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Urban residents' perspectives on eco-city: a second-order confirmatory factor analysis of Khon Kaen, Northeast Thailand

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The concept of eco-cities has gained prominence and become a central focus of urban design in recent decades. While theoretical models are well-recognized among policymakers, the extent to which these approaches are understood and embraced by urban residents remains underexplored. Using a quantitative approach, specifically second-order confirmatory factor analysis (Second-Order CFA), this study examined whether the eco-city concept applied by professionals in Khon Kaen, a city located in northeastern Thailand, aligns with residents' perceptions. A total of 400 residents and stakeholders in Khon Kaen were surveyed using a structured questionnaire. The analysis of urban residents' perceptions reveals that the economic aspect exerts the most influence on the eco-city concept, followed by environmental and sociocultural aspects. This finding suggests that residents' perspectives on eco-cities are generally consistent with professional ideas and theoretical models. However, the contribution of latent factors—economic, sociocultural, and environmental—is shaped by complex interactions among the observed factors. The results indicate that transforming the existing economic and environmental structures of the city is challenging, while the sociocultural aspect, from residents' perspectives, may be more easily addressed. This study recommends prioritizing the retrofitting of social infrastructure and recognizing its contributions to improving both the economy and environment in urban planning.

KEYWORDS

eco-city, smart city, perspectives on eco-city, green city, urban resident perspectives, Northeast Thailand

1 Introduction

This past several decades have been marked by unprecedented urban environmental crises such as unpredictability rainfalls causing floods, air pollutions, water pollutions etc. often these problems are seen to associated with climate changes. Such crises have required urgent action, which in turn has led to the increasing prominence of ecological urbanism and green urbanism in urban planning. Ecological urbanism is based on ecology, emphasizing that the environment and social inclusiveness are core elements in urban planning. It suggests that the urban must be viewed through the lens of ecology, where all parts of the system are interdependent (Chen et al., 2020; Colding et al., 2022). As urban growth continues, the environment degrades (Akhtar et al., 2020). Rydin (2014) argues that cities are both perpetrators and victims of climate change, affecting urban sustainability. Odum (1971), an American biologist known for his pioneering work in ecosystem ecology, presents a stronger view of ecological urbanism, describing cities as "parasites" on natural and built environments, stating that cities produce no food, clean little air, and only purify a small amount of water. Whereas ecological urbanism is undergirded by ecological concepts, green urbanism is more politically driven, aiming to achieve a triple-zero framework—zero fossil fuel use, zero waste, and zero emissions.[1]

Both ecological and green urbanism provide strong foundations for the eco-city framework, though they differ significantly in conceptualization and implementation. In addition to being influenced by the 1992 Rio Declaration on Environment and Development, the eco-city concept evolved from Frank Lloyd Wright's urbanistic idea of the "broadacre city" (Wright, 1932) and the garden city movements (Dummett, 2009). The term "eco-city" was more recently coined by Register (1987, 2001), who defined it as "a human settlement modelled on self-sustaining resilient structure and function of natural ecosystems" (Ecocity Builder, https://ecocitybuilders.org/what-is-an-ecocity/). The International Eco-city Framework & Standards expands on this definition, describing an eco-city as "… a human settlement model for self-sustaining resilient structure and function of natural ecosystems. An eco-city provides a healthy abundance to its inhabitants without consuming more renewable resources than it produces, without generating more waste than it can assimilate, and without being toxic to itself or neighboring ecosystems. The ecological impact of its inhabitants reflects supportive planetary lifestyles, fairness, justice, and reasonable equity." Additionally, Beatley's (2000) summary of the key characteristics of green cities, which are also prevalent in eco-cities, defines green cities as cities which: (1) strive to live within ecological limits, (2) includes urban design that functions analogously to nature, (3) aims for a circular rather than linear metabolism, (4) promotes sustainable lifestyles, and (5) emphasizes high-quality neighborhoods and community life.

