi Street as a hybrid physical-digital public space in which gendered behaviors, urban form, cultural norms, and social media influence intersect, combining qualitative and quantitative methods, including thematic analysis of walk-along interviews, behavioral mapping, and GIS analyses. The findings reveal a clear pattern of gendered spatial distribution, with adolescent and young men clustering in peripheral, high-visibility nodes while women's presence remains concentrated in central and safer segments. Social media significantly mediated these behaviors: adolescent boys responded strongly to viral, geotagged, and event-driven posts, whereas young women tended to follow cultural or commercial content. These patterns demonstrate that spatial behaviors today are co-produced by physical design and digital representations.

AUTHOR CONTRIBUTIONS

A. Nasri conceived the original research idea, designed the methodology, collected and validated the data, performed formal analysis and interpretation of results, conducted the literature review, wrote the original draft (including theoretical foundations and manuscript text), and handled editing and final preparation of the manuscript. K. Habibi contributed to the conceptualization of the study, supervised the research process, ensured methodological validity and reliability, and provided critical revisions to the manuscript. M. Saidi (Corresponding Author) oversaw the overall research integrity, assisted in data analysis and interpretation, validated analytical frameworks, supervised data interpretation, contributed to critical revisions for intellectual content, and finalized the manuscript for submission.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the research, authorship, or publication of this article. All ethical principles in research, including informed consent, data integrity, and originality of the work, have been strictly adhered to.

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ABBREVIATIONS (NOMENCLATURE)

SNSs	Social Networking Sites
GIS	Geographic information system

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ORIGINAL RESEARCH PAPER

Political parties, communication strategies, and public opinion after the 2024 regional elections

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ABSTRACT

BACKGROUND AND OBJECTIVES: Political parties played a strategic role in preparing and promoting candidates for the 2024 regional head elections in Indonesia, which were held nine months after the presidential election. The political dynamics from the presidential contest were expected to influence public perception and candidate selection at the regional level. This study examined the role and political communication strategies employed by political parties to promote their cadres in the 2024 regional elections.

METHODS: This research adopted a mixed-methods approach, combining qualitative methods—interviews, observations, and literature studies—with quantitative analysis through surveys distributed to 117 respondents across West Java. The qualitative component explored communication patterns and internal strategies, while the quantitative component measured public opinion and media preferences.

FINDINGS: The survey results revealed that 42.7% of respondents supported PKS, followed by Gerindra (16.2%), PDIP (10.3%), Golkar (8.5%), and PKB (6%). Social media was the most utilized political communication channel, with 76.9% of respondents accessing messages through Instagram (61.5%) and TikTok (14.5%). Most political parties preferred to promote native cadres and conducted face-to-face campaigns in addition to digital outreach. The data showed that message consistency and community proximity were key variables influencing voter trust.

CONCLUSION: Political parties in West Java employed relatively similar communication strategies, integrating both digital and conventional media channels. Despite the proximity of the presidential election, its residual effects on public opinion during the regional elections appeared limited, due to the overlapping coalitions among parties. Internal cadre strengthening and social media engagement were pivotal in shaping favorable public perceptions.

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INTRODUCTION

Background of the study

Political parties have a central role in the democratic process, especially in formulating state policies and determining leadership figures at various levels, from national to regional (Fraccaroli *et al.*, 2022). Since the 1998 political reform, direct elections of regional heads have become one of the important milestones in Indonesia's democratic journey. This election not only opens up space for the involvement of the wider community in determining their regional leaders but also emphasizes the strategic role of political parties in selecting and nominating candidates who are considered capable of leading the region according to the aspirations of the community (Kristiyanto *et al.*, 2023). As part of the implementation of the 2024 simultaneous regional elections, political parties are expected to be able to screen prospective leaders who have vision, integrity, and can answer increasingly complex local and national challenges. Political communication conducted by political parties is one of the key instruments in the selection and socialization process of prospective regional leaders (Akyuz, 2024).

Problem statement

Political communication is one of the keys to success for the party as an articulation institution for the political organization of the community, through which the community is expected to become a dialogical bridge, a channel for people's aspirations, and ideas to be poured into programs offered during the election campaign (Baraybar-Fernández *et al.*, 2023). Windelesham (1972) states that political communication is the delivery of political messages that are deliberately carried out by communicators to communicants to make communicants behave in certain ways. In the era of fast-paced information, political parties utilize various platforms, ranging from mass media to social media to Artificial Intelligence (AI) technology to influence public opinion (Maximova & Lukyanova, 2020). By utilizing these various channels, political parties attempt to build a positive image of their candidates, as well as create a medium to accommodate the aspirations of their constituents (Magdaci *et al.*, 2022). This shows that political communication is a fairly effective way of shaping the public perception of prospective leaders, which has an impact on the determination of people's political choices (Antypas *et al.*, 2023). This is particularly evident among Indonesian voters who increasingly rely on social media as a major source of political information. Although the role of political parties in shaping public opinion and promoting prospective leaders is very significant, reality shows that there is a gap between expectations and reality in the selection of regional leaders. The hope is that political parties can produce leaders who have a good track record, integrity, and popularity, and are able to bring positive changes. But in reality, the figures that emerge are often chosen based on their popularity alone or even due to considerations of political pragmatism, not because of their quality as a leader (Al Izzati *et al.*, 2024). This has created a gap between people's expectations of ideal leaders and the figures that emerge. This gap is one of the focuses in the formulation of this research problem.

1) How do political parties, through their political communication, play a role in producing qualified regional leaders?
2) How does party-political communication shape public opinion regarding regional leader candidates after the 2024 elections?"

This question arises as a response to the phenomenon where political communication is often used not to promote the substantial quality of candidates, but to strengthen electability based on image strategies alone.

Literature review

Based on the above problem, this section reviews previous studies on political communication theory, the role of political parties in Indonesia's democratic context, and recent developments in post-election public opinion research. In addition, previous studies have focused more on the strategic aspects of political communication, such as how political parties create candidate images or design campaigns. However, this research offers novelty by examining how interactions between political parties and the public can shape a more holistic public perception of prospective leaders. The political world needs as much support as possible to succeed a party or candidate; the main key in the process is the extent to which the interaction is carried out; that is the main essence of political communication strategy (Papakyriakopoulos *et al.*, 2019). One of the political communication strategies used is political marketing (Ediraras *et al.*, 2013). Through marketing activities such as advertisements

and promotions, information and knowledge will be easily disseminated by the contestants (Arofah & Nugrahajati, 2014). Political marketing is carried out by involving TV, radio, newspapers, and pamphlets that need to be delivered to the public. Meaning in interactional political communication is not fixed. Instead, meaning is formed from the continuous interaction between the sender and receiver of the message. For example, a campaign promise delivered by a prospective leader can be perceived differently by various groups of people. In delivering political messages, persuasion strategies are used as a technique for delivering messages through campaigns, propaganda, and raising public opinion. Persuasion strategy is a tool used by organized groups to reach individuals who are psychologically manipulated and incorporated into the organization (Safiullah *et al.,* 2017). "The interactional political communication model describes political communication as a dynamic process in which meaning is formed through interactions between the sender and receiver of the message (Antir *et al.,* 2024). Nowadays, people are used to seeing banners, advertisements, and various types of political communication methods from political parties ahead of regional head elections (Glate *et al.,* 2024; Kübler *et al*., 2025). Along the roads, both in urban areas and on village roads, are full of banners of candidates from political parties. In addition, political activities such as mass gatherings and political campaigns, open debates and discussions both online and offline, which in the end all of these actions will form perceptions in the eyes of the community. Audiences interpret these actions based on their social and political context. In political communication, this interpretation process is key to understanding how political messages influence public opinion and shape perceptions of potential leaders or political parties.

Theoretical framework

This research is based on saturation theory, and its novelty mostly lies in its concept of an interactional political communication model. Political communication in this study is imagined as a two-way process; one that does not only mean sending messages from parties but the transmission of meaning and formation of perception through parties-public symbolic interactions. This model also enables research to study more sophisticated communication dynamics, such as how the symbols, messages, and actions of political parties are interpreted by citizens. Unlike linear models that assume communication runs in one direction, this model emphasizes the non-systemic and non-linear nature, where the meaning of messages continues to develop based on interactions between individuals or groups. The function of political communication is a political structure that absorbs various aspirations, views, and ideas that develop in society and channels them as material in determining policies. Thus, the function of bringing the flow of information back from the community to the government and the government to the community. In the political context, messages conveyed by prospective leaders or political parties are not taken for granted but are interpreted according to the social, cultural, and political background of the audience. Political communication in a political party is a link for all information or messages, both verbal and nonverbal, to the wider community and members of the political party itself (Falkenberg *et al*., 2024). One of the main concepts in this model is self and other, which refers to the active role of the sender and receiver of the message. Political communicators, such as leadership candidates not only convey messages, but also build a self-image that the audience wants to accept. Conversely, the audience, which consists of people with diverse backgrounds, not only receives messages passively but also interprets them according to their experience and understanding. In this case, political parties also function to discuss and disseminate plans and policies that will be carried out (Arranz *et al.,* 2024). This shows that political meaning is contextual and can change depending on the situation and interactions that take place. Furthermore, meaning in political communication always pursues public opinion, because it is an early indication of public perception of the figure. Public perception is an accumulation of image-building activities managed in public relations management (Gesualdi, 2018). Symbols also play an important role in this model. In political communication, symbols such as slogans, logos, or body language have active and reflective meanings. These symbols help build an image and a political message that is easier to understand, although the interpretation remains variable depending on the audience. Therefore, the same political symbol can be interpreted differently by different groups of people. These symbols in the

media as a political communication process become one of the points where the process of forming political leadership of a prospective leader takes place more complexly. To visualize the theoretical relationships described above, this study develops a conceptual framework that illustrates how political communication operates as an interactional process between political parties and the public. The model emphasizes the two-way, dynamic exchange of meaning, showing how symbolic messages—such as narratives, images, and gestures—shape citizens' perceptions of leadership and public opinion in the post-election context. Fig. 1 below illustrates the interactional political communication model and its influence on voter perception.

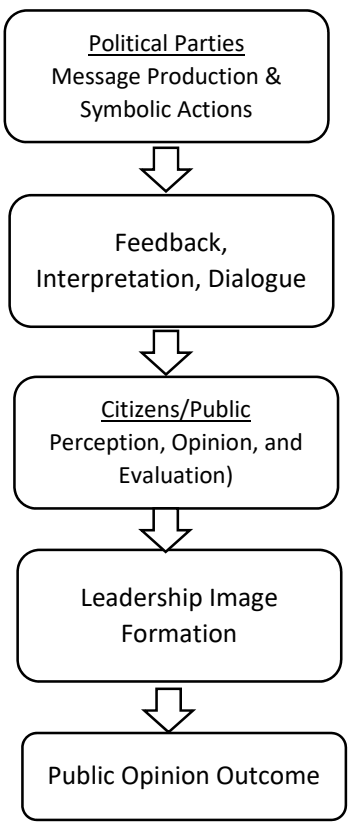


Fig. 1: Conceptual Framework of Interactional Political Communication

This framework illustrates a reciprocal communication loop were political parties act as message senders and citizens as active interpreters. Through continuous symbolic interactions, meanings are co-constructed, leading to public perceptions that shape the legitimacy and image of regional leadership. The arrows indicate dynamic feedback and non-linear interpretation processes, consistent with the interactional model of political communication (Antir *et al.,* 2024).

Research objectives and questions

Building upon the theoretical framework, this study focuses on understanding how political parties use interactional political communication to shape public perception and voter decisions in Indonesia's post-2024 regional election context. Political communication in this research is conceptualized as a two-way process involving the exchange of meaning between parties and citizens through symbols, messages, and social interactions. Accordingly, the objectives of this study are to:

1. *Analyze the communication patterns and strategies used by political parties in shaping public perception of regional leadership after the 2024 elections.*
2. *Explore how symbolic and interactional political messages influence voters' perceptions and decision-making processes*.

Through this analysis, the study aims to provide insights into how interactive and dialogical communication can strengthen the democratic function of political parties and promote more informed and participatory political engagement in Indonesia.

Significance of the study

This research contributes to the understanding of political communication in Indonesia's post-election context, particularly how parties manage meaning through symbolic and dialogical engagement with citizens. The findings are expected to inform:

1. *Academia, by strengthening models of interactional political communication;*
2. *Political practitioners, by identifying effective strategies to balance image politics and substantive political education;*
3. *Policy and governance, by promoting ethical, participatory, and transparent leadership formation in regional contexts*.

MATERIALS AND METHODS

Research design

This study employs a mixed-methods design, combining qualitative and quantitative approaches to examine the phenomenon of political communi-

cation and the role of political parties in determining regional leadership candidates ahead of the 2024 elections in West Java. Qualitative research observes people in their environment interacting, by trying to understand the language and interpretation of the object being studied in the surrounding world (Creswell, 2002). This method allows researchers to explore the factors that influence the political communication process and party behavior in selecting prospective leaders. Qualitative research is conducted in natural conditions, where the researcher acts as the main instrument to observe and collect data directly from the field. With an exploratory and descriptive approach, this research seeks to map the problem in depth and explore the causes that influence the political process.

Participants and sampling

An inductive approach is used in this research, where the researcher concludes findings based on data and facts collected in the field. This induction process starts from the collection of general information, which is then analyzed to form more specific conclusions related to the role of political parties in determining regional leader figures. Through this method, researchers can describe and understand broader political interactions and find relevant patterns and relationships between political communication and the creation of public opinion. The research subjects consisted of key informants who were political party leaders at the central and regional levels, as well as additional informants such as politicians and community leaders. The key informants in this research are the key informants in this research included Informant A (PKS leader), Informant B (PDIP representative), and Informant C (NasDem official), each holding leadership roles at the regional level.

Instruments and data collection

In this case, the researcher limits the informants in purpose of obtaining data and informants that can be accounted for, comprehensive, precise, and accurate. Informants consist of representatives of the top 9 political parties in Indonesia. Primary data was collected through observation and in-depth interviews with these informants. There are several methods in data collection carried out in qualitative research, namely: First, interviews are a means of rechecking or verifying information or information previously obtained. The interview technique used in qualitative research is the in-depth interview, which is the process of obtaining information for research purposes with questions and answers while meeting face to face between the interviewer and the informant or interviewee, with or without using an interview guide, where the interviewer and informant are involved in a relatively long social life (Creswell, 2007). In addition, quantitative data were obtained from 117 respondents from West Java through a survey distributed online. Secondary data were obtained from institutional documents, scientific journals, and relevant references on political communication and the role of parties in selecting leaders.

Validity and reliability

The aspects of communication studied include symbols and forms of verbal and nonverbal communication used by political parties in the selection process of the regional head leader. The data collection process uses a thick description technique, which emphasizes a detailed description of the phenomenon under study. This technique provides an in-depth understanding of the political communication process, especially in the interaction of political parties with the community and prospective regional leaders (Moleong, 2000). With in-depth interviews with each informant, the data that will be obtained is actual data, and researchers can directly confirm it by asking for validity directly to the informant (source triangulation). In addition, observation and interview methods allow researchers to directly capture the dynamics of communication and decision-making within political parties related to the 2024 elections. Data analysis was conducted through six stages, namely: organizing data, generalizing themes, coding data, applying themes and categories, looking for alternative explanations, and compiling research reports. Each stage aims to identify the main themes and patterns of political communication that exist, as well as explain the political realities faced by parties in choosing the figures of regional head candidates. The results of this analysis are organized systematically to produce a comprehensive understanding of the role of political parties in the 2024 regional elections in West Java.

Ethical considerations

This study was reviewed and approved by the Research Ethics Committee of Universitas Padjadjaran,

Bandung, under approval number 1178/UN6.KEP/EC/2024. All research procedures complied with the ethical principles of social science research, ensuring the protection of participants' rights, welfare, and privacy. Each participant received an informed consent form detailing the purpose of the study, voluntary participation, and their right to withdraw at any stage without consequence. Data were collected only in public and permitted settings. Personal identifiers were removed during transcription, and all data were stored securely in accordance with the University's ethical guidelines. At the conclusion of the research, a final report will be submitted to the Research Ethics Committee, as required by the approval letter.

RESULTS AND DISCUSSION

Coding and theme generation

Data from interviews, observations, and online surveys were analyzed using thematic analysis following Braun and Clarke's (2006) six-phase framework: (1) familiarization with the data; (2) generating initial codes; (3) searching for themes; (4) reviewing themes; (5) defining and naming themes; and (6) producing the report. Through inductive coding, three dominant themes emerged: Hybrid Communication Strategy, Youth Engagement through Digital Platforms, and Religious and Moral Framing in Political Messaging. Each theme represents recurring patterns of meaning identified across qualitative and quantitative data.

Theme 1 – Hybrid communication strategy

Political communication is one of the main functions of political parties, especially in facing the 2024 regional head elections. Political communication involves campaign style, vision, mission delivery strategies, and efforts to attract public attention to gain votes. Political communication is an important means of mobilizing support and building positive public perceptions (Papakyriakopoulos *et al.,* 2019). The success of this strategy can only be assessed after the voting process is complete. PKS, as explained by the Chairman of the West Java Regional Executive Board (DPW), Haru Suandharu, remains consistent in carrying out a polite, refreshing, and Islamic political communication strategy. He emphasized that his party's political communication focuses on empowering the people and making politics a means of struggle that benefits the community. Good political messages that prioritize cultural and religious values can create a deeper resonance with the audience (Sunarso *et al.,* 2022). PKS also shows the success of this strategy through the solidity of the party machine that has been built. This is evidenced by PKS's position as one of the top three parties with the highest vote share in West Java in the 2024 legislative elections. According to Haru Suandharu, this achievement shows that their political communication strategy is accepted by the community. However, he also underlined that this success is a big responsibility to continue to prove that PKS is present for the community. This statement supports the hybrid communication theory, which explains that effective political communication must be able to bridge traditional and modern values (Gearhart *et al.,* 2024). Meanwhile, PDIP acknowledged the challenges in equalizing the frequency of political communication with the people of West Java. Ineu Purwadewi, Treasurer of DPD PDIP West Java, emphasized that her party focuses on conveying societal struggles to the public. This strategy reflects Habermas' (1984) theory of the public sphere, which emphasizes the importance of dialogue and reflective communication to build mutually understanding relationships between political parties and the community. This can be seen from the many dialogical events between the party and the community through open dialogue events in the mass media, social media, and other public spaces. Ineu also admitted that the number of PDIP supporters in West Java was relatively smaller than in Central or East Java. However, the approach taken, including conveying the "spirit and breath of the community's struggle", has helped PDIP to occupy the top five positions in the legislative vote in West Java. This suggests that community narratives can be an effective tool for building public trust and support (Utami *et al.,* 2024). However, until now, there are no qualified indicators to be able to say whether community narratives are a check on the acceptance of a political party or not. PDIP continues to implement a political communication strategy that focuses on community struggles in West Java. The nearly three million votes in the region's legislative elections show that some people have accepted PDIP's messages, albeit not fully. This approach is in line with Habermas' (1984) theory of the public sphere, which states that dialogue and reflective communication can strengthen the relationship between political parties and society. According to Ineu

Purwadewi, the party's struggle is not only carried out during the campaign period, but also when party cadres have been elected as representatives of the people. The council members from PDIP are responsible for hearing the aspirations of the community and fighting for their rights in parliament. On the other hand, the Chairman of the West Java Nasdem DPW, Saan Mustopa, considered that his party had carried out progressive political communication by winning eight seats in the West Java regional parliament. However, he also admitted that this achievement still needs to be improved. Nasdem plans to prioritize digital communication strategies through social media to engage young people in political discussions. It can be argued that social media can expand the reach and deepen interactions with the younger generation (Lei *et al.,* 2019). Gerindra's Vice Chairman of West Java DPD, Buky Wibawa, has made certain clarifications in this regard about the political communication of his party as he voiced the narrative of nationalism and national independence. This strategy is consistent with the principle of framing, as messages that promote the vision and ideology of a particular party may create a positive perception in society. Political communication of the Gerindra Party was performed via several platforms such as social media, TV debates, and direct campaigns to reach the people and listen to their concerns. Social media platforms managed by the Gerindra political parties also elegant more about Gerindra imagery into the public outlook. To illustrate, some gerindra social accounts on Instagram have been focused on promoting gerinda speculations on its posters. With the Instagram accounts of the party have consistently promoted the views across authoritative gerindra administrators. They have focused on social messages and rather humorous political persuasions netizens have captured that empathy. As Gerindra's attention to the presidential and the regional head elections focus on the applied communication strategies, then reconofolowers will be justified. Findings and analysis of Utami *et al.,* (2024), about the consistency of party messages reinforce the political credibility of the party that manages to portray a sense of stability to the public. The Democratic Party appears to be gaining the support of the younger generation with the use of a social media strategy. According to Anton Sukartono, the Chairman of the West Java Democrats DPD, his party applies a constant approach in posting narrative material with emotional emphasis. In this regard, the Democrats also try to keep their interaction with the population of West Java by addressing the issues of economic and political stability that are need-based. This shows that social media, in particular, can be used with great effectiveness for the instilling emotions and messages that are unique and specific to the youth (De Coninck *et al.,* 2021). Further, this also indicates that emotion is more appealing to the younger supporters of the party. At the same time, PKB considers their political communication strategy to be quite simple since the party leader is outright running for the presidency in the next election. Syaiful Huda, who is the DPW PKB Head in West Java, stressed that his party has not lost focus by allowing the youth to participate in party politics. This involves a strategy of communication that is meant to be participatory and where the youth are active players, not mere figures within a political strategy. It is however believed that dialog is one of the means through which political parties and society can achieve shared comprehension (Livingstone & Bulger, 2014). Golkar which is commensurate with PKS in the race for second position in the upcoming 2024 elections in West Java also uses a political communication approach that seeks to be close to the people. According to Cucu Sugyati, Vice Chairperson of Women Affairs, Golkar DPD West Java, apart from social media, campaign and personal approach is what the party considers to be more important. This is a commendable approach as it emphasizes the need to first understand the community and its specific needs instead of just creating graphics or videos for social media. Golkar also showed that face-to-face campaigning is more effective than relying only on social media. This move is in support of the ideal of Lubis & Tagor (2022), that direct contact within the community builds closer bonds and allows the political parties to understand the needs in the community much better. PAN sees youth engagement as an important element in political communication. According to Raden Tani, Vice Chairman of PAN West Java's Autonomous Organization Division, young people have higher creativity and are more aware of the trends. He further said that politics should be packaged in a carefree and fun way so that it is easily accepted by the public. It is important to adapt the style of communication to the audience for effective engagement. Raden also pointed out that the thinking of young people is often un-

derestimated, yet it is very often more relevant and current than that of the older generation. PPP, which this year failed to pass the threshold to enter parliament, finally realized how important it was to evaluate their political communication strategy. Chairman of DPW PPP West Java, Pepep Saepul Hidayat, said their strategy targeted young people but the approach used still needs adjustments to be more acceptable to the public. He also mentioned that the failure this time was an important lesson to build a better strategy in the future. This perspective is supported by the ideas of Lubis & Tagor (2022), who, in their paper, noted that political communication strategies have to be developed through the continuous evaluation and adjustment of narratives to meet the needs of the electorate.

Each political party has unique political communication strategy characteristics, especially in terms of the narrative and substance offered to the public. However, the means and channels of communication chosen tend to be uniform, such as the use of social media, the involvement of young people, direct campaigns, and direct engagement with the community. Lubis & Tagor (2022) highlighted that this similarity is understandable because modern political communication patterns demand multi-channel penetration to reach various audience segments. Even so, the main differentiating factor between parties lies in the storytelling, substance, and ideology communicated.

In the context of future strategies, political parties need to evaluate the approaches used during the 2024 elections and consider modifying strategies for local elections. It is important to craft relevant and easy-to-understand political narratives to build resonance with public needs. In addition, data from digital media should also be optimally utilized to map the voter base and develop more effective strategies (Boulianne *et al.,* 2024). In this case, political parties need to understand that the battlefield between legislative elections and regional head elections has different characteristics, so the strategies applied must also be adjusted. Each political party has a distinctive political communication strategy, especially in terms of the narrative and substance offered to the public (Lubis & Tagor, 2022). The main difference is in the narrative. However, the communication methods and channels chosen are relatively the same: penetration through social media, efforts to engage young people, direct campaigns, and going to the community. The similarity of methods in communicating the vision is understandable, because that is the pattern of today's political communication strategy. One thing that makes a difference is storytelling, narrative, substance, and ideology. Political parties must be able to package ideology into political education that is easy to digest and relevant according to public needs. Data as a digital media compass must also be used to map the voter base, especially if you want to target certain groups (Hidayat, 2020). Political parties contesting the 2024 general election and returning to the political arena at the regional head election level certainly need to think about new approaches, ways, and strategies in conducting campaigns and political communication. They need to evaluate political communication during the 2024 general election and what approaches will be effective if they are redone, improved, or even completely changed. The battlefield of the 2024 general election, with the regional head elections, is certainly different, so the strategy must also be different. You cannot expect the results to be the same if the methods used are still the same. As shown in Table 1, political parties in West Java adopted various communication narratives and media strategies tailored to their ideological positioning and target audiences. Each party framed its messaging to resonate with specific demographic groups, such as youth, professionals, traditional Muslim voters, or nationalist constituents. Despite similarities in channel usage—such as the reliance on social media and face-to-face campaigns—the substance and ideological focus of their communication differentiated their approaches. These strategies were designed not only to increase electability but also to solidify voter loyalty and expand influence in the 2024 regional election context.

Political parties have an important role in creating a conducive climate for the life of the nation and state in Indonesia (Prianto, 2024). Political stability resulting from the role of political parties greatly affects security and economic stability. Political parties function as the main driving force in the democratic process, which should encourage the creation of a harmonious atmosphere in the socio-political life of the community. In this case, the role of political parties is not only limited to political decision-making, but also in maintaining state stability. In addition, political parties play a major role in political education for the community. Ardiyanti *et al.,* (2024) mentioned that massive political education can increase com-

Table 1: Political ¸ommunication strategies of each political party

No.	Political Party	Communication Narrative	Media Used	Target Audience	Expected Results
1	MCC	Polite politics, people empowerment	Social media, face-to-face campaigns	Muslims	Voter support and public political awareness
2	Nasdem	Progressive, inclusive, and embracing the youth	Social media, online discussion	Young generation, progressive	Increase electability and influence in the region
3	PDIP	Community struggle and close to the people	Social media, face-to-face, print media	General public	Maintaining a support base in West Java
4	Gerindra	Strong nationalism, national independence	Social media, television, and in-person campaigns	Nationalist society	Support from voters loyal to nationalism
5	Democrats	Political and economic stability	Social media and dialogue events	Middle-class, young voters	Increase trust in the party, especially among young voters
6	ESC	Moderate Islam, people's welfare	Social media, face-to-face, social-religious activity-based campaigns	Traditional Muslims and young voters	Strengthening the support base
7	Golkar	Economic development, political stability	Social media, direct campaigns	Professionals and the general public	Maintain position as a strong party
8	PAN	Pluralism, moderate Islam	Social media, face-to-face and community campaigns	Young voters and the general public	Attracting young and professional voters
9	PPP	Islamic morality	Social media, direct campaigns, and religious lectures	Traditional Muslims, general public	Muslim support and expanding voter base

munity participation, especially in rural areas. This political education is conducted regularly by parties, including the Prosperous Justice Party (PKS), which provides national insight and political information to cadres and constituents. Such political education would help people understand their political rights and obligations, and increase active participation in the democratic process. These educational programs are expected to shape a better understanding of the importance of healthy political engagement at the national and local levels. Haru Suandharu, Chairman of DPW PKS West Java, said that one of the primary roles of a political party in general is to become the bridge between the aspirations of the people and political regulation. He further stated, "Political parties become agents for political education through which citizens understand how their lives could be affected by the ruling policies. The point here is in line with Yamin *et al.,* (2024), who said that not only were political parties tasked to forward aspirations, but efforts also had to be made to build people's political awareness to increase active participation. In the context of political recruitment, political parties in Indonesia play an important role. Political parties can be divided into two types: electoral parties and cadre parties. Electoral parties rely on popularity to grow in the short term, while cadre parties rely on structured regeneration for long-term stability. According to Ineu Purwadewi from PDIP, her party is not only a channel for the aspirations of the people but also a political school for prospective leaders. She said learning national ideology, principles, and values is very important so that every policy taken will follow the party's vision. Each political party must prepare its cadres through learning about ideology and values to be able to produce honest leaders. In addition, political parties also have a role as mediators in overcoming horizontal conflicts that often occur

in society. Saan Mustopa from Nasdem emphasized that political parties are not only tasked as political communicators or educators, but also as mediators who resolve conflicts through regulatory channels and cultural approaches. Buky Wibawa, Syaiful Huda, and Cucu Sugyati, representing Gerindra, PKB, and Golkar, respectively, agreed that political parties function as channels of political participation for the community. They explained that political parties become a medium for people to convey their political aspirations, as explained by Yamin *et al.,* (2024) that one of the pillars of democracy is direct community involvement through political parties. Meanwhile, one key word uttered by Pepep Saepul Hidayat (PPP), Anton Sukartono (Democrat), and Raden Tedi (PAN) was: socialization. Political parties have the role of political socialization in the community. The public understands that political parties are the mouthpiece for political programs and policies to be rolled out, and parties argue in parliamentary seats to pass a regulation. The whole process is impossible without socialization to the community, and that is what is meant by a political socializer - a messenger of political policies, programs, and regulations. In general, Yamin *et al.,* (2024) stated that political parties have four roles: as a means of political communication, a means of political socialization, a means of political recruitment, and a forum for socio-political control of the phenomena that occur. In addition, the specific goal of political parties is to increase the political participation of its members and the community. After the 2024 General Election, the process of forming regional leaders in Indonesia is strongly influenced by the dynamics of political communication and the active role of political parties. Qualified regional leaders are not only required to be able to convey their vision and mission clearly, but also to be able to build strong relationships with the community. Effective political communication during the campaign period until post-election is a key factor in building the image and credibility of prospective leaders (Farkas & Bene, 2021). In the context of politics in Indonesia, the figure of the leader is often the main aspect that people consider in determining their choice. The role played by the political parties in this process is that of the key guarantor. Immediately after an election, political parties become the most relevant mediators and scrutinize candidates for regional elected leaders. Political parties evaluate candidate performances and ability to lead at regional levels. This involves an in-depth scrutiny of a candidate's background, vision, and strategy concerning regional problems. They can also get the right direction and support from political parties for the effective execution of their responsibilities. Political communication during the campaign and post-election transition period is an important determinant of how a local leader is received by the community. Face-to-face campaigns and direct interaction with constituents provide an opportunity for regional head candidates to build strong emotional connections (Alayya, 2022). This way, the candidates can listen directly to the needs and aspirations of the community and show concern for local issues. Besides, the public opinion and perception of the regional head candidates are also created by the delivery of political messages through mass media and social media. Moreover, the role played by political parties in creating a conducive political climate also plays a huge role in forming regional leadership figures. The political stability maintained by the political parties means that the process of changing leadership happens smoothly. This gives regional head candidates enough space to carry out their duties without distraction by political instability. With a stable political climate, the candidates for regional heads can become more effective in designing and implementing policies that will affect regional development.

The quality of local leadership also depends on the political education carried out by parties. In their case, political education programs aimed at regional head cadres and candidates make them understand how local politics are and how to deal with local society. This education builds up the competency needed to handle local problems effectively and find constructive solutions to difficulties. Through knowledge and skills acquired, aspiring local leaders can execute their duties better and live up to the expectations of the community more effectively. Haru Suandharu, Chairman of DPW PKS West Java, stated that his party has a high commitment to building cadres that are worth running as regional head leaders. He pointed out that the leader figures to be promoted by PKS are the result of a regeneration process that takes a long time and has been tested. In the view of Haru, it is impossible to create real figures in an instant, but through hard work and ideological strengthening. Similar confidence was also expressed by Ineu Purwadewi, Chairman of DPD PDIP West Java. She said

that PDIP, as a cadre party, places cadres as the main step in creating leader figures. This process includes learning ideology, closeness to the people, and a strong track record of service. This statement supports the theory of leadership development that is oriented towards track records and closeness to the community (Ardiyanti *et al.,* 2024). Saan Mustopa, Chairman of the West Java Nasdem DPW, added that political parties have to advance their cadres as leaders. However, he also mentioned that in some situations, the interests of the people can be a top priority compared to promoting internal cadres. According to Buky Wibawa from Gerindra, the leader figures are the result of political consistency and continuous hard work. He emphasized that originality is key in building figures in society, as Gerindra has shown through the consistency of the vision of national sovereignty championed by its chairman. Syaiful Huda, Chairman of the West Java PKB DPW, said that the leaders promoted by PKB must reflect moderate Islamic values that embrace differences. He emphasized that character cannot be fabricated, but must emanate from a track record that is already known to the public. This supports that the reputation and credibility of a leader is the result of experience and interaction with the community (Fraccaroli *et al.,* 2022). Cucu Sugyati, Vice Chairman of DPD Golkar West Java, revealed that Golkar always has the right strategy in introducing leader figures to the public. According to him, the figures promoted by Golkar are the result of community aspirations, so they have a strong relevance to public needs. This means that it is important to ensure that the leader figure reflects the aspirations of the community being represented. The Democratic Party, PPP, and PAN are of one mind that building a leader figure is not an easy matter, especially in the context of the people of West Java. They believe that they need to introduce their cadres to the community so that their vision of building society can be better accepted by the West Java public. In addition, one thing they are concerned about is the involvement of young people to participate in conveying the party's vision and ideology. After the 2024 elections, public opinion about regional leadership figures is strongly influenced by the way political communication and the role of political parties in the election process and leadership transition. Effective political communication during the campaign and transition period plays a key role in shaping the public's image and perception of regional head candidates (Ardiyanti e*t al*., 2024). Research found that consistent campaigns and local needs of the community can strengthen the credibility of candidates in the eyes of the public (Roemmele & Gibson, 2020). Political messages that are delivered clearly and consistently help create positive views and strengthen public support for the candidate. Structured and sustained political communication is proven to increase public trust in the long term. Another factor is the political party's role in handling the process of candidate selection for regional heads, which bears consequences for public opinion. Political parties able to handle the screening and evaluation of their candidates well will obtain more trust from the public towards them. Where political parties have good credibility—with past experience in selecting future leaders—the public will also have a higher propensity to give their support. On the other hand, if political parties are seen as opaque or even having some vested interests, public confidence will be lost and affect negative views toward regional head candidates. The socialization done by the political parties will shape public opinion on the regional head candidates. According to Malabar (2020), appropriate socialization would enhance more public involvement in the process of politics and yield favorable views of regional head candidates. Through socialization programs, regional head candidates will be better known by the public. The parties that actively take part in organizing social events and campaigns give ample opportunity to the candidates for meeting face-to-face with the constituents, thus articulating their vision and mission and showing concern for the local problems. Those face-to-face interactions contribute to the strong emotional relation with the community and create a positive opinion of the candidates. Political communication in the mass media and social media also significantly influences public opinion. The mass media acts as the main channel in disseminating information about regional head candidates and their programs. If the media provides objective and balanced coverage, the public will get accurate information and be able to make better judgments. However, if the media becomes a vehicle for negative campaigns or favors certain parties, public opinion may be formed based on biased or incomplete information. Social media, as a highly influential platform, allows people to actively participate in political dis-

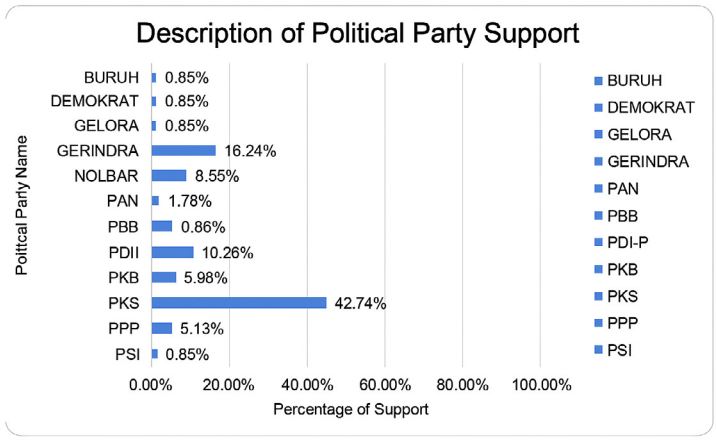


Fig. 2: Respondents' support for political parties (source: 2024 research results)

cussions and disseminate their views (Farkas & Bene, 2021). Local leaders who are active in social media can more easily communicate with constituents and build support. However, social media also has the potential to generate controversy and hoaxes that can negatively influence public opinion. Therefore, it is important for regional head candidates to manage their presence on social media wisely. The role of political parties in political education also contributes to public opinion. By providing a better understanding of the political process and the role of candidates, political parties help people make more informed decisions. Effective political education increases public awareness and knowledge of important issues and competing candidates, thereby positively influencing public opinion. PKS, according to Haru Suandharu, Chairman of DPW PKS West Java, continued to show high electability in the West Java regional head election despite facing internal dynamics after the 2024 election. He revealed that dynamics in political parties are natural and must be managed for the benefit of the people. Haru also emphasized the importance of uniting post-election to win the next regional head election. PDIP, which is in the public spotlight after the 2024 election, continues to focus on community issues as an ideological party. Ineu Purwadewi, Deputy Chairperson of the PDIP Women's Division in West Java, said that her party is confident to nominate its own cadres in the regional head elections in West Java. This approach shows PDIP's consistency as a cadre party committed to its ideology. In addition, she noted that public opinion towards PDIP will evolve based on two possibilities: continuity of post-election political stances or changes in strategy according to political dynamics.

Theme 2 – Youth engagement through digital platforms

In an effort to map public preferences and opinions towards political parties in West Java, researchers surveyed 117 respondents. The first question was about political party support, and the results showed that PKS, Gerindra, PDIP, Golkar, and PKB were the top five parties of interest to West Java residents. A total of 50 respondents chose PKS, 19 respondents chose Gerindra, 12 respondents chose PDIP, 10 respondents chose Golkar, and 7 respondents chose PKB. The data is representative of the results of the legislative votes in West Java, where the top five political parties with the highest votes are the five parties. However, the order is different. If referring to the legislative votes in West Java in the 2024 general election, the top five political parties are Gerindra, PKS, Golkar, PDIP, and PKB. As shown in Fig. 2, respondents' support for political parties in West Java revealed that PKS ranked highest with 50 votes, followed by Gerindra (19), PDIP (12), Golkar (10), and PKB (7). These five parties emerged as the most prominent among survey participants. Although the order differs from the official legislative election results in the 2024 general election—where Gerindra leads, followed by PKS, Golkar, PDIP, and PKB—the composition of the top parties remains consistent. This indicates a general alignment between public sentiment captured in the survey and formal electoral outcomes, albeit with some variations in rank. The mass media channel most used by respondents in listening to various forms of political

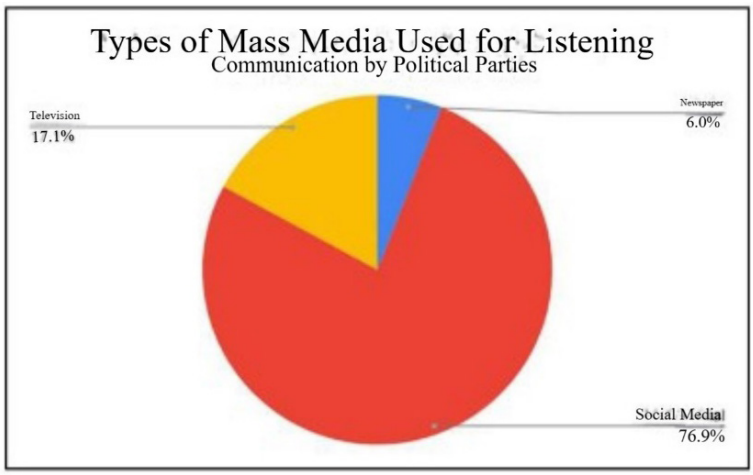


Fig. 3: Types of mass media used by respondents in listening to political party communication (source: 2024 research results)

communication from parties is social media. 76.9 percent stated that they saw social media as the main channel for receiving political communication. Positive conversations on social media can build positive public opinion towards political parties (Kizgin *et al.,* 2018). A smaller percentage, such as 17.1 percent of respondents, claimed to see political communication through television, and 6 percent through newspapers. This finding is in line with and relevant to the interview results of political party representatives, who stated that they focus on delivering political communication through social media.

As shown in Fig. 3, the majority of respondents (76.9%) reported that social media served as their primary source for receiving political communication from parties. In contrast, only 17.1% relied on television, and a smaller portion (6%) accessed political content through newspapers. This pattern confirms the interview findings with political party representatives, who emphasized prioritizing social media channels to engage with the public, especially the younger demographic. The data highlights a significant shift from conventional mass media toward digital platforms in political messaging strategies. The mass media *platform* most often used by respondents to view various political communications from parties is Instagram (61.54 percent). The next order is TikTok (14.53%), and Facebook and X have the same percentage of 11.97 percent.