Several towns and cities are considered examples of eco-cities. Bibri (2020) examined green energy technologies and their integration with data-driven smart solutions in the Stockholm Royal Seaport district. This study demonstrated that green technologies can reduce energy consumption and mitigate pollution. Coskun (2023) explored eco-city planning concepts and architectural designs in global eco-city prototypes. A comparison of Sino-Asian eco-cities, including Tianjin (China), Kucukcekmece (Turkey), and Masdar (United Arab Emirates), revealed both commonalities and differences in terms of purpose, design ideas, architectural materials, sustainability and energy efficiency, and road and street systems. This study emphasized that eco-city planning is an evolving concept, with many projects still in the planning phase. It recommended adopting a holistic approach to reconcile urban planning and architecture. For instance, the Tianjin project, which began in 2008, sought to restore wastewater ponds into functional lakes. Another example is Curitiba, Brazil, where numerous eco-city principles have been implemented. The city introduced a Bus Rapid Transit system, banned cars in the city center, rehabilitated wetlands instead of building expensive dams, and created a citywide public recycling system, among other initiatives.

While the above examples emulate that eco-city concept is widely adopted in professional urban planning, the concept is apparently encountered two challenges. Firstly, the transformation into an eco-city requires significant investment. This includes the construction of new infrastructure and the retrofitting of existing buildings to enable the efficient use of energy and modern technologies. Such expensive investments may surpass the financial capacities of towns and cities in developing countries. Moreover, these high costs could contribute to gentrification—leading to increased property values, rising living costs, and the displacement of lower-income groups—thereby worsening social inequality. Secondly, the perception of urban residents supporting the ecocity initiatives is critical, especially where the infrastructures of urban have been used shaping the path dependence (Schindler and Dionisio, 2021). However, the International Growth Centre highlights the comparative advantages of cities in developing countries in pursuing eco-cities (Delbridge et al., 2022). This advantage stems from their natural endowments such as the richness of wetlands, natural waterways, tracks of occupied lands but have not been developed, and the near-by agricultural lands, etc., which can aid the transition to net-zero emissions. This shift presents new opportunities for developing urban industries and services that can create employment while promoting sustainability.

Thailand, where the study was conducted, has experienced a steady pattern of increasing urbanization. Although a significant portion of Thailand's population still resides in rural areas (approximately 54% in 2021), urban growth is notable. In response, national policy has recognized this upward trend of urbanization and the increasing rural–urban interface with the introduction of long-term plans for managing increasing urbanization on a national scale. For example, Thailand's Long Term National Strategy (2018–2037) outlines two strategic issues under the "liveable Smart City" agenda to be addressed by government agencies. The first issue focuses on developing liveable and "Smart Cities" to support economic development, provide residential spaces, reduce inequality, and improve the quality of life for all population groups. The second issue emphasizes the development of towns, rural areas, agriculture, and industry in accordance with an "ecological spatial plan." This issue stresses the importance of utilizing big data at the national level to construct a national ecological spatial plan. Such a plan would support regional development in line with ecosystem services, such as large infrastructure projects, natural resource management, and the creation of buffer zones. This includes urban and rural planning that meets the standards or requirements for land use control, transportation, and public utilities.

The "eco" concept is more narrowly defined in the Ministry of Industry's policy known as the Eco-Industrial Town initiative. Under this policy, the focus is on adapting manufacturing industries and their interactions with their surroundings, including the natural environment and socioeconomic factors. Five dimensions of eco-industrial towns have been identified: physical, economic, environmental, sociocultural, and management. Within these dimensions, 20 indicators have been established, categorized into two aspects: spatial planning and building and surrounding design. The Ministry of Industry selects cities for development into eco-industrial towns. Currently, the initiative is in its third cohort, with industries in nominated cities eligible for support from the Ministry. In addition, the Eco-Industrial Town concept is promoted by the Industrial Estate Authority of Thailand (IEAT) and large corporations like the Siam

1 https://www.strategy-business.com/article/How-to-build-a-sustainable-city-at-scale

Cement Group, with a focus on reducing natural resource use and pollution, while increasing energy efficiency and waste management (IEAT, https://eco.ieat.go.th/th/eco-development-concept; https://www.thainews-online.com/th/articles/251742). In Northeast Thailand, two provinces, Khon Kaen and Mukdahan, were selected to be promoted as eco-industrial towns. In Khon Kaen, the city where this study was conducted, the designated Eco-Industrial Townsite is approximately 20 km from the provincial town center, within an industrial estate zone.

Within Khon Kaen Municipality, the provincial town center was also designated as one of several pilot cities for Thailand's 'Smart City' initiative. Nationally, the "Smart City" initiative is overseen by the Ministry of Digital Economy and Society (DE), which aimed to upgrade all of Thailand's 76 provincial towns into Smart Cities by 2022 (BE 2565). Although the "Smart City" initiative primarily focuses on digital technological advancements, it also includes core elements of an eco-city, such as (1) smart environments, (2) smart mobility, (3) smart living, (4) smart people, (5) smart energy, (6) smart economy, and (7) smart governance.[2] According to the Provincial Development Plan, Khon Kaen Municipality aims to internationalize the city and improve its inhabitants' happiness. The municipality's programs and projects include greening initiatives and smart city developments. It can be observed that the eco-city concept has been incorporated into both the Eco-Industrial Town and Smart City frameworks, although the specific terminology of the eco-city is less prominent.

Despite the strong support for the eco-city concept among policymakers and professionals, the actual progress in implementing these ideas remains unclear, with potential obstacles arising throughout the urbanization process. The Eco Industrial Town promoted by Ministry of Industry and IEAT is apparently followed to the eco-city ideas, while the smart city promoted by DE is more in line with green urbanism. Thinphanga and Friend (2024) note that urbanization involves various heterogeneous elements, including material substances, technologies, discourses, practices, and urban land-use planning, which often lags significantly behind the current reality. Taweesaengsakulthai et al. (2019) argue that the ramifications of the Thai bureaucratic system, particularly the "highly centralized management of the country," pose a major obstacle to addressing local issues (p. 150). Given that the eco-city concept, which encompasses broad ideas related to urban planning and management, is largely driven by policymakers and professionals, it is important to question how well these professional ideas align with the perspectives of local residents. This inquiry involves constructing indicators based on theoretical models of eco-cities, which are verified by professionals. These constructed indicators are then used to assess local perspectives on eco-cities and to analyze the importance of various indicators from the viewpoint of local residents within the eco-city model.

This paper aims to examine to whether residents' perspectives on eco-city is aligned with technical construction (indicators) and policy makers' perspectives. To elucidate the technical and policy perspectives, the following section provides a literature review of theoretical models of eco-cities, the reviews will guide the construction of tool (questionnaire) in the subsequent section.

2 https://www.depa.or.th/th/smart-city-plan/smart-city-office

2 Literature review

The eco-city model, rooted in ecological and green urbanism, encompasses a wide range of theoretical issues, including urban metabolism, sustainable development, resilience, environmental justice, the circular economy, compact cities, and smart growth. These concepts are typically categorized into three pillars: economic, sociocultural, and environmental.

As discussed, earlier, the eco-city model, which has evolved from ecological and green urbanism, is largely theoretical. The theoretical component plays a critical role in the successful development of an eco-city, as the success of an eco-city depends on acknowledging both general concerns (theoretical issues) and local conditions (Antuña-Rozado et al., 2018). However, though both the theoretical and local perspectives are of equal importance, studies examining local perspectives on eco-cities are limited, with the research of Hu and Xi (2023) being one of the few examples. Their study evaluated the key factors necessary for achieving an eco-city by comparing the views of city residents and scientists. The study found that from the perspective of residents, the top three factors for achieving an eco-city are: (1) an independent and self-sufficient economy, (2) prevention of the spread of various types of pollution, and (3) job opportunities that are appropriate to the cultural and local environment. In contrast, scientists and experts consulted in their study identified their top three factors as: (1) an independent and self-sufficient economy, (2) the promotion of simple living and reduction of resource consumption, and (3) the preparation and implementation of ecological laws and regulations. The study concludes that there is no significant difference between residents' and professionals' prioritization of the key components necessary for building an eco-city.