As shown in Fig. 4, Instagram dominated as the most frequently used social media platform for accessing political communication, with 61.5% of respondents indicating it as their primary source. TikTok followed with 14.5%, while Facebook and Twitter/X each accounted for 12% of the responses. These findings reinforce the growing dominance of visually driven platforms in political outreach, especially among younger demographics. The preference for Instagram suggests that political messages packaged through visual storytelling, reels, and influencer-based narratives may have greater engagement potential in the current electoral landscape. In general, all interviewees from each political party agreed that they engage in political communication through social media, without prioritizing any particular platform. However, the public considers Instagram to be the social media channel that they most often access to consume news or political party communication products. This is supported by global trends, where social media Instagram and Twitter are the main platforms for delivering political communication, especially to attract the attention of young people (Safiullah *et al.,* 2017). Social media is the primary channel for political communication, as more than half of voters are young people who spend almost all their time on social media (Magdaci *et al.,* 2022). This is in line with the phenomenon of young people who are fond of online political discussions (Papakyriakopoulos *et al.,* 2019). In addition, political parties still have to conduct face-to-face campaigns to greet and engage in dialogue with people who are relatively less active on social media, namely the older generation who prefer face-to-face meetings. Therefore, political communication combines two approaches: social media and direct campaigns. The

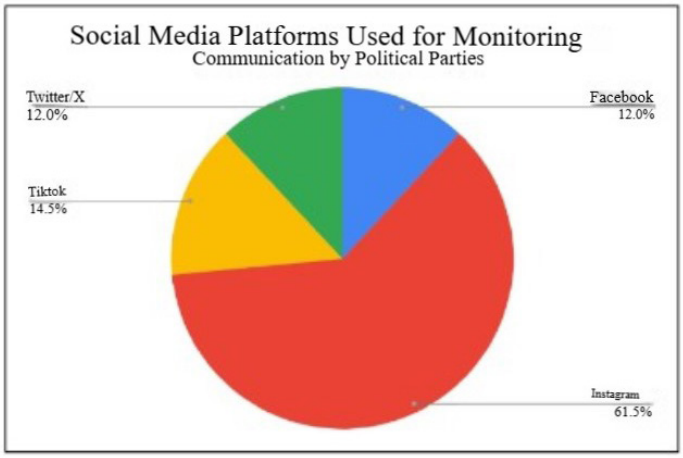


Fig. 4: Social media platforms used by respondents in listening to political party communication (source: 2024 research results)

combination of face-to-face and digital campaigns is believed to double public support and affect the electability of candidates. The physical campaigns carried out by political parties vary, ranging from organizing special activities to attract the attention of the masses, visiting areas as an effort to "pick up the ball", to working visits by political parties to sub-districts. This strategy is considered effective and significant in increasing support (de Vreese *et al.,* 2018).

Theme 3 – Religious and moral framing in political messaging

Among the top five political parties in West Java, direct campaign activities are carried out differently, such as Gerindra focusing more on organizing activities initiated by political parties, Golkar conducting working visits to sub-districts, PDIP being similar to Gerindra, which focuses on organizing internal activities, and PKB and PKS focusing on visiting areas to conduct dialogue.

As shown in Fig. 5, the most frequently attended direct meetings with political parties varied across the top five supported parties. PKS had the highest engagement rate across all categories, with 52.0% of respondents attending party-organized events, 41.3% participating in local visits (silaturahmi), and 35.3% encountering party work visits to sub-districts. This suggests a strong grassroots mobilization strategy by PKS. Gerindra and PDIP showed moderate engagement in party events (21.3% and 12.0%, respectively), while Golkar had the highest percentage (23.5%) of respondents attending work visits to sub-districts. PKB showed balanced participation, with 16.0% attending local visits and 11.8% attending work visits. These findings reflect the diverse outreach methods utilized by political parties to maintain direct contact with constituents during the election period. Based on the processed data, it can be concluded that the phenomenon of political communication in Indonesia is strongly influenced by several main factors, including the role of political actors, the delivery of political messages, and the role of mass media and social media. Political actors have a central role in influencing political stability in Indonesia. They not only function as policy makers, but also as figures capable of influencing security and economic stability. Their role in political communication is huge, as their messages have a direct impact on public opinion and the direction of state policy. Mass media such as radio, television, newspapers and magazines play a significant role in disseminating ideas from political parties to the public. Political figures often get the spotlight through the media, either directly or indirectly. However, there is a phenomenon where the media is used as a tool to increase the momentary popularity of political figures, which ultimately doubts the neutrality of the media as a pillar of democracy. Nevertheless, there are still many credible media outlets that fulfill their role as watchdogs of democracy and disseminators of objective information. Social media such as Facebook, WhatsApp, Instagram, and Twitter are now very important platforms for political communication (Mazzoleni & Bracciale, 2018). The development of information technology allows politicians to direct-

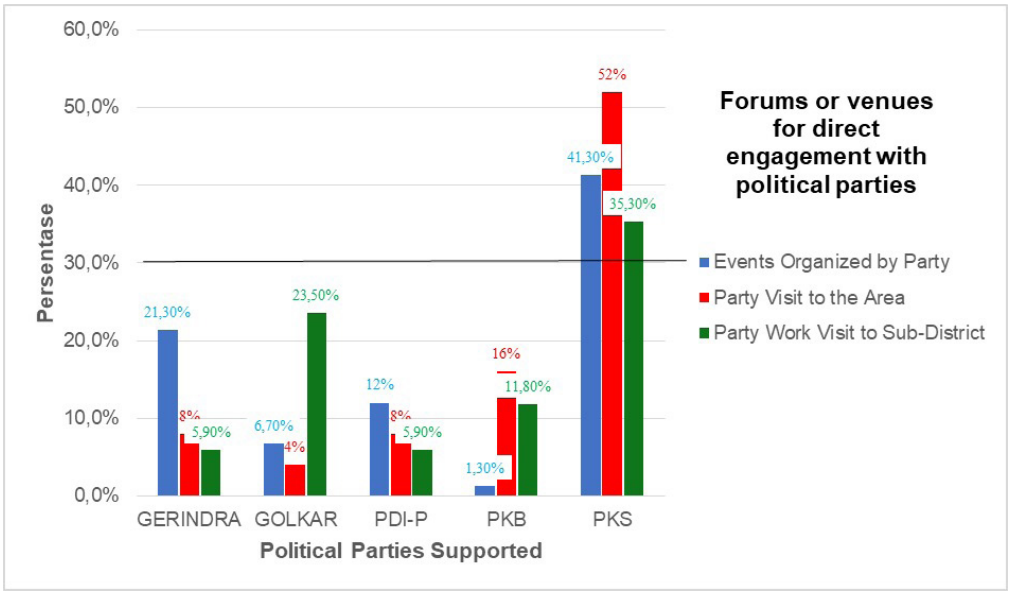


Fig. 5: Direct meeting forums conducted by political parties (source: 2024 research results)

ly communicate with the public and netizens. Social media has changed the way people get information, as they are not only consumers of information but also disseminators of news and opinions. This creates a more interactive political communication, where people can provide direct feedback on emerging political issues. More effectively, however, direct communication via face-to-face methods like campaigns, blusukan, and field meetings is still most capable of creating links in emotions. This will let the politicians come up with first-hand experience, understanding the needs and hopes of the community; establishing deeper levels of confidence and support are also provided while this is done. Face-to-face interactions present several opportunities through which leaders would appear concerned by local situations and therefore provide solutions that local populations find appropriate. The direct campaign exposure is still effective in gaining public attention, especially to attract support that has not been touched by digital media (Kreiss & Mcgregor, 2018). In the post-2024 election context, all these factors contribute to public opinion forming toward regional leadership figures. Effective and continued political communication will influence the public's assessment of success or failure of the regional head candidates. The role of the media in relaying information about the candidates and their programs can strengthen or dampen public perceptions. Social media fast-tracks this process by providing a forum for the airing of views and assessment of the performance of the candidates in real-time. Moreover, direct communication in the process of creating emotional ties with the community will also determine the support that regional head candidates get after an election. The politicians able to build good relations with their constituents through direct campaigns and open dialogue will have a stronger base of support. Otherwise, those who fail in these direct interactions may find it hard to gain stable support from the community. Generally speaking, political communication carried out by the parties, be it through mass media, social media, or direct contact, is what greatly affects public opinion after the elections in 2024. All these factors interlink to influence public perceptions of the elected regional leaders. Deep knowledge of the dynamics of this political communication is necessary in assessing how the regional leadership figures can accomplish their duties and meet community expectations.

CONCLUSION

The article *"Political Communication and the Role of Political Parties in Producing Regional Leadership Figures and Their Impact on Public Opinion After the 2024 Election"* contributes to understanding how political actors shape Indonesia's political, security, and

economic stability through communication processes that go beyond policymaking. Political actors act as key communicators who influence public perceptions and policy orientation. The messages conveyed by political parties reflect their ideological visions and strategic objectives, serving to mobilize support and frame public opinion toward parties and candidates. Transparency and clarity in message delivery are fundamental to building public trust and sustaining democratic credibility. Traditional mass media—such as radio, television, newspapers, and magazines—continue to play an influential role in disseminating political information. However, the tendency to use media for instant popularity often raises questions about neutrality. Despite this, reliable media remain crucial as trusted sources of accurate political information. In contrast, social media has transformed political communication into an interactive and dialogic process, allowing citizens not only to consume but also to produce and share information in real time. Direct face-to-face interactions, including community visits (*blusukan*), remain powerful for fostering emotional engagement and strengthening grassroots support networks. These dynamics collectively shape public opinion about regional leadership figures after the 2024 elections. The interplay between mass media, social media, and interpersonal communication channels determines how citizens perceive the success or failure of political candidates. Therefore, political parties must reform their communication strategies toward greater transparency, factual consistency, and ethical responsibility. They should leverage social media constructively—avoiding disinformation—while revitalizing direct community interactions to strengthen emotional and moral connections with constituents.

AUTHOR CONTRIBUTIONS

D. F. Sjoraida developed the conceptual framework, coordinated the overall research design, and prepared the final version of the manuscript. K. A. Wibowo performed the literature review, designed the research instruments, and contributed to the analysis and interpretation of the findings. S. Perbawasari contributed to the fieldwork coordination, data collection, and initial manuscript drafting. P. Subekti conducted data analysis (qualitative and quantitative), contributed to literature synthesis, and finalized the manuscript formatting and editing.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, have been fully addressed by the authors.

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ABBREVIATIONS (NOMENCLATURE)

AI	Artificial Intelligence
DPD	Regional Representative Council
DPW	Regional Executive Board
PAN	National Mandate Party
PDIP	Indonesian Democratic Party of Struggle
PKB	National Awakening Party
PKS	Prosperous Justice Party
PPP	United Development Party

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ORIGINAL RESEARCH PAPER

Flexible manufacturing systems and their role in human resource sustainability: Analytical study

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ABSTRACT

BACKGROUND AND OBJECTIVES: This study investigated how Flexible Manufacturing Systems—including workstations, automated handling/storage, inspection equipment, ancillary components, and computer control—were related to Human Resource sustainability (justice, job well-being, and employee development) at the Samarra Pharmaceutical Factory. The objective was to identify which FMS dimensions most strongly supported sustainable HR outcomes.
METHODS: A descriptive–analytical design was used. A structured questionnaire was administered to 230 employees; 207 valid responses were obtained (response rate = 90%). The measurement model and hypotheses were tested in AMOS v26 using standard validation criteria and structural equation modeling.
RESULTS: Overall FMS capability was positively associated with HR sustainability (standardized regression weight = 0.932; unstandardized estimate = 2.079; 95% CI = 0.896–0.971; p = 0.02). Bivariate correlations between individual FMS components and HR sustainability were significant: workstations r = 0.841 (α = 0.05), handling & storage r = 0.833 (α = 0.05), inspection equipment r = 0.644 (α = 0.05), computer control systems r = 0.902 (α = 0.05), and other components r = 0.928 (α = 0.05). Model fit indices met accepted thresholds (e.g., GFI = 0.927, AGFI = 0.916, RMR = 0.068, NFI = 0.913, RFI = 0.905).
CONCLUSION: Strengthening Flexible Manufacturing Systems—particularly computer control systems—was associated with higher HR sustainability by improving safety, reducing physical/psychological strain, and expanding development opportunities. Managers seeking technology investments that advance operational efficiency and workforce well-being could prioritize FMS upgrades aligned with these results.

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INTRODUCTION

The modern business landscape is evolving rapidly under the pressures of technological advancement, globalization, intensifying competition, and the growing salience of sustainability. These forces pose a central challenge for organizational leaders: reconciling short-term profitability with the development of long-term capabilities that secure survival and growth. In this milieu, sustainability has broadened beyond its environmental origins of the 1970s to encompass an integrated perspective that includes economic and social dimensions. Organizations pursue sustainability because strategically valuable, scarce, and hard-to-imitate resources are foundational to lasting competitive advantage. Chief among these is human capital—a distinctive strategic asset that creates value through interactions at the individual, organizational, and societal levels. Advancing sustainability, therefore, cannot occur in isolation at any single level; rather, it requires balancing the needs and aspirations of stakeholders across all three levels simultaneously within the organization (Ehnert, 2006). Insufficient attention to sustainability in the business sector has contributed to economic slowdowns, prompting firms to adopt innovative responses. Flexible Manufacturing Systems (FMS) represent one such strategic response, enabling the creation of a culture that aligns day-to-day operations with long-term strategic objectives. This study focuses on how FMS can strengthen human resource sustainability by improving employee well-being and building workforce capabilities. Accordingly, the work is organized into four sections. The first outlines the research methodology. The second develops the theoretical foundations and clarifies the variables and dimensions under study. The third presents the empirical component. The fourth offers the principal conclusions and actionable recommendations derived from the analysis. Together, these sections explain the pathways through which FMS can enhance human resource sustainability while reinforcing organizational resilience and performance. To achieve the paper's objectives, the research survey was conducted at Samarra Pharmaceutical Factory in Iraq in 2025. In practice, many organizations adopt flexible manufacturing systems to improve efficiency, yet the implications of these systems for the long-term sustainability of their human resources remain unclear. In particular, there is limited empirical evidence on whether the main components of FMS—workstations, automated handling and storage, inspection equipment, computer control systems, and other supporting elements—actually contribute to justice, job well-being, and employee development within industrial settings such as the Samarra Pharmaceutical Factory. In response to this gap, the present study pursues three main targets: (1) to assess employees' perceptions of the presence and maturity of FMS components in the factory; (2) to estimate the influence of overall FMS capability and each of its components on human resource sustainability; and (3) to identify which FMS components most strongly support sustainable human resource outcomes, thereby providing practical priorities for managers in pharmaceutical manufacturing.

Research problem

Modern organizations increasingly recognize that achieving their objectives requires adopting sustainability across their environmental, social, and economic dimensions. Sustainability today goes beyond improving corporate image or gaining a competitive edge; it also exerts a direct and positive influence on employees. Despite this recognition, many organizations continue to confine sustainability to corporate social responsibility activities, failing to integrate it into the core of their operations—an oversight that can have serious long-term consequences. Since human resources constitute the intellect and driving force of any organization, sustainability must begin with individuals and be reflected in HR policies. This is particularly critical in modern workplaces that depend on FMS, which demand renewable skills and high adaptability (Cherian & Farouk, 2017). Neglecting to embed sustainability principles within such environments can weaken an organization's ability to retain and develop skilled personnel, ultimately undermining overall performance. Accordingly, the central research problem is framed in the following question:

How can organizations that adopt flexible manufacturing systems integrate sustainability principles into their human resource management practices? This overarching question leads to three sub-questions:

A. Are the research variables and dimensions present in the studied field?

B. *In what ways do FMSs* contribute to *Human Resource Sustainability (HRS)*?

C. Is there a significant relationship between flexible manufacturing systems and HRS within the company?

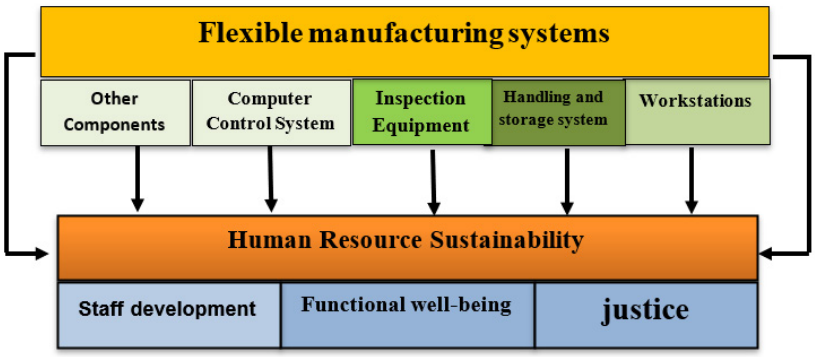


Fig. 1: The relationships serve as the basis for empirical testing

Research objective

The main objective of this study is to highlight the role of FMSs in achieving HRS, thereby enabling adopting organizations to strengthen their market position and achieve distinctiveness over competitors. To meet this aim, the study pursues three sub-objectives:

A. Assessing the extent to which employees recognize the importance of adopting flexible manufacturing systems.

B. Analyzing the contribution of flexible manufacturing systems to achieving human resource sustainability.

C. Measuring and evaluating the relationship between flexible manufacturing systems and human resource sustainability.

Research importance

This research carries significant methodological and practical value, especially in the Iraqi industrial context:

A. Bridging a research gap: While existing studies on flexible manufacturing systems primarily emphasize technological and production aspects, they often overlook implications for the human element. This study addresses that gap by examining how FMS affects human resource sustainability.

B. Addressing industry challenges: Modern industries—particularly pharmaceuticals and medical supplies—face challenges linked to adapting to rapid market fluctuations and evolving customer needs. FMS provides a strategic response to these challenges, but its success depends on the adaptability and continuous learning of human resources. Thus, this study underscores how FMS can support rather than replace workers.

C. Advancing sustainable development: Sustaining human resources is a cornerstone of organizational sustainable development. By maintaining and developing employee competencies, organizations can ensure ongoing productivity and innovation. This research demonstrates the role of FMS in this regard.

D. Providing actionable recommendations: The study seeks to deliver practical and applicable recommendations suited to the capacities of industrial organizations, particularly in the pharmaceutical and medical supply sectors.

Hypothetical research plan

Addressing the research problem requires a structured framework that clarifies the relationships between the study's variables and their dimensions. The proposed research model, illustrated in Fig. 1, depicts these relationships and serves as the basis for empirical testing.

Research hypotheses

To guide empirical testing, the study proposes the following hypotheses:

Hypothesis 1 (H1). The collective components of flexible manufacturing systems exert a significant statistical effect on human resource sustainability, considered as a composite construct within the focal organization.

Hypothesis 2 (H2). Each component of flexible manufacturing systems has a significant statistical effect on human resource sustainability, considered as a composite construct within the focal organization.

MATERIALS AND METHODS

The study employs a descriptive–analytical approach. A desk- and web-based literature review was conducted to develop the theoretical framework. Pri-

mary data were gathered through a structured questionnaire administered in the field, and subsequently analyzed with appropriate statistical techniques to test the proposed hypotheses. The theoretical framework presented in the previous section conceptualizes flexible manufacturing systems as a multidimensional construct comprising workstations, handling and storage systems, inspection equipment, computer control systems, and other supporting components, while human resource sustainability is defined through justice, job well-being, and employee development. These conceptual dimensions directly informed the design of the questionnaire: items were grouped according to the corresponding FMS and HRS dimensions and adapted from established studies in manufacturing flexibility and sustainable HRM. On this basis, structural equation modeling was selected as the main analytical technique because it allows simultaneous estimation of measurement models (via confirmatory factor analysis) and structural paths between latent variables. Thus, the empirical strategy is explicitly derived from the theoretical model illustrated in Fig. 1 and from the hypotheses formulated for H1 and H2.

Research boundaries

Clear boundaries were established to define the scope of the inquiry:

Temporal Scope: The research (theoretical and fieldwork) was conducted between June 25, 2025, and September 2, 2025.

Spatial scope: The empirical setting is the General Company for the Manufacture of Medical Equipment and Supplies / Samarra Pharmaceutical Factory, selected as a mature organization that has operated under diverse leadership styles.

Human scope: The sample comprises employees working at the above organization.

Data collection

Data were collected using a questionnaire and interviews administered to a randomly selected group of employees. A total of 230 questionnaires were distributed; 207 were returned, yielding a 90% response rate. The instrument comprised two main sections: Items measuring flexible manufacturing systems and items measuring human resource sustainability. All variables and dimensions were assessed using a five-point Likert scale.

Sampling adequacy tests

Before conducting factor analysis, the suitability of the data for multivariate analysis was examined using the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. The overall KMO statistic was 0.79, which exceeds the commonly recommended threshold of 0.60 and indicates that the items share a sufficient level of common variance. Bartlett's test of sphericity was also highly significant ($\chi^2 = 1120.3$, df = 276, $p < 0.001$), confirming that the correlation matrix is not an identity matrix and that the data are appropriate for factor-analytic procedures.

Theoretical framework

FMS

Concept of FMS

The notion of FMS emerged in the 1960s with the integration of robots, programmable controllers, and digital control into computer-operated machinery. FMS can be described as an interconnected set of digitally controlled tools and machines managed by a central computer system. Work cells are linked through automated loading/unloading units and conveying systems, allowing efficient coordination across operations. Such systems enhance operational adaptability by executing manufacturing tasks for multiple product designs in small batches with shorter delivery times. In this way, FMS functions as an automated production model capable of producing one or more sets of parts with flexibility to sustain competitiveness (Kostal & Velisek, 2011). Contemporary manufacturing environments face new challenges—marked by complexity, product variety, and a demand for higher customization. This has increased reliance on FMS, which are particularly suited to accommodate product diversity (Lafou *et al.,* 2016). Kaushal *et al.,* (2016) define FMS as a highly automated cell of machines connected by automated material handling and storage, overseen by a distributed computer system. Similarly, Shukla and Gangwar (2021, p. 641) describe it as the speed and efficiency with which a production line can shift from existing to new products. Groover (2008) and Kavaliauskiene *et al.,* (2022) emphasize the integration of multiple processing stations and computer-based control, while Hamidi (2018) highlights machine groups supported by electronic handling and storage. More recently, Al-Ghannam (2022) views FMS as a set of tools designed to reduce non-value-adding activities, eliminate waste, and support continuous production improvement.

Advantages of FSM

Flexible manufacturing systems help organizations meet specialized production needs while responding swiftly to changing market demands. By lowering inventory levels, reducing lead times, and producing high-quality goods at competitive costs, FMS provides organizations with an effective mechanism to expand market share (Groover, 2008). Some of the primary advantages include:

- Workstation control via computerized systems.
- Centralized control instructions coordinating multiple stations.
- Production control for product mix, scheduling, and planning.
- Traffic control to regulate the flow of parts between stations.
- Shuttle control to align primary and secondary handling systems.
- Workpiece monitoring to track the status of parts throughout production.
- According to Al-Ghannam (2022), additional benefits include first-time quality through early problem detection, waste reduction, continuous improvement, cost efficiency, productivity gains, adoption of pull systems, and rapid adaptability to varying product specifications.

Types of flexibility in FMS

Flexibility is the distinguishing attribute of FMS, enabling uninterrupted production despite shifts in product design or demand. A system that can simultaneously process multiple product models and adjust output volumes accordingly is considered flexible (Kaushal *et al.,* 2016; Kumar *et al.,* 2017). The main types include:

Machine flexibility – the ability of machines to perform diverse operations, influenced by setup time, tool storage, programming ease, and operator skills.

Production flexibility – the scope of part designs producible within acceptable cost and time, determined by the range of processes supported across stations.

Mix flexibility – the ability to vary product proportions while maintaining constant overall output, thus mitigating market volatility.

Product flexibility – the capacity to shift quickly and economically to new product lines, depending on design compatibility and machine adaptability.

Volume flexibility – the ability to adjust production volumes to meet demand fluctuations while retaining profitability.

Shukla Gangwar (2021) & Ewis *et al.,* (2025) classify flexibility into machine flexibility, where specific machines produce varied products, and routing flexibility, where multiple machines can perform the same process.

Key components of FMS

Globalization and shifting market dynamics have compelled industries to prioritize responsiveness, quality, and customer satisfaction over mere cost reduction. FMS integrates automation, robotics, and advanced planning tools (e.g., JIT, PPC, ERP) to meet these needs (Kaushal et al., 2016). According to Kostal and Velisek (2011), FMS rely on three primary subsystems—machine tools, material-handling systems, and computer control—coordinated to achieve end-to-end automation from design to storage. Once a part passes through technological processing, it undergoes inspection; approved items are stored automatically, while defective ones are routed to designated storage areas, all without human intervention. Kaushal *et al.,* (2016) identify the following essential components:

Workstations – CNC machine tools, machining centers, inspection and assembly units, presses, and forming stations.

Automated Material Handling and Storage Systems (AMHS) – systems enabling random transfer, temporary storage, and seamless integration with computer controls.

Inspection equipment – such as coordinate measuring machines programmed for dimensional and surface accuracy.

Computer Control System (CCS) – managing workstation activities, material flow, production scheduling, system monitoring, and reporting.

Other supporting components – sensors, inspection tools, temporary storage, and skilled human resources- all contribute to system efficiency, adaptability, and organizational success.

HRS

Concept: During the final decades of the twentieth century, the strategic approach to Human Resource Management (HRM) emphasized compliance with legal requirements, reducing litigation, and supporting organizational economic goals. In the twenty-first century, however, the discourse has shifted toward sustainability. A sustainable society cannot be achieved without organizations safeguarding the sustainability of their human resources. In this context, HRS refers

to practices that simultaneously enhance economic, social, and environmental performance while promoting long-term employee well-being, satisfaction, and commitment. Its essence lies in creating workplace conditions that balance organizational objectives with the quality of employees' professional lives (Genari, 2022). Sustainability encompasses two complementary aspects: the sustainability of human resources, which involves meeting evolving human needs, and environmental sustainability, which relates to protecting ecosystems while recognizing the interdependence of people and nature (Spooner & Kaine, 2010). An HRS framework typically includes transparent procedures for recruitment, retention, training, performance management, and motivation. Its long-term orientation emphasizes socially responsible policies that enhance engagement and reduce turnover. Success is thus measured not only financially but also by social and environmental contributions (Cherian & Farouk, 2017; Vanka *et al.,* 2020). In practice, HRS means planning, attracting, and supporting employees in ways that allow them to achieve the organization's economic, social, and environmental goals, while ensuring intergenerational equity (Sas, 2022). As Lu *et al*., (2023) observe, HRS emerges when HRM adopts policies and strategies enabling employees to actively pursue organizations' long-term triple-bottom-line objectives.

Importance of HRS

Organizations that embrace sustainability can reduce costs and expand revenues through improved efficiency, innovation, and growth. However, many change initiatives fail due to neglect of the human dimension, where goals are set without adequate consideration of employee roles in achieving them (Spooner & Kaine, 2010; Schroeder, 2012). Implementing HRS policies fosters a productive, motivated workforce that contributes not only to financial success but also to social and environmental advancement. Employees in such organizations feel stronger connections to their employers, reinforcing loyalty and long-term commitment (Cherian & Farouk, 2017). The concept further guards against exploitation of human capital by preserving and enhancing knowledge, skills, and physical capacity. Motivated and engaged employees become catalysts for achieving sustainable development. According to Sas (2022) and Dumitrana *et al.,* (2009), the importance of HRS can be summarized as follows:

- Supporting the organization's sustainability strategy.
- Ensuring fairness and employee well-being.
- Developing skills and confidence that reinforce commitment to sustainability.
- Addressing both internal stakeholders (employees) and external ones (partners and communities).
- Promoting environmentally responsible practices.

Additionally, HRS strengthens competitiveness by attracting and retaining talent, promoting workplace justice, safeguarding occupational health and safety, and embedding social responsibility into corporate culture (Anlesinya & Pattanee, 2020).

Requirements for HRS

HR professionals are uniquely positioned to drive sustainability within organizations. Key requirements include (Schroeder, 2012):

- Awareness and Dialogue. Building employee awareness of sustainability through training, workshops, newsletters, and digital resources to encourage participation and commitment.
- Technical and Scientific Competence. Ensuring adequate skills for sustainability implementation through training or targeted recruitment, along with systematic skills audits.
- HR Policies and Processes. Revising performance management, recruitment, and reward systems to integrate sustainability factors into competencies and job descriptions.
- Socially Responsible Recruitment. Aligning hiring practices with corporate social responsibility by attracting employees who value sustainability, ensuring fair employment terms, and training suppliers as well as internal staff.

Expanding on this, Anlesinya and Pattanee (2020) and Liu (2024) highlight additional requirements, including long-term workforce planning, employee well-being, environmentally friendly behaviors, profitability and engagement programs, active participation and social dialogue, job rotation and training, stakeholder partnerships, flexible work arrangements, compliance beyond statutory minimums, teamwork and cooperation, and promotion of fairness and equality in wages and opportunities.

Dimensions of HRS

Sustainability concerns have increasingly drawn academic attention to HR, labor relations, and the role of organizations in advancing sustainable development. HRS is frequently associated with employee engagement and emotional well-being, reinforcing the idea that employees are the foundation of organizational sustainability (Spooner & Kaine, 2010). According to Stankeviciute and Savaneviciene (2018), HRS emphasizes employability, personal responsibility, and work–life balance, conceptualized through three key dimensions: justice, job well-being, and employee development. These align with the current study's framework. Justice. Justice reflects fairness in treatment, whether understood as equality or as recognition of individual differences (Jones *et al.,* 2010). Research highlights its role in shaping trust, citizenship behaviors, and innovation, both within and between organizations (Yeoman & Santos, 2016). Balal (2025) stresses that justice directly influences performance by shaping how employees perceive organizational fairness through social, moral, and religious values. Well-being encompasses positive emotions, psychological stability, and workplace satisfaction. It includes life, workplace, and psychological dimensions (Al-Abadi, 2017). Practices supporting well-being range from health programs and stress-free environments to activities that enhance motivation and productivity (Al-Awimer & Al-Shabli, 2024). Employee Development. Training and development are essential for equipping employees with evolving skills. Training provides knowledge and technical expertise, while development prepares staff for higher responsibilities and long-term adaptability. Continuous investment in employee development ensures competitiveness in dynamic environments (Al-Khalayleh, 2019; Nashash, 2020; Stavros,2022).

RESULTS AND FINDINGS

Description of the research sample

A purposive sample was selected, focusing on individuals who possess direct experience with—and awareness of—the laboratory's operations and tasks. This approach was intended to ensure high-quality, actionable responses and to solicit ideas that could enrich the study's contribution. In total, 230 questionnaires were distributed, and 207 usable responses were obtained for analysis, yielding a 90% response rate.

Sampling adequacy

Preliminary diagnostics supported the factorability of the correlation matrix. The Kaiser–Meyer–Olkin measure of sampling adequacy reached 0.79, indicating acceptable shared variance among the observed variables. In addition, Bartlett's test of sphericity was significant ($\chi^2 = 1120.3$, df = 276, $p < 0.001$), demonstrating that the inter-item correlations are sufficiently large for factor analysis. These results justify the use of confirmatory factor analysis and structural equation modelling in testing the proposed relationships between flexible manufacturing systems and human resource sustainability.

Confirmatory Factor Analysis (CFA)

CFA was employed to test the measurement model using standard goodness-of-fit criteria to judge acceptability and suitability for hypothesis testing. The analysis relied on the Scale-Free Least Squares (SLS) estimator, which typically presumes: (i) approximately normal data, (ii) absence of extreme outliers, and (iii) a sample size at least five to ten times the number of observed indicators. In the present dataset, these preconditions were not fully satisfied, as evidenced in Fig. 2 and Table 1, which document deviations from normality and sizing requirements.

From Table 1, the model's fit indices are satisfactory and lie within accepted thresholds for measurement quality. Accordingly, the hypothesized model is retained without modification and deemed suitable for subsequent hypothesis testing.

Third hypothesis testing

With the CFA confirming that the measurement model aligns with the field data and meets required fit standards, we proceed to test the study hypotheses as follows:

First Main Hypothesis Statement: There is a significant correlation between flexible manufacturing systems and human resource sustainability (overall). Result. As reported in Table 2, the correlation between flexible manufacturing systems and human resource sustainability (total) is positive and statistically significant, with . Therefore, the first main hypothesis is supported.

Sub-hypothesis (A) of the first main hypothesis

There is a significant correlation between each component of flexible manufacturing systems and human resource sustainability. According to Table 3:

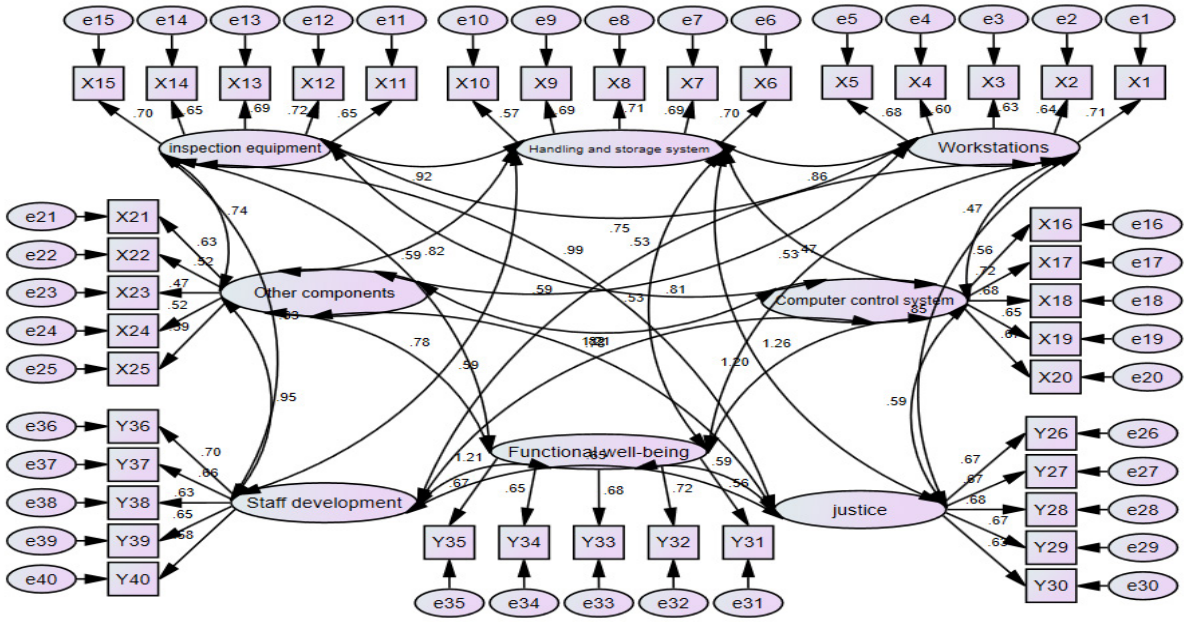


Fig. 2: The proposed prototype of the system

Table 1: Quality indicators of the initial research model

Standard indicators	Acceptance limits	Model indicators	Matching result
GFI	0.90 > GFI Model quality	0.927	Matching
AGFI	0.90 > AGFI Best Match	0.916	Matching
RMR	RMR value between 0.08 and zero	0.068	Matching
NFI	0.90 > NFI Best Match	0.913	Matching
RFI	0.90<(RFI) Data fit to model	0.905	Matching
PGFI	The closer to (1), the better the match.	0.805	Matching
PRATIO	PRATIO > 0.90 Best Match	0.913	Matching

Table 2: The relationship between flexible manufacturing systems and human resource sustainability (combined)

independent variable / **Dependent variable**	Flexible Manufacturing Systems
Human Resource Sustainability	0.932*

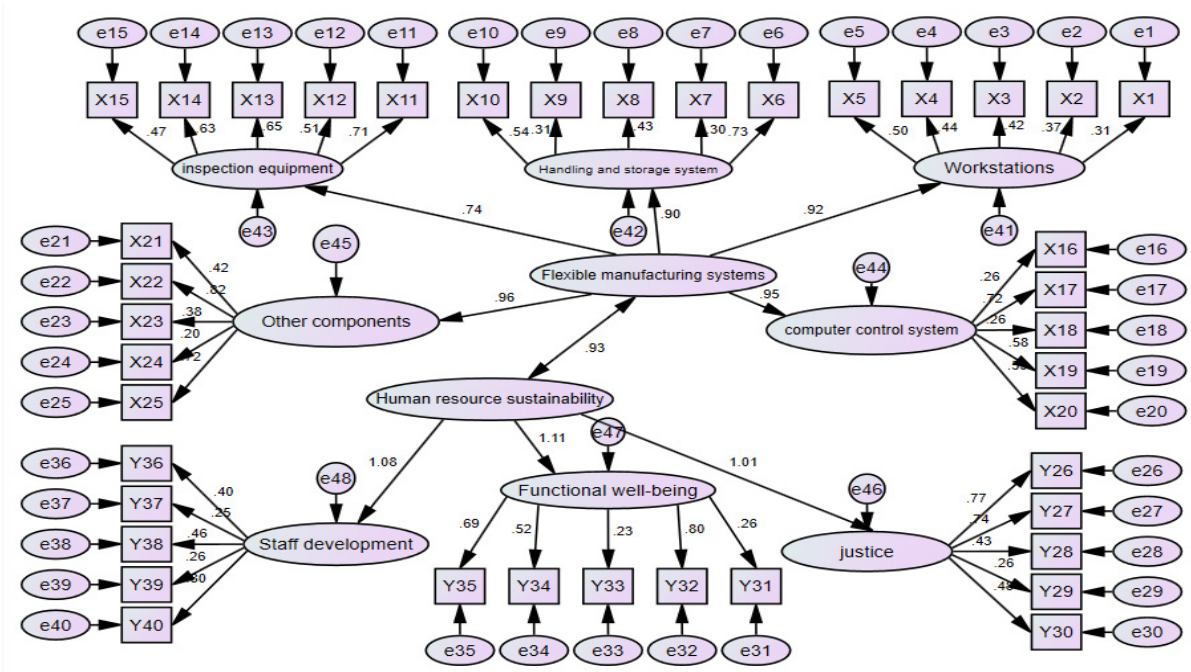


Fig. 3: Model of the correlation between flexible manufacturing systems and human resource sustainability (combined)

Table 3: Correlations between components of FSM and HRS

Components of Flexible Manufacturing Systems	Other components	Computer control system	Inspection equipment	Handling and storage system	Workstations
Human Resource Sustainability	0.928*	0.902*	0.644*	0.833*	0.841*

1. Workstations → HRS. The correlation is positive and significant (r = 0.841*, α = 0.05).
2. Handling & Storage Systems → HRS. The correlation is positive and significant (r = 0.833*, α = 0.05).
3. Inspection Equipment → HRS. The correlation is positive and significant (r = 0.644*, α = 0.05).
4. Computer Control Systems → HRS. The correlation is positive and significant (r = 0.902*, α = 0.05).
5. Other Components → HRS. The correlation is positive and significant (r = 0.928*, α = 0.05).

In summary, all five FMS components exhibit statistically significant positive associations with human resource sustainability; therefore, Sub-Hypothesis (A) is supported. Accordingly, Sub-Hypothesis (A) of the first main hypothesis is accepted, confirming that each component of flexible manufacturing systems demonstrates a significant positive correlation with human resource sustainability.

Second main hypothesis

There is a significant effect of flexible manufacturing system components on the dimensions of human resource sustainability (overall) in the organization under study. To test this hypothesis, a Structural Equation Model (SEM) was specified and estimated (see Fig. 6). For the evaluation. Model fit indices and path estimates were examined to judge hypothesis support; the relevant test statistics and criteria are reported in Table 4. These results determine whether the second hypothesis is accepted or rejected.

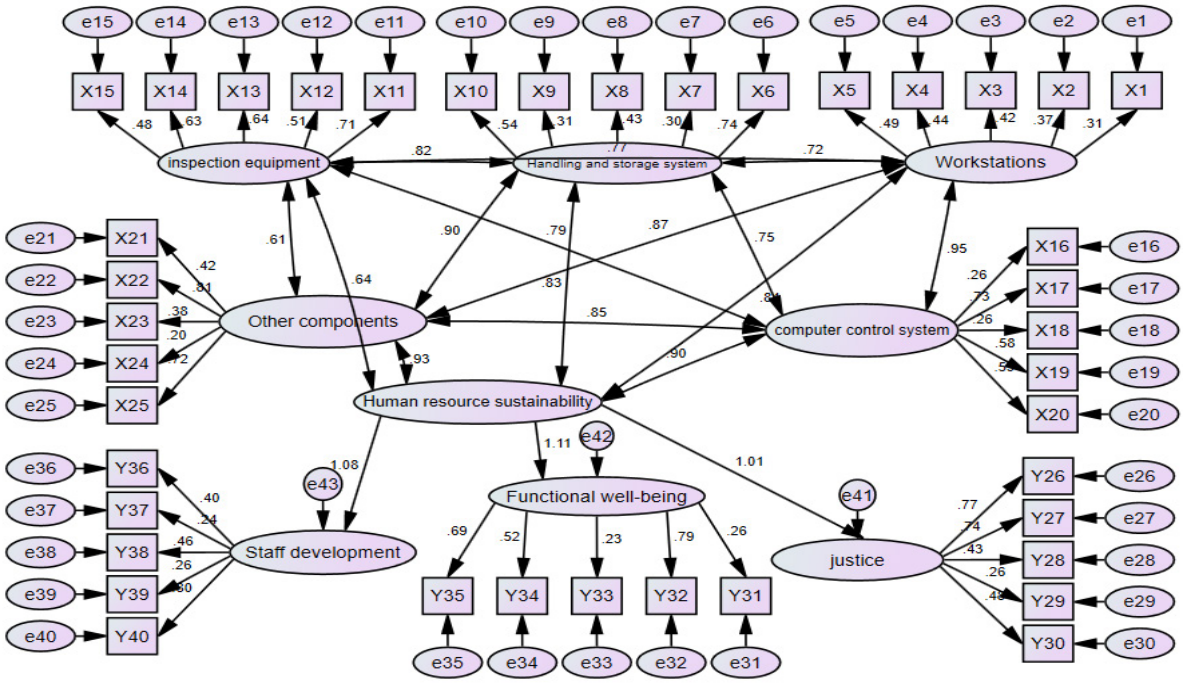


Fig. 4: A model of the correlation between the components of FSM (individually) and HRS

Table 4: Values of the analysis of H2 (combined).