The increasing recognition of eco-cities among international policy stakeholders is partly due to the ability of eco-city models to align with the promotion of economic growth, which remains a key agenda for international development agencies. Organizations such as the World Bank have acknowledged that while economic growth in previous decades has lifted millions of people out of poverty, it has often occurred at the expense of the environment. The World Bank argues that "green growth is the only way to reconcile the rapid growth required to bring developing countries to the level of prosperity they aspire to" (World Bank, 2012, p. xii). In linking economic growth to urban development, the Organisation for Economic Co-operation and Development (OECD) developed and promoted a comprehensive conceptual framework for green-growth cities, which aims to guide city planners (Hammer et al., 2011). In China, where urbanization is highly dynamic, Lijuan et al. (2011) constructed an eco-city model encompassing social progress, environmental protection, and economic factors. The economic index in this model includes indicators such as gross domestic product (GDP), GDP per capita, the share of tertiary industries in GDP, and the share of real estate investment in total social fixed asset investment. A review of theoretical eco-city models by Eryıldız and Xhexhı (2012) suggests that such models could serve as a foundation for urban planning, promoting harmony between the environment and the quality of life for residents. However, some critics argue that the eco-city concept remains utopian.

Although in practice eco-city development and conceptualization has largely focused on the economic components of the eco-city framework, the true core concept of an eco-city is inherently focused on the environment, making environmental indicators crucial components of eco-city theoretical models. These indicators often encompass low-carbon emissions and air quality (Yin and Guo, 2022). Environmental regulations can obscure the relationship between low-carbon city development and green growth (Chen et al., 2023; Mattari et al., 2023). Research on green areas has emphasized that urban parks serve as natural filters, improving air quality and reducing noise pollution, thus creating healthier and more enjoyable environments in densely populated cities. Additionally, urban parks play a vital role in supporting biodiversity by serving as essential habitats for wildlife in urban areas (Tuna, 2015). Furthermore, green infrastructure, which consists of a network of interconnected green spaces, helps link ecological islands into larger networks. This promotes urban ecology by maintaining ecological balance, supporting biological populations, and preserving natural biodiversity (Liu and Russo, 2021). A qualitative study on eco-cities in Northwest China by Lijuan et al. (2011) revealed that the environmental indicators of eco-cities include industrial wastewater discharge, industrial sulphur dioxide emissions, green areas per capita, urban sewage treatment rates, harmless treatment rates of domestic waste, and green coverage in built-up areas.

Urbanization is primarily a process of spatial transformation, which largely occurs through changes in land use, infrastructure development, and the construction of built environments. These built environments can be either planned or retrofitted to minimize energy consumption and ensure the functionality of spatial environmental systems. Urban parks are examples of built environments that can help reduce urban air pollution while simultaneously providing social benefits such as recreational spaces. Features like pedestrian walkways, sidewalks, building façades, and bike lanes are considered environmentally friendly urban designs and are typically integrated into the eco-city model (Khelfat and Baouni, 2018; Carvalho et al., 2023).

Previous studies have explored the relationship between city size and environmental performance, though these relationships can vary. Borck and Tabuchi (2019) suggested that the link between pollution and city size is shaped by the way population size impacts production, commuting, and housing consumption (Peter et al., 2024). Studies have shown that larger cities tend to have better environmental performance than smaller cities, benefiting from economies of scale and more substantial financial resources. Smaller cities, on the other hand, often face challenges in implementing environmental policies due to resource shortages (Chen and Du, 2022). Conversely, Borck and Pflüger (2019) argued in favor of compact cities, suggesting that the more dispersed a city becomes, the greater the environmental damage from pollution.

Another essential aspect of an eco-city is its complex human dimension. This involves a range of sociocultural factors, including power dynamics among resident groups and between urban entities and external actors. Wong and Yuen (2011) argued that consumerism increases as cities grow, placing additional strain on the physical environment. It has been proposed that, as cities expand, urban planning should aim to minimize the use of land, energy, and materials to create healthier urban spaces.

Human or sociocultural attributes are another key component of eco-city models. These attributes encompass all non-physical aspects of cities, making the human dimension a complex issue. Urban planners often distil these complexities into indicators that guide their work, but these indicators are frequently fragmented and selectively applied.

Currently, the eco-city model places a strong emphasis on how modern technologies, particularly digital technologies, and education play a crucial role in the development of eco-cities. Cheshmehzangi et al. (2021) explored the modern direction of pedagogy within the context of educational eco-urbanism, recommending the use of interdisciplinary approaches to design training courses and establish competence centers for urban residents. Several studies underscore the importance of public participation in eco-city movements. Li and de Jong (2017) examined citizen involvement in China's eco-city development and found that rural communities tend to be more collectivist and reactive, while urban communities are more individualist and proactive. Moreover, in both contexts, citizen participation in decision-making is limited. However, during the implementation phase, local governments value the practical input and support provided by residents. The study recommends promoting "new-type urbanization," with a focus on legislative reform and the professionalization of officials to better incorporate bottom-up input.

Resident participation in eco-cities is given high priority, though it is sometimes viewed as a panacea, as participation is emphasized in most development concepts. Among the factors influencing the effectiveness of eco-cities, studies highlight the importance of "political will," particularly from local leaders (Matamanda and Chirisa, 2014). Additionally, the success of eco-city movements is tied to the entire urbanization process, encompassing urban planning, land-use management, infrastructure development, population density regulation, housing, and the governance of public services and resources.

In sum, the indicators used for measuring the success and effectiveness of an eco-city vary widely but can largely be categorized under the three following categories: (1) economic, (2) sociocultural, and (3) environmental. In Table 1, below, we illustrate how such indicators compare across three theoretical models commonly used to measure the success of an eco-city. As evidenced in the table, while there is some overlap of indicators across all three models, some models prioritize indicators which are not considered by others. For example, income, albeit calculated differently across models, is a standard indicator used to measure the economic performance of an eco-city. However, the loan-to-debt ratio of households is only considered by one model, while it is not at all considered by the two others. These differences have been accounted for by our research team. Thus, when we developed the questionnaire used to survey Khon Kaen residents, we elected to use all indicators outlined in all three models. This ensures our eco-city indicator measurement index is comprehensive and thorough.

3 Materials and methods

The 31 variables (indicators) identified from the table above were used to design a structured questionnaire, in which the residents—respondents of the questionnaire—were asked to rate these indicators. Following Comrey (1973), the appropriate and acceptable sample size should be approximately 10–20 times the number of variables (31 variables). This study utilized a sample of 400 residents of Khon Kaen City. The questionnaire was piloted with 30 samples to ensure

TABLE 1 Comparing variables of eco-city.

Eco-city (based on theoretical models and professional input)	Merino-Saum et al. (2020)	Zhou and Williams (2013)	Organization for Economic Co-operation and Development (OECD) Green Growth model
Economic			
Incomes of residents	Income level	Average income	Income
Expenditure of residents			
Employment	Employment/unemployment rate	Employment/unemployment rate	Labor markets (employment/ unemployment)
GDP per capita	GDP per capita	GDP per capita	Economic growth
Gross provincial product			Productivity & competitiveness
Investment in real estate		Loan-to-debt ratio of households	
Investment in city area			
Sociocultural			
Density of population	Population density	Population density	Urban density
Literacy		Educational attainment	
Education access	Population with higher education	Percentage of eligible students graduating from high school	Education
Health service access	Number of doctors/physicians	Doctors per capita	Environmental health & risks
Social justice			
People participation	Voter participation	Public participation	
Effective leadership			
Continuity of culture	Cultural infrastructure		
Capacity of organization personnel			Training & skill development
Clear development plan and policy			Regulations & management approaches
Urban development mechanisms			Environmentally related taxation
Environmental			
Low carbon emission	CO_2 emissions	Air quality	CO_2 emissions
Wastewater discharge		Wastewater treatment	
Wastewater treatments		Wastewater treatment	Access to sewage treatment
Greenhouse gas emission reduction	GHG emissions	Waste treatment	Air quality
Green areas	Green areas	Green space	Forest resources
Wetland areas			
Bike lanes	Length of bicycle network	Length (km) of cycle paths per city area (km^2)	
Pedestrian areas		Length (km) of pedestrian areas	
Public transport coverage	Public transport use		
Water adequacy	Water consumption	Water availability and filtration	Freshwater resources
Use of renewable energy (hydro, wind, and solar)	Energy consumption	Energy and climate (industry, building, and transportation)	Energy productivity
Technology and science			Technology and innovation
City size			Land use and changes in land cover

The headings of the variables (economic, sociocultural, and environmental) may differ among various sources. For instance, the variables related to water adequacy from the three sources include water consumption, water availability and production, and freshwater resources.

reliability. The statistical test yielded a Cronbach's alpha of 0.977, indicating acceptable reliability.