Influencing variable	Direction of effect	Variable affected by	Estimate	SRW	Upper	Lower	P
FMS	→	HRS	2.079	0.932	0.971	0.896	0.02

Table 4, compiled by the researchers from the softwaBluere output—shows a direct, statistically significant effect of FMS dimensions on HRS. The Standardized Regression Weight (SRW) is 0.932, and the unstandardized coefficient (Estimate) is 2.079. This effect is significant given p = 0.02 < 0.05. The 95% confidence interval for the coefficient (0.896–0.971) excludes zero, further confirming the robustness of the effect. Accordingly, the second main hypothesis is accepted.

Sub-hypothesis (A) of the second main hypothesis

Each dimension of the flexible manufacturing system exerts a significant effect on human resource sustainability within the organization under study. To evaluate this sub-hypothesis, an SEM was specified and estimated (see Fig. 6). The corresponding fit indices and path coefficients used to determine acceptance or rejection of the sub-hypothesis are reported in Table 5. These statistics provide the basis for judging the significance and direction of the effects from each FMS dimension to the HRS construct.

The SEM results confirm the significance of the model used to test Sub-Hypothesis (A) of the second main hypothesis. As shown in Table 5, the model exhibits positive fit indicators and high saturation (factor loading) values exceeding 45%, consistent with the acceptable thresholds (see Fig. 6). Examining the path estimates and their standard errors indicates that the largest effect among individual FMS components on human resource sustainability stems from the Computer Control System, suggesting that the organization prioritizes computerization and production-line automation to support long-term HRS. By contrast, the smallest

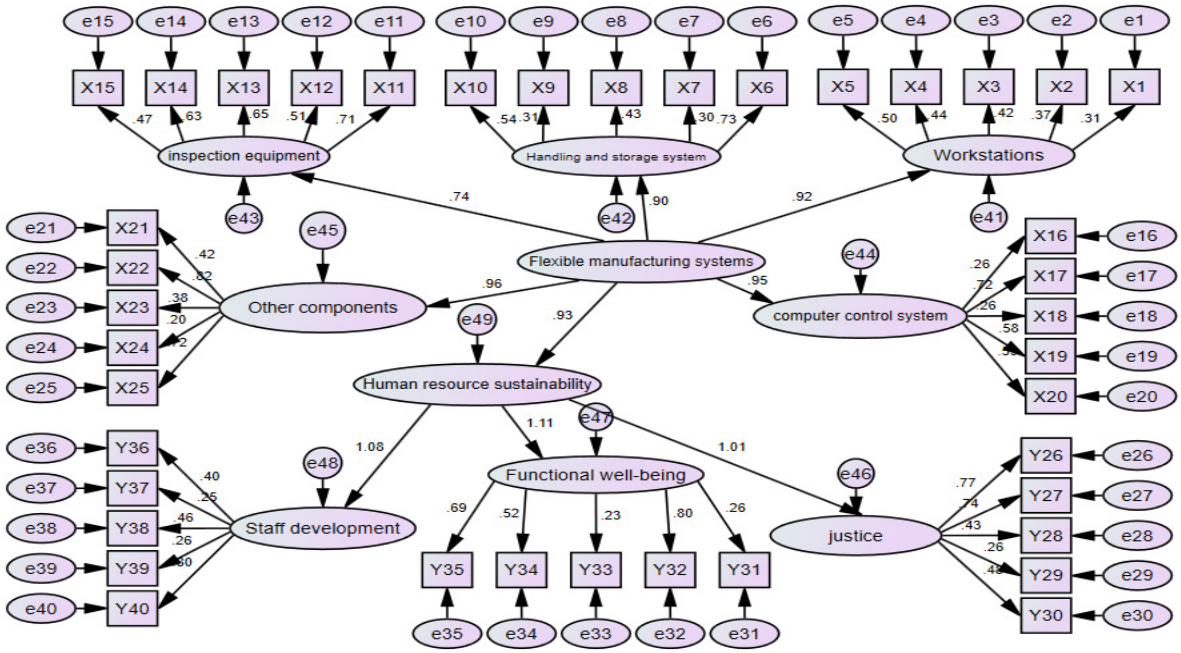


Fig. 5: Model of the influence relationships between the components of flexible manufacturing systems (together) on human resource sustainability

Table 5: Values of the H2

Influencing variable	Direction of effect	Variable affected by	Estimate	SRW	Upper	Lower	P
Workstations	→	Human resource sustainability	0.717	0.347	0.456	.....	0.29
Handling and storage system	→	Human resource sustainability	1.000	0.601	0.763	0.415	0.04
Inspection equipment	→	Human resource sustainability	1.114	0.515	0.145	.....	0.02
Computer control system	→	Human resource sustainability	5.460	1.189	.....	0.673	0.00
Other components	→	Human resource sustainability	0.003	0.003	2.218	0.902	0.99

effect is associated with Other Components, a result attributable to environmental turbulence, resource constraints, and adherence to legal and regulatory requirements that collectively limit the organization's ability to adopt ancillary technologies at pace. The critical ratio (C.R.) = 3.18 exceeds the reported critical values (1.96 and 1.99) at the stated significance levels (0.005 and 0.01, respectively), which are equivalent to the t-statistic benchmarks in conventional regression testing. Accordingly, Sub-Hypothesis (A) is accepted: each FMS component exerts a significant effect on human resource sustainability within the organization under study. For future work, it can be summarized as follows, according to the proposed methods (Haller *et al.*, 2025; Blecha et al., 2025; Blondheim, 2025):

- Prioritize Computer Control Systems, which allocate targeted funding for software and hardware upgrades (e.g., control platforms, HMIs, SCADA/MES links), with a staged rollout plan and ROI/KPI tracking (e.g., error rate, un-

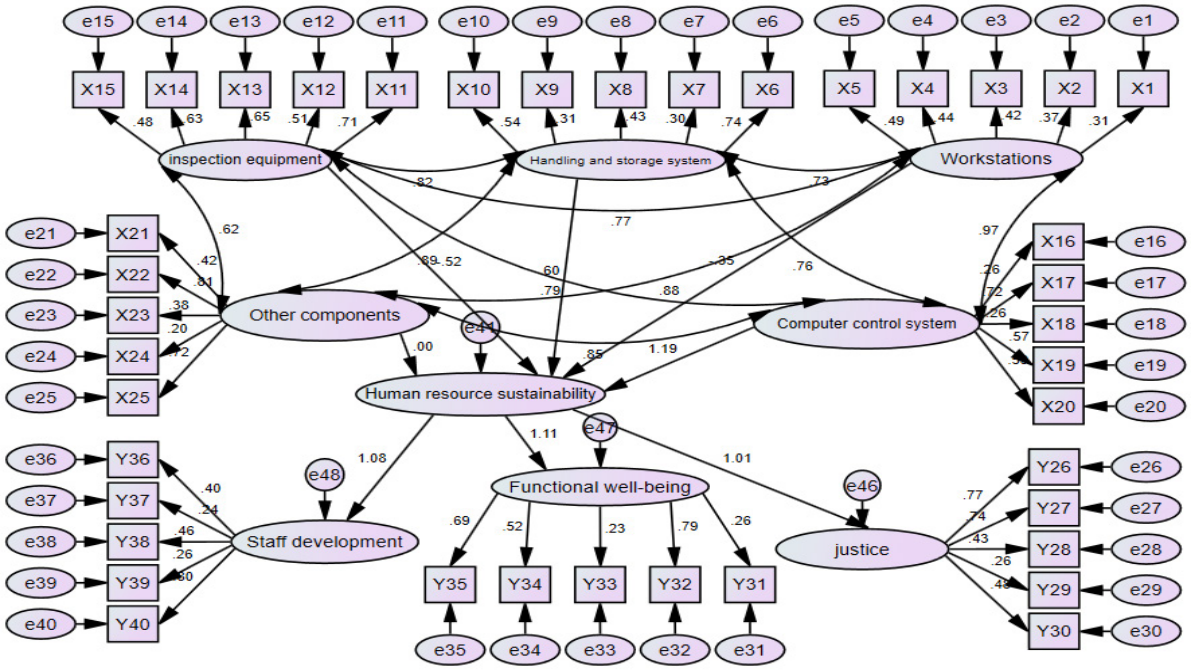


Fig. 6: Model of the influence relationships between the components of flexible manufacturing systems (individually) on human resource sustainability

planned downtime).

- Capability Building is implementing structured training (initial + refresher) on FMS/CCS use, with competency checklists and certification; link completion to performance objectives.
- Modernize Handling & Storage, which upgrades AMHS elements (conveyors, AGVs, racking, sensors) to reduce manual handling, improve flow, and enhance safety; track outcomes via near-miss incidents, MTTR/MTBF, and throughput.
- Optimize Internal Workflows: map value streams for high-volume lines; remove bottlenecks, standardize work, and establish visual management. Monitor lead time, WIP, and OEE to verify gains.
- Environmental Scanning & Constraints Management conducts periodic internal–external analyses (e.g., SWOT/PESTLE) to identify opportunities and regulatory/resource constraints; integrates findings into annual capex and risk registers.
- Strategic Partnerships. Pursue vendor, academic, and integrator partnerships to access expertise, pilot technologies, and share cost/benefit—especially for high-capex components.
- Advance Inspection Capability, which shifts toward automated/assisted inspection (e.g., CMM upgrades, in-line sensing, SPC dashboards) to reduce human error and accelerate feedback to operators.
- Integrated HRS–FMS Strategy, which develops a comprehensive HRS strategy explicitly linked to FMS design, deployment, and continuous improvement (not siloed by component). Include KPIs such as: lost-time injury frequency rate, ergonomic risk scores, training completion, engagement index, turnover, rework/scrap rate, and OEE.

Taken together, these results provide several empirical contributions. First, they offer rare evidence from the Iraqi pharmaceutical industry on how FMS components are related to human resource sustainability, a context that has received limited attention in prior research. Second, by showing that all five FMS

components are positively associated with HRS and that computer control systems exert the strongest standardized effect, the study identifies which technological investments are likely to yield the greatest sustainability benefits for employees. Third, the validated structural equation model integrates FMS and HRS into a single analytical framework that can be replicated or extended in future studies on sustainable manufacturing.

CONCLUSIONS AND FUTURE WORK

Workstations ↔ HRS: The analysis shows a strong positive association between workstation design/functionality and HRS. Enhancing ergonomics and task design improves the work environment, reduces physical/psychological strain, raises job satisfaction, and lowers turnover.

Handling & storage systems ↔ HRS: There is a strong positive correlation between the efficiency of handling and storage systems and HRS. Better flow, reduced manual effort, and improved safety procedures lower occupational risk, strengthen employee health and safety, and increase productivity and satisfaction—thereby supporting HRS.

Inspection equipment ↔ HRS: Results indicate a moderately strong positive relationship. Accurate inspection tools raise product quality and reduce rework and errors, which eases time pressure and stress on employees and, in turn, supports HRS.

Computer control systems ↔ HRS: The correlation is very strong and positive. Effective computer control—through automation and reliable data—reduces repetitive tasks, improves operational accuracy, and enhances employee satisfaction, reinforcing HRS.

Other components ↔ HRS: A very strong positive correlation is observed. Supporting elements (e.g., advanced software, communications, infrastructure) enable system integration and better working conditions, reducing stressors and providing adequate operational support, thus advancing HRS.

FMS as an Integrated System → HRS: Collectively, FMS dimensions exert a direct, significant impact on HRS. Investment in FMS improves not only production efficiency but also the sustainability of the workforce by enhancing the work environment, mitigating risks, and increasing job satisfaction.

In summary, the results of the present study are broadly consistent with earlier work on sustainable HRM and organizational flexibility. Studies such as Cherian and Farouk (2017), Stankeviciute and Savaneviciene (2018), and Lu *et al.,* (2023) report that human resource practices aligned with sustainability principles enhance employee well-being, commitment, and performance, which accords with our finding that higher levels of HRS are associated with better-designed FMS components. Similarly, research on flexibility and manufacturing systems (e.g., Kalogiannidis *et al.,* 2022; Kavaliauskiene *et al.,* 2022) emphasizes the strategic value of flexible technologies for building resilient organizations. By demonstrating that computer control systems and handling and storage systems show particularly strong links to human resource sustainability in a pharmaceutical setting, this study extends these insights to a new empirical context and highlights the human side of flexible manufacturing.

AUTHOR CONTRIBUTIONS

All authors contributed to the study conception and design. The authors performed data collection and analysis. All authors contributed to drafting and revising the manuscript and approved the final version.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the authors have acknowledged the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, which have been fully addressed.

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ABBREVIATIONS (NOMENCLATURE)

AMHS	Automated Material Handling and Storage (System)
CFA	Confirmatory Factor Analysis
CI	Confidence Interval
CMM	Coordinate Measuring Machine
CNC	Computer Numerical Control
CCS	Computer Control System
C.R.	Critical Ratio (SEM test statistic, ≈ *t*-value)
ERP	Enterprise Resource Planning
FMS	Flexible Manufacturing System(s)
HRS	Human Resource Sustainability
HRM	Human Resource Management
JIT	Just-in-Time
p (P-value)	Probability value (significance level)
PPC	Production Planning and Control
r	Pearson Correlation Coefficient
SEM	Structural Equation Modeling
SLS	Scale-Free Least Squares (SEM estimator)
SRW	Standardized Regression Weight
α	Significance Level (Type I error rate)

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ORIGINAL RESEARCH PAPER

Human capital as a key driver of micro-small-medium enterprises' performance: Examining the roles of entrepreneurial orientation, business capital, and strategic agility

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ABSTRACT

BACKGROUND AND OBJECTIVES: Micro, small, and medium enterprises play a vital role in Indonesia's urban economy, contributing 60.5% to Gross Domestic Product and fostering employment and economic resilience. However, despite policy support through Law No. 20/2008 on MSMEs, performance gaps persist in secondary cities where over 60% of MSMEs fail within five years due to managerial, financial, and adaptive constraints, a critical concern for Indonesia's 98 secondary cities, housing 40% of national micro, small, and medium enterprises. This study examines how entrepreneurial orientation, owner's education, and business capital influence MSME performance, with strategic agility as a mediating variable, in Mojokerto, East Java.

METHODS: A quantitative-explanatory design was applied using Partial Least Squares Structural Equation Modeling (PLS-SEM) in SmartPLS 4.0. Data were collected through face-to-face interviews conducted from February to March 2024 with 60 micro, small, and medium enterprise owners registered under *the Badan Usaha Milik Desa or* village-owned enterprises in Mojokerto Regency. Five constructs, entrepreneurial orientation (5 indicators), owner's education level (4), business capital (4), strategic agility (4), and MSME performance (4), were measured using five-point Likert scales. The measurement model was tested for reliability and validity, followed by structural model evaluation and hypothesis testing via bootstrapping with 5,000 resamples at $\alpha = 0.05$.

FINDINGS: All constructs demonstrated satisfactory validity and reliability, with indicator loadings above 0.787, composite reliability (CR) ranging from 0.878 to 0.928, and average variance extracted ranging from 0.644 to 0.766. The owner's education level had a significant positive effect on MSME performance ($\beta = 0.342$, $t = 2.203$, $p = 0.028$), accounting for 12.6% of its variance. Entrepreneurial orientation (EO) did not significantly affect performance ($\beta = -0.152$, $p = 0.296$) or strategic agility ($\beta = -0.180$, $p = 0.263$). Likewise, business capital had no significant effect on either performance ($\beta = 0.184$, $p = 0.168$) or agility ($\beta = -0.041$, $p = 0.755$). The effect of strategic agility on performance was positive but not statistically significant ($\beta = 0.237$, $p = 0.101$). Mediation analysis confirmed that strategic agility did not significantly mediate any relationships (all $p > 0.40$).

CONCLUSION: Owner's education level emerges as the primary determinant of MSME performance in Indonesia's secondary cities, exerting a direct influence rather than through strategic agility. Strengthening human capital is therefore essential for urban entrepreneurial resilience. These findings suggest that while Law No. 20/2008 on MSMEs provides the legal framework for MSME development, implementation should prioritize human capital enhancement over capital provision alone. Policymakers should emphasize accessible education, managerial development, and digital literacy for MSME owners through targeted programs aligned with Presidential Regulation No. 2/2022 on Job Creation, over financial or promotional incentives.

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NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
46	1	7

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INTRODUCTION

Urban micro, small, and medium enterprises and economic resilience

In contemporary urban development discourse, micro, small, and medium enterprises (MSMEs) have emerged as fundamental pillars sustaining economic vitality and social cohesion within city ecosystems. Urban centers across developing nations increasingly rely on MSMEs not merely as employment generators but as critical agents of economic diversification, spatial regeneration, and community resilience. In Indonesia, MSMEs constitute approximately 60.5% of the national gross domestic product (Wahyudi *et al*., 2024), with substantial concentrations operating within urban and peri-urban zones where population density, market accessibility, and infrastructure availability converge to create entrepreneurial opportunities. This urban-centric positioning renders MSMEs indispensable to municipal economic strategies, particularly in secondary cities and regional urban centers where formal employment structures remain underdeveloped and economic vulnerability persists. The significance of MSMEs extends beyond aggregate economic indicators to encompass their role in shaping urban spatial dynamics and fostering inclusive growth patterns. Urban management scholars have increasingly recognized that sustainable city development requires nurturing local entrepreneurial ecosystems capable of absorbing labor, generating innovation, and responding flexibly to market disruptions (Audretsch & Belitski, 2021). Within this framework, MSMEs function as decentralized economic nodes that distribute wealth more equitably across urban neighborhoods, reduce dependency on large-scale industrial employment, and enhance the adaptive capacity of urban economies facing global uncertainties. However, the capacity of MSMEs to fulfill these urban developmental functions depends critically on the quality of human capital embedded within their ownership and management structures, alongside their ability to mobilize financial resources and demonstrate strategic agility in response to changing market conditions. Despite their pivotal contributions to urban economic ecosystems, MSMEs in Indonesian cities encounter persistent structural constraints that limit their potential to drive sustained urban development. Limited access to formal financial services, inadequate managerial competencies, and insufficient technological adoption constrain their capacity to scale operations and penetrate broader markets (Chen *et al*., 2016). These challenges become particularly acute in smaller urban centers and peri-urban areas where institutional support mechanisms remain fragmented, and infrastructure development lags behind metropolitan regions (Yaskun *et al*., 2023). Mojokerto, a regency encompassing both urban municipalities and rural hinterlands in East Java, exemplifies this developmental paradox. While its strategic location within the Surabaya metropolitan region offers market proximity and connectivity advantages, many MSMEs in Mojokerto operate with limited organizational capabilities and face difficulties translating entrepreneurial intentions into measurable performance outcomes. Understanding how these enterprises navigate constraints and leverage available resources becomes essential for formulating effective urban economic policies that strengthen local entrepreneurial ecosystems and enhance overall urban resilience.

Theoretical framework and dynamic capabillities

The relationship between entrepreneurial attributes, human capital endowments, financial resources, and business performance has attracted considerable scholarly attention across entrepreneurship and urban economics literature (Widjaja *et al*., 2022). Entrepreneurial orientation, conceptualized as the strategic posture encompassing innovation propensity, proactive market engagement, and calculated risk acceptance, has been identified as a behavioral foundation influencing firm-level outcomes (Al-Momani *et al*., 2023). Similarly, the educational attainment of business owners represents a critical dimension of human capital that shapes managerial decision-making, strategic planning capabilities, and adaptive learning processes (Maria *et al*., 2024). Business capital, reflecting perceived financial resource adequacy, enables operational stability and investment capacity essential for growth trajectories (Mahendra *et al*., 2017). However, empirical findings regarding these relationships remain inconsistent, with contextual variables such as institutional quality, market maturity, and geographical location moderating their effects. Moreover, existing research predominantly examines these factors in isolation, overlooking the dynamic interplay through which they collectively influence urban MSME performance. A notable gap persists in understanding how internal firm resources

translate into performance outcomes within urban contexts characterized by rapid change and competitive intensity. Strategic agility, defined as an organization's capability to sense environmental shifts, mobilize resources rapidly, and reconfigure operational processes in response to emerging opportunities or threats, has gained prominence as a mediating mechanism linking resource endowments to competitive outcomes (Weber and Tarba, 2014). Within urban entrepreneurial ecosystems where market conditions fluctuate frequently due to demographic shifts, technological disruptions, and policy changes, the capacity to adapt swiftly becomes indispensable for MSME survival and growth. Yet empirical investigations exploring strategic agility as a mediating variable connecting entrepreneurial orientation, education, and capital to performance remain scarce, particularly in urban developing economy contexts where institutional voids and resource constraints amplify the importance of adaptive capabilities. This theoretical and empirical lacuna limits the development of evidence-based urban management policies aimed at strengthening MSME contributions to urban economic development. This study addresses these gaps by examining how entrepreneurial orientation, owner's education level, and business capital influence MSME performance through the mediating role of strategic agility within an urban management framework. Grounded in dynamic capabilities theory (Teece and Pisano, 1994), which posits that sustainable competitive advantage derives from an organization's ability to integrate, build, and reconfigure competencies in response to environmental turbulence, the research conceptualizes strategic agility as a specific manifestation of dynamic capability, particularly relevant for resource-constrained urban MSMEs. The dynamic capabilities perspective offers theoretical coherence for understanding how MSMEs operating in urban ecosystems leverage human capital and entrepreneurial attributes to develop adaptive mechanisms that enhance performance resilience. By positioning strategic agility as a mediating construct, this study illuminates the processes through which static resources transform into dynamic competitive advantages within urban entrepreneurial contexts. From an urban management perspective, this research contributes actionable insights regarding how municipal authorities and development agencies can foster entrepreneurial ecosystems that enhance urban economic resilience. Urban management encompasses the coordinated governance of physical infrastructure, social services, economic activities, and environmental resources within spatially bounded city systems (Fang and Yu, 2017). Within this domain, nurturing productive entrepreneurial activity represents a strategic priority for achieving sustainable urban development goals, reducing unemployment, and building economic diversification. Understanding which dimensions of human capital and firm resources most significantly drive MSME performance, and through what mechanisms, enables more targeted policy interventions. Rather than generic support programs emphasizing financial capital provision alone, evidence-based urban management strategies can prioritize capacity-building initiatives that strengthen the specific capabilities most consequential for entrepreneurial success in urban settings. The empirical context of this study, Mojokerto Regency in East Java, Indonesia, provides a relevant setting for examining urban MSME dynamics. Mojokerto encompasses both urban municipalities with relatively developed infrastructure and peri-urban zones exhibiting transitional characteristics between rural and urban economies. MSMEs in this region operate within a complex institutional landscape where village-owned enterprises (*BUMDes*) serve as organizational platforms linking individual entrepreneurs to broader market networks and government support programs. This institutional arrangement reflects Indonesia's broader strategy of leveraging community-based economic organizations to foster inclusive development and strengthen local economic resilience (Saputra and Havlicek, 2025). By focusing on MSMEs affiliated with *BUMDes* structures, this research captures entrepreneurial dynamics within an urban-rural interface zone where adaptation to market changes and resource optimization become particularly critical for sustained performance. The findings, therefore, offer transferable lessons for urban managers in similar secondary cities and regional growth centers across developing economies.

Literature review and research gap

Previous empirical investigations have produced mixed findings regarding the direct effects of entrepreneurial orientation, education, and capital on MSME performance. Al-Hakimi *et al*. (2021) demonstrated that entrepreneurial orientation enhanc-

es supply chain resilience and performance among manufacturing SMEs, yet emphasized that this relationship operates through mediating mechanisms such as absorptive capacity and innovation capability. Kurniawan and Nuringsih (2022) found positive associations between entrepreneurial orientation and performance in Indonesian food MSMEs, suggesting contextual relevance within the local entrepreneurial ecosystem. However, other studies indicate that entrepreneurial orientation alone may be insufficient without complementary organizational capabilities and supportive institutional environments. These inconsistencies underscore the necessity of examining mediating variables that clarify the conditions under which entrepreneurial attributes translate into measurable outcomes. Similarly, research investigating education's influence on MSME performance reveals nuanced relationships contingent upon how educational capital manifests in managerial practices. Syafi'i *et al*. (2021) established that owner education level significantly affects MSME growth in Sidoarjo, Indonesia, through enhanced managerial competence and financial literacy. Maria *et al* (2024) further demonstrated that entrepreneurial education influences opportunity recognition and venture performance, particularly when combined with practical experience and network access. These findings suggest that education functions as a foundational human capital dimension that enables superior strategic decision-making and organizational learning. However, the mechanisms through which education enhances performance, particularly within urban entrepreneurial contexts requiring rapid adaptation, remain underexplored. Integrating strategic agility as a mediating construct potentially clarifies how educational capital translates into adaptive organizational behaviors that subsequently drive performance improvements. Business capital's role in MSME performance likewise exhibits complexity, dependent on how financial resources are deployed strategically. Kayani *et al*., (2025) demonstrated that working capital management significantly influences firm performance in African emerging markets, emphasizing that capital availability alone proves insufficient without effective resource allocation and liquidity management. Siregar and Daulay (2024) highlighted that digital transformation mediates the relationship between entrepreneurial leadership and MSME performance, suggesting that capital investments in technological capabilities yield superior returns compared to operational expenditures. These insights indicate that capital operates as an enabling resource whose performance impact depends on strategic utilization patterns. Within urban entrepreneurial ecosystems characterized by competitive intensity and rapid market evolution, capital adequacy may contribute to performance primarily by facilitating agile responses to emerging opportunities rather than through direct operational scaling. Strategic agility has gained recognition as a critical organizational capability, particularly relevant for small enterprises operating in volatile environments. Weber and Tarba (2014) conceptualized strategic agility as encompassing three core dimensions: strategic sensitivity to environmental changes, leadership unity in decision-making, and resource fluidity enabling rapid reconfiguration. Within urban contexts where market conditions shift frequently due to consumer preference changes, regulatory adjustments, and competitive dynamics, MSMEs require superior agility to maintain performance stability. Hosen (2022) examined agile strategies among Indonesian MSMEs and found that agility significantly enhances operational effectiveness and market responsiveness, particularly when combined with digital technology adoption. Rahmayanti and Pratiwi (2023) similarly demonstrated that organizational agility mediates the relationship between digitalization and competitive advantage in Denpasar's fashion MSMEs, confirming agility's role as a transformative mechanism connecting resources to outcomes. These empirical findings establish strategic agility as a theoretically coherent mediating construct warranting systematic investigation within urban MSME performance models. The dynamic capabilities framework provides theoretical grounding for conceptualizing strategic agility as a mediating mechanism. Teece and Pisano (1994) argued that sustainable competitive advantage in rapidly changing environments stems from organizational processes that sense opportunities, seize resources, and transform operations accordingly. Strategic agility operationalizes these dynamic capability dimensions at the organizational behavior level, encompassing rapid environmental scanning, flexible resource deployment, and swift strategic adjustments. For urban MSMEs facing resource constraints and institutional uncertainties, developing dynamic capabilities becomes essential for converting entrepreneurial intentions, educational knowledge, and financial resources into tangible performance

outcomes. The mediating role of strategic agility, therefore, represents the behavioral and cognitive processes through which static resource endowments transform into dynamic competitive advantages within urban entrepreneurial ecosystems. Drawing on these theoretical foundations and empirical precedents, this study proposes and tests a comprehensive model examining how entrepreneurial orientation, owner's education level, and business capital influence MSME performance both directly and indirectly through strategic agility. The research advances ten specific hypotheses structured around three main pathways: direct effects of the independent variables on performance, direct effects on strategic agility, and indirect mediated effects through agility. By empirically testing these relationships within an urban-focused sample of MSMEs in Mojokerto, the study contributes to urban management scholarship by clarifying which internal firm attributes most significantly drive entrepreneurial performance within secondary urban contexts and through what adaptive mechanisms these effects operate. The findings hold implications for designing urban economic development policies that strengthen local entrepreneurial ecosystems through targeted capacity-building interventions rather than generic financial support programs.

Hypothesis development

The specific hypotheses tested in this research are as follows: Entrepreneurial orientation positively influences MSME performance (H1) and strategic agility (H2). Owner's education level positively influences MSME performance (H3) and strategic agility (H4). Business capital positively influences MSME performance (H5) and strategic agility (H6). Strategic agility positively influences MSME performance (H7). Strategic agility mediates the effect of entrepreneurial orientation on MSME performance (H8), the effect of education level on MSME performance (H9), and the effect of business capital on MSME performance (H10). These hypotheses collectively constitute an integrated framework examining the dynamic interplay between human capital dimensions, financial resources, adaptive capabilities, and performance outcomes within urban entrepreneurial contexts.

Research contributions and objectives

This research makes three principal contributions to urban management and entrepreneurship literature. First, it provides empirical evidence on strategic agility's mediating role in linking entrepreneurial attributes and human capital to performance within an Indonesian urban context, addressing a notable gap in developing economy entrepreneurship research. Second, it offers a theoretically grounded perspective on how urban MSMEs can enhance resilience and competitiveness through developing dynamic capabilities, informing evidence-based urban economic development strategies. Third, it enriches the discourse on human capital's multidimensional influence within urban entrepreneurial ecosystems by demonstrating how education operates both directly through enhanced managerial competence and indirectly through enabling adaptive organizational behaviors. The practical implications extend to urban policymakers, development agencies, and entrepreneurial support organizations seeking to design interventions that strengthen MSME contributions to sustainable urban development. Therefore, the main objective of this study is to analyze the influence of entrepreneurial orientation, owner's education level, and business capital on MSME performance through the mediating role of strategic agility within an urban management framework, with a specific focus on MSMEs operating in Mojokerto, East Java, Indonesia.

MATERIALS AND METHODS

Research design and paradigm

This research employed a quantitative-explanatory design within a positivist epistemological framework to examine causal relationships among entrepreneurial orientation, owner's education level, business capital, strategic agility, and MSME performance in an urban management context. The study utilized Partial Least Squares Structural Equation Modeling (PLS-SEM) via SmartPLS version 4.0, selected for its suitability in handling complex models with multiple latent variables, mediating relationships, and modest sample sizes while maximizing explained variance in endogenous constructs (Hair *et al*., 2021).

Population and sampling

The target population comprised MSME owners registered with village-owned enterprises (*BUMDes*) in Mojokerto Regency, East Java, Indonesia. *BUMDes* are community-based economic organizations facilitating local entrepreneurial development and channeling government support to micro

and small enterprises (Srirejeki, 2018). The study employed purposive and incidental sampling techniques, focusing on MSMEs operating in urban and peri-urban zones. From an estimated population of 120 eligible MSMEs, sample size determination using Slovin's formula (10% error margin) yielded a minimum requirement of 55 respondents. After distributing 86 questionnaires and conducting data screening, 60 valid responses were retained for analysis, exceeding the minimum requirements for PLS-SEM (Hair *et al*., 2022). Inclusion criteria required: (1) continuous operation for a minimum of one year; (2) primary ownership with decision-making authority; (3) active *BUMDes* registration; and (4) substantial business activities in urban/peri-urban zones. Exclusion criteria eliminated enterprises functioning solely as suppliers without direct consumer engagement.

Measurement instruments

A structured questionnaire measured five constructs using established scales adapted to Indonesian urban MSME contexts through forward-backward translation (Brislin, 1970). All items employed five-point Likert scales (1 = strongly disagree to 5 = strongly agree).

- Entrepreneurial Orientation was assessed using five indicators adapted from Al-Hakimi *et al*., (2021) and Lumpkin and Dess (1996), measuring risk-taking propensity, innovation orientation, proactive behavior, decision autonomy, and competitive aggressiveness.
- Owner's Education Level was measured through four dimensions capturing formal education attainment, managerial knowledge, technical skills, and financial literacy, extending beyond credentials to functional competencies (Unger *et al*., 2011).
- Business Capital was operationalized as perceived capital adequacy through four indicators adapted from Kayani *et al*., (2025): access to capital, operational sufficiency, financial stability, and capital growth capacity.
- Strategic Agility employed four indicators reflecting environmental adaptability, operational responsiveness, strategic flexibility, and innovation speed, capturing dynamic capabilities relevant for urban MSMEs (Doz & Kosonen, 2010).
- MSME Performance was assessed through four indicators: revenue growth, market expansion, profitability, and operational efficiency, representing multidimensional entrepreneurial success (Lechner & Gudmundsson, 2014).

The questionnaire underwent content validity assessment by three academics and two MSME practitioners, face validity evaluation through cognitive interviews with five owners, and pilot testing with 15 MSMEs, resulting in minor refinements.

Data collection procedures

Data collection occurred during February-March 2024 through face-to-face interviews conducted by four trained enumerators. Field visits were coordinated through BUMDes administrators, with enumerators explaining study purposes, obtaining informed consent, and ensuring confidentiality. Each interview lasted approximately 25-35 minutes, with assisted administration ensuring data quality given varying respondent literacy levels (Fowler, 2014).

Ethical considerations

The study received approval from the Research Ethics Committee of Universitas Negeri Malang (Approval Number: 028/KEPK-UM/2024, dated January 15, 2024). Written informed consent was obtained from all participants, with confidentiality protected through anonymous coding and secure data storage. Small tokens of appreciation (traditional snacks, ~IDR 20,000) were provided following interviews as culturally appropriate gratitude gestures.

Data analysis

Data analysis followed established PLS-SEM protocols (Hair *et al*., 2019) through three stages:

- Stage 1: Measurement Model Assessment. Convergent validity was evaluated through indicator loadings (≥0.708), composite reliability (≥0.70), and average variance extracted (≥0.50). Discriminant validity was assessed using the Fornell-Larcker criterion, cross-loadings, and heterotrait-monotrait (HTMT) ratios (<0.85) (Fornell & Larcker, 1981; Henseler *et al*., 2015).
- Stage 2: Structural Model Evaluation. Model quality was assessed through R^2 (variance explained), adjusted R^2, effect sizes (f^2), and pre-

dictive relevance (Q^2) using blindfolding procedures (Cohen, 1988; Geisser, 1974; Stone, 1974).

- Stage 3: Hypothesis Testing. Direct effects (H1-H7) and indirect mediated effects (H8-H10) were tested using bootstrapping with 5,000 resamples. Statistical significance was determined at $\alpha = 0.05$ using bias-corrected confidence intervals (CI). Mediation analysis followed contemporary guidelines (Nitzl *et al*., 2016; Zhao *et al*., 2010), calculating indirect effects as the product of predictor-to-mediator and mediator-to-outcome paths.

RESULTS AND DISCUSSION

Demographic profile of respondents

The investigation encompassed 60 MSME proprietors operating within Mojokerto's urban landscape, presenting a demographic composition characteristic of entrepreneurial activities in Indonesia's secondary urban centers. Male entrepreneurs constituted 65% of the participant pool, while the predominant age cohort (70%) ranged between 30 and 50 years, a developmental stage where accumulated business acumen intersects with the vigor required for sustained operational management. Culinary ventures dominated the sample composition (70%), mirroring established patterns in urban MSME sectors where minimal entry requirements enable entrepreneurs with constrained resources to establish commercially viable operations serving immediate community needs (Sancono and Kertati, 2023). Educational attainment demonstrated substantial heterogeneity: 28% of participants had completed primary or junior secondary schooling exclusively, 47% attained senior high school certification, 20% possessed vocational diplomas, while merely 5% held bachelor's degrees or advanced qualifications. This distribution illuminates how urban entrepreneurship maintains accessibility across diverse educational backgrounds, simultaneously revealing potential capability deficits that may influence operational outcomes. Table 1 consolidates descriptive statistics for all measured constructs. Entrepreneurial orientation indicators registered means ranging from 3.60 to 3.70, indicating moderate risk acceptance and innovation propensity among Mojokerto's MSME proprietors. Education-related measurements spanned from 3.33 to 3.47, with financial literacy recording the lowest score (3.33), identifying a targeted capability deficit warranting intervention through structured training initiatives. Business capital indicators exhibited marginally elevated means (3.53 to 3.67), potentially reflecting beneficial outcomes of *BUMDes'* institutional mechanisms in facilitating financial accessibility. Strategic agility demonstrated the most elevated scores, with operational responsiveness achieving 4.00, suggesting that urban MSMEs have cultivated reasonable adaptive competencies through necessity-driven experiential learning within competitive marketplace environments (Weber and Tarba, 2024). Performance indicators averaged between 3.35 and 3.55, with market expansion registering the lowest score, indicating that whilst numerous MSMEs sustain profitability, operational scaling remains problematic due to resource limitations and competitive impediments (Belitski *et al*., 2022).

Evaluation of the measurement model

Before hypothesis examination, a rigorous assessment of the measurement instrument's reliability and validity was conducted. Table 2 demonstrates that all indicator loadings surpassed 0.787, substantially exceeding the 0.708 benchmark required for measurement reliability. Composite reliability coefficients ranged from 0.878 to 0.928, confirming exceptional internal consistency across all latent constructs (Hair *et al*., 2022). Average Variance Extracted (AVE) coefficients spanned from 0.644 to 0.766, universally exceeding the 0.50 threshold, indicating that constructs captured substantially greater true variance than measurement error.

Discriminant validity assessments verified that the five constructs represented genuinely distinct theoretical dimensions. Table 3 presents Fornell-Larcker criterion results, wherein diagonal values (square roots of AVE) exceeded all corresponding inter-construct correlations, confirming that each construct shared greater variance with its constituent indicators than with alternative constructs (Fornell & Larcker, 1981). The heterotrait-monotrait (HTMT) ratios consistently remained below 0.85, with the maximum value reaching merely 0.267, substantially within acceptable parameters (Henseler *et al*., 2015). These convergent findings provide robust evidence supporting the measurement model's psychometric adequacy.

Structural model and hypothesis testing

Having established measurement model adequacy,

Table 1: Descriptive statistics of measurement indicators

Construct & indicator	Mean	Median	Min	Max	Std. Dev
Entrepreneurial orientation					
EO1: Risk-taking	3.70	4.00	2.00	5.00	0.53
EO2: Innovation	3.62	4.00	2.00	5.00	0.58
EO3: Proactive behavior	3.60	4.00	2.00	5.00	0.58
EO4: Decision autonomy	3.60	4.00	2.00	5.00	0.61
EO5: Competitive aggressiveness	3.65	4.00	2.00	5.00	0.63
Owner's education					
EDU1: Formal education	3.37	3.00	2.00	5.00	0.66
EDU2: Managerial knowledge	3.47	3.00	2.00	4.00	0.53
EDU3: Technical skills	3.43	4.00	2.00	4.00	0.62
EDU4: Financial literacy	3.33	3.00	2.00	5.00	0.68
Business capital					
CAP1: Access to capital	3.67	4.00	3.00	4.00	0.47
CAP2: Operational sufficiency	3.65	4.00	3.00	4.00	0.48
CAP3: Financial stability	3.53	4.00	2.00	4.00	0.62
CAP4: Growth capacity	3.65	4.00	2.00	4.00	0.51
Strategic agility					
AGI1: Environmental adaptability	3.90	4.00	1.00	5.00	0.94
AGI2: Operational responsiveness	4.00	4.00	2.00	5.00	0.82
AGI3: Strategic flexibility	3.85	4.00	2.00	5.00	0.76
AGI4: Innovation speed	3.78	4.00	2.00	5.00	0.69
MSME performance					
PERF1: Revenue growth	3.53	4.00	1.00	4.00	0.59
PERF2: Market expansion	3.35	3.00	2.00	4.00	0.51
PERF3: Profitability	3.55	4.00	2.00	4.00	0.53
PERF4: Operational efficiency	3.48	3.50	2.00	4.00	0.56

Note. N = 60; five-point Likert scale (1 = strongly disagree to 5 = strongly agree).

Table 2: Measurement model assessment

Construct	Indicator	Loading	CR	AVE
Entrepreneurial Orientation	EO1-EO5	0.847-0.863	0.915	0.725
Owner's Education	EDU1-EDU4	0.787-0.815	0.878	0.644
Business Capital	CAP1-CAP4	0.842-0.869	0.916	0.734
Strategic Agility	AGI1-AGI4	0.849-0.885	0.924	0.754
MSME Performance	PERF1-PERF4	0.868-0.881	0.928	0.766

Note. All values meet established quality thresholds (Hair *et al.*, 2022).

Table 3: Discriminant Validity (Fornell-Larcker Criterion)

Construct	PERF	CAP	EO	AGI	EDU
MSME Performance	0.875				
Business Capital	0.151	0.857			
Entrepreneurial Orientation	-0.136	-0.033	0.851		
Strategic Agility	0.223	-0.034	-0.176	0.868	
Owner's Education	0.208	-0.071	-0.047	0.045	0.803

Note. Diagonal (bold) = √AVE; off-diagonal = correlations.

Table 4: Structural model quality

Endogenous Variable	R^2	Adjusted R^2	Q^2	Interpretation
MSME Performance	0.126	0.062	0.089	Weak but acceptable; positive predictive relevance
Strategic Agility	0.034	-0.019	0.021	Very weak; marginal predictive relevance

attention shifted toward evaluating structural model quality. Table 4 reveals that the proposed model accounted for 12.6% of MSME performance variance ($R^2 = 0.126$). While this proportion may appear modest superficially, it represents reasonable explanatory power for entrepreneurship investigations within emerging market contexts where innumerable unmeasured factors ranging from local regulatory frameworks to familial obligations shape business outcomes (Audretsch *et al.*, 2024). The adjusted R^2 coefficient of 0.062 provides a more conservative variance estimate accounting for model complexity relative to sample size. Strategic agility exhibited markedly weak explanatory power ($R^2 = 0.034$), suggesting that the measured antecedent factors inadequately capture determinants driving adaptive capabilities within these urban MSMEs. The positive Q^2 values confirm that the model demonstrates superior predictive capacity compared to mean-based predictions, supporting its practical utility.

Effect size analysis (Table 5) revealed that the owner's education exerted the most substantial impact on performance ($f^2 = 0.049$), followed by strategic agility's influence on performance ($f^2 = 0.041$). Although classified as "small" according to Cohen's (1988) conventional thresholds, these magnitudes align with typical patterns observed in entrepreneurship research where multiple factors collectively determine outcomes through complex interactions (Rauch *et al.*, 2009). Education and capital demonstrated negligible effects on agility ($f^2 = 0.001$-0.002), reinforcing the inference that these predictor variables fail to adequately explain variance in MSMEs' adaptive capabilities. This pattern necessitates exploration of alternative theoretical mechanisms potentially underlying agility development.

With structural model quality established, we proceeded to test the ten formulated hypotheses through bootstrapping procedures. Table 6 presents comprehensive hypothesis testing outcomes. Remarkably, merely one hypothesis received empirical support: owner's education demonstrated a significant positive influence on MSME performance (H3: $\beta = 0.342$, $t = 2.203$, $p = 0.028$). This finding provides robust empirical validation for human capital theory's fundamental proposition—that educational attainment enhances entrepreneurial success through improved analytical thinking, strategic planning capabilities, and problem-solving proficiency (Marvel *et al.*, 2016). The standardized coefficient indicates that each unit increase in education-related competencies corresponds to a 0.342 standard deviation improvement in performance outcomes, representing a meaningful practical effect within this population.

To visualize the structural relationships and the significance levels of each hypothesized path, Fig. 1 illustrates the empirical structural model derived from the PLS-SEM analysis.

Notes: Solid arrows indicate significant relationships ($p < 0.05$); dashed arrows indicate non-significant relationships. Only Owner's Education (EDU) significantly predicted MSME Performance (PERF). R^2 values denote variance explained for endogenous constructs. Contrary to theoretical expectations, entrepreneurial orientation exhibited no statistically significant effects on either performance (H1: $\beta = -0.152$, $p = 0.296$) or

Table 5: Effect Sizes (f^2)

Path	f^2	Classification
EO → PERF	0.020	Small
EO → AGI	0.032	Small
EDU → PERF	0.049	Small
EDU → AGI	0.001	Negligible
CAP → PERF	0.030	Small
CAP → AGI	0.002	Negligible
AGI → PERF	0.041	Small

Table 6: Hypothesis testing: Direct effects

H	Path	β	t	p	95% CI	Decision
H	EO → PERF	-0.152	1.047	0.296	[-0.438, 0.134]	Not Supported
H2	EO → AGI	-0.180	1.121	0.263	[-0.495, 0.135]	Not Supported
H3	EDU → PERF	0.342	2.203	0.028	[0.038, 0.646]	Supported
H4	EDU → AGI	0.035	0.241	0.809	[-0.249, 0.319]	Not Supported
H5	CAP → PERF	0.184	1.382	0.168	[-0.079, 0.447]	Not Supported
H6	CAP → AGI	-0.041	0.312	0.755	[-0.301, 0.219]	Not Supported
H7	AGI → PERF	0.237	1.645	0.101	[-0.047, 0.521]	Not Supported

Note. Bootstrap = 5,000 samples; α = 0.05; significant results in bold.

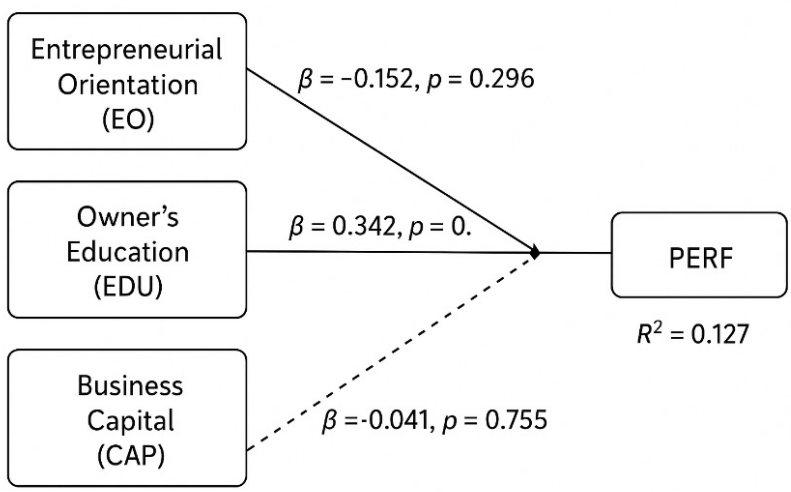


Fig. 1: Empirical structural model results

Table 7: Mediation analysis: Indirect effects

H	Path	Indirect Effect (β)	t	p	95% CI	Decision
H8	EO → AGI → PERF	-0.043	0.814	0.416	[-0.147, 0.061]	Not Supported
H9	EDU → AGI → PERF	0.008	0.186	0.853	[-0.075, 0.091]	Not Supported
H10	CAP → AGI → PERF	-0.010	0.289	0.773	[-0.077, 0.057]	Not Supported

strategic agility (H2: β = -0.180, p = 0.263). Although the negative coefficients failed to achieve statistical significance, their direction diverges from mainstream entrepreneurship literature documenting positive EO-performance associations (Hernández-Perlines *et al.*, 2023). This counterintuitive pattern suggests that within resource-constrained urban environments, entrepreneurial attitudes absent supporting infrastructure remain insufficient for performance enhancement. Lacking innovation resources, market intelligence systems, or growth financing mechanisms, entrepreneurial intentions may fail to materialize into tangible outcomes (Neumeyer & Santos, 2020). Additionally, excessive risk-taking behavior by undercapitalized MSMEs could potentially generate adverse consequences when owners lack the requisite managerial competencies for effective strategy execution. These findings challenge conventional wisdom regarding entrepreneurial orientation promotion as a universal performance driver, highlighting contextual contingencies moderating its effectiveness. Similarly, business capital demonstrated no statistically significant effects on performance (H5: β = 0.184, p = 0.168) or agility (H6: β = -0.041, p = 0.755). Despite the capital-performance coefficient approaching conventional significance thresholds, its confidence interval encompassed zero, precluding definitive conclusions. This pattern contradicts widespread assumptions that financial resource availability automatically generates superior business outcomes, instead suggesting that capital represents a necessary yet insufficient condition, its value depending entirely upon strategic deployment proficiency (Saoula *et al.*, 2024). This finding carries significant implications for urban policy formulation: merely providing credit facilities proves inadequate absent complementary interventions addressing financial management competencies and strategic resource allocation capabilities. The contrast between our findings and Kayani *et al.*'s (2025) significant capital effects in African markets underscores how institutional contexts and market maturity moderate capital's performance impact. Strategic agility's influence on performance approached but failed to achieve statistical significance (H7: β = 0.237, p = 0.101). The positive coefficient magnitude and confidence interval [-0.047, 0.521] that marginally encompasses zero suggest a potentially meaningful relationship that larger sample investigations might confirm. This near-threshold result aligns with theoretical expectations that adaptive capabilities facilitate MSMEs' navigation of volatile urban marketplace conditions (Soetanto & Jack, 2018). The marginal significance possibly reflects measurement limitations or genuine variability in how agility translates into performance across different operational contexts within Mojokerto's urban landscape. Mediation analysis was conducted to examine whether strategic agility functions as an intermediary mechanism through which entrepreneurial orientation, education, and capital influence performance. Table 7 presents indirect effect coefficients for the three hypothesized mediation pathways. Results indicate that strategic agility failed to mediate any of the proposed relationships (H8-H10), with all indirect effects demonstrating statistical nonsignificance and p-values exceeding 0.40. This null finding stems primarily from the weak associations between predictor variables and strategic agility documented in Table 6. Fundamental prerequisites for mediation effects cannot be satisfied when antecedent factors fail to predict the mediating variable.

The absence of significant mediation for education (H9) proves particularly illuminating given education's robust direct effect on performance. This pattern indicates that educational capital operates through direct cognitive and knowledge application pathways rather than by initially enhancing organizational agility. Educated proprietors apparently improve business performance through superior decision-making quality, financial management sophistication, and strategic planning effectiveness, not necessarily by first developing dynamic adaptive behaviors (Unger *et al.*, 2011). This finding suggests that strategic agility in urban MSMEs develops through alternative mechanisms, potentially including experiential learning pro-

cesses, social network quality, institutional support effectiveness, or individual cognitive characteristics not captured within our conceptual model (Amankwah-Amoah *et al*., 2021).

Discussion of findings

The empirical findings present a counterintuitive pattern that challenges conventional assumptions about MSME performance drivers in urban contexts. While existing entrepreneurship literature frequently emphasizes the importance of entrepreneurial orientation, capital adequacy, and strategic agility as critical success factors, this study reveals a markedly different reality within Indonesia's secondary urban centers. Only owner's education level demonstrated a significant direct effect on MSME performance ($\beta = 0.342$, $p = 0.028$), while entrepreneurial orientation, business capital, and strategic agility showed no statistically significant relationships with performance outcomes. This pattern warrants careful interpretation through both theoretical and contextual lenses. The absence of significant effects for entrepreneurial orientation (H1 and H2 not supported) contradicts findings from studies in more developed entrepreneurial ecosystems (Al-Hakimi *et al.*, 2021; Rauch *et al.,* 2009) but aligns with emerging evidence suggesting that EO's effectiveness depends critically on institutional and resource contexts. In secondary urban environments characterized by limited market sophistication, underdeveloped support infrastructure, and constrained consumer purchasing power, proactive risk-taking behaviors may not translate into performance advantages. MSMEs in Mojokerto operate within relatively stable, localized markets where survival depends more on consistent operational execution and relationship management than on aggressive innovation or market experimentation. Furthermore, the measurement of entrepreneurial orientation in resource-constrained contexts may capture aspirations rather than implementable strategic behaviors, explaining the disconnect between orientation and outcomes. This finding suggests that entrepreneurial orientation functions as a necessary but insufficient condition for performance its benefits materialize only when complemented by enabling institutional conditions and sufficient resource endowments absent in many secondary cities. The non-significant effect of business capital on performance (H3 not supported) and strategic agility (H6 not supported) similarly reflects context-specific realities diverging from mainstream entrepreneurship theory. While capital adequacy enables growth in environments with accessible markets and scalable business models, MSMEs in Mojokerto face structural constraints that limit capital's transformative potential. Market size limitations, infrastructure deficiencies, and supply chain inefficiencies mean that additional capital cannot easily translate into expanded operations or new market penetration. Moreover, the capital measures in this study captured perceived adequacy rather than absolute financial resources, potentially reflecting owners' subjective assessments that may not align with objective capital utilization effectiveness. This finding resonates with Kayani *et al.,* (2025), who demonstrated that capital's performance impact depends critically on strategic deployment rather than mere availability. In secondary urban contexts, knowing how to optimize limited resources through superior managerial capabilities may matter more than possessing abundant capital a pattern consistent with education's dominant role in this study. The failure of strategic agility to significantly influence performance (H7 not supported) or mediate relationships between resources and outcomes (H8-H10 not supported) represents this study's most theoretically challenging finding. Dynamic capabilities theory posits that organizational agility enables firms to adapt to environmental turbulence and leverage resources effectively (Teece and Pisano, 1994), yet this mechanism appears inoperative within Mojokerto's MSME context. Several explanations merit consideration. First, the measurement of strategic agility may not adequately capture the informal, tacit adaptive practices characteristic of micro and small enterprises operating with minimal formal organizational structures. Strategic agility scales developed for larger firms may fail to detect the improvised, relationship-based flexibility that defines MSME adaptation in developing contexts. Second, the relatively stable, slow-changing market conditions in secondary urban areas may reduce the salience of agility as a competitive differentiator when environments evolve gradually, consistent operational competence may outweigh rapid adaptive capacity. Third, strategic agility's benefits may require a minimum threshold of organizational resources and capabilities to manifest, thresholds that many MSMEs in this sample may not reach. The finding suggests that for resource-constrained urban MSMEs, direct application of foundational human capital through

informed decision-making proves more consequential than developing dynamic reconfiguration capabilities. In contrast, owner's education level emerges as the unambiguous performance driver, accounting for 12.6% of performance variance and operating through direct rather than agility-mediated pathways. This finding strongly supports human capital theory's predictions (Marvel *et al.,* 2016; Unger *et al.,* 2011) while extending understanding of how education functions in resource-constrained contexts. Education appears to enable superior performance through multiple direct mechanisms: enhanced financial literacy facilitating better resource allocation, broader market knowledge supporting strategic positioning, improved problem-solving capabilities enabling operational efficiency, and greater confidence in navigating bureaucratic and institutional interfaces. Importantly, education's direct effect suggests it operates through cognitive and knowledge application rather than by first enhancing organizational capabilities educated owners make better immediate decisions rather than building agile organizations. This pattern aligns with research emphasizing education's role in improving entrepreneurial judgment and reducing cognitive biases (Maria *et al.,* 2024; Syafi'i *et al.,* 2021). For urban policymakers, this finding carries profound implications: investments in human capital development yield more direct and substantial returns than initiatives focused on capital provision or entrepreneurial attitude cultivation in secondary urban contexts. These collective findings contribute to entrepreneurship theory by demonstrating that resource-based and dynamic capabilities frameworks, while powerful in explaining performance in resource-rich, institutionally developed contexts, require substantial modification when applied to resource-constrained secondary urban environments in developing economies. The primacy of human capital over financial capital, entrepreneurial orientation, and dynamic capabilities suggests that foundational competencies precede strategic sophistication in entrepreneurial development trajectories. Urban management scholarship benefits from understanding that effective MSME support in secondary cities demands human capital prioritization over the financial incentives and promotional programs that dominate many development agendas. The absence of mediation effects further indicates that capability-building interventions must address concrete knowledge and skill deficits rather than assuming that enhanced agility or orientation will spontaneously emerge from resource provision.

Practical implications for urban management

These empirical patterns collectively paint a nuanced understanding of performance determinants for MSMEs operating in Indonesian secondary urban centers. Education emerges unequivocally as the primary driver, the sole factor directly enhancing business performance with statistical confidence. This result provides compelling support for contemporary urban management scholarship treating human capital investment as foundational to sustainable urban competitiveness (Glaeser and Hausman, 2020). Within complex institutional environments characterized by weak formal support systems and irregular market information flows, educated proprietors navigate challenges more effectively through superior analytical capabilities, enhanced learning orientation, and greater capacity to mobilize productive networks. The failure of entrepreneurial orientation to predict performance outcomes challenges prevailing assumptions that promoting entrepreneurial mindsets automatically yields beneficial results. Within Mojokerto's specific context, entrepreneurs may possess risk tolerance and innovation orientations yet lack essential ecosystem support infrastructure, innovation hubs, mentorship networks, and regulatory flexibility necessary for converting intentions into measurable achievements (Mezei *et al*., 2025). Urban managers should consequently transition beyond motivational campaign approaches toward constructing tangible support infrastructure enabling entrepreneurial behaviors to materialize into outcomes. This reorientation recognizes that attitude promotion proves insufficient absent enabling institutional frameworks. Capital's nonsignificant effects similarly challenge finance-first intervention paradigms dominating development policy discourse. Financial resources enable operational stability yet fail to guarantee performance improvements absent strategic deployment capabilities, which themselves require managerial competence and market understanding. Urban policymakers should therefore reconceptualize MSME financial support as integrated intervention programs combining credit accessibility with business training, mentorship provision, and peer learning facilitation (Faridi *et al*., 2022). This holistic approach acknowledges that financial, human, and social capital op-

erate synergistically to determine entrepreneurial ecosystem vitality rather than functioning as independent performance drivers. Strategic agility's weak performance both as a predictor and a mediator suggests that adaptive capabilities, whilst conceptually important for theoretical understanding, require specific enabling conditions to generate competitive advantages within real-world settings. Institutional voids, infrastructure deficiencies, and resource constraints may prevent agile behaviors from translating into superior performance outcomes (Linnenluecke, 2021). Building MSME resilience, therefore, demands not merely skill development interventions but ecosystem-level investments in digital infrastructure, market information systems, and regulatory frameworks permitting rapid adaptation to yield sustained competitive benefits. Our findings additionally illuminate unique dynamics characterizing the urban-rural interface zone. Mojokerto straddles urbanized municipalities and peri-urban territories, creating hybrid conditions wherein MSMEs confront urban-level competition intensity whilst operating with rural-level infrastructure availability. The BUMDes institutional framework represents an innovative governance approach connecting micro-enterprises to broader support networks, yet our results suggest it remains insufficient absent concurrent human capital development initiatives. Secondary cities require educational infrastructure and skill-building programs as essential complements to institutional capacity-building rather than as alternative intervention pathways. Contemporary urban management increasingly conceptualizes entrepreneurial ecosystems as foundational elements supporting resilience, innovation capacity, and inclusive growth trajectories (Stam and van de Ven, 2021). However, ecosystem vitality depends critically upon entrepreneurial quality shaped by human capital depth and resource deployment effectiveness rather than merely entrepreneur quantity. Our findings suggest that strengthening urban entrepreneurial ecosystems necessitates prioritizing educational infrastructure and capability-building over purely financial interventions or attitude-focused promotional campaigns lacking tangible support mechanisms.

Policy recommendations

Drawing upon these empirical insights, we propose five actionable recommendations for urban managers and development agencies:

First, municipal authorities should establish continuing education programs specifically tailored to practicing MSME proprietors, offering flexible evening and weekend formats addressing authentic operational challenges in financial management, digital technology adoption, strategic planning methodologies, and market analysis techniques. These programs must transcend generic business training to provide contextualized knowledge applicable within secondary urban market conditions.

Second, urban development agencies should cultivate mentorship networks systematically linking established successful entrepreneurs with emerging MSMEs, facilitating tacit knowledge transfer and social learning processes that complement formal educational interventions. Such networks leverage experiential wisdom accumulated by veteran entrepreneurs whilst providing nascent ventures with practical guidance unavailable through classroom instruction alone.

Third, municipalities should create dedicated urban entrepreneurship hubs providing shared infrastructure, technology access, market information resources, and peer collaboration opportunities that reduce individual resource constraints whilst fostering collective learning environments (Spigel & Vinodrai, 2021). These physical spaces function as ecosystem nodes catalyzing knowledge exchange and network formation beyond what isolated entrepreneurs could achieve independently.

Fourth, support program designers should integrate human capital assessment mechanisms into intervention design processes, enabling tailored interventions addressing specific capability gaps rather than applying generic one-size-fits-all approaches that ignore entrepreneur heterogeneity. Diagnostic assessments can identify whether particular MSMEs require financial literacy training, technical skill development, or strategic planning support, allowing resource-efficient targeted interventions.

Fifth, urban policymakers should strengthen university-MSME linkages through collaborative research initiatives, internship programs, and knowledge transfer mechanisms that simultaneously enrich academic curricula whilst channeling specialized expertise to practicing entrepreneurs (Guerrero *et al*., 2021). These partnerships create mutually beneficial relationships, advancing both pedagogical innovation and practical problem-solving within local entrepreneurial commu-

nities. These strategic recommendations collectively constitute a human capital-centered approach recognizing education as a high-leverage intervention pathway for strengthening entrepreneurial ecosystems and enhancing urban economic resilience, precisely what our empirical evidence demonstrates matters most substantially for MSME success within Indonesian secondary urban contexts. This study contributes to scholarship in four key dimensions. Theoretically, it challenges the universal applicability of dynamic capabilities frameworks by demonstrating that foundational human capital precedes strategic-level capabilities in resource-constrained secondary urban contexts, extending human capital theory by revealing that education operates through direct cognitive pathways rather than by first enhancing organizational agility. Empirically, it addresses a significant geographical gap by providing quantitative evidence on MSME performance determinants within Indonesia's secondary cities, with the null findings for entrepreneurial orientation, capital, and strategic agility constituting substantive contributions revealing what does not drive performance in these contexts. Methodologically, it demonstrates rigorous PLS-SEM application to small sample entrepreneurship research with transparent reporting of nonsignificant results, contributing to balanced evidence accumulation often absent in literature biased toward positive findings. Practically, it provides evidence-based guidance prioritizing human capital development over financial capital provision in MSME support interventions, challenging prevailing policy assumptions and suggesting substantial resource reallocation toward education and training programs tailored to practicing entrepreneurs' operational needs. Several limitations qualify these findings and suggest caution in generalization. The cross-sectional research design precludes definitive causal inference, as reverse causality whereby successful MSMEs enable owners to pursue further education remains plausible. The sample size of 60 respondents, while adequate for PLS-SEM analysis, limits statistical power for detecting small effect sizes and the modest R^2 of 12.6% indicates substantial unexplained variance attributable to unmeasured institutional, psychological, and market factors. Geographical specificity to Mojokerto Regency constrains external validity, as findings may not generalize to secondary cities with different infrastructure development, institutional capacity, or cultural entrepreneurial norms. Reliance on self-reported perceptual measures introduces potential common method bias despite procedural remedies employed, and the focus on BUMDes-affiliated MSMEs may not represent independent entrepreneurs operating outside community-based organizational structures. Future research should employ longitudinal designs to strengthen causal claims, incorporate larger samples across multiple secondary cities to enhance generalizability, triangulate self-reported measures with objective performance indicators, and explore through qualitative methodologies the mechanisms through which education influences performance in the absence of strategic agility mediation.

CONCLUSION

This study addressed the research objective of analyzing how entrepreneurial orientation, owner's education level, and business capital influence MSME performance through strategic agility's mediating role within Mojokerto's urban entrepreneurial ecosystem. The empirical findings provide clear yet unexpected answers to the research questions posed. Of the ten hypotheses tested, only one received empirical support: owner's education level demonstrated a significant positive direct effect on MSME performance (H3: $\beta = 0.342$, $p = 0.028$), accounting for 12.6% of performance variance. This finding confirms that human capital, specifically educational attainment and associated knowledge competencies, operates as a critical performance determinant in secondary urban contexts. Contrary to theoretical expectations grounded in entrepreneurship and dynamic capabilities literature, nine hypotheses were not supported by empirical evidence. Entrepreneurial orientation failed to significantly influence either MSME performance (H1: $\beta = -0.152$, $p = 0.296$) or strategic agility (H2: $\beta = -0.180$, $p = 0.263$), challenging conventional assumptions about EO's universal relevance across entrepreneurial contexts. Business capital similarly demonstrated no significant effects on performance (H5: $\beta = 0.184$, $p = 0.168$) or strategic agility (H6: $\beta = -0.041$, $p = 0.755$), suggesting that perceived capital adequacy alone does not translate into competitive advantages within resource-constrained secondary cities where structural market limitations constrain capital's transformative potential. Strategic agility, hypothesized as a dynamic capability linking resources to outcomes, exhibited no significant direct effect

on performance (H7: β = 0.237, p = 0.101) and failed to mediate relationships between any predictor variables and performance (H8, H9, H10: all p > 0.40). The absence of education's indirect effect through agility (H4 and H9 not supported) proves particularly illuminating, indicating that educational capital operates through direct cognitive and knowledge application pathways rather than by first enhancing organizational adaptive capabilities. These findings collectively answer the research question by revealing that among the examined factors, only owner's education directly and significantly drives MSME performance in secondary urban Indonesian contexts, with entrepreneurial orientation, business capital, and strategic agility proving statistically irrelevant. This pattern suggests that foundational human capital competencies precede strategic-level capabilities in entrepreneurial development trajectories, particularly within institutional environments characterized by limited support infrastructure, underdeveloped markets, and resource constraints typical of secondary cities. The results challenge mainstream entrepreneurship theory's assumptions about universal performance drivers and underscore the necessity of context-sensitive theoretical frameworks acknowledging how resource availability and institutional quality moderate relationships between entrepreneurial attributes and outcomes. The implications for urban management policy and practice are profound and actionable. Given that education emerged as the sole significant predictor while capital and entrepreneurial orientation proved ineffective, urban managers and policymakers should fundamentally reorient MSME support strategies toward human capital development rather than continuing predominant emphases on financial capital provision or generic entrepreneurship promotion. Specifically, municipal authorities should prioritize accessible continuing education programs, managerial training initiatives, and financial literacy workshops tailored to practicing entrepreneurs' operational needs and delivered through flexible formats accommodating business owners' time constraints. Development agencies should establish mentorship networks systematically linking educated, successful entrepreneurs with emerging MSMEs to facilitate tacit knowledge transfer and social capital formation that formal education alone cannot provide. Urban entrepreneurship hubs offering shared infrastructure, technology access, and peer learning opportunities would amplify education's benefits by creating environments where knowledge application and experimentation occur collaboratively. Future research should investigate several critical questions emerging from these findings. Longitudinal studies tracking MSMEs across multiple time points would strengthen causal inference regarding education's performance effects and illuminate dynamic processes through which human capital accumulation translates into business growth over entrepreneurial lifecycles. Qualitative investigations could explore specific mechanisms through which education influences performance decisions, potentially revealing cognitive processes, network activation patterns, or bias reduction pathways not captured by quantitative constructs. Comparative studies across multiple secondary cities varying in infrastructure development, institutional capacity, and market characteristics would establish whether education's primacy and orientation's ineffectiveness represent universal patterns in secondary urban contexts or context-specific phenomena unique to Mojokerto. Research examining threshold effects could determine minimum education levels necessary for performance benefits to materialize, informing targeted program design. Finally, intervention studies evaluating educational programs' causal effects through quasi-experimental or randomized designs would provide the strongest evidence guiding policy investments and resource allocation decisions for urban MSME development initiatives.

AUTHOR CONTRIBUTIONS

Ade Setia Pratama contributed to the research conception and design, data collection, data analysis, and drafting of the manuscript. Sudarmiatin provided conceptual guidance, supervised the research process, and critically reviewed the manuscript for important intellectual content. Ery Tri Djatmika contributed to the development of the research framework, methodology refinement, and validation of the analysis. Cipto Wardoyo contributed to the interpretation of results, manuscript revision, and final approval of the version to be published. All authors have read and approved the final manuscript.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the authors have acknowledged the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, which have been fully addressed.

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ABBREVIATIONS (NOMENCLATURE)

Abbreviation	Definition
AGI	Strategic Agility
AGI1	Environmental Adaptability
AGI2	Operational Responsiveness
AGI3	Strategic Flexibility
AGI4	Innovation Speed
AVE	Average Variance Extracted
BUMDes	*Badan Usaha Milik Desa* (Village-Owned Enterprises)
CAP	Business Capital
CAP1	Access to Capital
CAP2	Operational Sufficiency
CAP3	Financial Stability
CAP4	Growth Capacity
CI	Confidence Interval
CR	Composite Reliability
EDU	Owner's Education
EDU1	Formal Education
EDU2	Managerial Knowledge
EDU3	Technical Skills
EDU4	Financial Literacy
EO	Entrepreneurial Orientation
EO1	Risk-Taking
EO2	Innovation
EO3	Proactive Behavior
EO4	Decision Autonomy
EO5	Competitive Aggressiveness
f^2	Effect Size (Cohen's f-squared)
GDP	Gross Domestic Product
H	Hypothesis
H1-H10	Hypothesis 1 through Hypothesis 10
HTMT	Heterotrait-Monotrait Ratio
IDR	Indonesian Rupiah (Currency)
MSMEs	Micro, Small, and Medium Enterprises
PERF	MSME Performance
PERF1	Revenue Growth
PERF2	Market Expansion
PERF3	Profitability
PERF4	Operational Efficiency
PLS-SEM	Partial Least Squares Structural Equation Modeling

Q^2	Predictive Relevance (Stone-Geisser Q^2)
R^2	Coefficient of Determination
SMEs	Small and Medium Enterprises
α	Alpha (Significance Level)
β	Beta (Standardized Coefficient)

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ORIGINAL RESEARCH PAPER

Bridging the intention–behavior gap: Digital engagement and low-carbon tourism among urban digitally literate seniors

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ABSTRACT

BACKGROUND AND OBJECTIVES: Low-carbon tourism was recognized as a crucial contributor to mitigating the effects of climate change; however, tourists often failed to translate pro-environmental intentions into actions. This study examined the influence of Digital Information Perception, the perceived credibility and usefulness of online information, and Social Media Engagement, the active interaction with social media content and peer networks, the perceived behavioral control through social media, on pro-environmental attitudes among urban, well-educated, and digitally literate seniors. The research aimed to identify the predictors of intention and behavior toward low-carbon tourism within a digital context.

METHODS: A cross-sectional online survey was conducted with 400 respondents. The data were analyzed using Structural Equation Modeling to test the extended Theory of Planned Behavior (TPB) model incorporating digital constructs. The variables included DIP, SME, attitude, subjective norms, perceived behavioral control, intention, and low-carbon behavior.

FINDINGS: The primary evidence from the SEM analysis reveals the significant predictors of intention to adopt low-carbon practices. The mean score discrepancy highlights the large gap between pro-environmental intentions and actual behaviors, with 78% of respondents reporting high pro-environmental intentions, reflected in a mean score of 4.29, in contrast to only 54% exhibiting consistent low-carbon behaviors, indicated by a lower mean score of 2.56. Additionally, the beta coefficient for the pathway from behavioral intention to low-carbon tourism behavior was found to be $\beta = 0.610$, emphasizing its strong influence in the model. These findings underscore the substantial intention–behavior gap in the context of low-carbon tourism among urban seniors.

CONCLUSION: The model fit was satisfactory, with indices indicating a good fit (CFI > 0.90, RMSEA < 0.08). This supports the validity of the extended Theory of Planned Behavior model in predicting low-carbon tourism intentions among urban seniors. This suggests that seniors find the credibility and usefulness of general online information (DIP) more influential for intention than active interaction with social media. So, to develop eco-friendly tourism among elders, the focus should be on low-carbon tourism options. Due to purposive, non-random sampling of urban, digitally literate seniors, the results should be interpreted as exploratory; future studies should employ representative and longitudinal designs to examine the persistence of low-carbon behaviors over time.

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INTRODUCTION

Background and rationale

The issue of climate change is among the most urgent problems of societies globally. Tourism presents a paradox in this regard: on the one hand, it contributes to economic growth and employment, while on the other hand, it is one of the primary sources of greenhouse gas emissions worldwide, primarily due to the energy-intensive nature of transportation and accommodation (Pathmanandakumar *et al.,* 2021). Despite recognition of the importance of low-carbon tourism in mitigating climate change, there is a notable lack of existing research exploring how elderly-specific barriers, such as physical limitations and health concerns, interact with the intention-behavior gap in this context. Understanding these barriers is essential, as they may significantly influence the ability of older adults to translate their pro-environmental intentions into consistent low-carbon behaviors. As the elderly population continues to grow, particularly among digitally literate urban seniors, addressing this gap becomes increasingly important in fostering sustainable tourism practices that cater to their unique needs and circumstances. In an effort to ensure the sector has a limited environmental impact, the low-carbon tourism concept has been introduced, which encourages the adoption of activities that limit carbon emissions at all levels of the travel experience, including transport, accommodation, consumption, and recreational activities (Scott *et al*., 2012). Establishing low-carbon initiatives in Thailand, where tourism forms a main pillar of its economy, and promoting sustainable development. According to the United Nations World Tourism Organisation (Sofronov, B. (2017), tourism is a significant contributor to Thailand's GDP and helps sustain millions of jobs; however, it also adds pressure on the country's natural resources. Even though policymakers and operators within the tourism sector can create greener infrastructure and services, the environmental impact is highly dependent on the actions and decisions made by tourists themselves. The intention formation process among travelers who intend to participate in low-carbon tourism, and the reasons that lead to failure to act, has been an interesting area of research to understand. The elderly form a rapidly growing tourist market worldwide. Thailand is approaching the stage of a super-aged society, with the number of individuals aged 60 and above anticipated to be close to 30 percent of the population by 2031 (Teerawichitchainan *et al.,* (2015). Most of the elderly have the time and financial resources to travel; thus, they are a good yet complex market. They are choosing according to their personal preferences, as well as in light of their health and risk perceptions, and their generational attitude towards the environment (Patterson and Balderas, 2020). Simultaneously, the rapid process of digitalization is changing the way senior tourists plan and consume tourism. In defiance of stereotypes of digital illiteracy among older adults, an increasing proportion of Thai elderly living in urban areas are using the internet and social media to find insights into traveling and make bookings (Supansa, 2018; Caragliu *et al*., 2011; Zhao *et al*., 2024). For these digitally literate seniors, the credibility of information on the internet and social media usage can influence their attitudes towards the environment and perceived norms. This also raises key questions about whether online communication can reduce the intention-behaviour gap that persists, namely the disparity between claims of pro-environmental intentions and actual low-carbon behaviour in travel (Kollmuss and Agyeman, 2002). The study of the dynamics between urban, digitally literate, and educated Thai seniors is both theoretically and practically valuable: it applies the Theory of Planned Behaviour to the digital antecedents, and it offers policymakers and tourism operators insights into the design of effective low-carbon interventions to appeal to this powerful demographic. Digital Information Perception (DIP) refers to the understanding and evaluation of the credibility and usefulness of online information about low-carbon tourism, serving as an antecedent to the core Theory of Planned Behavior (TPB) constructs: attitudes (ATT), subjective norms (SN), and Perceived Behavioral Control (PBC). Similarly, Social Media Engagement (SME) represents the PBC derived from interactions on social media platforms. Both DIP and SME influence the formation of pro-environmental attitudes and behaviors among urban, digitally literate seniors.

Literature review

Theoretical lens: The theory of planned behavior

Ajzen (1991) has applied the Theory of Planned Behavior (TPB) widely in tourism and environmental psychology to explain the reasons behind pro-environmental behaviors. TPB assumes that a person's inten-

tions to act depend on Attitudes Towards the Behavior (ATB), Subjective Norms (SN), and PBC. TPB is a widely used tool in sustainable tourism, such as eco-friendly options (Han *et al*., 2010) (Dolnicar and Leisch, 2008) and sustainable transport (Chen and Tung, 2014). But tourists don't act on good intentions towards the environment; they fail to act sustainably because of convenience and cost. To acknowledge this clearly, researchers have expanded the factors to include environmental concern, trust, or identity (Stern, 2000; Meng *et al.,* 2023). Nowadays, Digital Information Perception (DIP) and Social Media Engagement (SME) are antecedents of attitudes, norms, and PBC in the digital age. For example, exposure to credible online information can enhance knowledge and attitudes towards sustainable practices, whereas active involvement with influencers or peer networks can strengthen subjective norms (De Veirman, Cauberghe, and Hudders, 2017; Harrigan *et al.*, 2021). However, the existing empirical studies do not pay much attention to seniors in the context of non-Western settings, and significant gaps in knowledge remain about how digital practices are intertwined with intentions toward pro-environmental tourism (Lu *et al*., 2024).

Research gap

Despite the significant expansion of the literature on sustainable tourism, there are still substantial gaps. To begin with, the majority of the available literature focuses on younger tourists or tourists of mixed age, and rarely considers digitally engaged elderly people, despite older adults becoming a fast-growing consumer group with unique decision-making behaviors and their travel limitations (Shen, S. & Abdul Aziz, A. B., 2023). Second, although the TPB (Ajzen, 1991) is generally a popular theory to explain pro-environmental behaviour, it has rarely been applied to incorporate the digital factors of the theory like the credibility of online information or trends of online social media use—factors that are increasingly influencing the travel planning in new economies (Supansa, 2018; Wut *et al.,* 2023; Reinhold *et al*., 2023). Third, the longstanding intention-behaviour gap, namely the long-reported failure of pro-environmental intentions to be translated into actual low-carbon behaviours, is not thoroughly studied among elderly people, whose physical constraints, convenience, and health-related concerns may pose specific obstacles. The need to fill these gaps is the main reason why this study is necessary.

Objectives and research questions

The study pursues the following objectives:

1. To investigate the influence of DIP and SME on TPB antecedents (ATT, SN, PBC).
2. To examine the relationships among TPB constructs in shaping behavioral intention and behavior within the context of low-carbon tourism.
3. To assess the existence and extent of the intention–behavior gap in senior tourists' adoption of low-carbon practices.
4. To identify structural, informational, and social barriers that hinder seniors from translating intentions into actual low-carbon tourism behavior.

Accordingly, the central research question is:
Which digital and psychological factors explain the formation of intention and the execution of low-carbon tourism behavior among digitally engaged Thai seniors, and how can the intention–behavior gap be understood in this demographic?

Significance of the study

The importance of the given research is both theoretical and practical. It is conceptually a continuation of TPB, which explicitly includes the constructs of digital engagement and provides information on how seniors perceive online information and social media signals in sustainable tourism contexts. It is also used to contribute to discussions on the intention-behavior gap by placing it in a demographic setting that is highly digitally engaged, but less likely to be adaptable to behavioral change. In practice, the study has presented practical policy suggestions to policymakers, destination managers, and tourism companies in Thailand and other similar settings. Knowledge about what motivates or discourages the use of low-carbon practices by seniors can be used to shape interventions, whether in the form of digital information campaigns or infrastructural enhancements, to close the gap between intention and sustainable behavior.

MATERIALS AND METHODS

The study employed a robust cross-sectional online survey with a sample size of 400 respondents, which falls within the recommended range for Structural Equation Modeling (SEM) analyses (200-400). The

model fit indices were satisfactory, indicating a good fit of the data to the proposed model. These factors enhance the credibility of the findings, suggesting that the extended TPB effectively captures the predictors of low-carbon tourism intentions and behaviors among urban, digitally literate seniors.

Research design

The paper has used a cross-sectional quantitative survey to test an extended Theory of Planned Behaviour (TPB) model that incorporates two digital factors—DIP and SME — in explaining low-carbon tourism behaviour among urban, educated, digitally literate Thai elderly. A survey was suitable for investigating numerous latent variables and estimating how they are related to each other at a single point in time. The analysis of the measurement and structural model was conducted using Structural Equation Modelling (SEM), which enables the simultaneous estimation of direct, indirect, and mediating effects. The questionnaire was supplemented with short open-ended questions, which were asked at the end to encourage respondents to comment on their personal motivation and barriers to adopting low-carbon travel practices, thereby making the quantitative analysis more comprehensive and contributing to the interpretation of the identified intention-behavior gap.

Population and sampling

The target group consisted of Thai elderly individuals aged 60 years and older who frequently used the internet and showed an interest in traveling. The sampling strategy employed was purposive, as the study aimed to capture a digitally literate group of elderly individuals, as opposed to the general population, which would encompass a considerable number of non-technology users. The data were collected using an online questionnaire administered between April and May 2025. Respondents were checked by screening questions that ensured that they were:

1. Aged 60 or above,
2. Internet users, and
3. Interested in or experienced with travel.

Four hundred valid responses were received, and that is higher than the minimum sample size requirements of SEM. According to Henseler *et al*., (2014), the minimum sample size for the model is ten times the maximum number of paths to a latent construct that can be detected. In this case, seven predictors are taken into account, which means that a minimum of 70 cases is required. On the same note, as observed by RosakSzyrocka &Tiwari (2023), the samples required for SEM are typically 200-400, and the current study falls within a suitable range for analysis.

Demographic Profile of Respondents

The sample exhibited features characteristic of a digitally active elderly population. Statistics. Most were women 85.3% with only 12.8% being males and 2% identifying as LGBTQP. The concentration of age in the 60 64 bracket was 89.8%, indicating the study centered on the young-old seniors. Most respondents have a high level of education, with 58.3% holding a bachelor's degree and 8.5% holding a postgraduate degree, and most of them belong to the middle-class group. Similarly, 82.8% used the internet and social media daily, with 34.5% rating themselves highly proficient. The highest geographic proportion (39%) was found in Bangkok and metropolitan areas; next in line were central, northern, and northeastern provinces. These figures suggest that the sample is not representative of the typical Thai elderly, but rather a well-educated, urban, and digitally proficient subgroup with a higher disposable income.

Research Instrument

The structured questionnaire was made up of four sections:

1. Eligibility screening questions,
2. Latent variables (DIP, SME, ATT, SN, PBC, BI, and LCTB) measurement items,
3. Demographics and socioeconomic data,
4. Open-ended questions on perceived barriers and motivations.

Data Analysis

The analysis of the data took a two-step SEM procedure, using AMOS 26:

Confirmatory Factor Analysis (CFA): It was performed to test the validity and reliability of the model of measurement.

- The standardized factor loading ranges were positive, and all of them are higher than 0.70, with a range between 0.716 and 0.892.
- Cronbach's alpha values were between 0.709 (LCTB) and 0.889 (BI), which are above the standard of 0.70.

- The values of Composite Reliability (CR) were between 0.712 and 0.879, and the Average Variance Extracted (AVE) values were between 0.553 and 0.758, which also substantiate convergent validity.

2. Structural Model Analysis: Hypothesized relationships were compared to determine the causal relationships between latent variables.
   - Model fit: satisfactory CFI > 0.90, RMSEA < 0.08, and 8 (5) /df.
   - 8 of the 8 hypothesized paths were found to be supported, with the strongest effects being DIP to ATT (= -0.559), PBC to BI (= -0.677), and BI to LCTB (= -0.610). Unexpectedly, however, SME was not a significant predictor of BI (0.068, p > 0.05).

There was also a significant gap between attitudes/intentions and behaviors as revealed by descriptive statistics. Although the means of attitudinal and intentional items were high (i.e., ATT1 mean = 4.26, BI3 mean = 4.29), the actual behaviors were moderate (mean 2.5), which is an indication of the intention-behavior gap.

Ethical considerations

The research described in this article was reviewed and approved by the University of Phayao Human Ethics Committee, Thailand. The approval reference number is *HREC-HSS 2.2/175/68*. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study (Wu & Zhao, 2022).