The obtained data were cleaned and analyzed, comprising the following steps:

First, the 31 variables were analyzed for their associations (determinants) with the eco-city using multiple regression analysis. The analysis revealed that 14 variables were associated with eco-cities. The variables are (see also Table 2):

TABLE 2 Mean scores and standard deviations of observed variables of eco-city from multiple regression analysis.

Variables	Mean	SD	Sig.
Economic: Mean = 2.98, SD = 0.70			
x1 Income of residents	2.79	2.79	0.002*
x2 Expenditure of residents	2.73	2.73	0.890
x3 Employment	3.00	3.00	0.794
x4 GDP per capita	2.87	2.87	0.294
x5 Provincial per capita product	3.13	3.13	0.507
x6 Investment in real estate	3.03	3.03	0.719
x7 Investment in the city area	3.28	3.28	0.000*
Sociocultural: Mean = 3.84 SD = 0.59			
x8 Population density	3.43	0.97	0.493
x9 Literacy	3.62	0.95	0.008*
x10 Educational access	3.79	0.88	0.000*
x11 Health service access	4.12	0.85	0.000*
x12 Social justice	3.90	0.83	0.150
x13 People's participation	4.01	0.83	0.000*
x14 Effective leadership	4.01	0.98	0.000*
x15 Continuity of culture	3.99	0.96	0.158
x16 Capacity of organization personnel	3.88	0.78	0.000*
x17 Clear development plan and policy	3.74	0.83	0.002*
x18 Urban development mechanisms	3.76	0.78	0.485
Environmental: Means = 2.94, SD = 0.84			
x19 Low carbon emission	2.46	1.06	0.035*
x20 Wastewater discharge	2.91	1.23	0.529
x21 Wastewater treatment	2.85	1.27	0.313
x22 Greenhouse gas emission reduction	2.52	1.19	0.573
x23 Green areas	3.25	1.20	0.035*
x24 Wetland areas	3.03	1.30	0.164
x25 Bike lanes	2.83	1.23	0.196
x26 Pedestrian areas	3.09	1.20	0.005*
x27 Public transport coverage	3.00	0.98	0.125
x28 Water adequacy	3.10	1.27	0.449
x29 Use of renewable energy (hydro, wind, and solar)	2.62	1.24	0.015*
x30 Technology and science	2.95	1.10	0.120
x31 City size	3.59	1.02	0.067

*A *p*-value less than 0.05 is considered to be statistically significant.

- x1: Incomes of residents
- x7: Investment in the city area
- x9: Literacy
- x10: Education access
- x11: Health services access
- x13: People participation
- x14: Effective leadership
- x16: Capacity of organization personnel
- x17: Clear development plan and policy
- x19: Low carbon emissions
- x23: Green areas
- x26: Pedestrian areas
- x29: Use of renewable energy (water, wind, and solar)
- x31: City size

Second, a second-order confirmatory factor analysis (Second-Order CFA) was used to evaluate models with hierarchical structures of latent variables. The second-order latent variable, sustainable eco-city, is described by the relationships between the first-order latent variables, which consist of economic, social, and environmental factors. First-order latent variables were explained by observed variables (x…). The following checks and tests were performed:

3.1 First-order measurement model

This involved creating and testing a first-order measurement model for each first-order latent variable. The model fit was evaluated using residual-based fit indices and independence model-based fit indices. The factor loadings of the observed variables on the first-order was examined, with a *p*-value greater than 0.05 considered acceptable.

3.2 Second-order CFA

Second-order latent variables were added to the model and linked to the first-order latent variables tested in step 2. The paths between the second-and first-order latent variables were created using analysis software (AMOS).

3.3 Model testing

This step involved running the model using structural equation modelling software to assess the fit of the second-order model using the same fit indices as in step 1. The relative Chi-Square, RMSEA, CFI, and TLI were also checked to ensure they met acceptable criteria.

4 Results

The table below shows that the mean scores of the sociocultural aspects of the eco-city appear to be the highest (3.84), followed by economic and environmental (2.98 and 2.94, respectively). Public participation and effective leadership have the highest mean scores, while low carbon emissions, GHG emission reduction, and the use of recycled energy have the lowest scores (2.46, 2.52, and 2.62, respectively). The scores shown in the table reflect that, from the residents' perspective, the sociocultural aspect of the eco-city is the most achievable, while the environmental aspect presents the most challenges.