Limitations of the methodology

Although the design and procedures were strict, several methodological limitations need to be mentioned. To start with, the non-random purposive sample will limit the extrapolation of the findings to the broader Thai seniors who are digitally engaged. Second, the cross-sectional design does not allow for causal inference, but only correlation. Third, self-reporting measures can be prone to social desirability bias, particularly when assessing pro-environmental attitudes. However, the sample size, good measurement validation, and the mix of quantitative and qualitative aspects contribute to the credibility and relevance of the results.

RESULTS AND DISCUSSION

Descriptive statistics of the sample

Demographic information obtained from evaluating 400 interviewees constitutes valuable insights into the study population. There is a significant imbalance in gender representation, with the vast majority of 85.3% being female, as shown in Fig. 1. There is also a representation of males, who make up 12.8 percent of the sample and 2.0 percent of the LGBTQ+ population. Such overrepresentation of women is not a remote issue in survey-based tourism research, as women tend to be more involved in trip planning within families and are more likely to complete online survey forms. Such a skew implies that the results can be particularly valuable to elderly female travelers, who constitute a promising market niche for low-carbon tourism. The findings address the interpretation of the non-significant findings related to SME, framing it in the context of "slacktivism." The negative beta value associated with SME should not be misinterpreted as indicating an inhibitory effect on low-carbon tourism behaviors. Instead, it highlights the lack of significance, suggesting that SME does not have a meaningful impact on the intention-behavior gap in this context. This distinction is crucial for accurately understanding the role of SME in influencing pro-environmental actions among seniors.

According to the age profile, the sample is denser in the 60-64 age group, with 89.8 respondents living in this age group. The number of those aged 65-69 was only 7.8 percent, and those above 70 were less than 3% are shown in Fig. 2. This can be assumed to indicate that the group of seniors captured by the study is more of the so-called young-old seniors who are still relatively healthy, mobile, and digitally involved. Low participation of elders highlights the lower visibility and underscores the need to recognize generational differences with elders.

The level of education in the sample is 58.3% with a bachelor's degree and 8.5% with a postgraduate degree. This sample suggests that respondents are generally capable of understanding sustainable information online. In terms of economic crises, 34.5% reported a monthly income of around 15,001-30,000 THB, whereas 28.3% earn above 30,000 THB. The

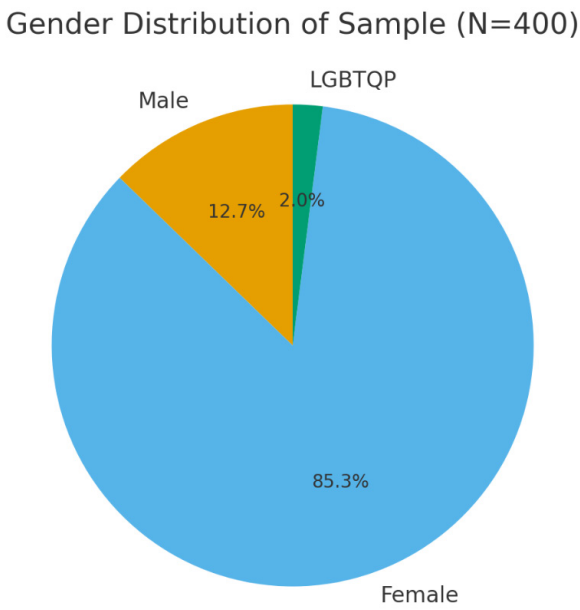


Fig 1: Gender distribution of the Sample(N=400)

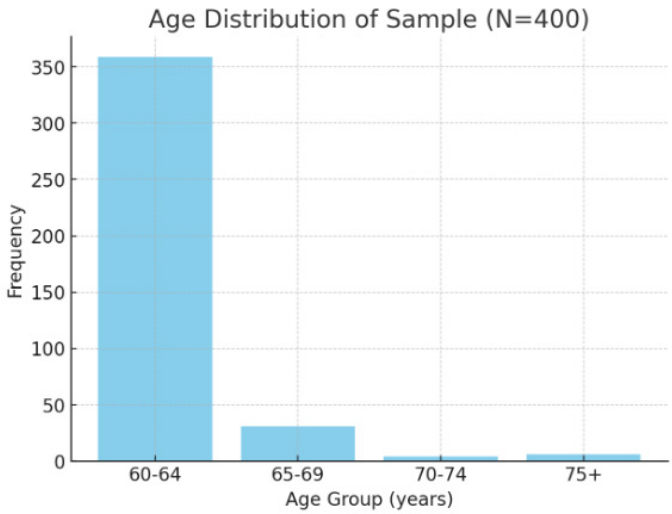


Fig. 2: Age distribution of the sample

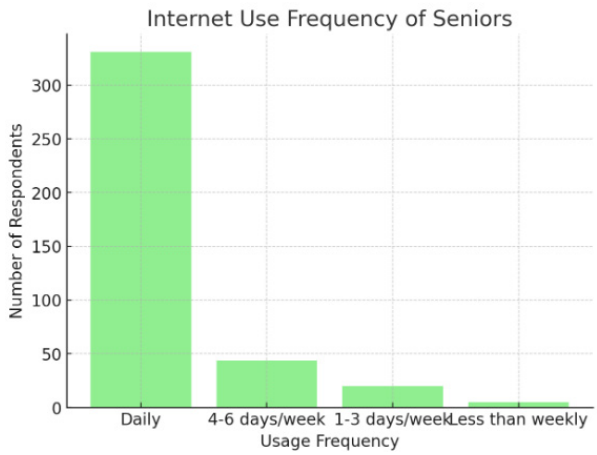


Fig 3: Internet use frequency of Seniors

middle-class and upper-class incomes are enough to spend on eco-friendly travel opportunities, which are viewed as the most expensive. Clues of online savvy suggested that the sample actually consisted of a set of highly connected individuals. 82% of respondents reported being online every day, with another 11% reporting being online 4 to 6 days a week. This was the same case with social media use, as shown in Fig. 3. Regarding their self-rated internet skills, 47.8% belong to the intermediate user population, and 34.5% belong to the more advanced population. This is indicative of a group that is not only connected but also assured of navigating digital tools.

This study reveals that 75.8% of people travel through information from social media, and 75.5% of people travel from recommendations from their family and friends, far surpassing traditional sources such as television, radio, and newspapers. These findings suggest that digital platforms influence the travel choices of respondents. However, the descriptive method indicates that this study is not for Thai older seniors because they have less knowledge of digital platforms. Rather, the results demonstrate that this study is for a specific group of urban, educated, and financially stable early seniors who frequently use digital platforms for travel options (Thébault *et al*., 2013). The intention-behavior gap is the R^2 value of 37.2%, which indicates that behavioral intention explains a substantial portion of the variance in low-carbon tourism behavior. This finding underscores the gap between the high levels of pro-environmental intentions reported by respondents and their actual low-carbon behaviors. The significant yet incomplete explanatory power of behavioral intention suggests that other factors are likely influencing the discrepancy, further emphasizing the need for additional research to identify and address these barriers.

Descriptive statistics of latent variables

A further understanding of the cognitive and behavioral orientations of seniors toward low-carbon tourism is achieved through the analysis of the measurement items. Attitude variables/measures (ATT) and Behavioral Intentions (BI) consistently had high mean scores of above 4.0 on a 5-point scale, indicating a high proportion of respondents supported the value of low-carbon tourism. For example, the measure of activity that requires low-carbon tourism had a mean of 4.26, whereas the measure of activity that I will also attempt to reduce the types of waste I produce during my travels (BI3) scored even better, with a mean of 4.29. This research suggests that participants have positive attitudes toward sustainable tourism. On a 3-point scale, the average score of approximately 2.5 indicates that Low-Carbon Tourism Behavior (LCTB) practices are for occasional use and fill a gap between what they believe and do. Indicatively, LCTB3, which involves bringing a reusable water bottle and a cloth bag when I travel, provides a mean response of 2.56, whereas LCTB2, which involves attempting to save water and electricity in my hotel room, records 2.46. This deviation between the bold plans and moderate actions is the initial indication of

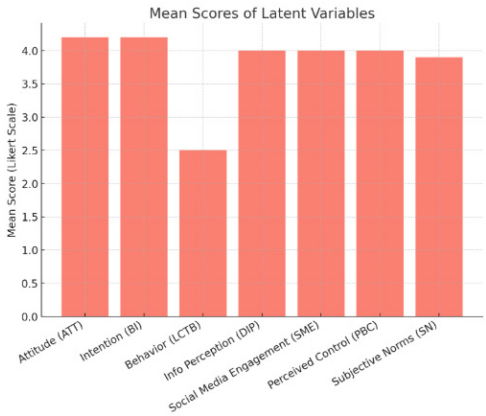


Fig 4: Mean scores of Latent variables

the intention-behavior gap in this population (Zainal Abidin *et al*., 2023).

Similar factors, such as Digital Information Perception (DIP), latent Social Media Engagement (SME), PBC, and SN, are reported near 4.0 and are shown in Fig. 4. This suggests that seniors are highly engaged in digital activities and perceive effective sustainable behavior. These frequent positive ratings suggest that the challenge is not in convincing seniors; it depends on the mindset to make it easier and sustainable actions during travel. The mean low-carbon tourism behavior score of 2.5 on a 3-point scale indicates moderate behavior, contrasting with the high behavioral intention mean of 4.29 on a 5-point scale. This inconsistency in scales could lead to misunderstandings, particularly in the bar chart (Fig. 4), which mixes these scales. Standardizing the presentation of all scores will enhance the comprehensibility of the findings and facilitate accurate interpretations of the intention-behavior gap.

Measurement model assessment

Confirmatory factor Analysis (CFA) was conducted to examine the reliability and validity of the measurement model. All factor loadings were greater than 0.70, indicating good reliability of the indicators. They are DIP4 (0.876), SME5 (0.832), ATT3 (0.845), and PBC4 (0.821). Internal consistency was high, with Cronbach's alpha ranging from 0.709 (LCTB) to 0.889 (BI), which exceeds the acceptable threshold of 0.70. The values of Composite Reliability (CR) ranged from 0.712 to 0.879, and the Average Variance Extracted (AVE) was between 0.553 and 0.758, confirming convergent validity. Discriminant validity was, however, less desirable. There were correlations between DIP, SME, and PBC exceeding the square roots of their AVEs. For example, the square root of 0.788 is lower than the correlation between DIP and SME of 0.909. This implies that the elderly may not have a fine line between information reception, interaction with social networks, and the ability to act. Even though all these constructs are reflected as one dimension of digital empowerment, this is a statistical limitation, as it views various digital factors for seniors.

Structural model and hypothesis testing

The SEM results revealed several key findings:

1. *DIP → ATT (Supported):* Digital information perception significantly influenced attitudes toward low-carbon tourism (β=0.559, p<0.001). Seniors who perceived online information as credible and useful were more likely to develop positive attitudes.
2. *SN → ATT (New Path):* Subjective norms significantly influenced attitudes (β=0.294, p<0.001). While not originally hypothesized, this finding suggests that family and peer approval enhance positive evaluations.
3. *ATT → BI (Supported):* Attitudes significantly predicted intentions (β=0.305, p<0.001), consistent with TPB.
4. *PBC → BI (Supported):* Perceived behavioral control was the strongest predictor of intention (β=0.677, p<0.001). This indicates that seniors' sense of feasibility and capability

plays a more decisive role than attitudes or norms.

5. *SME → BI (Not Supported):* Social media engagement had no significant effect on intention (β=-0.068, p=0.676). Despite daily use of social media, mere interaction with content did not translate into stronger intentions.
6. *BI → LCTB (Supported):* Intention significantly predicted behavior (β=0.610, p<0.001). However, intention explained only 37.2% of behavioral variance, leaving 62.8% unexplained, evidence of a substantial intention–behavior gap.

Together, these results demonstrate that while seniors hold positive attitudes and intentions, actual behaviors are influenced by perceived feasibility and external conditions more than by social media trends.

Model fit

The last model of SEM fitted well to the fundamental measures: 2/df = 2.71, CFI = 0.93, TLI = 0.91, and RMSEA = 0.067. Such values are within acceptable limits, which validates the model's intensity in providing a sound depiction of the data.

Summary of findings

Most implications of the extended TPB version are supported by the findings. DIP and PBC turned out to be the most positive predictors of intention, which explains the use of credible information and a sense of feasibility. SN has influenced attitudes, demonstrating the role of social networks in shaping them. Surprisingly, SME did not have that impact, implying that the seniors do not use social media as a source of behavior more than they use it as an information source. Lastly, the significant intention-behavior gap highlights the need to more fully convert well-meaning intentions into regular, sustainable behaviors, a subject of further discussion.

Discussion

Overview of key findings

This research outcome supports the stance that the extended Theory of Planned Behavior (TPB) provides a constructive framework for explaining low-carbon tourism behavior among digitally competent Thai elderly individuals. DIP and PBC emerged as the strongest predictors of intention, while Behavioral Intention (BI) was a significant predictor of Low-Carbon Tourism Behavior (LCTB). Subjective Norms (SN), which indirectly affected intention, did so through attitude; however, this was not the case with Social Media Engagement (SME). Notably, intentions were high, but the actual behaviors were middling, signifying a significant gap between intention and behavior. These results support the previous studies, which emphasize the explanatory potential and the limitations of TPB (Ajzen, 1991; Han *et al*., 2010; Chen and Tung, 2014). The existing work contributes to the literature by incorporating digital constructs into TPB and focusing on an underrepresented population group (the elderly in Thailand) and empirically illustrating an interaction of digital-specific factors, perceptions of its feasibility, and attitudes to form pro-environmental behavior.

Digital information perception as a driver of attitudes

The significant impact of Digital Information Perception (0.559, p < 0.001) indicates that seniors' positive attitudes towards tourism strongly depend on online information; the more credible the information, the more interest they show in sustainable travel (Cheung and Thadani, 2012; Harrigan *et al*., 2021). In the case of seniors, whose travel choices can necessitate a significantly more considered approach to health, safety, and convenience, online information, credibility, and clarity can hold even greater significance than in the case of younger generations. This implies that online information that is clear, reliable, and easy to use must be targeted in sustainable tourism campaigns for seniors. Complicated or unconfirmed content cannot only demotivate sustainable decisions but also erode the confidence of providers. Conversely, attitudes and later intentions may be influenced by information that demonstrates the actual advantages, protection, and affordability of low-carbon behaviors.

The role of perceived behavioral control in forming intentions

The strongest predictor of intention was PBC (β = 0.677, p < .001), which validated its key role in TPB applications to pro-environmental behavior. Past reports have reached the same conclusion, with the role of feasibility perceptions overriding that of attitudes in determining the choice of a green hotel (Han *et al*., 2010) or the preference for eco-friendly accommodation (Chen and Tung, 2014). In the current setting, the perception that seniors have of the feasibility of low-carbon operations, including

saving energy at hotels or reducing emissions from vehicle use, could influence whether they would follow through on the action. This points to the hard-faced fact that positive attitudes are not enough. The seniors might also appreciate the concept of low-carbon tourism, but they may not implement it simply because they do not see it as feasible. This is consistent with the application of Ajzen (1991), which states that PBC is used to portray the existence of actual conditions of control, closing the gap between cognition and limitations. Managerially, this observation suggests that low-carbon tourism promotion among seniors should focus on comfort and convenience. In one example, hotels might make recycling easier, explicitly lay out eco-advisories, or offer low-carbon transport services and accommodation that are accessible to seniors. The intentions are strengthened through the empowerment of seniors with the resources and support, which makes them feel in charge.

The limited role of social media engagement

Surprisingly, SME was not a significant predictor of intention (β = -0.068, p = 0.676). This was unexpected, as 82.8 percent of respondents used social media daily, and the literature names engagement as a source of normative and attitudinal change (De Veirman *et al*., 2017; Wut *et al.,* (2023). One reason could be that, for seniors, social media serves more as a source of information than motivation. Seniors can scroll, like, or share content, but these actions do not lead to meaningful engagement or behavior change. This observation also aligns with critiques of 'slacktivism' (Morozov, 2009), which suggests that social network support does not necessarily translate into real-life actions. For seniors, engagement offers exposure rather than commitment. Since SME was not significant, it is crucial to distinguish between digital activity and digital influence. Social media may provide awareness, but it might not influence motivation unless the information is credible and appears feasible.

Attitudes, subjective norms, and their indirect effects

The showing practice of attitudes positively influencing intention ($p < 0.001$, $\eta^2 = 0.305$) is in line with the TPB and the literature on sustainable tourism in general (Dolnicar and Leisch, 2008; Han *et al*., 2010). Older generations that regarded low-carbon practices as important and useful were more willing to adopt them. Attitudes were also influenced by subjective norms (B = 0.294, p = 0.001), indicating that ratings by seniors are shaped one-third by family and peer endorsement. This circuitous route serves to highlight the importance of utilizing social networks in enhancing positive assessments, especially in collectivist cultures like Thailand's, where family and community may tend to dominate the decision-making process. However, in contrast to some TPB applications, norms overall had no direct effect on intention. This means that in the case of seniors, peer pressure does not contribute adequately to behavioral modeling unless it provides attitude transformation. This implication further enriches TPB to underscore the fact that exposure to influence can vary depending on demographics and culture.

Intention–behavior gap in senior tourism

Those findings were the most striking, as a considerable intention-behavior gap was observed. Although intentions were strong predictors of behavior (0.610, p=0.001), intentions accounted for only 37.2 percent of the variance of behavior. There were only moderate practices in actual low-carbon behaviors, including the use of reusable bottles and energy-conservation practices in hotels (mean ≈ 2.5 on a 3-point scale). This is reminiscent of past work, which has consistently shown that pro-environmental intentions are not realized (Kollmuss and Agyeman, 2002; Li, Liu, and Li, 2023; Warren, J. P. & Burns, P. M., (2011).

In older individuals, such a discrepancy can be because of several factors:

1. Physiological constraints: lugging reusable products or travelling in eco-friendly vehicles can be regarded as inconvenient, or even a strain on the body.
2. Health issues: behaviors that are regarded as risky (e.g., walking long distances to cut carbon) can be foregone.
3. Structural barriers: the interventions can be hindered by the lack of accessible eco-infrastructure (e.g., hotels without obvious ways to recycle).
4. Cognitive dissonance: the elders can consider intended actions as sufficient contributions, without acting.

It shows the difficulty of converting pro-environmental thinking into action, especially with ageing individuals. It reconfirms the necessity of psychological intervention (in order to make these commitments stronger) as well as structural intervention (in order to make these commitments less impeded).

Theoretical implications

The study aids the literature in the following three aspects:

1. Duration of TPB with digital variables: Basing the study on combining DIP and SME, the study answers the call of providing an updated version of information on the need to revise models of behavior to adapt to digital reality. DIP was very influential, and the lack of an effect of SME questions the assumptions regarding the motivational effect of social media.
2. Lighting up to the evidence of digital empowerment being a latent feature: The discriminant validity of the situational case of DIP, SME, and PBC being a collection of seniors proposes that they may be subject to one such attribute of digital empowerment. This provides a fresh theoretical insight for future research.
3. Precision in TPB pathways among an aged population: The indirect role of norms through attitudes demonstrates the specifics of a demographic and cultural process and introduces yet another feature of TPB explanatory variability.

A significant limitation of this study is the potential failure of discriminant validity, as indicated by the Fornell-Larcker criterion. If the criterion is not met, it suggests that DIP and SME may be measuring the same underlying construct rather than functioning as distinct factors. This overlap weakens the argument that these constructs independently contribute to the intention-behavior gap in low-carbon tourism. Consequently, further research is needed to clarify the relationships among these constructs and establish a more nuanced understanding of how they influence pro-environmental behaviors among seniors. This study's findings show the importance of the quality of interaction between digital and low-carbon tourism and seniors, highlighting the need to bridge the digital divide to enhance sustainable tourism. Urban locations can feature technological innovations that largely promote sustainable tourism, as proposed by Vujko, Knezevic, and Arsio (2025). Mohan *et al.,* (2024) note that it is necessary to ensure that the elderly group is digitally inclusive to encourage their participation in this type of initiative. Similarly, Diana *et al.,* (2025) observe the influence of urban and rural environments on the well-being of elderly citizens, affecting their participation in low-carbon tourism. Heiets and La (2025) also explain how digital technologies assist in enhancing the travel experience of older patients. According to Lin *et al.,* (2022), expanding knowledge about low-carbon tourism can lead to more positive outcomes in collective happiness and environmental growth. Zhang, Papp-Vary, and Szabo (2025) comment on how digital interaction improves visitor satisfaction in tourist locations and is essential for ensuring sustainable tourism. Furthermore, Marin Diaz, Galdon Salvador, and Galan Hernandez (2023) consider the role of digital maturity in personalizing tourist recommendations. In their study, Loos *et al.,* (2020) emphasize that creating transport systems friendly to the elderly is crucial for enabling them to move around. According to Ai, Zhang, and Yan (2024), the digital economy should be integrated into urban low-carbon approaches for successful transitions. Sylaiou *et al.,* (2025) suggest that integrating older adults into the digital age could be improved through the empowerment of older adults, which could be achieved with the support of digital heritage. Together, these findings can lead to special interventions to attract older generations to sustainable tourism by enhancing their online availability and designing personalized programs. This study further demonstrates that digital engagement plays a significant role in closing the gap between intention and action in low-carbon tourism among urban seniors. According to Koufodontis *et al.,* (2025), affective-symbolic urbanism is still relevant in determining tourists' perceptions, which is crucial for understanding low-carbon practices among senior travelers. Ni *et al.,* (2025) also point out that older adults need specific solutions to climate change that can enhance their interest in sustainable tourism practices. Aina *et al.,* (2023) explain how digitalization can improve cities' resilience and positively impact the tourism industry in a post-pandemic environment. Additionally, Zeqiri *et al.,* (2025) highlight the importance of digital platforms in promoting Sustainable Development Goals, which can

help integrate sustainability into tourism practices. Similarly, the article by Pan *et al.,* (2024) emphasizes the significance of digital inclusion in helping older adults acquire the necessary digital skills and influence their attitudes towards the environment and eco-friendly behavior. Collectively, these sources support the claim that improving digital literacy among the elderly can enhance their participation in low-carbon tourism and reduce the intention-behavior gap observed in this consumer group.

Practical implications

Stakeholders should simplify the sustainability of low-carbon tourism for seniors, making it believable and personal. With real-life performance (e.g., refill stations, towel reuse, and ways to get there), tourism operators can redesign touchpoints using content that is simple, elderly-accessible (e.g., large-type multilingual guides, plain infographics), and strategic (e.g., in-room cues). The importance of accessibility to infrastructure must be enhanced by policymakers' attractive features, such as low-energy usage hotels, shaded footways, self-reliant, low-emission transport with priority seating, and noticeable recycling and water-efficient features, which increase the perceived locus of control. Marketers must utilize social media as a point of entry for awareness, with posts featuring valid links, checklists, and how-to reels that can turn interest into actionable procedures at the booking and pre-departure levels. One way community organizations can utilize family influence is through the marketing of intergenerational eco-itineraries, a volunteer weekend, and a pledge program, making sustainable solutions accepted by all age groups. Collectively, these activities ensure that the quality of information, feasibility, and social support —the three levers —will translate positive attitudes and plans into stable, low-carbon practices among digitally active Thai seniors.

Limitations and future research

There are several limitations to the study. The study primarily focused on urban, digitally literate seniors. By expanding the sample to encompass digitally less-active seniors, future research can provide a more comprehensive understanding of the diverse attitudes and behaviors related to low-carbon tourism across different segments of the elderly population. This inclusion will help to identify specific barriers and opportunities for promoting sustainable tourism practices among all seniors, not just those who are more digitally engaged. A purposive sample was used, focusing on digitally active seniors, which limited the potential extrapolation of the targeted technologies to lower digital literacy groups. It lacks causal inferences, as the employed design is cross-sectional, and there is a possibility of social desirability bias due to self-reports. The next research should utilize longitudinal study designs, as this approach would observe changes in intentions as they are converted into behaviors in the future. Comparative cross-cultural research would evaluate the possibility that norms have a more direct effect in more collectivist contexts. Lastly, a qualitative study might examine the lived experiences of seniors with barriers and provide more details on the intention-behavior gap.

Summary of discussions

The discussion suggests that the concern driving low-carbon tourism among Thai seniors is based on plausible online information and perceived as possible, although it is limited by physical, structural, and cognitive costs. The findings refine TPB theory by incorporating digital constructs and highlighting the indirect nature of norms. In practical terms, they demand interventions that integrate clear information, help improve the infrastructure, and support social contexts to bridge the intention-behavior gap.

CONCLUSION

This study investigated low-carbon tourist behavior among digitally active Thai seniors, focusing on two digital variables: DIP and SME. Data gathered from the survey of 400 participants were evaluated using Structural Equation Modeling (SEM). The outcome revealed that intention was strongly affected by DIP and perceived Behavioral Control (PBC) in comparison to attitudes, and SME was not found to have a significant impact. Intentional subjective norms had an indirect effect on intentions through attitudes, identifying an intention-behavior gap. The study has contributed to the literature on sustainable tourism by incorporating digital constructs, emphasizing the importance of cultural sensitivity in decision-making, and exploring the role of family in influencing decisions. The policy implications are to make digital information seniors-friendly, increase control by having ready infrastructure, utilize family and peer influence, and revise social media

strategies to transform awareness into action. Limitations include a purposive sample, a cross-sectional study design, self-report data, and limited broad applicability. Further studies should adopt longitudinal and cross-cultural designs, incorporate digitally fewer literate seniors, and employ mixed-methods designs to gain a better understanding of the intention-behavior gap. From a policy and practical standpoint, this research highlights that improving the credibility, accessibility, and personalization of online environmental information can significantly strengthen intention formation among seniors. Governments, tourism boards, and industry operators should develop senior-friendly digital communication platforms and inclusive eco-tourism programs that simplify sustainable choices while addressing perceived constraints. Encouraging intergenerational digital mentoring and family-inclusive low-carbon campaigns may further bridge the intention–behavior gap by leveraging social support and familiarity with digital systems. While the study contributes meaningful insights, several limitations must be acknowledged. The non-probability sampling method limits the generalizability of the findings, and the cross-sectional design restricts causal inference. Additionally, reliance on self-reported measures introduces potential biases in respondents' representation of actual behaviors. Future studies should employ longitudinal approaches to assess behavioral consistency over time, adopt mixed-methods designs to capture qualitative nuances, and include digitally less-active seniors for a more representative perspective. Cross-cultural comparisons could also reveal how digital behaviors and environmental attitudes vary across aging populations in diverse socio-economic contexts. In essence, the research underscores that fostering sustainable tourism among older adults in the digital era requires integrating credible digital communication, structural support, and cultural sensitivity. Bridging the intention–behavior gap in this demographic is not merely a behavioral challenge but a digital inclusion imperative, calling for collaborative action between policymakers, scholars, and industry practitioners.

AUTHOR CONTRIBUTIONS

W. Madhyamapurush: Conceptualization; Methodology; Investigation; Data Curation; Formal Analysis; Writing – Original Draft; Writing – Review & Editing; Visualization; Supervision; Project Administration.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the authors have acknowledged the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, which have been fully addressed.

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ABBREVIATIONS (NOMENCLATURE)

α (Cronbach's α)	measure of internal consistency/ reliability
AMOS	Analysis of Moment Structures
ATT	Attitude toward the Behavior
AVE	Average Variance Extracted
β	Standardized Regression Coefficient
BI	Behavioral Intention
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index (model fit measure)
CR	Composite Reliability
DIP	Digital Information Perception
HREC	Human Research Ethics Committee
HREC-HSS	Human Research Ethics Committee – Human and Social Sciences
LCTB	Low-Carbon Tourism Behavior
N	Sample Size
p	Probability Value indicating statistical significance
PBC	Perceived Behavioral Control
R^2	Coefficient of Determination (explained variance in a model)
RMSEA	Root Mean Square Error of Approximation (model fit index)
SD	Standard Deviation
SEM	Structural Equation Modeling
SME	Social Media Engagement
SN	Subjective Norms
TLI	Tucker–Lewis Index (model fit indicator in SEM)
TPB	Theory of Planned Behavior
η^2	Eta Squared measure of effect size in statistical analysis
χ^2/df	Chi-Square divided by Degrees of Freedom – model fit ratio

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CASE STUDY

Strengthening non-timber forest product sustainability: A multidimensional framework for forest honey management

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ABSTRACT

BACKGROUND AND OBJECTIVES: Forest honey is a non-timber forest product that supports community welfare while maintaining ecosystem biodiversity. This study aimed to evaluate the level of sustainability of forest honey production in Riau Province by determining and analyzing the sustainability index.
METHODS: Data were collected through literature review, focus group discussions, and expert questionnaires involving practitioners and stakeholders with more than five years of experience in forest honey production and management. The data obtained were then analyzed using a multidimensional scale technique covering environmental, economic, social, technological, and institutional aspects. Monte Carlo analysis and the alternating least-squares algorithm were used to examine the sustainability status and significant characteristics.
FINDINGS: The results showed that the sustainability index reached 76.26 percent, categorized as highly sustainable. The environmental, economic, and social dimensions were found to be sustainable, while institutional and technological aspects remained moderately sustainable and need further strengthening. Key attributes influencing sustainability include distribution systems, product prices, training opportunities for honey collectors, digital marketing, and product certification.
CONCLUSION: Strategic recommendations include improving institutional capacity, expanding the use of digital technology, continuous technical training, and developing long-term business strategies. This study introduces a multidimensional sustainability assessment model that integrates ecological, economic, social, technological, and institutional aspects, offering a replicable framework for sustainable forest honey management in Indonesia and beyond.

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INTRODUCTION

Forests play a strategic role in achieving global sustainable development goals, especially in the context of climate change mitigation, biodiversity conservation, and food security. Forest ecosystems serve not only as carbon sinks but also as habitats for numerous species and sources of livelihood for local communities (Djenontin *et al.*, 2024). The increasing global concern about forest degradation and deforestation has prompted reevaluating how forests are managed, including the sustainable utilization of Non-Timber Forest Products (NTFPs). These products, including resins, medicinal plants, and forest honey, have garnered attention for their potential to align conservation efforts with local economic development (Yumantoko *et al.*, 2025). In Indonesia, with its vast tropical forests, the sustainable management of NTFPs has become a key issue at both national and regional levels (Djenontin *et al.*, 2024). Among various NTFPs, forest honey stands out as a significant ecological and economic commodity. It provides an alternative livelihood for forest-edge communities while fostering environmental stewardship. The province of Riau, located in Sumatra, is one of Indonesia's major forest honey-producing regions, with production zones categorized based on forest cover types (Pribadi and Wiratmoko, 2020). Forest honey production in this region depends heavily on the integrity of forest ecosystems, particularly the availability of nectar-producing flora and stable microclimates suitable for wild bee colonies. The high dependency of forest bees on intact ecosystems positions honey production as an indicator of biodiversity health and forest sustainability. Previous studies have emphasized the socio-economic importance of forest honey, particularly its contribution to household income improvement and conservation-oriented livelihoods (Asmara and Nurlia, 2020). However, despite its strategic potential, forest honey production in Riau faces significant sustainability challenges. Land conversion into monoculture plantations has disrupted ecological balance and altered bee foraging patterns due to declining floral diversity. Additionally, frequent anthropogenic forest fires contribute to habitat degradation, smoke pollution, and displacement of bee colonies. These environmental pressures are compounded by unsustainable harvesting practices—such as cutting entire hives—which reduce long-term productivity and hinder colony regeneration (Triyatno *et al.*, 2024). Limited technical capacity in post-harvest handling, storage, and packaging further affects honey quality and market competitiveness (Irmawanty *et al.*, 2023). Although various community-based forest honey initiatives have emerged across Indonesia, existing studies remain largely fragmented. Most research has focused on isolated dimensions, such as socio-economic outcomes or ecological indicators, without integrating the broader institutional and technological contexts that shape sustainability outcomes. This partial approach has resulted in limited understanding of the complex interactions among ecological integrity, economic viability, social acceptance, technological capability, and institutional support within forest honey production systems. Consequently, a significant knowledge gap persists in the form of comprehensive, multidimensional assessments that can effectively inform policy formulation and adaptive forest management strategies. The absence of integrated diagnostic frameworks has also contributed to a disconnect between sustainability policies and the practical challenges faced by forest-dependent communities. There is therefore an urgent need for empirical, evidence-based assessment models that holistically capture multiple sustainability dimensions and identify key leverage factors for long-term intervention design. This study addresses these gaps by applying a comprehensive multidimensional sustainability assessment to forest honey production systems in Riau Province. The research employs a Multidimensional Scaling (MDS) approach through the Rapid Appraisal for Fisheries (RAPFISH) method to evaluate sustainability status across five dimensions: environmental, economic, social, technological, and institutional. A participatory approach is adopted by integrating primary data from structured questionnaires, interviews, and Focus Group Discussions (FGDs), alongside secondary data from literature and institutional reports. The use of MDS is particularly suited to identifying key sustainability attributes, understanding relationships between variables, and offering a visual representation of sustainability levels in each dimension (Fadilah *et al.*, 2021). Its flexibility and ease of application in participatory rural assessments make it an effective tool for sustainability diagnostics. MDS has been successfully applied in various sectors to evaluate sustainability performance. For instance, it has been employed in the analysis of algal biomass farming (Santoso *et al.*, 2023a), integrated

duck production systems (Bakrie *et al.*, 2023), cattle production (Rohaeni *et al.*, 2024), coconut sugar production (Handayani *et al*., 2025), In the realm of NTFPs, MDS has also been used to examine the sustainability of animal feed from sago (Allaily *et al.*, 2024), landslide management (Sittadewi *et al*., 2025) and agricultural compost systems (Santoso *et al.*, 2023b). However, limited research has applied this method to evaluate forest honey production systems, especially with an emphasis on ecological and socio-institutional interactions within forest-dependent communities in Indonesia. This research offers a novel contribution by integrating the MDS approach into the assessment of forest honey sustainability, which is rarely conducted in the current literature. Its uniqueness lies in the inclusion of multi-stakeholder perspectives in identifying critical leverage factors across the five dimensions. The framework developed here has the potential to be replicated in other NTFP-producing regions across Indonesia. Moreover, by employing a diagnostic lens rather than a merely descriptive one, this study bridges the knowledge-policy gap and supports sustainable forest governance models grounded in empirical evidence. From a practical standpoint, this study is expected to not only reveal the sustainability level of forest honey production in Riau but also to identify key barriers and enabling factors in each dimension. These findings can inform the prioritization of policy interventions, such as improving harvesting techniques, strengthening institutions, or enhancing technological adoption among local actors. Furthermore, by mapping the relationships among sustainability indicators, the research enables targeted strategies that can enhance the resilience of forest honey enterprises while maintaining biodiversity conservation goals. Ultimately, this research serves as a strategic input for the formulation of integrated and evidence-based forest development policies in Riau Province. The study aims to synchronize the interests of diverse stakeholders, including honey farmers, cooperatives, technical government agencies, local governments, and legislators. The outcomes are expected to contribute to a more inclusive, data-driven, and sustainable forest management system that not only enhances local well-being but also strengthens Indonesia's national agenda for biodiversity and climate resilience. To achieve these objectives, the research survey was conducted in Riau Province, Indonesia, during July and August 2025.

MATERIALS AND METHODS

Study area

This study was conducted by examining data related to forest honey production activities in Riau Province (Fig. 1). The research locations represent collection and processing centres for honey produced by local communities in each regency of Riau Province. These locations include areas that still maintain forests with *sialang* trees and other large trees as the primary habitat of *Apis dorsata* bees. Honey harvesting and processing begin with several stages, such as site selection and *sialang* tree surveys, followed by traditional forest honey harvesting. Post-harvest, the honey undergoes extraction, filtration, and packaging, as well as marketing.

The honey hunters are predominantly of Malay ethnicity and Muslim. Knowledge transfer occurs from parents to children within honey hunter families, where children are involved by observing harvesting practices or participating in the work carried out by their parents during honey collection. In terms of formal education, the older generation generally completed elementary school and junior high school, whereas some younger generations have continued their education through senior high school and even to university level. Information regarding forest honey production in Riau Province is presented in Table 1, and documentation of forest honey harvesting activities in Siak and Pelalawan Regencies, Riau Province, is shown in Fig. 2.

Research materials and procedure

Secondary data were obtained from scientific journals and other literature related to the sustainability of forest honey production. In addition, data were gathered through FGD and the distribution of questionnaires to nine experts who have extensive experience and understanding of forest honey production. The selected experts had a minimum of three years of experience in forest honey production. Respondents consisted of representatives of cooperatives, forest honey entrepreneurs, distributors, and experts involved in forest honey production programs. To determine relevant research attributes, an in-depth literature review and expert consultations were carried out. A total of approximately a dozen expert informants were involved in this study. These experts were purposively selected based on their demonstrated expertise and practical experience across the

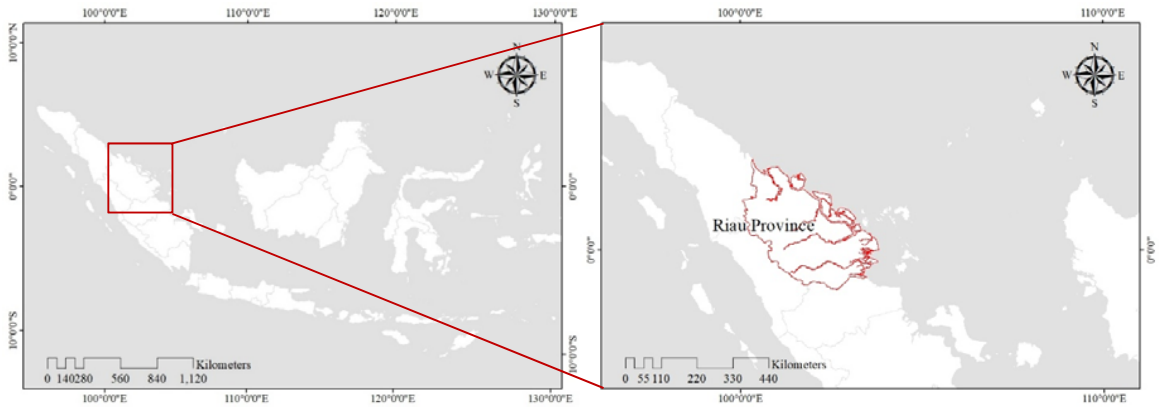


Fig. 1: Study location in Riau Province, Indonesia

entire forest honey value chain. The expert group included forest honey collectors and beekeeping practitioners, forest ecosystem specialists, entomologists, post-harvest and processing experts, honey collectors and traders, laboratory analysts responsible for honey quality testing, as well as actors involved in product distribution and marketing. All experts had a minimum of three years of professional experience in their respective fields related to forest honey production and management. Expert consultations were conducted iteratively through FGDs and follow-up discussions to identify relevant sustainability attributes for forest honey production. Attribute selection was guided by an extensive literature review and validated through expert consensus. The attributes were organized into five sustainability dimensions: environmental, economic, social, technological, and institutional. Each expert completed a structured questionnaire assessing the condition of each attribute using a standardized scoring scale. To ensure data robustness and saturation, expert responses were examined for consistency across consultation



a)



b)



c)



d) e) f)

Fig. 2: Documentation of forest honey harvesting in Siak Regency: a) Sialang tree; b) Bee nest on a sialang tree; c) Harvesting process of forest bee nests; d) Harvested Forest bee nests; e) Transportation of forest honey; f) Storage of forest honey. Source: Author's documentation

rounds. Data saturation was considered achieved when additional expert inputs no longer resulted in substantive changes to attribute scores or dimension-level patterns. The individual scores provided by experts were then aggregated by calculating the average value for each attribute. Attribute weighting was derived from FGD outcomes, reflecting the perceived importance of each attribute within its respective dimension. Weight normalization was applied so that the total weight of all attributes equaled one (1), ensuring internal consistency and transparency in the MDS analysis. The processed dataset consisting of averaged attribute scores and normalized weights was subsequently formatted and analyzed using the MDS method implemented through the RAPFISH software, as developed by Pitcher and Preikshot (2001).

The sustainability of the honey production program was evaluated using the MDS approach and the Rapid Appraisal (RAP) quick assessment tool for forest honey production programs. The identified attributes indicate levels of sustainability across various dimensions, adjusted according to the availability of specific resource information (Kavanagh and Pitcher, 2004). Five dimensions were analyzed: environmental, economic, social, technological, and institutional. A total of 52 attributes were evaluated. These attributes were organized in a questionnaire using a Likert scale with three options: 1 for low, 2 for medium, and 3 for high. The sustainability index value derived from the data processing ranges from 0 to 100 and is divided into four sustainability categories. The sustainability assessment index used in this study is presented in Table 2. Rapfish operates using a rapid appraisal scoring system. Scores in Rapfish generally originate from three main sources: peer-review scoring, in which scores are based on reviews of scientific documentation with predetermined thresholds; grey literature, where scores are derived from previous analyses, whether published or unpublished; and expert judgment, where scoring is determined through expert consensus, either via FGD or through other methods such as the Delphi Technique.