The Second-Order CFA (Diagram 1) of the economic aspect (the second-order latent variables) contributes the most to the eco-city (the first-order latent variables), followed by environmental and sociocultural aspects. When considering the weight of individual observed variables relative to the second-order latent variables, it was found that the use of circular energy, low carbon emissions, and people participation were among the top three contributors, while the size of the city, income of residents, and access to education were the lowest. Notably, the observed variables under the environmental group exhibited a high weight, followed by those in the sociocultural and economic groups. The fit of the model was acceptable (*p*-value = 0.069).

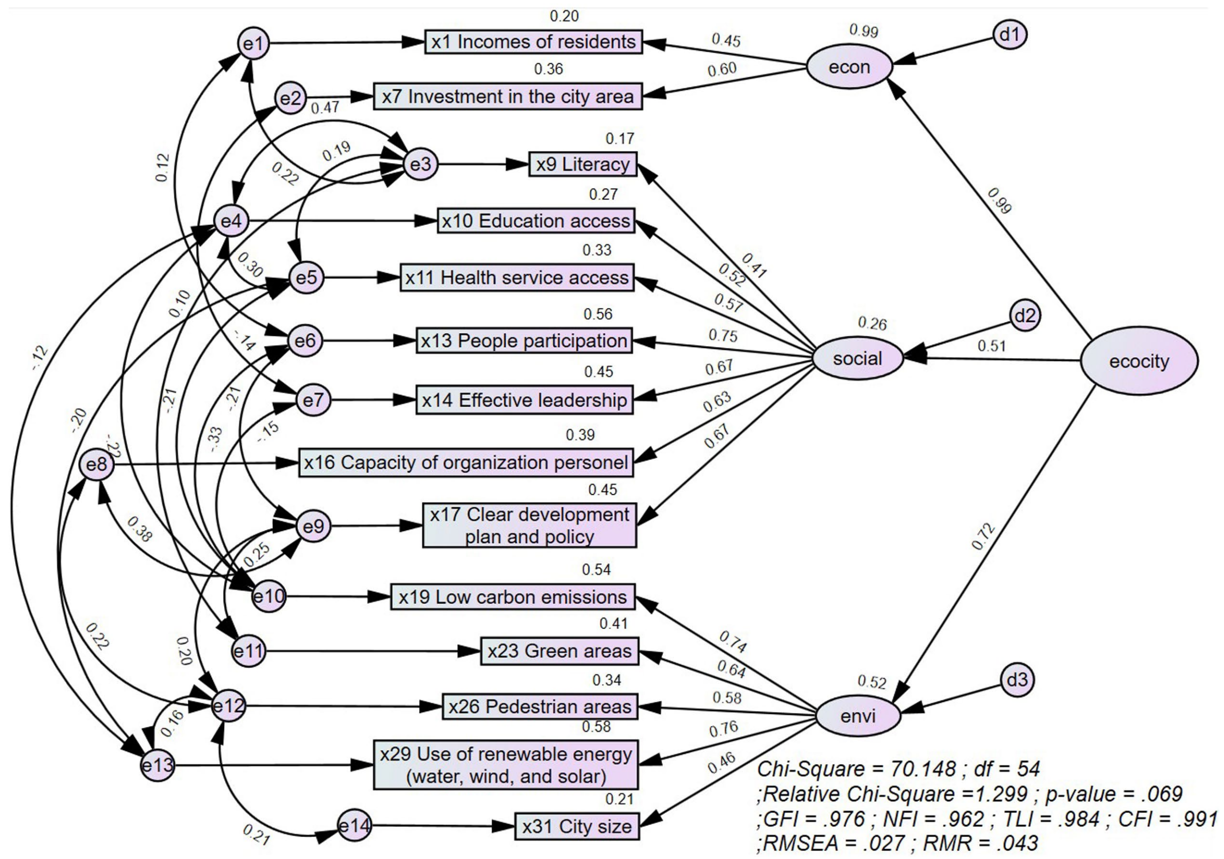

DIAGRAM 1
Second-Order CFA model for eco-city.