To determine the level of influence of each attribute on the sustainability of forest honey production, a leverage factor analysis was conducted using the MDS approach. Leverage factors are used to measure the sensitivity of an attribute to changes in the sustainability index value. The resulting leverage values are

Table 1: Forest honey production data in Riau Province

Harvest Location	Number of Farmer Groups	Production (kg/ month)	Honey Selling Price (IDR/Kg)	Honey Distribution Areas	Remarks
Sungai Apit Sub-district, Siak Regency	8	300 - 450	100,000 – 150,000	Tanjung Balai Karimun, Padang, Kampar, Pekanbaru, Jakarta, Yogyakarta	Primary data, 2025
Tesso Nilo National Park	-	156 - 167	120,000	-	Susanto *et al.*, 2022
RAPP Area	-	146	120,000	-	Susanto *et al.*, 2022
Rantau Baru, Pelalawan	-	175	80,000 -120,000	-	Primary data, 2025
Pelalawan, Kampar, Siak	-	70	125,000 -140,000	Medan, Jakarta, Bekasi, Banten, Melaka (Malaysia)	Primary data, 2025
Kuala Tolam, Pelalawan	1	3,600 – 4,000	80,000	Sumatra and Malaysia	Primary data, 2025

Data analysis

Table 2: Sustainability index values

Category Index	Value	Sustainability Status
0.00 – 24.99	Poor	not sustainable
25.00 – 49.99	Fairly Poor	less sustainable
50.00 – 74.99	Moderate	moderately sustainable
75.00 – 100.00	Good	highly sustainable

Table 3: Parameter values of the leverage factor

Factor value	Category	Description
<2.0 %	neutral	not influential
2–8 %	influential	moderate to good impact
>8.0 %	significant	dominant

interpreted based on specific categorizations, allowing the identification of which factors are dominant and should be prioritized in system improvements. The criteria for leverage factor values are explained in Table 3, as outlined by Pitcher and Preikshot (2001). In the MDS method, each object or point is represented in a multidimensional space, where the distance between two points reflects the degree of difference between objects; the closer they are, the more similar they are. The distance analysis is carried out using Euclidean distance in *n*-dimensional space (*n*-space). Widely separated points were employed to denote items or points that differed from each other. In MDS, ordination or distance determination is based on Euclidean distance in *n*-space using *Eq. 1* (Lloyd *et al.*, 2022).

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + \cdots} \quad (1)$$

In MDS, configurations of objects or points were estimated by regressing Euclidean distance () from point *i* to point *j* with the point of origin () using *Eq. 2* (Lloyd *et al.*, 2022):

$$d_{ij} = \alpha + \beta\delta_{ij} + \varepsilon \quad (2)$$

The Alternating Least Squares Scaling (ALSCAL) algorithm was employed for the regression analysis of *Eq.*

2. The ALSCAL method optimizes squared distance (squared distance = () against squared data (point of origin = (), which in three dimensions (*i*, *j*, *k*) is called *s*-stress using *Eq. 3* (Lloyd *et al.*, 2022):

$$s = \sqrt{\frac{1}{m}\sum_{k=1}^{m}\left[\frac{\sum_i\sum_j\left(d_{ijk}^2-o_{ijk}^2\right)^2}{\sum_i\sum_j o_{ijk}^4}\right]} \quad (3)$$

Where the squared distance is the Euclidean distance assigned a value using Eq. 4 (Lloyd *et al.*, 2022):

$$d_{ijk} = \sum_{a=1}^{r} w_{ka}\left(x_{ia}-x_{ja}\right)^2 \quad (4)$$

Sustainability analysis of honey production

The levels of sustainability performance of honey production are divided into 4 levels, resulting in intervals of 0, 25%, 50%, 75%, and 100%. The assessment categories are as follows: 0.00 - 25, poor category and unsustainable; 25.01 - 50, less category, less sustainable; 50.01 - 75, adequate category, fairly sustainable; 75.01 - 100.00, good category, sustainable (Arofi *et al.*, 2015). Employing analysis techniques can also assist in pinpointing characteristics that are attuned to sustainability considerations. The indicator with the highest Root Mean Square (RMS) value is the most sensitive (Pitcher and Preikshot, 2001). The values of the leverage factors fall within the range of 2%-8%, indicating a moderate to good impact. If < 2%, the factor is considered not influential, while if > 8%, the factor is considered dominant (sustainable) according to Pitcher and Preikshot (2001). Table 4 presents the factors that have an impact and are dominant.

Monte Carlo analysis helps in determining the error and assessing the uncertainty in MDS. If the discrepancy between the MDS value and the Monte Carlo value is small, it indicates that the MDS analysis for determining sustainability is sufficiently accurate with a 95% confidence level. An overview of the comprehensive research analysis techniques, with an emphasis on the stages and various steps carried out in conducting the research or analysis, is visualized using a flowchart to facilitate understanding.

RESULTS AND DISCUSSION

The MDS technique is applied to produce a sustainability index value in the forest honey production process and to identify variable features. The MDS dimensions measured include five dimensions and their attributes. Input data for this calculation are obtained through a scientific assessment questionnaire. In addition, this analysis will reveal sensitive attributes and influential variables that play a role in the sustainability of the process.

Sustainability index

Scientific assessment of the attributes within each sustainability dimension is crucial for accurately estimating the sustainability index level. Consideration of specific and temporal characteristics is essential in determining an attribute (Pitcher and Preikshot, 2001). The attributes of all dimensions consist of environmental, economic, social, technological, and institutional aspects, as listed in Table 5. The environmental dimension attributes include flowering tree availability, bee smoking materials, harvesting habitat damage, production tool condition, waste management, energy source, honey packaging material, honey storage condition, distribution system, and eco-friendly packaging. The economic dimension includes market delivery cost, harvest travel cost, labor cost, honey volume increase, filtered honey yield, price increase, net profit, selling price, production cost percentage, sales improvement, branded packaging impact, and utility cost. The social dimension is determined by beehive location knowledge, community cooperation, training frequency, farmer group role, local harvesting ethics, honey quality acceptance, community involvement, education outreach, price negotiation, and local promotion participation. The technological dimension includes honey extraction method, moisture reduction tool, filtration process, storage method, laboratory testing, digital record-keeping, digital marketing, and temperature control. The institutional dimension includes legal group basis, management structure, activity planning, member attendance, participatory monitoring, administrative completeness, capacity building, distribution permit, the Indonesian National Standard (SNI), and Halal certification.

To determine the sustainability level of each forest honey production process, the attributes within each dimension were incorporated into a questionnaire and submitted for relevant scientific assessment. In addition, the MDS approach and the Rapfish program were used to evaluate the results of expert assessments. The MDS analysis results for forest honey production performance in Riau show a sustainability score of 76.26% on a 0–100 scale, with $R^2 > 0.97$. This indicates that the program falls into the highly sustainable category. The score represents the evalua-

Table 4: List of dimensions and their attributes

Environment	Economy	Social	Technology	Institution
1. Flowering tree availability	1. Market delivery cost	1. Beehive location knowledge	1. Honey extraction method	1. Legal group basis
2. Bee smoking materials	2. Harvest travel cost	2. Community cooperation	2. Moisture reduction tool	2. Management structure
3. Harvesting habitat damage	3. Labor cost	3. Training frequency	3. Packaging and labeling	3. Activity planning
4. Production tool condition	4. Honey volume increase	4. Farmer group role	4. Filtration process	4. Member attendance
5. Waste management	5. Filtered honey yield	5. Local harvesting ethics	5. Storage method	5. Participatory monitoring
6. Energy source	6. Price increase	6. Honey quality acceptance	6. Laboratory testing	6. Administrative completeness
7. Honey packaging material	7. Net profit	7. Community involvement	7. Digital record-keeping	7. Capacity building
8. Honey storage condition	8. Selling price	8. Education outreach	8. Digital marketing	8. Distribution permit
9. Distribution system	9. Production cost percentage	9. Price negotiation	9. Temperature control	9. SNI certification
10. Eco-friendly packaging	10. Sales improvement	10. Local promotion participation		10. Halal certification
	11. Branded packaging impact			
	12. Packaging cost			
	13. Utility cost			

tion of 52 attributes across five different dimensions. The environmental dimension scored 87.36 %, the technological dimension 66.49%, the social dimension 82.12%, the economic dimension 86.81%, and the institutional dimension 58.51 %. The detailed results of the sustainability analysis can be seen in Table 5. Two of the five sustainability dimensions for forest honey were found to be moderately sustainable: the institutional dimension (58.51%) and the technological dimension (66.49%). Institutional capacity is a common weakness in NTFP development. It remains a weak link not only in NTFPs management but also in broader sectors such as oil palm plantations. Therefore, strong local institutions are crucial for ensuring conservation and long-term economic sustainability of NTFPs (Harbi *et al.*, 2023). Hence, improvements are needed in all three areas to achieve long-term sustainability. Forest honey production still requires legal intervention, official administrative systems, and support mechanisms. A synergistic pattern can be established in which economic and social dimensions can be strengthened relatively quickly, while technological and institutional improvements require medium-term planning that includes incentives, training, and integrative regulations. This supports the development of an inclusive, sustainable, and adaptive model for NTFP products that can respond to both market and ecological challenges.

Environmental dimension

Among various aspects, the environmental dimension stands out by contributing the highest sustainability index score, recorded at 87.36% (Table 5), with a stress value (R^2) of 0.98 (Table 5). This means that 98% of the data variation is explained by the factors included in the model. Based on the stress value and R^2, the MDS result for the environmental dimension can be considered a good model that effectively captures the existing issues. Therefore, it is not necessary to add additional attributes to reflect

Table 5: Results of RAPFISH analysis on the sustainability status of forest honey

Dimension	Index Score (%)	Stress Value	SQR/R^2	Sustainability Status	Monte Carlo Simulation	Index Difference and Monte Carlo
Environmental	87.36	0.12	0.98	Highly	87.57	0.21
Economical	86.81	0.11	0.99	Highly	86.83	0.02
Social	82.12	0.11	0.99	Highly	82.17	0.05
Technological	66.49	0.11	0.99	Moderately	65.85	0.64
Institutional	58.51	0.11	0.99	Moderately	58.51	0.00
Average	76.26			Highly		

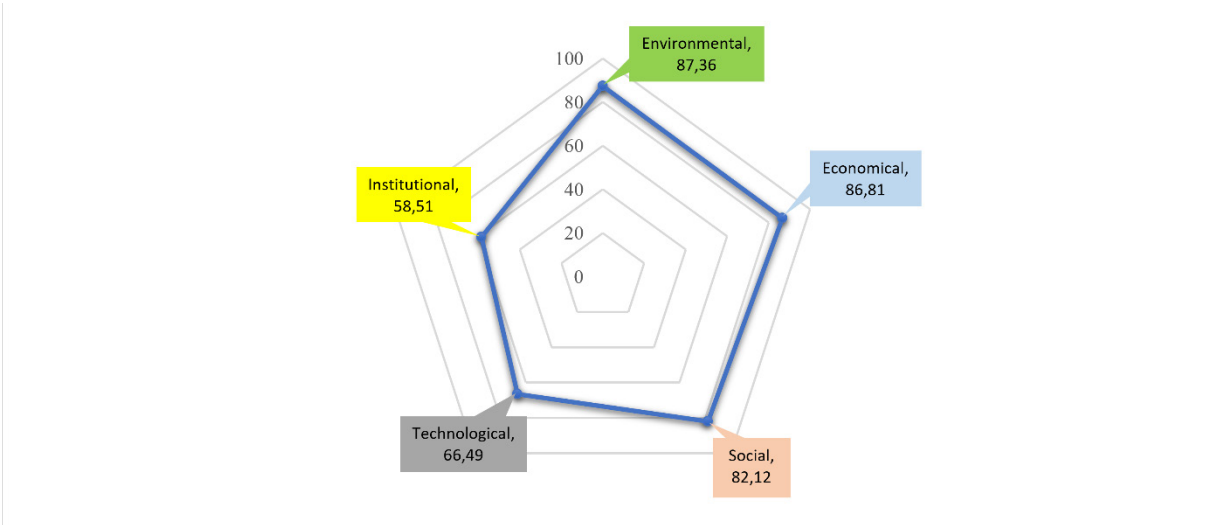


Fig. 3: Sustainability status of forest honey production

the actual conditions. A Monte Carlo simulation of the sustainability of forest honey production in Riau Province for the environmental dimension shows an average value of 87.57. The results of the Monte Carlo analysis indicate a relatively dense distribution of units, suggesting that there are no significant errors affecting the environmental dimension. The MDS analysis results indicate that the attribute with the highest impact (3.95%) is the distribution system and the energy source, which relates to the type of energy used by vehicles in honey production activities. In contrast, the environmental attribute with the lowest impact is eco-friendly packaging, with a score of 1.15% (Fig. 4). The long-distance (inter-island) and fossil fuel-based distribution system of forest honey can significantly increase its carbon footprint. Fossil fuel-powered transportation emits greenhouse gases (GHGs) that are harmful to the environment, including carbon dioxide, nitrogen oxides, sulfur dioxide, and particulate matter (PM2.5 and PM10). Long-distance shipping can contribute up to 35–40% of the total GHG emissions in the food supply chain, thereby increasing the overall carbon footprint (Arzoumanidis *et al.*, 2019). Extended distribution in forest honey production also results in hydrocarbon waste and soil contamination. These substances are difficult to degrade, may accumulate in the food chain, reduce soil fertility, and pose toxicity risks to aquatic organisms if they enter drainage systems (Stepanova *et al.*, 2022). This is closely related to the energy source attribute, which also shows a high environmental impact (3.54%). To reduce these negative impacts, it is necessary to localize distribution and adopt low-emission transportation modes. Transitioning to renewable energy sources such as bioenergy or solar panels is a key element in enhancing the sustainability of agro-industrial systems (Zahrawi and Aly, 2024).

The attribute within the environmental dimension

Fig. 4: Sensitivity of attributes in the environmental dimension

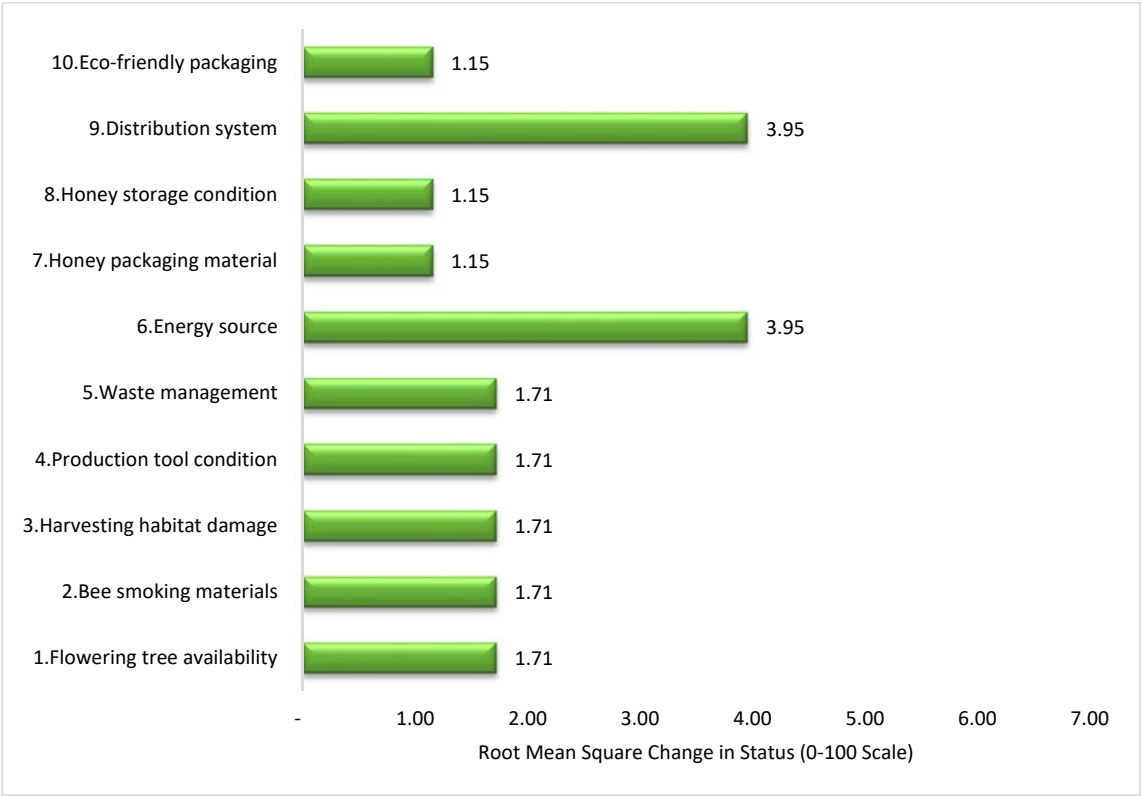


Fig. 4: Sensitivity of attributes in the environmental dimension

that has the lowest impact is eco-friendly packaging, which relates to storage conditions and packaging materials. This attribute plays an important role in maintaining honey quality and reducing the potential for environmental pollution. The use of single-use plastics or unhygienic containers can accelerate product degradation and contribute to non-biodegradable waste. Non-eco-friendly packaging materials are a major source of pollution in small-scale food supply chains. In addition, five other attributes, including waste management, production tool condition, harvesting habitat damage, bee smoking materials, and flowering tree availability, each show a leverage value of 1.01 %, which is considered low. Although their individual impact on the sustainability index is minor, these attributes remain relevant for shaping long-term environmental strategies when managed in an integrated manner. Waste management in beekeeping involves treating by-products such as residual wax, damaged combs, and cleaning wastewater. Improper handling may contaminate soil and water, threatening environmental sustainability. Effective management is therefore essential to maintain ecosystem health and product quality, as honey and bees serve as bioindicators of environmental contaminants. Production tool condition is associated with energy efficiency and hygiene in the harvesting and extraction processes. Outdated or poorly maintained tools can increase energy consumption and the risk of product contamination. In the honey industry, energy and transportation represent the dominant sources of carbon emissions, exceeding 90%, while machinery and tools contribute less than 10%. Despite this smaller proportion, optimizing production tools remains a relevant strategy for emission mitigation (Pignagnoli *et al.*, 2021). Even though their contribution is relatively small, optimizing production tools holds significant potential for emission reduction. Other studies show that modernizing equipment, such as using electric extractors or ultrasonic technology and performing regular maintenance, can reduce the risk of leakage and excessive energy use (Landaverde *et al.*, 2023). Harvesting habitat damage refers to disturbances in bee ecosystems resulting

from unsustainable harvesting practices such as cutting down nesting trees, especially sialang trees. Habitat degradation of this kind can decrease food availability and disrupt colony regeneration. Agroforestry approaches around bee habitats, as implemented in Wanagama, have been proven to preserve natural habitats and enhance sustainable pollination services (Anita *et al.*, 2022). Flowering tree availability is also a crucial factor in maintaining bee populations. The presence of local flowering species such as Melaleuca (Gelam), Sonneratia, and Avicennia plays a role in reproductive cycles and supports the foraging activity of wild honey bees. Although some attributes show leverage values below 2 %, implementing collective strategies and improving technologies can result in a significant cumulative impact on sustainability. The recommended policy actions include modernization of production tools through incentives for transitioning to energy-efficient and contaminant-free technologies, as well as technical training for farmers in the maintenance and calibration of production equipment. In addition, routine certification and inspection of tools and production facilities are necessary to ensure quality and safety standards. Habitat restoration and the participatory planting of flowering trees should also be encouraged as part of forest honey agroforestry programs. Lastly, the implementation of integrated waste management systems is essential to minimize the impact of local environmental pollution.

Economic dimension

The MDS analysis shows that the sustainability index for the economic dimension is 86.81%, classified as sustainable, with a stress value of 0.12 and an R^2 of 0.99 (Table 5, Fig. 3). This dimension ranks as the second strongest contributor to sustainability, with the most dominant attribute being selling price (3.52%). The selling price of honey is a key determinant of business unit profitability. Price increases, whether through organic certification, local branding, or premium packaging design, can directly boost profit margins. Organic and nationally branded honey enjoys a price premium of 18–69% compared to conventional honey, significantly enhancing the product's economic competitiveness (Bimbo *et al.*, 2025). The attributes Branded Packaging Impact and Sales Improvement each have a leverage value of 2.55%, placing them in the moderate influence category. Branded packaging is strongly correlated with consumer perception, loyalty, and purchasing preferences. Labels such as 100% Local, Geographical Indications, and Protected Designation of Origin (PDO) have been shown to increase consumer willingness to pay (Min *et al.*, 2023). In addition, the use of aesthetically pleasing and eco-friendly premium packaging positively impacts the upper-market segment. Meanwhile, increased sales volume plays an important role in improving medium-term economic performance. Digital marketing strategies, online promotional channels, and e-commerce expansion have been proven to accelerate the growth of the forest honey market. Sales transformation through digital approaches and branding strategies can increase revenue by up to 40% for a small-scale honey producer (Min *et al.*, 2023). Other attributes, such as utility costs, packaging costs, net profit, and logistics expenses, show leverage values below 2%, categorized as having low influence. Although these attributes may not significantly contribute to the structural sustainability index, they remain relevant in the context of operational efficiency. When managed collectively, these cost components can have a cumulative effect on improving business margins and stability.

Based on the analysis, several strategic recommendations can be implemented to improve the economic sustainability of forest honey production. These strategies include optimizing selling prices through the adoption of organic certification, geographical origin labels, and informative premium packaging, which are believed to increase product value and expand market reach. Furthermore, enhancing branding and packaging by using eco-friendly, ergonomic materials that reflect local identity, thereby increasing consumer appeal and strengthening brand positioning in both domestic and export markets. Additionally, strengthening distribution channels and digitizing sales through the integrated use of online platforms and digital promotions is necessary to drive sales volume growth and reach a wider consumer base. Finally, operational cost efficiency can be improved through large-scale procurement of packaging materials, conducting utility cost audits, and optimizing supply chain management to sustainably increase profit margins.

Social dimension

Based on the analysis of the Sustainability Index using MDS for forest honey production, the sustainability index score for the social dimension is 82.12%, indicating a sustainable condition. This dimension has

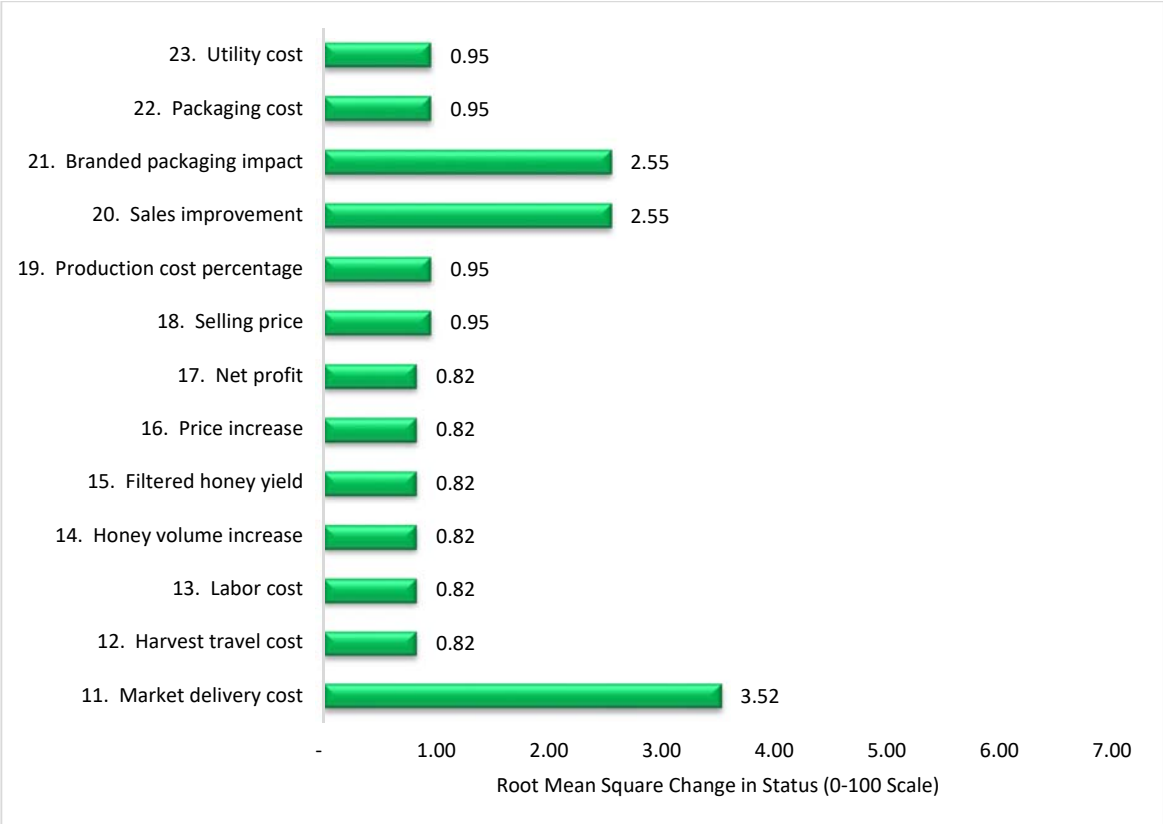


Fig. 5: Sensitivity of attributes in the economic dimension

a stress value of 0.11 and an R^2 of 0.99. The Monte Carlo simulation results yielded a score of 82.17 with a dense repetition distribution (Table 5). These findings indicate that community involvement plays a significant role in supporting the sustainability of forest honey production. The leverage factor analysis for the social dimension reveals that the frequency of training (3.68%) is the most dominant attribute influencing the sustainability index (Fig. 6). Training frequency is directly related to increasing the knowledge capacity of honey hunters regarding harvesting practices that optimize both the quantity and quality of honey, as well as understanding the benefits of forest honey sustainability. Higher training frequency correlates positively with the quality of forest honey production. Structured and repeated training can strengthen network governance, accelerate the adoption of sustainable production practices, and enhance ecosystem conservation participation (Punya *et al.*, 2024). Meanwhile, the attributes within the social dimension that have the lowest impact are price negotiation and education outreach, each contributing only 0.93%. Price negotiation reflects the capacity of honey hunters to negotiate the selling price of honey with buyers (Hernandez-Martinez *et al.*, 2021). This attribute represents structural social change, such as the formation of community institutions or networks. Education outreach relates to efforts in increasing community education and public awareness about the benefits of honey and sustainability. Although it raises awareness, this attribute also influences social sustainability through the formation of groups and collective forest honey production practices. However, these impacts tend to be indirect and temporal, placing them in the category of low leverage. Furthermore, price negotiation and education outreach show low impacts in the social sustainability analysis because their contributions are individual, long-term, and dispersed, rather than contributing to the establishment of robust social systems and institutions.

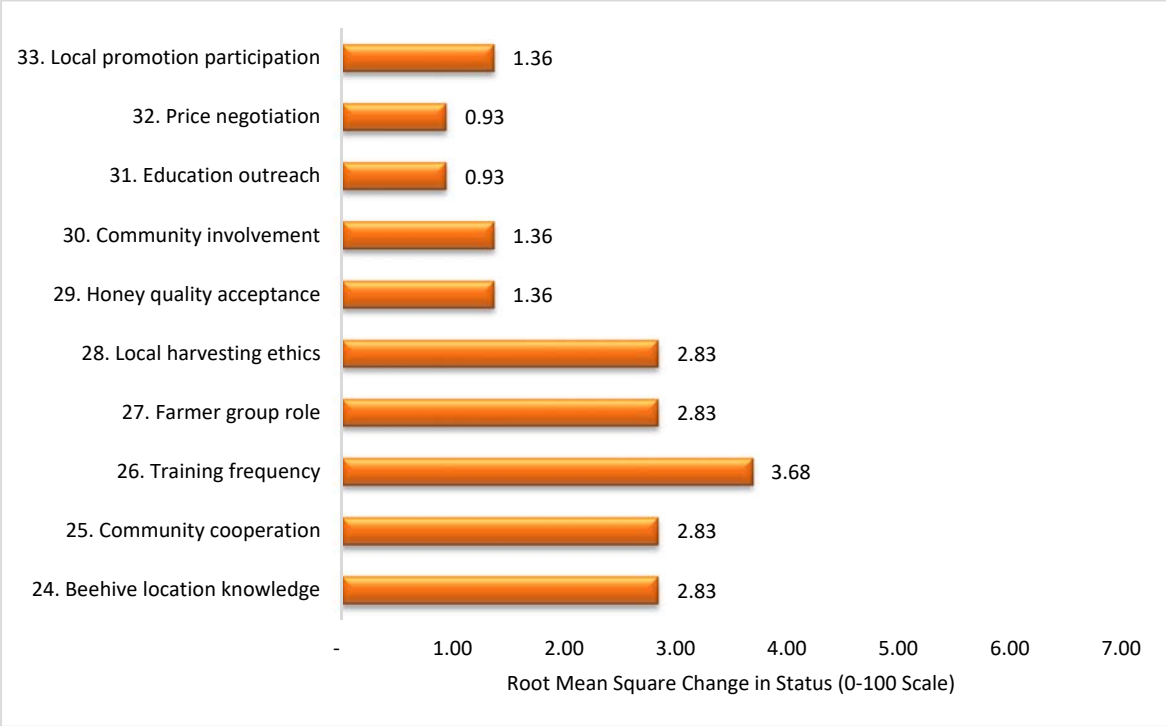


Fig. 6: Sensitivity of attributes in the social dimension

Four other attributes, namely Local harvesting ethics, Farmer group role, Community cooperation, and Beehive location knowledge, each have a leverage value of 2.83% and are interrelated in strengthening the structure of local social systems (Fig. 6). Local harvesting ethics function to prevent habitat degradation and preserve the cultural values of the community. The role of farmer groups has been shown to enhance institutional capacity, broaden access to information, and strengthen bargaining power. Community cooperation is essential for building locally based distribution systems and reinforcing promotional networks. Accurate knowledge of beehive locations correlates with the productivity and stability of forest honey production. Meanwhile, attributes such as Local promotion, Honey quality acceptance, and Community involvement have leverage values of 1.36%, while Price negotiation and Education outreach each have a leverage value of 0.93%. Although these values fall below the 2% threshold, the attributes remain relevant in strengthening social capacity and collective awareness, even if their impact on changes in social sustainability status is indirect. The social dimension plays a vital role in ensuring the sustainability of forest honey production. High-leverage attributes such as training frequency, the role of farmer institutions, and community cooperation serve as key social foundations that can be mobilized to increase competitiveness and the long-term sustainability of the production system. On the other hand, low-leverage attributes still act as supporting elements in fostering an inclusive and resilient social environment. A participatory approach and active community engagement are essential to the success of the social transformation rooted in the forest honey ecosystem in Riau Province. To enhance social sustainability in forest honey production, several actions can be taken. These strategies include conducting regular and continuous training by organizing sessions at least two to three times per year, covering ethical harvesting techniques, post-harvest management, and product marketing. These trainings should be tailored to local conditions and involve supporting partner organizations. Furthermore, strengthen farmer institutions and harvesting ethics by encouraging the formation of legally recognized cooperatives or beekeeping and honey hunter groups, supported by a harvesting Standard Operating Procedure (SOP) that

promotes habitat conservation and ecological ethics. Additionally, promoting local educational campaigns and product marketing by implementing public education programs and local promotions through village events, honey festivals, and digital platforms to raise awareness, enhance the social value of forest honey, and increase youth engagement.

Technology dimension

The sustainability analysis of the five attributes indicates that the technological aspect is moderately sustainable, as evidenced by a sustainability index score of 66.49%, a stress value of 0.09, and an R^2 of 0.99. The Monte Carlo simulation produced a score of 65.85 with a dense distribution of iterations (Table 5). Within the technological dimension, the attribute with the greatest influence is the utilization of digital marketing and digital record-keeping, with a leverage value of 4.09% (Fig. 7). This indicates that the implementation of digital marketing has proven effective in enhancing product visibility, expanding market access, and improving sales record management, particularly in the premium market segment. These findings align with previous research showing that honey enterprises in Indonesia adopting digital marketing strategies experienced increased resilience and sales growth under certain conditions, such as during the COVID-19 pandemic. Active use of websites significantly improves consumer responsiveness and accelerates sales conversion. The digital record-keeping attribute highlights the importance of digitized records in managing production systems. The digitalization of production, financial, and supply chain data enables real-time quality tracking and simplifies the auditing process. Platforms such as ApiManager and HiveTracks are widely used for managing colony data, bee health, and production efficiency (Volokhovych, 2024). Moreover, Internet of Things (IoT) technologies contribute to more accurate and timely monitoring of beekeeping operations. Leverage values ranging from 2% to 4% reflect a moderate but significant impact, suggesting that technology-based interventions should be prioritized in strategies to develop a sustainable production system. With the highest leverage value of 4.09%, digital marketing is categorized as an influential factor. Its application has clearly demonstrated the ability to boost product visibility, broaden market reach, and enhance sales records, especially in premium segments. A study by Putriamara *et al.* (2023) revealed that honey businesses in Indonesia that adopted digital marketing strategies showed increased resilience and sales growth during the COVID-19 pandemic. Active website utilization significantly improves customer response and accelerates sales conversions.

The Digital Record-Keeping attribute shares the highest leverage value of 4.09%, indicating its critical role in the management of production systems. The digitalization of production, financial, and supply chain data enables real-time quality tracking and facilitates the auditing process. Platforms such as ApiManager and HiveTracks have been widely used for managing colony data, bee health, and production efficiency (Volokhovych, 2024). IoT technologies also contribute significantly to the accuracy and precision of operational monitoring in beekeeping practices. The Storage method attribute recorded a leverage value of 3.91%, suggesting that proper storage methods have a considerable impact on product sustainability. Storing honey under controlled temperature and humidity conditions helps preserve its chemical and microbiological quality and prevents fermentation or contamination. IoT technology can be utilized to monitor hive temperature and humidity in real time, thus protecting against post-harvest spoilage and quality degradation (Krishnasamy *et al.*, 2023). Two other attributes, Temperature control and laboratory testing, each recorded leverage values of 2.33%. Temperature regulation and laboratory testing are essential components of quality assurance systems. Innovative technologies, such as IntelliBeeHive, facilitate precise environmental monitoring through temperature-based data collection, while visual recognition methods enable the identification of ion activity, assessment of bee health, and detection of disease risks, thereby enhancing the comprehensiveness and scientific rigor of hive quality evaluations (Alex *et al.*, 2024). Meanwhile, other attributes such as filtration, labeling, moisture reduction tools, and extraction methods showed leverage values below 2%, indicating that their individual contribution to the sustainability index is relatively low. However, collectively, these attributes still play a vital role in shaping an integrated technological system that supports holistic and sustainable honey production practices. The following recommendations can be implemented to enhance technological sustainability in forest honey production systems. The first is comprehensive adop-

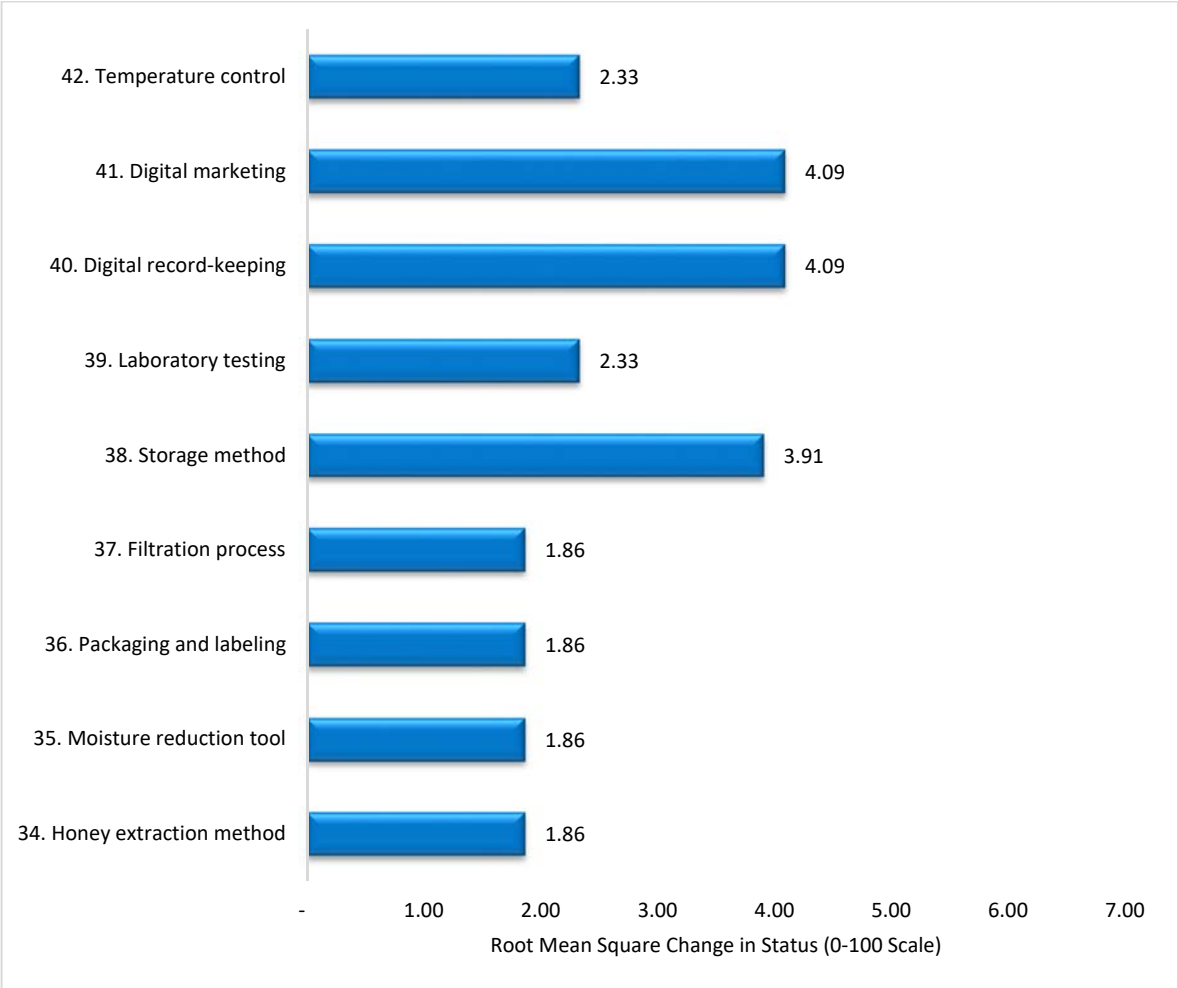


Fig. 7: Sensitivity of attributes in the technological dimension

tion of digitalization by encouraging the use of digital platforms such as social media, websites, and online marketplaces to expand market reach and strengthen the identity of local honey products. Furthermore, the implementation of digital record-keeping systems through the integration of digital platforms such as HiveTracks or ApiManager for efficient and structured management of production and financial data. Additionally, improvement of storage facilities and quality testing by ensuring proper temperature and humidity control, along with the establishment of local laboratories to conduct routine honey quality testing in accordance with national food safety standards. Finally, technology training for honey producers through intensive capacity-building programs for honey hunters and beekeepers focused on the use of digital tools, quality monitoring, and data-driven product evaluation.

Institutional dimension

The institutional dimension has the lowest sustainability index compared to the other dimensions, as indicated by a sustainability index score of 58.51%, with R^2 of 0.99 (Table 5). The Monte Carlo simulation yielded a similar score of 58.51, with a tightly clustered repetition distribution. The attribute with the highest impact, SNI certification of forest honey products, has a leverage value of 6.01% (Fig. 8). SNI certification, including international standards such as ISO 22000, plays a crucial role in ensuring the quality, safety, and credibility of honey products. These certifications not only enhance consumer trust but

also broaden market access, especially for export and premium market segments. Quality certification significantly improves product quality perceptions and economic value among global consumers (Huang *et al.*, 2024). The attributes Participatory Monitoring and Management Structure recorded leverage values of 4.34% each, indicating a moderate to strong influence. Participatory monitoring within the forest honey institutional system fosters transparency, accountability, and trust among farmers and stakeholders. Furthermore, a well-established institutional structure, such as legally recognized and active cooperatives or farmer groups, has a direct impact on the success of production management, quality control, marketing, and access to financing. Collaborative monitoring systems between village governments and beekeeping groups have been shown to significantly improve regulatory compliance, organizational stability, and long-term institutional sustainability (Roengtam and Agustiyara, 2022).

On the other hand, several other attributes showed leverage values below 2% and are thus categorized as having insignificant influence. Attributes such as member attendance, activity planning, and legal group basis, while essential for the day-to-day operations of farmer groups, do not exert a strong structural impact on the institutional sustainability index. Similarly, distribution permits, capacity building, and administrative completeness, though relevant from a governance perspective, have limited influence on institutional outcomes based on the MDS results. There are recommendations to improve the stability of forest honey production in the province. Firstly, improving access to certification (SNI), where local governments and supporting institutions should facilitate technical training, assistance in document preparation, and subsidize certification costs for SNI or other NTFP certification schemes. These efforts will enhance the product's added value and expand its market competitiveness. Furthermore, strengthening participatory monitoring systems by developing a collaborative reporting mechanism between honey farmer groups and stakeholders, including village authorities and forestry agencies.

This regular monitoring can be used to assess group performance, evaluate production quality, and ensure compliance with ethical and environmental standards. Additionally, optimizing the organizational structure of farmer groups by restructuring institutional governance alongside management training, capacity building, and the development of standardized operating procedures. Such improvements are crucial for enhancing the group's legitimacy in the eyes of business partners and government bodies. Finally, formulating long-term strategies by encouraging each forest honey production group to develop business plans and long-term strategies, including market development, risk management, and institutional sustainability. This is essential to reduce dependency on short-term programs and strengthen organizational resilience.

The future and prospects of forest honey production

Forest honey production is one form of NTFP utilization that has high ecological, social, and economic value. In Riau Province, which is known for its peat swamp forests and tropical rainforests, forest honey is produced through traditional beekeeping practices rooted in the local wisdom of indigenous peoples and rural communities. Based on the sustainability dimensions, the environmental and economic dimensions fall into the strong category. This is attributed to the fact that forest ecosystems and floral forage sources still support honey production, combined with high market demand and the value of NTFPs. Literature indicates that tropical forest landscapes enhance the diversity of bee foraging resources and support the quality of forest honey, providing a competitive advantage in honey marketing. Another factor supporting the sustainability of honey production is consumer interest in health aspects, as the antioxidant content and biological properties of forest honey are often perceived as higher, boosting consumer perception of its health benefits and thus supporting product sustainability (Mahani *et al.*, 2025). These factors maximize market opportunities in line with the growing global demand for organic honey and environmentally friendly forest-based products (Bimbo *et al*., 2025). The main constraints that need to be addressed from the institutional aspect are certification and organizational capacity. Forest honey production is currently still dominated by traditional production and distribution systems that are less adaptive to technological developments and global quality standards (Harianja *et al.*, 2023). This results in low supply chain efficiency, potential loss of added value, and difficulties in penetrating export markets. The high leverage of SNI and certification (6.01) indi-

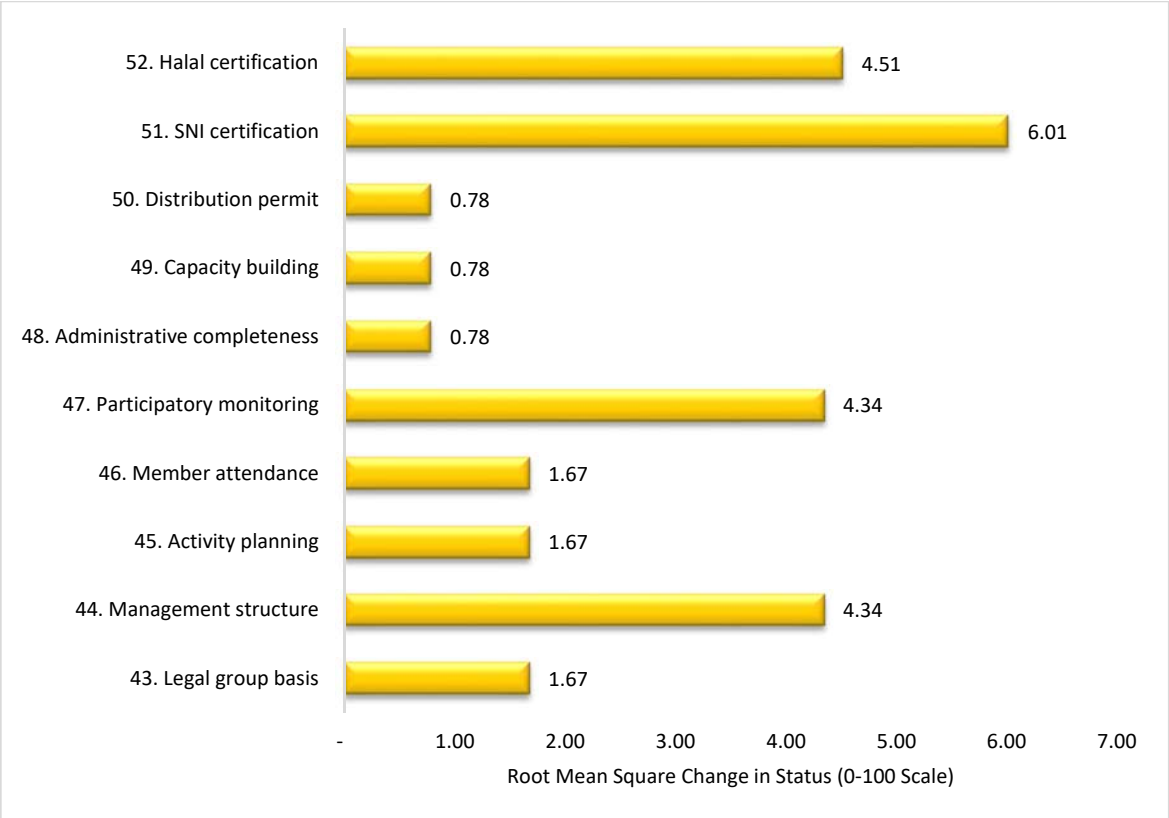


Fig. 8: Sensitivity of attributes in the institutional dimension

cates that the absence of or low compliance with national standards (SNI 8664:2018) and weak institutions (participatory monitoring, management structure) can restrict market access, particularly in premium and export segments. Without quality standards and certification, forest honey struggles to enter labeled markets (SNI, halal, organic), leading to lower prices and a higher risk of rejection. BSN/SNI 8664 is the quality reference that Indonesian producers need to comply with. From the technological aspect, namely digital marketing, digital record-keeping, and storage, digital marketing and record-keeping (RMSE ~4.09), as well as storage methods (~3.91), have a strong influence on the status. The lack of traceability, online marketing, and proper storage facilities causes products to lose value or deteriorate in quality (HMF, moisture content, and fermentation). Producers who adopt digital marketing and traceability systems can improve market reach, reputation, and selling value. Concerns have arisen regarding habitat fragmentation and the loss of forage trees due to the conversion of natural forests in Riau into large-scale plantations such as oil palm and industrial timber estates. This conversion has led to the disappearance of *sialang* trees (*Koompassia excelsa*), which serve as nesting sites for wild honey bees (*Apis dorsata*). As a result, bee colony populations have declined, leading to reduced honey yields. Other environmental disturbances, such as forest and land fires, have direct impacts on bee habitats, colony migration, and population quality, resulting in drastic declines in forest honey production. Without habitat conservation and ecosystem regeneration efforts, forest honey production is at risk of sharp declines in the future. Currently, forest honey is not only an alternative source of income for farmers and forest-adjacent communities, but also plays an important role in supporting biodiversity conservation and ecosystem sustainability (Buchori *et al.*, 2022). Building on these challenges, the following synthesis highlights how recommendations across all sustainability dimensions can be integrated to shape the future of

forest honey production. The sustainability assessment indicates that ecological, economic, and social dimensions are already relatively strong, while institutional and technological aspects require significant improvement. Therefore, future strategies must not only address weaknesses but also build on existing strengths through an integrated approach. Ecological sustainability should be reinforced by conserving sialang trees and restoring flowering tree habitats, while economic value can be enhanced through certification, branding, and digital marketing. On the social side, continuous training and cooperative strengthening are essential for ensuring inclusive participation. Technological upgrades such as digital record-keeping, improved storage, and quality testing will raise product competitiveness, while institutional reforms, including participatory monitoring and easier access to certification, will ensure credibility and long-term resilience. This synthesis underscores the importance of viewing each dimension not in isolation but as interdependent pillars that must be advanced simultaneously to secure the future of forest honey production in Riau Province. Various efforts are needed to promote sustainable forest honey production. In light of the Social Forestry program, which provides legal access and institutional arrangements for forest communities to form farmer groups, this legality helps local communities access training, obtain capital, and improve marketing opportunities. Such support facilitates the transformation of forest honey production from a subsistence activity into a community-based sustainable management unit. Future strategies involving certification, strengthening of farmer institutions, digital marketing, and the application of post-harvest technologies are expected to enhance the competitiveness of Riau Forest honey in both domestic and international markets (Yunianto *et al.*, 2024). The government, which plays a central role in creating a policy framework and supervision that supports wild bee conservation, is expected to develop regulations for sustainable honey harvesting by establishing standard operating procedures for ethical harvesting that do not damage bee nests or habitats. The government should also take an active role in enforcing laws against land burning and illegal deforestation near bee habitats, strengthening the Social Forestry program as a platform for empowering forest-adjacent communities, providing technical assistance for local bee cultivation and sustainable forest honey management, mapping and designating wild bee conservation zones into regional spatial plans, and integrating these efforts into climate change adaptation policies. As large-scale forest landscape users, Industrial Plantation Forest companies carry ecological responsibilities within their business practices, including the implementation of High Conservation Value and High Carbon Stock approaches to protect the natural habitats of bees within concession areas. They are expected to collaborate in bee agroforestry programs (*bee-friendly plantations*) that integrate local flowering species such as *Melaleuca*, *Acacia auriculiformis*, and *Shorea* spp., to implement environment-based Corporate Social Responsibility schemes through training for honey farmers, provision of sustainable harvesting equipment, and marketing support, as well as to monitor bee biodiversity as part of regular environmental impact assessments. Non-Governmental Organizations (NGOs) act as facilitators, providers of technical knowledge, and independent monitors of conservation efforts. Their roles include conducting outreach on sustainable honey harvesting techniques, training local farmers to strengthen their capacities, developing local certification systems such as forest honey eco-labels to increase product value without harming habitats, conducting research, monitoring wild bee populations to provide scientific data for policymaking, and engaging in advocacy for bee conservation as an indicator species of ecosystem health while promoting biodiversity. Local communities and honey farmers or honey hunters, as the main actors in honey harvesting, play a crucial role. They are expected to adopt sustainable harvesting techniques (honey hunting ethics), such as minimizing the use of fire, avoiding the felling of nesting trees, and practicing partial harvesting; conserve local flowering trees (bee forage flora) through agroforestry and reforestation practices; diversify their livelihoods based on honey and other NTFPs to reduce pressure on wild bees; and establish and strengthen forest honey cooperatives as collective platforms for production, marketing, and quality control. Therefore, an analysis of the prospects of forest honey production in Riau Province becomes essential. This study is important for formulating policies and intervention strategies capable of addressing multidimensional challenges to ensure the transformation towards an inclusive, adaptive, and sustainable forest honey production system.

CONCLUSION

This study concludes that forest honey production in Riau Province has reached a highly sustainable status, with an average sustainability index of 76.26%, primarily supported by strong environmental, economic, and social dimensions. The research offers novelty by applying an MDS approach that integrates ecological, economic, social, technological, and institutional aspects into a single sustainability assessment framework, which has rarely been applied to NTFPs such as forest honey. Ecological integrity, market potential, and community participation are relatively well established, whereas institutional and technological dimensions remain moderately sustainable, indicating the need for targeted improvements in eco-friendly distribution systems, digital record-keeping, advanced storage technologies, and institutional governance. Key leverage attributes such as selling price, training frequency, digitalization, and certification play a critical role in shaping holistic sustainability outcomes. Policy actions should prioritize strengthening technological capacities, enhancing the skills of honey hunters, and embedding participatory monitoring into institutional frameworks. These insights are highly relevant for regional governments, cooperatives, NGOs, and the private sector, as they provide an empirical basis for designing adaptive forest governance and community-based livelihood programs. Looking ahead, the sustainability assessment model developed in this study can be replicated in other regions of Indonesia to strengthen the management of non-timber forest products. Positioning forest honey as a flagship sustainable commodity not only enhances local economic competitiveness but also contributes to biodiversity conservation and climate resilience at the national level. The findings further highlight that forest honey production in Riau is not only an economic enterprise but also a cornerstone for biodiversity conservation and cultural heritage preservation. Strengthening farmer cooperatives, promoting ethical harvesting practices, and aligning production systems with global quality standards will enhance the competitiveness of Riau's Forest honey in both domestic and international markets. Collaborative efforts among government institutions, the private sector, NGOs, and local communities are vital for positioning forest honey as a flagship sustainable commodity that simultaneously supports rural livelihoods and safeguards ecosystems.

AUTHOR CONTRIBUTIONS

The study was conceptualized and designed by H. Ikhsani, H. Daulay, and A. D. Santoso, who laid the foundational framework for the research. Data collection was carried out by M. Maryani, A.D. Santoso, and E.T.B. Sabri, while the analysis and interpretation of the gathered data were subsequently performed by M. Maryani and A.D. Santoso. The initial manuscript was drafted by Hanifah Ikhsani, after which it underwent critical review and revision by H. Ikhsani, M. Maryani, and E.T.B. Sabri to ensure accuracy and coherence. Additional contributions, including technical support and other forms of assistance, were provided by E.T. B. Sabri, G. Mohta, and H. Daulay, who played supporting roles throughout the research process.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, have been completely addressed by the authors.

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ABBREVIATIONS (NOMENCLATURE)

%	Percent
AI	Artificial Intelligence
ALSCAL	Alternating Least Squares Scaling (an algorithm of MDS)
d	Euclidean Distance
dij	Euclidean distance from point i to point j
dijk	Squared distance
Eq	Equation
FGD	Focus Group Discussions
GHGs	Greenhouse Gases
IDR	Indonesian Rupiah
ISO	International Organization for Standardization
i, j, k	Dimensions
kg	Kilogram
MDS	Multidimensional Scaling
NGOs	Non-Government Organizations
NTFP	Non-timber forest product
Oij	Point of origin
PDO	Protected Designation of Origin
PM	Particulate Matter
RAP	Rapid Appraisal
RAPFISH	Rapid Appraisal for Fisheries
R^2	Coefficient of Determination
SNI	Standar Nasional Indonesia (The Indonesian National Standard)
Stress	Dissimilarities in MDS
RMS	Root mean square
S	Stress
SOP	Standart Operation procedure
SQR	Structured Query Report
SDGs	Sustainable Development Goals
y	Year

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REVIEW PAPER

Health-oriented urban planning and design: A comprehensive review of global evidence on urban environmental exposures and health outcomes (1984–2025)

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ABSTRACT

Rapid urbanisation has transformed cities into both concentrations of health risks and key arenas for improving population health. Understanding how urban environmental conditions influence multiple dimensions of health has therefore become a central concern for health-oriented urban planning and design. This study synthesises global scientific evidence on the relationships between urban environmental exposures and health outcomes published between 1984 and 2025 and develops an analytical framework for integrating health considerations into urban planning and design practice.

A systematic review with narrative synthesis was conducted in accordance with the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Relevant studies were identified through structured searches in major international and national academic databases. The records were screened using predefined inclusion and exclusion criteria, and eligible studies were systematically coded and analysed. The reviewed studies were classified according to key categories of urban environmental exposure, including green and blue spaces, public and recreational spaces, built form and urban morphology, transport systems and walkability, and environmental risks such as air pollution, noise, and urban heat exposure. Health outcomes were examined across four domains: physical, mental, social, and cognitive health. The findings reveal consistent evidence that access to green and blue spaces and high-quality public spaces is associated with improved mental health, increased physical activity, and higher overall quality of life. Urban form characteristics—particularly density, land-use configuration, and walkability—are systematically linked to patterns of physical activity, obesity, and non-communicable diseases. Conversely, exposure to environmental hazards such as air pollution, noise, and heat stress is strongly associated with mortality and the urban burden of disease. Recent research has also expanded to include cognitive health, child development, healthy ageing, and the mediating roles of perceptual and social factors. Despite these advances, important knowledge gaps remain regarding spatial health equity, the evaluation of urban design interventions, and empirical evidence from low- and middle-income countries. Based on this synthesis, the study proposes a multi-level analytical framework linking urban spatial structure and design, environmental exposures and behavioural pathways, perceptual and social mediators, and multidimensional health outcomes. The framework provides a conceptual basis for systematically integrating health considerations into urban policy, planning, and design.

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INTRODUCTION

Health is widely recognised as a fundamental indicator of societal development and a basic human right. Yet it is not produced solely within healthcare systems. Rather, it is continuously shaped through everyday life in urban settings and through people's interactions with the built environment (Mirgholami *et al.,* 2017). Over recent decades, rapid urbanisation, changing patterns of daily activity, sedentary lifestyles, unhealthy diets and chronic exposure to stress have contributed to a substantial rise in non-communicable diseases. Conditions such as obesity, type 2 diabetes, cardiovascular diseases and mental disorders now account for the majority of global mortality and disability (Helia Sareminia *et al.,* 2023). Within this context, urban planning, design and governance are increasingly recognised as strategic determinants of population health. Cities can be understood as complex socio-spatial systems in which environmental, social and behavioural factors interact across multiple scales. Urban areas simultaneously concentrate environmental risks while also providing opportunities for prevention and health promotion (Barton, 2005; Giles-Corti *et al.,* 2016). This perspective has important historical roots in planning theory. Early models such as Howard's Garden City and Perry's neighbourhood unit were grounded in the assumption that spatial form, land-use organisation and access to green and public spaces can influence residents' wellbeing and health outcomes (Howard, 1902; Perry, 1929). During the past two decades, these ideas have gained substantial empirical support. A growing body of primary studies, systematic reviews and meta-analyses demonstrates consistent associations between urban morphology, walkability, transport systems, green and blue infrastructure, public space design and environmental stressors—including air pollution, noise and heat—and multiple dimensions of physical, mental, social and cognitive health (Twohig-Bennett and Jones, 2018; Yang *et al.,* 2018; Mouratidis, 2021; Xian *et al.,* 2024). Despite this expanding evidence base, the literature on cities and health remains partially fragmented. Several thematic clusters have emerged within the field. One major stream focuses on the relationship between built-form characteristics, physical activity and obesity (Ferdinand *et al.,* 2012; Tcymbal *et al.,* 2020). A second cluster examines the role of green and blue spaces in shaping mental health and subjective wellbeing (James *et al.,* 2015; Gascon *et al.,* 2015; Browning *et al.,* 2022). A third strand investigates the health impacts of environmental exposures such as air pollution and noise (Dockery *et al.,* 1993; Katsouyanni *et al.,* 1997; Muonde *et al.,* 2024). Another body of research analyses the role of public spaces in fostering social interaction, social capital and social health (Mehta, 2014; Qi *et al.,* 2024). In recent years, additional domains have gained prominence. Research on transport safety highlights the health burden associated with traffic injuries and emphasises the importance of pedestrian- and cycling-oriented urban design. Studies on urban heat islands document increasing health risks linked to extreme heat events and climate change. Parallel work on climate resilience and environmental justice emphasises how vulnerabilities to environmental exposures are unevenly distributed across urban populations. Consequently, the concept of health equity has become central to contemporary urban health research, drawing attention to spatial inequalities in environmental conditions and health outcomes. At a broader conceptual level, several frameworks have sought to organise the relationship between cities and health. These include the Healthy Cities movement, liveability frameworks and models based on the social determinants of health (Ashton *et al.,* 1986; Kent and Thompson, 2012; Pineo, 2020; Yang *et al.,* 2018). While these paradigms provide important conceptual foundations, their translation into operational indicators that can directly inform urban planning and design practice remains uneven. A further challenge concerns the measurement of both urban conditions and health outcomes. Earlier studies often relied on relatively simple indicators, such as green space per capita or distance to the nearest park. More recent research conceptualises cities as multi-level systems and employs integrated indicators capturing urban morphology, accessibility patterns, spatial configuration of green and blue spaces, perceived environmental quality, environmental exposures, behavioural mediators and a broad range of physical, mental, social and cognitive health outcomes (Giles-Corti *et al.,* 2016; Markevych *et al.,* 2017; Yang *et al.,* 2018; Ruszanov *et al.,* 2023). However, existing studies rarely synthesise these heterogeneous indicators within a coherent analytical structure. In particular, few reviews simultaneously reconstruct the historical evolution of the field, map the thematic architecture of environmental exposures and health outcomes, and systematise the indicators used to measure urban conditions and health within a uni-

fied causal framework linking urban design, environmental exposure, behavioural and perceptual mediators and multidimensional health outcomes. The geography of knowledge production further reflects significant imbalances. Most empirical evidence derives from cities in Europe, North America and Australia, while urban areas in low- and middle-income countries remain underrepresented. This gap is notable given that many of these cities face rapid urbanisation, pronounced spatial inequalities, limited access to public and green spaces and high vulnerability to environmental and social risks (Shen, 2024; Andalib *et al.,* 2024). Within the Persian-language literature, a growing number of studies have examined relationships between neighbourhood environmental quality, green and public spaces, urban form and indicators of physical, mental and social health (Abrun *et al.,* 2018; Hakimian, 2015, 2016; Enayati *et al.,* 2021; Mahdi, 2020; Hosseini Mand *et al.,* 2021; Sarvar *et al.,* 2025; Shahvaran and Asadpour, 2024). Nevertheless, systematic syntheses that situate this body of work within the broader international literature remain limited. Against this background, the present study addresses a specific analytical gap in the literature. Rather than proposing an entirely new normative framework, the study advances the field by integrating diverse strands of research into a structured, multi-level analytical synthesis. It combines three complementary perspectives: the historical evolution of the field, the thematic clustering of environmental exposures and health outcomes, and the systematic organisation of variables and indicators within a causal chain linking urban form, environmental exposure, behavioural and social mediators, and multidimensional health outcomes. Based on a systematic review covering the period from 1984 to 2025, this article pursues three interrelated objectives. First, it reconstructs the historical trajectory of research on cities and health by identifying analytically meaningful phases in the development of the field. Second, it classifies the evidence into coherent thematic clusters defined by types of urban environmental exposure and categories of health outcome. Third, it extracts and organises the indicators used to measure urban conditions and health within a structured multi-level framework. The resulting framework provides an evidence-informed basis for integrating health considerations into urban policy, planning and design. It also contributes to bridging the gap between research and practice by offering a clearer analytical structure for understanding causal pathways between urban environments and health outcomes. Finally, by incorporating evidence from both international and Persian-language studies, the framework supports the development of context-sensitive approaches to health-oriented urban planning in Iranian cities and other urban contexts in the Global South.

METHODOLOGY

Review design

This study employs a systematic review methodology to synthesize the expanding body of knowledge on the relationship between urban environments and health outcomes. The review was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and MetaAnalyses) guidelines to ensure transparency, replicability, and procedural clarity. The review process followed four sequential stages consistent with PRISMA: Identification, Screening, Eligibility, and Inclusion.

Search strategy

A structured and comprehensive literature search was conducted primarily in Scopus and Web of Science as the principal indexed databases. To broaden the scope and capture regionally published research, Google Scholar and national databases (SID, Magiran, Civilica, and ISC) were used as supplementary sources. This multi-database strategy was designed to ensure both international coverage and contextual relevance. The review included studies published between 1984 and 2025, allowing the analysis to encompass early conceptual discussions as well as contemporary empirical developments in health-oriented urban planning and design. Search queries were developed using bilingual keyword combinations (English and Persian) combined with Boolean operators. Searches were performed within titles, abstracts, and keywords. A representative search string was structured as follows: (“Healthy City” OR “Urban Health”) AND (“Built Environment” OR “Urban Design” OR “Walkability”) AND (“Physical Health” OR “Mental Health” OR “Well-being”). Database-specific syntax adjustments were applied where necessary. Only publications in English and Persian were considered.

Inclusion and exclusion criteria

Explicit inclusion and exclusion criteria were defined to ensure analytical coherence and relevance.

Studies were included if they:

- *Were peer-reviewed journal articles, selected policy reports, or reputable conference papers;*
- *Examined the relationship between urban spatial characteristics and health outcomes;*
- *Reported measurable or clearly defined health indicators;*
- *Addressed planning, design, or built environment dimensions;*
- *Were published between 1984 and 2025.*

Studies were excluded if they:

- *Focused solely on clinical or biomedical health topics without spatial or environmental context;*
- *Did not include identifiable environmental exposure variables;*
- *Lacked explicit linkage between urban factors and health outcomes;*
- *Were editorials, commentaries, or non-academic publications;*
- *Were duplicate records.*

Study selection process

The identification stage yielded 640 records across all selected databases. After removing 110 duplicate records, 530 titles and abstracts were screened for relevance to the research objectives. Following the initial screening, 320 full-text articles were retrieved and assessed for eligibility. During this stage, 59 studies were excluded due to insufficient methodological clarity, weak linkage between environmental exposure and health indicators, or lack of relevance to urban planning and design dimensions. Ultimately, 261 studies met the inclusion criteria and were included in the final analysis**.** The complete study selection procedure, including numerical transitions across the four PRISMA stages (Identification, Screening, Eligibility, and Inclusion), is presented in Fig. 1.

Data extraction

For each included study, structured data extraction was conducted. The following information was systematically recorded: publication year, geographical context, type of urban environmental exposure, research design and methodological approach, health outcome indicators, and key findings.

This extraction framework enabled comparative synthesis across temporal, thematic, and methodological dimensions, forming the basis for the analytical categorization of the literature.

Data synthesis and analytical framework

The selected studies were coded and categorized along three principal analytical dimensions: temporal evolution of research trends, type of urban environmental exposure, and category of health outcome.

Urban environmental exposures were grouped into major domains, including green and blue infrastructure, urban morphology and density patterns, transportation systems and mobility structures, and environmental risks such as heat stress and air pollution. Health outcomes were classified into physical health, mental health, social well-being, and cognitive dimensions. A qualitative thematic synthesis approach was employed to identify recurring patterns and interpret the pathways linking spatial conditions to health outcomes. Particular attention was given to mediating mechanisms such as physical activity, social interaction, and perceptual experience that translate spatial characteristics into measurable health effects. Additionally, existing systematic and umbrella reviews were examined to identify converging findings and remaining research gaps within the field. This integrative analytical process resulted in the development of a multi-level framework illustrating the relationships between urban design, environmental exposure, behavioral responses, and multidimensional health outcomes, as presented in Fig. 2.

RESULTS AND DISCUSSION

Temporal evolution of research on urban environments and health

The temporal framework was developed to examine changes in research output over time. Publications were grouped into five consecutive periods based on the chronological distribution of studies in the dataset and observable shifts in publication frequency across the study period. This classification enables a consistent comparison of research activity across different phases of development in the field.

As summarized in Table 1, the temporal evolution of the literature reveals a clear acceleration in research activity over time. Between 1984 and 1999, 30 studies were identified, representing 11.5% of the total sample, and primarily explored general relationships between urban environments and health, particularly environmental pollution and access to natural

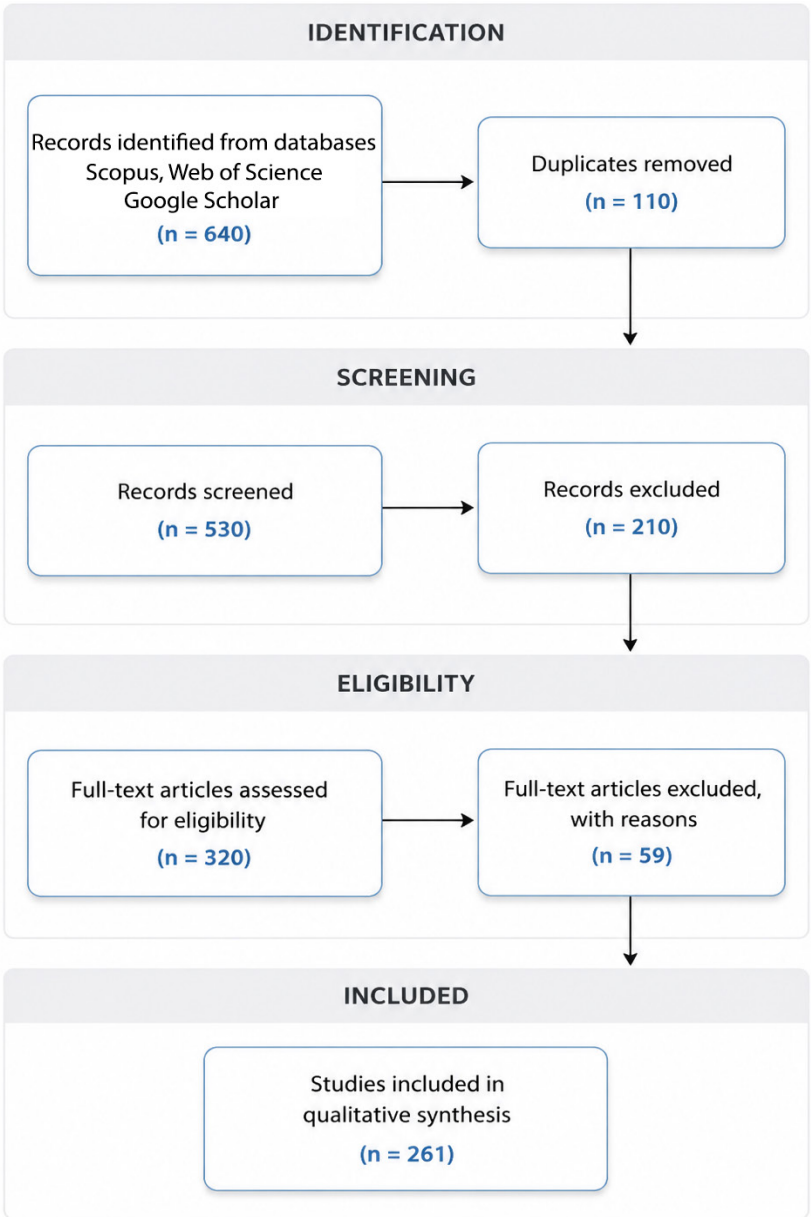


Fig. 1: PRISMA flow diagram of the systematic literature search and study selection process.

Data Collection

Sources: Scientific articles were primarily collected from online databases such as **Scopus, Web of Science, and Google Scholar.** Additionally, books, conference papers, and relevant urban planning reports were utilized to provide a comprehensive perspective on **health-oriented urban planning.**

Publication Type & Time Span: The primary focus was on peer-reviewed scientific articles published between **1984** and **2024**, supplemented by credible conference papers and authoritative reports. This timeframe captures the evolution of research in the field.

Search Parameters: A structured set of keywords and their synonyms was developed for systematic searching, including terms such as ***healthy city, urban health, physical health, mental health, social health, healthy urban environments, walkability, green infrastructure, and urban design for health*.** After applying screening criteria, **261 articles** were ultimately selected for detailed review.

Data Analysis

Analysis of Study Distribution: The reviewed studies were categorized according to the types of mediating variables linking urban environmental characteristics to health outcomes. The analysis examined the distribution of evidence across behavioral, functional, social, and perceptual dimensions to identify dominant research themes and methodological approaches in the literature.

Review of Existing Literature Reviews: Previous systematic and narrative reviews addressing urban health, environmental determinants of health, and healthy city research were examined to trace the conceptual development of mediating pathways between urban environments and health outcomes.

Key Topics of Focus: The analysis focused on major mediating variables including *physical activity and active use of urban space, patterns of park and open-space use, social interaction and social capital, and perceptual and psychological factors such as perceived stress, safety, place attachment, and environmental satisfaction,* evaluating their roles in translating urban environmental conditions into measurable health outcomes.

Findings And Frameworks

Analysis of Study Distribution: The findings were synthesized to identify the main health outcome domains associated with urban environmental conditions. The reviewed studies were categorized according to physical, mental, social, and cognitive health outcomes in order to clarify the range and frequency of health effects reported in the literature.

Review of Existing Literature Reviews: Previous review studies on urban health, healthy city frameworks, and urban livability were examined to contextualize the identified health outcomes and to trace how urban planning and environmental design have been linked to multidimensional health indicators in earlier research.

Key Topics of Focus: The synthesis focused on four principal outcome domains: physical health (including obesity, cardiovascular and respiratory conditions, and physical fitness), mental health (including stress, depression, anxiety, sleep quality, and wellbeing), social health and social capital (including social cohesion, trust, and civic participation), and cognitive health (including attention, memory, executive functioning, and cognitive development). In addition, composite indices such as Healthy City indicators, urban livability metrics, and multidimensional urban quality of life indices were considered to capture the broader impacts of urban environments on population health and wellbeing.

Fig. 2: Research process and analytical framework

Table 1: Five-period temporal framework for the development of research on urban environments and health (1984–2025)

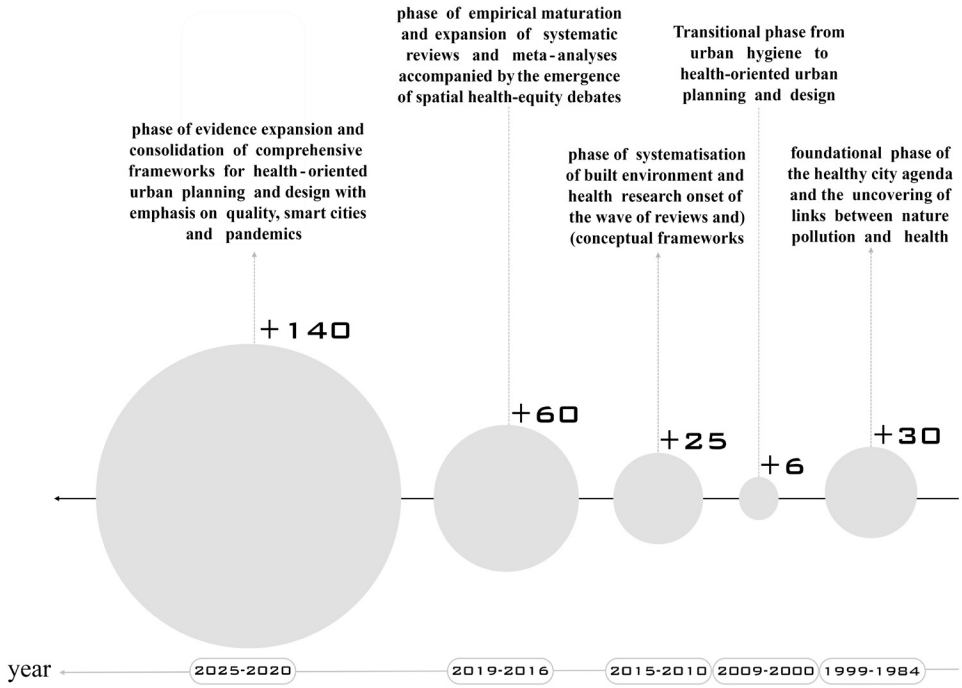
Time period (AD)	Number of studies	General research characteristics	Percentage of total sample
1984–1999	30	Foundational phase of the "healthy city" agenda and uncovering the links between nature, pollution, and health	11.5%
2000–2009	6	Transitional phase from urban hygiene to health-oriented urban planning and design	2.3%
2010–2015	25	Phase of systematisation of the built environment and health research (onset of the wave of reviews and conceptual frameworks)	9.6%
2016–2019	60	Phase of empirical maturation and expansion of systematic reviews, meta-analyses, and the emergence of spatial health equity debates	23.0%
2020–2025	140	Phase of evidence expansion and consolidation of comprehensive frameworks for health-oriented urban planning and design (with emphasis on quality, smart cities, and pandemics)	53.6%
Total	261		100%

elements. Between 2000 and 2009, only six studies were identified (2.3%), reflecting the transitional stage of research on the built environment-health relationship, which had not yet consolidated as a distinct research stream within urban planning scholarship. This pattern may also be partly associated with the gradual expansion of journal indexing in major international citation databases during the early 2000s. Furthermore, the strict inclusion criteria applied in this review—particularly the requirement that studies explicitly link urban design variables with measurable health outcomes—reduced the number of eligible studies during this period. Research output increased between 2010 and 2015, with 25 studies published (9.6% of the total sample). Studies in this period more frequently examined measurable associations between built environment characteristics and specific health indicators. Between 2016 and 2019, the number of publications increased to 60 studies (23.0% of the total sample). Quantitative methods, spatial analysis techniques, and systematic review approaches were applied more frequently to assess associations between urban environmental characteristics and health outcomes such as physical activity, noncommunicable diseases, mental health indicators, and quality of life. The highest concentration of publications occurred between 2020 and 2025, with 140 studies identified (53.6% of the total sample). More than half of all included studies were published during this period. Research topics during these years increasingly addressed health equity, distribution of environmental resources, urban resilience, smart city initiatives, environmental quality, and health implications associated with pandemics.

Fig. 3 further illustrates this temporal trajectory and shows that 200 of the 261 studies, equivalent to 76.6% of the sample, were published after 2015. This pattern confirms that research on urban environments and health has expanded markedly in recent years, shifting from exploratory environmental-health observations toward more integrated and evidence-based frameworks for health-oriented urban planning and design.

Topical classification of studies on urban environmental exposures and health outcomes

To examine the distribution of evidence within the



Evolution of health-oriented urban design research: A temporal analysis of urban and health studies, 1984–2025

Fig. 3: Temporal distribution of included studies examining the relationship between urban environments and health (1984–2025).

reviewed literature, the 261 included studies were classified into seven thematic domains based on the primary type of urban environmental exposure and the associated health outcomes investigated. Each study was assigned to the domain that most closely reflected its central research focus. This classification provides a structured overview of how research on health-oriented urban planning and design is distributed across different dimensions of the built and natural environment and their related health outcomes.

As presented in Table 2, the thematic distribution of the reviewed studies indicates a strong concentration of evidence in two dominant domains. Studies on green spaces, open spaces, and the urban landscape constitute the largest cluster (n=110), reflecting substantial empirical attention to the relationships between exposure to urban nature and outcomes such as psychological restoration, stress reduction, and overall well-being. The second major cluster concerns the built environment, urban form, and walkability (n=55), highlighting the importance of urban morphology, street network configuration, and spatial design characteristics in shaping physical activity patterns and noncommunicable disease outcomes. Together, these two domains account for the majority of the reviewed literature and underscore the central role of both natural and built urban environments in influencing health.

Two mid-sized domains—healthy cities and policy frameworks (n=30) and public and collective spaces (n=30)—provide an important conceptual and social complement to the physical environment literature. Studies in these domains emphasise policy-oriented determinants of health, the role of governance and planning frameworks, and the importance of everyday public environments in supporting social cohesion, place attachment, and social health. Although numerically smaller, the domains of environmental quality and environmental risks (n=14) and leisure and recreational environments (n=14) contribute important insights into direct environmental exposures, such as air pollution, noise, and heat, as well as lifestyle-related factors associated with recreational settings and subjective well-being. Finally, the foundational conceptual literature (n=8) provides the theoretical basis required to interpret the diverse health outcomes identified across the seven thematic domains.

Table 2: Thematic classification of studies by type of urban environmental exposure and health outcomes

Thematic domain of studies	Brief description of the domain	Number of studies
Green spaces, open spaces and urban landscape, and health outcomes	This domain includes studies examining the role of parks, green spaces, green–blue infrastructure, urban forests, and landscape quality in shaping health outcomes. Commonly investigated outcomes include physical and mental health, quality of life, subjective wellbeing, psychological restoration, stress reduction, decreased depressive symptoms, and increased vitality among residents. The domain also includes several large-scale systematic reviews and metaanalyses assessing the relationship between exposure to green and blue spaces and a wide range of health outcomes at the global level.	110
Built environment, urban form, walkability, transport and physical characteristics of the built environment and health	This domain comprises studies focusing on the structural and physical characteristics of the built environment, including urban form, street networks, density, landuse mix, walkability indicators, pedestrian routes, subcentre design, and urban morphology. These studies investigate how such characteristics are associated with physical activity, obesity, noncommunicable diseases, general health, and mental health outcomes. Systematic reviews and metaanalyses addressing relationships between the built environment and physical activity are also included in this category.	55
Healthy cities, urban health, conceptual and policy frameworks, and indicators of health and quality of life	This domain includes literature addressing conceptual and policy frameworks related to healthy cities and urban health. Topics covered include urban liveability, the right to urban health, health equity, social determinants of health, and the integration of health considerations into urban planning and development strategies. The category also includes studies examining international initiatives, policy frameworks, and broader conceptual discussions of the relationship between urban environments and population health.	30
Public and collective spaces, urban hangouts, markets and streets, social interactions, social capital and place attachment	This domain encompasses studies focusing on public spaces such as squares, streets, pedestrian corridors, markets, bazaars, urban gathering spaces, and cultural or recreational complexes. These studies examine outcomes related to social interaction, social cohesion, social capital, social trust, sense of belonging, place attachment, urban vitality, place meaning, and intergroup cohesion. A substantial portion of the Iranian literature on public space, together with several international studies assessing the quality and performance of public environments, is included within this category.	30
Environmental quality, air pollution, noise pollution, environmental risks, and physical and mental health outcomes	This domain comprises studies investigating environmental exposures within urban settings, including ambient air pollution, environmental and traffic noise, urban heat, and other environmental risks. These studies examine their associations with mortality, cardiovascular and respiratory diseases, blood pressure, sleep disorders, stress, and other physical and mental health outcomes. Both classic epidemiological studies on air pollution and more recent research on urban soundscapes are represented within this category.	14

Thematic domain of studies	Brief description of the domain	Number of studies
Leisure, recreational spaces, tourism facilities, recreational sports, and health and well-being	This domain focuses on urban leisure and recreational environments, including amusement and recreational parks, tourism facilities, cultural complexes, recreational sports spaces, and temporary urban programmes such as carfree events. Research in this category often examines outcomes such as mental health, happiness, vitality, life satisfaction, subjective wellbeing, social cohesion, and local social development.	14
Theoretical and foundational literature on mental health, social health, and broader supporting texts on health	This category includes theoretical and conceptual references related to mental health, social health, happiness, and wellbeing that provide the conceptual foundation for interpreting health outcomes in the context of healthoriented urban planning and design. Although these works do not directly analyse urban environmental exposures, they contribute to the theoretical framing of health dimensions used in the review.	8
Total		261

Overall, the thematic classification presented in Table 2 highlights both the dominant lines of inquiry within the field and the relatively limited number of studies addressing environmental risks and leisure environments. This distribution not only clarifies the balance of current evidence across thematic areas, but also establishes the analytical structure for the subsequent sections, where specific environmental indicators, exposure pathways, and health outcomes are examined in greater detail.

The distribution of studies indicates a strong concentration of research in two primary domains. Studies on green spaces, open spaces, and the urban landscape constitute the largest cluster (n=110), reflecting substantial empirical attention to the relationships between exposure to urban nature and outcomes such as psychological restoration, stress reduction, and overall wellbeing. The second major cluster concerns the built environment, urban form, and walkability (n=55), highlighting the importance of urban morphology, streetnetwork configuration, and spatial design characteristics in shaping physical activity patterns and noncommunicable disease outcomes.

Variables and indicators for assessing the urban environment and health in the research literature

Research on the relationship between cities and health has moved beyond simple indicators such as per capita green space or Euclidean distance to the nearest park. Contemporary studies increasingly conceptualise the urban environment as a multi-dimensional system and assess it through a combination of morphological, spatial, environmental, perceptual, and behavioural indicators linked to diverse health outcomes (GilesCorti *et al.,* 2016; Yang *et al.,* 2018; Pineo, 2020). These variables are measured at different spatial scales. At the macro scale, research commonly examines urban form, street-network configuration, land-use patterns, density, and neighbourhood structure. At the micro scale, studies focus on streetscape attributes, street furniture, visual quality, and fine-grained environmental characteristics. In parallel, many studies assess direct environmental exposures such as air pollution, noise, and heat, as well as perceived environmental quality, place experience, and patterns of social interaction (Ruszanov *et al.,* 2023; Helia Saremina *et al.,* 2023). Together, these variables form an integrated analytical framework linking characteristics of the urban environment to multiple dimensions of human health. In the literature, these relationships are typically conceptualised as a causal chain connecting environmental conditions, intermediate behavioural and social processes, and health outcomes. The indicators discussed in the following subsections are therefore organised according to their position within this environment–exposure–behaviour–health pathway, encompassing physical, mental, social, and cognitive health outcomes among urban residents.

Physical and morphological indicators of the urban environment

At the first analytical layer, the physical form and

spatial structure of cities are operationalised through a range of morphological indicators. Commonly applied variables include net and gross residential density, building density, site coverage ratio, floor area ratio, average building height, intersection density, urban grain and block size, as well as ratios such as street length relative to parcel or censusunit area. Additional indicators frequently used in empirical studies include block radius, compactness, and measures of streetnetwork connectivity and spatial integration. These variables constitute the core measurement framework in research examining walkability, healthoriented urban form, and the design of active urban environments (Sallis *et al.,* 2016; Smith *et al.,* 2017; Barnett *et al.,* 2017; Fathi *et al.,* 2020; Tcymbal *et al.,* 2020; Abusaada & Elshater, 2024; Mouratidis, 2021; Andalib *et al.,* 2024). In addition to these morphological measures, many studies analyse the functional and spatial composition of neighbourhoods. Indicators commonly used include landuse mix, permeability of the urban fabric, the proportion of pedestrianoriented versus caroriented streets, continuity of pedestrian networks, street hierarchy, and spatial legibility. Across diverse geographical contexts—including North American, European, Middle Eastern, and Iranian cities—empirical research has examined the associations between these structural characteristics and outcomes such as walking behaviour, patterns of social interaction, and residents' mental wellbeing (Hakimian, 2016; Hossein Abadi, 2021; Barati *et al.,* 2021; Khasto & Kiaei, 2021; Dehghan, Golkar & Hakimian, 2022; Enayati *et al.,* 2021). A further methodological approach focuses on the configurational properties of street networks. Using spaceconfiguration techniques, studies analyse the topology of urban networks through indicators such as centrality, connectivity, relative depth, the length of continuous pedestrian paths, the number of high throughmovement nodes, and the hierarchical distribution of the network. These metrics are used to explain patterns of movement, spatial utilisation, and the frequency of facetoface encounters within urban environments (Sheng *et al.,* 2021; Shao *et al.,* 2021). Complementing these spatialconfiguration measures, fieldbased studies of streets and public spaces have operationalised the quality of the public realm through microscale urban design indicators. These include street width and crosssection profile, the availability of pause and resting spaces, degree of edge activation, façade transparency, functional diversity along street frontages, and the intensity of landuse mix. Such indicators are widely recognised as fundamental components shaping the physical and social performance of public spaces (Montgomery, 1998; Madani Pour, 1996; Mehta, 2014; Andersson, 2016; Torkaman *et al.,* 2017; Takiehkhah *et al.,* 2013).

Indicators of accessibility, configuration, and quantity of green, blue, and public spaces

The second layer of indicators focuses on the spatial architecture and accessibility structure of networks of green, blue, and public spaces. In the literature, spatial accessibility to urban nature has most commonly been operationalised through measures such as Euclidean or network distance to the nearest park or green space, walking or driving time to green areas, and the number of parks located within different service radii. Additional metrics frequently include per capita green space at neighbourhood, district, and city scales, the percentage of green cover within analytical units, and the ratio of green surface to total developable land (Lee & Maheswaran, 2011; WHO, 2016; James *et al.,* 2015; Browning *et al.,* 2022; Banwell *et al.,* 2024; Bressane *et al.,* 2024; Twohig-Bennett & Jones, 2018).

These indicators have been applied in both global comparative studies and contextspecific case studies, including research focusing on Iranian cities. With the increasing availability of spatial datasets and remotesensing imagery, exposure to urban nature has also been operationalised through vegetation and canopy metrics derived from satellite data. Frequently used measures include the Normalized Difference Vegetation Index (NDVI), treecanopy density and height, the proportion of visible greenery within the pedestrian field of view, and the ratio of street trees to street length. These indicators have been widely linked to multiple physical and mental health outcomes across diverse climatic and socioeconomic contexts (Gascon *et al.,* 2015; Fong *et al.,* 2018; Engemann *et al.,* 2019; Ji *et al.,* 2019; Lee *et al.,* 2020; Liu *et al.,* 2023; Xie *et al.,* 2024; Xian *et al.,* 2024). At the scale of parks and urban open spaces, a further set of indicators captures spatial configuration and functional characteristics. These include park area and service radius, patch geometry, compactness or elongation of green patches, and structural diversity within parks, such as combinations of trees, shrubs, lawns, open areas,

hard surfaces, and water elements. Additional indicators describe the number and diversity of facilities—such as playgrounds, running tracks, sports fields, seating areas, cafés, and sanitary facilities—as well as the density and spatial distribution of entrances, the continuity of internal path networks, and their integration with surrounding street networks (McCormack *et al.,* 2010; Kaczynski *et al.,* 2008; McCormack *et al.,* 2014). Comparable indicator frameworks have also been applied in studies of urban parks and recreation systems in Iranian cities, including Hamedan, Gorgan, Tabriz, Birjand, and Borujerd. In these studies, variables such as per capita green space, service radius, continuity of pedestrian paths, number of entrances, lighting conditions, perceived and actual safety, furniture quality, the presence of incompatible land uses, and the spatial distribution of green and blue elements are analysed in relation to user experience and healthrelated behaviours (Hosseini Mand *et al.,* 2021; Arasteh & Heydarzadeh, 2020; Taheri, Ghasemi Seychani & Shabani, 2021). With respect to blue spaces and green–blue infrastructure, the literature employs indicators such as distance to rivers, canals, lakes, and urban water bodies, the length of accessible waterfronts, the number of pedestrian access points to the water edge, and the quality of spatial connections between blue spaces and the wider openspace network. These indicators are frequently analysed alongside their contributions to microclimate regulation, opportunities for physical activity, and processes of psychological restoration in urban environments (Gascon *et al.,* 2017; Tieges *et al.,* 2022; Leporelli & Santi, 2019; Orsetti *et al.,* 2022; Barton, 2005).

Indicators of environmental quality, perception, and experience

Quantitative spatial and physical indicators alone cannot fully explain the relationship between urban environments and health without considering environmental quality and lived experience. Consequently, a substantial body of research has developed conceptual and empirical frameworks under the heading of perceived environmental quality. These frameworks encompass dimensions such as spatial legibility and clarity of urban structure, visual coherence and order, spatial and functional diversity, aesthetic quality, perceived safety, thermal and acoustic comfort, cleanliness and maintenance, accessibility for different population groups, and the perceived vitality and liveability of urban environments (Mouratidis, 2021; Nguyen *et al.,* 2021; RíosRodríguez *et al.,* 2021; Veen *et al.,* 2020; Stangierska *et al.,* 2022). In empirical studies, these attributes are typically measured using multiitem Likertscale questionnaires and analysed as latent constructs representing perceived publicspace quality, perceived greenspace quality, soundscape quality, or overall neighbourhood environmental quality (Nguyen *et al.,* 2021; Stangierska *et al.,* 2022; Zhang, H. *et al.,* 2022; Wu *et al.,* 2024). The theoretical foundations of these constructs can be traced to classic work emphasising environmental legibility, mental image formation, aesthetic preference, and direct experiences of nature in shaping behaviour and psychological wellbeing (Kaplan & Kaplan, 1989; Kaplan, 1995; Hartig *et al.,* 1991; Hartig *et al.,* 2014; Marcus & Francis, 1998; Madani Pour, 1996). Empirical applications of these frameworks appear in studies conducted across diverse geographic contexts, including Northern Europe and Southwest Asia. Research focusing on Iranian cities has operationalised perceived environmental quality through indicators such as visual and landscape quality, spatial and functional diversity, landuse mix and compatibility, perceived safety during day and night, visual pollution, the presence and quality of green and blue elements, lighting conditions, seating provision, the presence of other users, perceived vitality, and the quality of leisure experiences in parks and pedestrian environments (Abrun *et al.,* 2018; Azimi *et al.,* 2020; Akbarian, 2019; Hosseini Mand *et al.,* 2021; Taheri, Ghasemi Seychani & Shabani, 2021; Karimi *et al.,* 2022; Gharavi Roodsari, 2023; Taheri & Taheri, 2019; Abdollahzadeh Fard & Shamseddini, 2020; Ghaffari Gilandeh & Mohammadi, 2023). Within this domain, a specific subset of indicators addresses the restorative potential of urban environments. These include experiences of psychological “being away” from daily pressures, attentional immersion, environmental coherence, compatibility between environmental characteristics and individual preferences, opportunities for solitude, and sensations of freshness and revitalisation. Such indicators have been widely applied in studies of parks, urban forests, blue spaces, and humanoriented streets, where their associations with reduced stress, improved mood, lower mental fatigue, and increased vitality have been demonstrated across different cultural and climatic contexts (Ulrich,

1984; Ulrich *et al.,* 1991; Hartig *et al.,* 1991; Hartig *et al.,* 2014; Patuano, 2020; RíosRodríguez *et al.,* 2021; Wu *et al.,* 2024; Stoltz, 2022; WajchmanŚwitalska *et al.,* 2021; Smyth *et al.,* 2022; Browning *et al.,* 2022).

Indicators of environmental exposure: air pollution, noise, heat, and environmental risks

The urban environmental epidemiology literature has established a standardised set of indicators for quantifying exposure to air pollution, environmental noise, thermal stress, and related urban risks. These indicators form the core measurement layer linking urban environmental conditions to physiological and psychological health outcomes.

Air pollution exposure

In the domain of air pollution, exposure is commonly operationalised using average daily and annual concentrations of fine particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen dioxide (NO_2), ozone (O_3), and other regulated pollutants. Measurements are derived from fixed monitoring stations, interpolated grid cells, landuse regression models, or streetlevel monitoring along transport corridors. These indicators have been extensively applied in crosssectional, timeseries, and longitudinal cohort studies across global urban contexts (Dockery *et al.,* 1992; Dockery *et al.,* 1993; Schwartz & Dockery, 1992; Schwartz, 1993; Pope *et al.,* 1995; Katsouyanni *et al.,* 1997; Yang *et al.,* 2018; Muonde *et al.,* 2024). Analytically, pollutant concentrations are integrated into regression and survival models to estimate associations with allcause and causespecific mortality, as well as cardiovascular and respiratory morbidity. This body of evidence constitutes one of the most methodologically consolidated segments of the urban health literature.

Environmental noise exposure

In the field of environmental noise, exposure is typically quantified using equivalent continuous sound pressure levels (LAeq), as well as timespecific indicators including Lday, Levening, and Lnight. The composite Lden index, representing weighted day–evening–night exposure, is widely used in European and international assessments. These indicators are derived from in situ measurements, acoustic propagation models, and traffic noise mapping (Pulles *et al.,* 1990; Lercher, 1996; Regecová & Kellerová, 1995; Muonde *et al.,* 2024). Empirical studies employ these metrics to examine associations with hypertension, cardiovascular disease, sleep disturbance, psychological stress, and behavioural problems in children. More recent research has expanded beyond purely quantitative decibel measures by incorporating the concept of the soundscape, which integrates the diversity and quality of sound sources, perceived annoyance, and the presence of natural sounds within urban environments (Gascon *et al.,* 2017; Zarei *et al.,* 2024).

Urban heat and thermal exposure

In relation to urban heat and climate change, exposure is assessed using indicators such as landsurface temperature derived from remote sensing, nearpedestrian air temperature, urban heatisland intensity, and the frequency and duration of heat waves. Composite thermal stress indices, including the Universal Thermal Climate Index (UTCI), are increasingly used to capture physiologically relevant thermal burden (Iungman *et al.,* 2023; Orsetti *et al.,* 2022; Frumkin *et al.,* 2020; Gao, 2024). These indicators are frequently analysed alongside urban morphological and ecological variables, such as vegetation structure, surface permeability, and shading patterns, to assess how spatial configuration moderates thermal exposure in public spaces.

Composite environmentalrisk indices

Within the healthycity and liveability literature, composite environmentalrisk indices have been developed to integrate multiple stressors into single neighbourhood or citylevel indicators. These indices typically combine air pollution, environmental noise, insufficient greenery, excessive density, service deficits, traffic unsafety, and related environmental burdens. Applications of such composite metrics are documented in European and Australian cities, as well as in rapidly urbanising regions and Iranian case studies addressing environmental risk and liveability (GilesCorti *et al.,* 2016; Yang *et al.,* 2018; Kruize *et al.,* 2019; Prokofyeva & LebedevaNesevrya, 2018; Esmaeilzadeh Farid *et al.,* 2025; Mahdi, 2020; Zarei *et al.,* 2024; Marques *et al.,* 2020). Together, these exposure indicators represent the environmental component of the causal pathway linking urban form and environmental conditions to behavioural responses, physiological stress, and longterm health outcomes.

Behavioural, functional, and social mediating variables

Between environmental exposures and health outcomes lies a range of behavioural, functional, and social mediating variables that play a critical role in explaining causal pathways between urban environments and health. In empirical models of urban health, these mediators capture the behavioural responses, patterns of social interaction, and subjective experiences through which environmental conditions influence physical and psychological outcomes.

Behavioural activity indicators

The most widely examined behavioural mediators relate to physical activity and active use of urban space. These constructs are commonly operationalised through indicators such as weekly minutes of ModeratetoVigorous Physical Activity (MVPA), daily step counts, duration of walking for transport and leisure, frequency of park and trail use, participation in recreational sports, and patterns of using streets and public spaces for physical activity (Ferdinand *et al.,* 2012; Sallis *et al.,* 2016; Smith *et al.,* 2017; Tcymbal *et al.,* 2020; Barnett *et al.,* 2017; Wang *et al.,* 2019; McCormack *et al.,* 2014; Grigoletto *et al.,* 2021; Kostrzewska, 2017; Cilliers & Ledwoń, 2024; Hartley *et al.,* 2020). These indicators have been employed both in large international cohort studies and in more localised research conducted in Iranian cities. Such studies examine behaviours including daily walking, bicycle use, participation in parkbased sports, and engagement with "health trails" as mediating mechanisms linking urban form and environmental characteristics to health outcomes (Hakimian, 2016; Khasto & Kiaei, 2021; Barati *et al.,* 2021).

Activity patterns within parks and public spaces

Research focusing on parks and urban open spaces has also examined behavioural patterns occurring within specific settings. Indicators frequently include the type of activity performed (such as walking, running, playing, sitting, or observing), duration of stay, movement patterns within the space, and the age and gender composition of users. These variables provide insight into how spatial attributes influence patterns of space use and, in turn, affect both physical activity levels and psychological wellbeing (McCormack *et al.,* 2010; Sheng *et al.,* 2021).

Social interaction and community processes

At the social level, mediating variables capture patterns of interaction and the structure of social networks embedded in everyday urban life. Indicators in this domain include the frequency and quality of facetoface contacts, the number and diversity of everyday social interactions, participation in community events and collective activities, the breadth and strength of informal local networks, perceived social support, sense of community belonging, and engagement in civic networks (Mehta, 2014; Qi *et al.,* 2024; Setiawan & Ningtyas, 2023; Purnomo, 2022; Andersson, 2016; OluOwolabi *et al.,* 2023). These constructs are widely operationalised under conceptual frameworks such as social capital, social cohesion, social trust, civic participation, and perceived social security. Empirical studies in both international contexts and Iranian cities have investigated how the structure and quality of urban spaces, access to public spaces, and the density of opportunities for interaction influence these social processes (Sam Aram, 2009; Vesali *et al.,* 2016; Abbasi *et al.,* 2018; Sami *et al.,* 2025; Alizadeh *et al.,* 2022; Sarvar *et al.,* 2025).

Perceptual and psychological mediators

A further group of mediators relates to perceptual and psychological processes through which individuals interpret and experience their environment. Commonly examined constructs include perceived stress, feelings of crowding and environmental pressure, perceived control over everyday life, place attachment, neighbourhood belonging, place meaning and identity, residential satisfaction, and perceived spatial justice (Hartig *et al.,* 2014; Markevych *et al.,* 2017; RíosRodríguez *et al.,* 2021; Pykett *et al.,* 2020; Nguyen *et al.,* 2021; Wu *et al.,* 2024; Menezes & Smaniotto Costa, 2024; Zhang, H. *et al.,* 2022). These constructs have been applied across diverse urban contexts, including studies of mental health in Iranian cities. In such research, variables such as place attachment and dependence, neighbourhood satisfaction, sense of belonging, perceived vitality, quality of everyday presence, and perceived neighbourhood quality are analysed as mediating mechanisms linking urban design characteristics to psychological wellbeing (Mirgholami *et al.,* 2017; Hakimian, 2019; Shahabi Shahmiri & Khatami, 2020; Khatami & Shahabi Shahmiri, 2021; Zeynali Azim *et al.,* 2024; Nasiri, 2023; Dehghan, Golkar & Hakimian, 2022).

Indicators of physical, mental, social, and cognitive health outcomes

At the outcome layer, the city–health literature encompasses a wide spectrum of health indicators that can be broadly grouped into four domains: physical, mental, social, and cognitive health. These indicators represent the endpoint of the causal chain linking urban environmental characteristics, environmental exposures, behavioural responses, and social processes to measurable health outcomes.

Physical health outcomes

In the physicalhealth domain, commonly examined variables include body mass index (BMI), prevalence of overweight and obesity, systolic and diastolic blood pressure, diabetes and other components of metabolic syndrome, and the prevalence or incidence of cardiovascular and respiratory diseases. Childhood asthma has also been frequently analysed in relation to urban environmental conditions. At the most aggregate level, studies have examined allcause and causespecific mortality, particularly cardiovascular and respiratory mortality, in relation to environmental exposures and urban form characteristics across different regions of the world (Ferdinand *et al.,* 2012; Barnett *et al.,* 2017; Hartley *et al.,* 2020; TwohigBennett & Jones, 2018; Yang *et al.,* 2018; Wies *et al.,* 2024; Muonde *et al.,* 2024; Helia Sareminia *et al.,* 2023). Several studies have also synthesised these variables into composite indices capturing the risk of noncommunicable diseases within urban populations (Mogo *et al.,* 2022; Abusaada & Elshater, 2024).

Mental health outcomes

Within the mentalhealth domain, commonly examined outcomes include overall mentalhealth scores, depressive symptoms, anxiety, perceived stress, psychosomatic complaints, sleep quality, life satisfaction, subjective wellbeing, and happiness. These outcomes are frequently analysed in relation to access to green spaces, exposure to environmental stressors, and the quality of urban environments (Gong *et al.,* 2016; Moore *et al.,* 2018; Hartig *et al.,* 2014; Fong *et al.,* 2018; Vanaken & Danckaerts, 2018; LečićToševski, 2019; Browning *et al.,* 2022; Liu *et al.,* 2023; Hu *et al.,* 2025; Xu *et al.,* 2025; Xian *et al.,* 2024). Parallel research in Iranian cities has operationalised mental health using standardised questionnaires and psychometric instruments, including depression and anxiety scales, general health indices, happiness scales, and lifesatisfaction measures. These studies relate mentalhealth outcomes to the characteristics of green spaces, parks, recreational areas, neighbourhood environments, and public spaces (Akbarian, 2019; Abrun *et al.,* 2018; Azimi *et al.,* 2020; Enayati *et al.,* 2021; Gharavi Roodsari, 2023; Hosseini Mand *et al.,* 2021; Taheri, Ghasemi Seychani & Shabani, 2021; Karimi *et al.,* 2022; Ghaffari Gilandeh & Mohammadi, 2023; Shahvaran & Asadpour, 2024).

Social health outcomes

Social health and social capital constitute another key domain of outcome variables. Indicators commonly include perceived social health, social cohesion and solidarity, interpersonal and institutional trust, civic engagement, participation in formal and informal networks, and perceptions of justice and social security (Qi *et al.,* 2024; Setiawan & Ningtyas, 2023; Lee, 2020; OluOwolabi *et al.,* 2023). These constructs are operationalised in both international and Iranian studies examining neighbourhood residents and occupational groups. Empirical research investigates how the structure and quality of urban spaces, access to public spaces, and the density of opportunities for interaction influence levels of social cohesion and collective life (Sam Aram, 2009; Vesali *et al.,* 2016; Abbasi *et al.,* 2018; Sami *et al.,* 2025; Qi *et al.,* 2024; Alizadeh *et al.,* 2022).

Cognitive health outcomes

An expanding segment of the literature focuses on cognitive outcomes associated with urban environmental exposure. Indicators in this domain include attention and concentration, memory performance, executive functioning, children's cognitive development, educational performance, and the risk of cognitive impairment or decline among older adults. These outcomes are commonly analysed in relation to both shortterm and longterm exposure to green spaces, neighbourhood environmental quality, and levels of environmental pollution (Engemann *et al.,* 2019; Islam *et al.,* 2020; Buttazzoni *et al.,* 2022; Trott *et al.,* 2025; Wies *et al.,* 2024; Xian *et al.,* 2024; McIntyre *et al.,* 2023; Vanaken & Danckaerts, 2018).

Composite health and liveability indices

At a broader analytical scale, the concepts of urban health and healthy cities are frequently op-

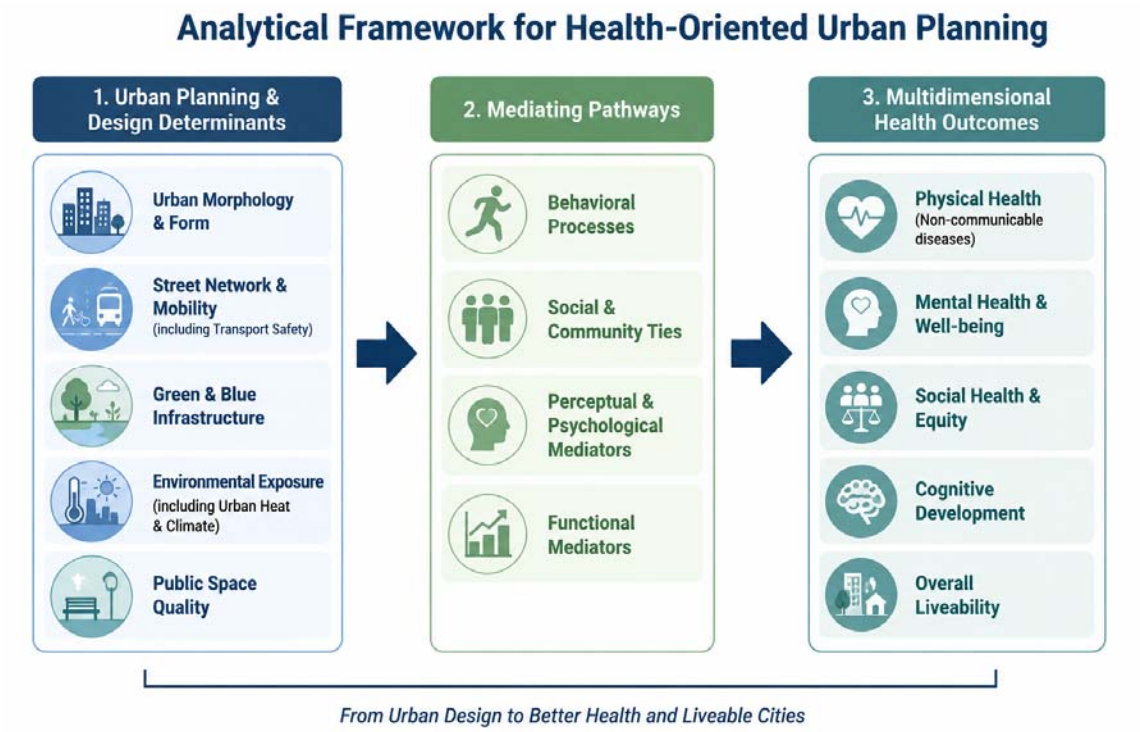


Fig. 4: Conceptual framework of healthoriented urban planning and design

erationalised through composite multidimensional indices that integrate physical, mental, social, environmental, and institutional dimensions. These indices are used to capture broader constructs such as urban liveability, urban quality of life, and overall urban health performance (Ashton *et al.,* 1986; Barton, 2005; Kent & Thompson, 2012; Yang *et al.,* 2018; Mouratidis, 2021; Pineo, 2020; Capolongo *et al.,* 2020; Marques *et al.,* 2020; Cilliers & Ledwoń, 2024). Such frameworks have been applied both in international comparative studies and in research conducted in Iranian cities. In these studies, multidimensional subjective indices of healthy city, neighbourhood liveability, urban health, and quality of life are used to evaluate the health performance of different urban contexts (Rahimi & Pazand, 2017; Ahmadi *et al.,* 2019; Taghipour *et al.,* 2023; Sarvar *et al.,* 2025; Taghizadeh *et al.,* 2025; Hemmati *et al.,* 2024; Esmaeilzadeh Farid *et al.,* 2025). Taken together, this constellation of indicators reflects a clear shift in the literature from onedimensional and purely biomedical measurements towards genuinely multilevel conceptualisations of urban health. In these frameworks, urban form and spatial structure, environmental quality and lived experience, behavioural responses and social interactions, and subjective perceptions are analysed as successive links in a causal chain connecting urban design, environmental exposure, mediating processes, and multidimensional health outcomes. This integrated perspective underpins the development of healthoriented analytical and intervention frameworks in which urban planning and design are guided not by single variables but by the deliberate combination of environmental, behavioural, social, and multidimensional health indicators.

Fig. 4 presents the conceptual framework derived from the systematic review, synthesizing the core relationships between urban planning and design determinants and multidimensional health outcomes. The framework consolidates the diverse body of evidence into a structured set of strategic domains, clarifying how spatial configurations, environmental qualities, mobility systems, and sociospatial conditions collectively influence human health in urban environments. By articulating the principal pathways linking urban form and planning interventions to physical, mental, and social health outcomes, the

framework provides an integrative analytical structure for interpreting the findings of the review. However, the systematic extraction and coding of the reviewed literature identified a substantially broader range of operational indicators and subcomponents associated with healthoriented urban planning and design. Incorporating all identified elements into the primary framework would compromise visual clarity and reduce the conceptual readability of the model. Therefore, to balance conceptual clarity with methodological transparency, the comprehensive taxonomy of the identified indicators and their detailed classifications is structured into three hierarchical levels, as illustrated in Figs. 5, 6, and 7. Specifically, Fig. 5 delineates the conceptual pathways through which urban environmental indicators influence health outcomes, establishing a logical flow from physical design interventions to physiological and psychological well-being. Together, these figures document the full analytical mapping derived from the reviewed studies and serve as a detailed reference for researchers seeking to operationalize or replicate this framework in future empirical investigations.

CONCLUSION

This systematic review synthesises international evidence on the relationships between characteristics of the urban environment and multiple dimensions of human health. The reviewed literature demonstrates consistent associations between several domains of the urban environment and population health outcomes. Urban green and blue spaces are widely associated with improvements in mental well-being, reductions in stress and depressive symptoms, and lower risks of cardiovascular and respiratory morbidity. Characteristics of the built environment, including residential density, land use mix, street connectivity, walkability, and transport systems, are closely related to patterns of physical activity and to major non-communicable diseases such as obesity and diabetes. A substantial body of epidemiological research also links environmental exposures, particularly air pollution, environmental noise, and urban heat, to mortality, cardiovascular and respiratory conditions, sleep disturbance, and psychological stress. Evidence concerning streets and public spaces further highlights the importance of the public realm in shaping social interaction, social cohesion, and place attachment.

Despite these advances, several important gaps remain in the current body of knowledge. Many empirical studies rely on relatively coarse spatial indicators, such as density measures, proximity metrics, or per capita provision, while the detailed spatial and design characteristics that structure everyday urban experience are rarely operationalised as measurable variables. Sensory environmental qualities, including sound environments, microclimatic conditions, tactile and olfactory dimensions, and the temporal distribution of shade and sunlight, are also largely absent from prevailing indicator systems. In addition, the differentiated experiences of diverse social groups remain insufficiently examined, with limited attention to women, children, older adults, and people with disabilities. Governance and institutional dimensions, including coordination between sectors, participatory planning processes, and monitoring frameworks for health-oriented urban interventions, are similarly underrepresented in many approaches that assess the relationship between environment and health.

Addressing these limitations requires several directions for future research. First, there is a need to develop measurable indicators that capture detailed spatial and sensory characteristics of urban environments and allow them to be incorporated into quantitative and mixed-method analyses of urban health. Second, future studies should more systematically investigate the experiences and mobility patterns of different population groups through longitudinal research designs, spatial tracking techniques, and integrated qualitative and quantitative approaches. Third, greater attention should be given to underutilised and informal urban spaces, including vacant land and marginal parcels within the urban fabric, as potential opportunities for creating recreational and social environments that support health and well-being. From a planning and design perspective, improving urban health requires moving beyond general correlations between environmental provision and health indicators. Urban planning and design strategies should incorporate detailed spatial qualities, inclusive design principles, and governance mechanisms capable of translating scientific evidence into effective spatial interventions. Strengthening the connections between environmental indicators, spatial design decisions, and measurable health outcomes is therefore essential for advancing health-oriented urban planning and design in diverse urban contexts.

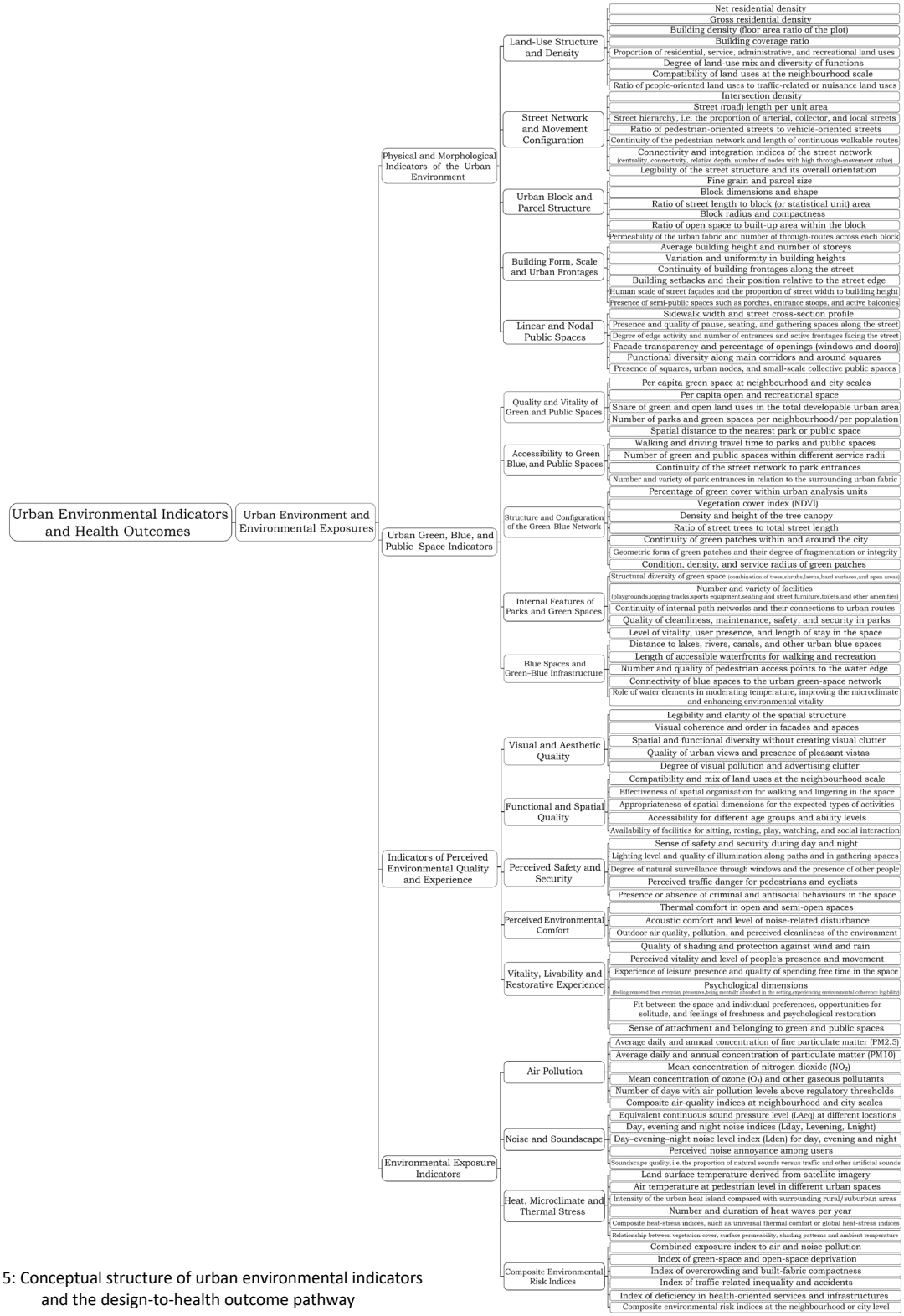


Fig. 5: Conceptual structure of urban environmental indicators and the design-to-health outcome pathway

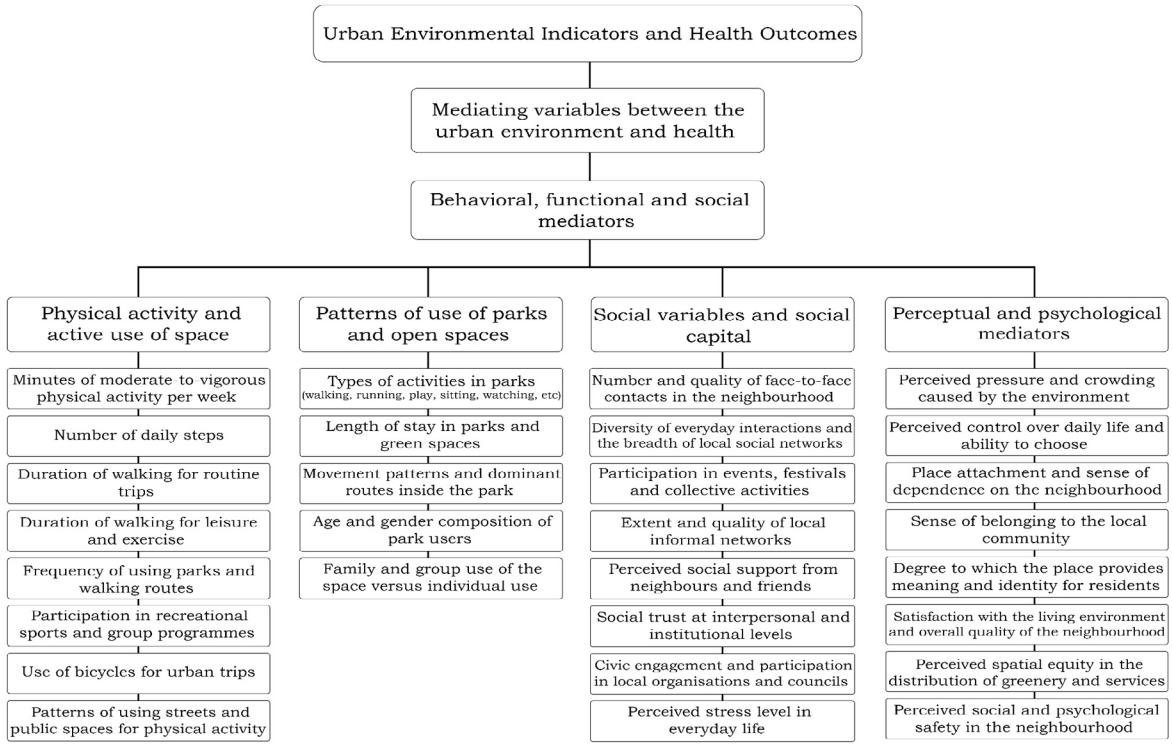


Fig. 6: Taxonomy of behavioral, functional, and social mediators in the urban environment-health nexus.

AUTHOR CONTRIBUTIONS

M. Beyrami had primary responsibility for all core stages of the study, including the conceptualization of the research, development and refinement of the review protocol and search strategy, definition of inclusion and exclusion criteria, systematic screening, data extraction and coding, thematic and comparative synthesis of the evidence, preparation of tables and figures, and drafting as well as substantive revision of the manuscript. A. Molaei provided overall supervision and methodological guidance, contributed to the development and consolidation of the analytical and conceptual framework, helped resolve ambiguities in study selection and interpretation of the evidence, and critically reviewed and edited the manuscript for intellectual rigor and coherence. M. Ayashm contributed to the development of the conceptual framework and positioning of the study within the broader field of health-oriented urban design, assisted in the interpretation and contextualization of the findings, and critically reviewed the manuscript for clarity, consistency, and scholarly quality.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, have been completely witnessed by the authors.

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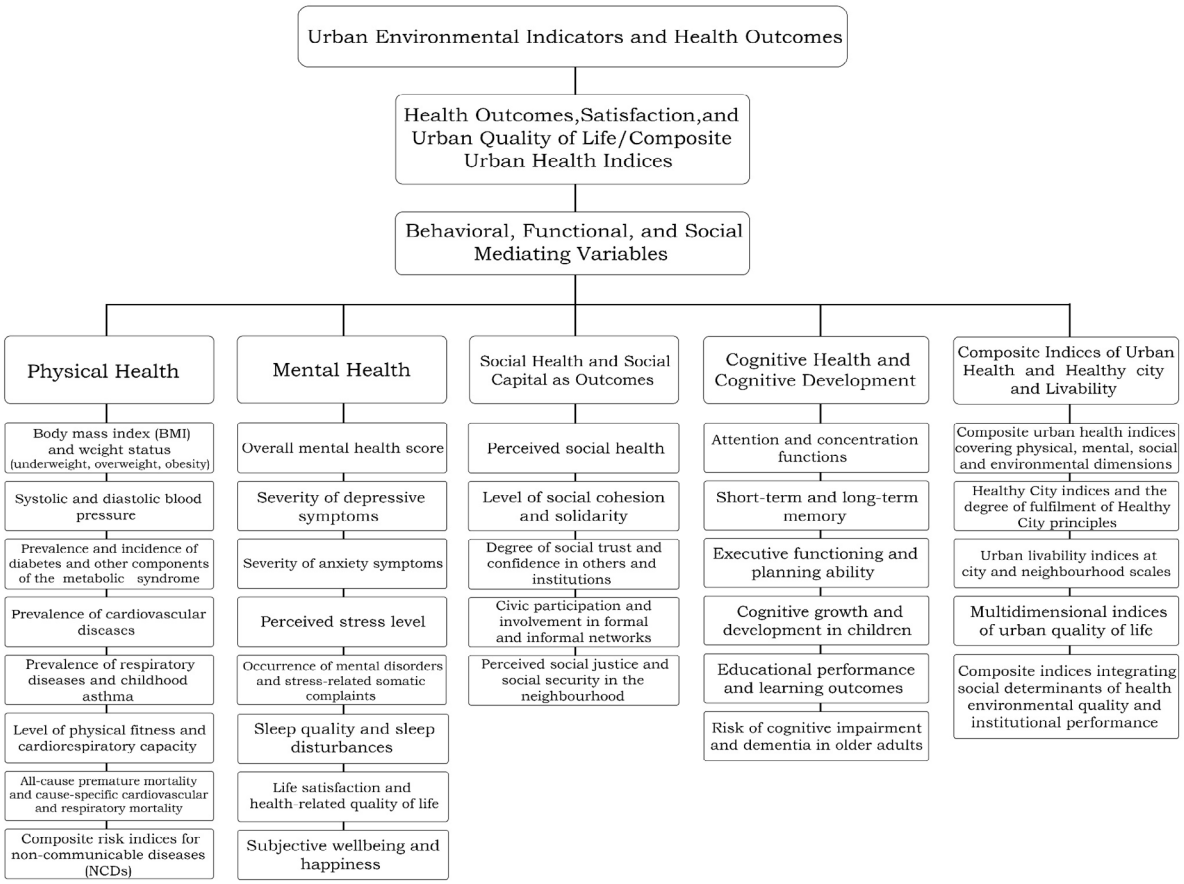


Fig. 7: Taxonomy of health outcomes, urban quality of life, and composite urban health indices

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ABBREVIATIONS

PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
AD	Anno Domini (Gregorian calendar year)
BMI	Body mass index
LAeq	Equivalent continuous A-weighted sound pressure level
Lday	A-weighted long-term average sound level for daytime period
Levening	A-weighted long-term average sound level for evening period

Lnight	A-weighted long-term average sound level for night-time period
Lden	Day–evening–night noise level indicator
MVPA	Moderate-to-vigorous physical activity
NO_2	Nitrogen dioxide
O_3	Ozone
$PM_{2.5}$	Particulate matter with aerodynamic diameter ≤ 2.5 µm
PM_{10}	Particulate matter with aerodynamic diameter ≤ 10 µm
UTCI	Universal Thermal Climate Index
NDVI	Normalized Difference Vegetation Index
UTCI	Universal Thermal Climate Index
MVPA	Moderate-to-Vigorous Physical Activity

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