5 Discussion

The Second-Order CFA revealed that the residents' perspective is generally consistent with theoretical models—the observed variables derived from professional and theoretical frameworks contribute to the economics, sociocultural, and environmental (second-order latent variables) aspects of the eco-city (third-order latent variables). However, the descriptive analysis shown in Table 2 implies that urban residents of Khon Kaen prioritize the sociocultural aspect of the city. The following discussion will be divided into three sub-headings—the generalization of the above findings, reflections on theoretical and methodological understanding, and policy recommendation.

5.1 Khon Kean ecocity in global urbanization

The findings outlined above are based on a case study of Khon Kaen, some findings may be consonant to the existing studies. As mentioned earlier, this may be because residents perceive the sociocultural dimension as more achievable than the economic and environmental dimensions. Additionally, Khon Kaen City—a provincial town covering an area of 47 km^2—evolved prior to the eco-city plan. Achieving eco-city goals related to economics and the environment will require the retrofitting of city infrastructure, such as buildings, roads, and pedestrian pathways. The rebuilding of a town that developed prior to the eco-city plan necessitates investments that are likely beyond the affordability of residents. Furthermore, the retrofitting process to meet eco-city requirements could displace local economies, including street vendors, small businesses, and informal residents (shanty zones). This interpretation aligns with the study by Hu and Xi (2023), which suggests that urban residents prioritize independent and self-sufficient economies as key factors contributing to the success of an eco-city.

Our study revealed that only two observed variables (out of 14) within the economic group—specifically, the level of income of residents and investment in the city area—contribute to the overall weight of the city. However, the aggregated weights of these two variables were higher than those of the sociocultural and environmental variables. This reflects the primary function of cities: urban areas have become conducive to investments that contribute to economic growth (UN-Habitat, 2023).

A descriptive analysis of the environmental factors influencing eco-cities highlights the significance of issues such as low carbon emissions, green areas, pedestrian infrastructure, circular energy, and city size. This finding is consistent with several studies discussed in the literature review section (Khelfat and Baouni, 2018; Carvalho et al., 2023; Borck and Tabuchi, 2019). However, an interesting observation is that although residents may concern about environmental problems, the options for them to take relevant actions could be limited. In an urban poor community, we observed that people are living in a bad environmental conditions which general residents would not be bearable. These people remain living with poor environmental conditions because number of reasons, but the lack of income to rent a proper shelter elsewhere is a primary one. In addition, urban growth, both that has long before or currently taking place, does not prioritize the spatial function of ecosystem. A number of infrastructures built without water treatment systems, blockading or destroying natural waterways and wetlands. In recent years, the impacts of urban development on wetland loss have attracted significant attention from researchers (Basu et al., 2021). In Southeast Asia, where urban development is driven by state-led strategies, investment in real estate fuels urban growth (Shutkin, 2001), resulting in substantial wetland loss. This occurs because urbanization increases land prices, while wetlands remain largely unoccupied and thus have relatively low prices.

The most striking result of the analysis, as shown in Diagram 1, is that the number of observed variables under sociocultural conditions contributes to the eco-city, although the weight is lower than that of the other two aspects (economics and environment). The environmental issues such as water treatment and greenhouse gas that are received less attention from residents reflect the perception that these matters are the government responsibilities. The impact of greenhouse gas caused by household energy consumption and urban transportation is less tangible. In addition, the finding shows that the high contribution of economic and environment to eco-city shown in the Diagram 1 happened through the complex interwoven with sociocultural factor. This finding raises an issue of which linearity of impact suggested and assumed by most indicators of ecocity.

For instance, an increase in urban parks reduces GHG emissions (Tuna, 2015), green infrastructure can reconnect ecological islands to ecological networks (Liu and Russo, 2021), and investments compliant with the green growth framework are deemed to ensure environmental sustainability (World Bank, 2012; Hammer et al., 2011). Our analysis suggests that the sociocultural factors could be potentially 'priori' to, or even mediating between the economics and environment and ecocity.

5.2 Reflections on theoretical and methodological account

As mentioned above, it is challenging to distinguish between green urbanism and ecourbanism at the practical level of ecocity. However, green urbanism can be conceived as the macro-lelvel driver shaping ecourbanism at micro level. From the case of Khon Kaen ecocity we discussed earlier, it is evident that initiative is driven by central government. Behind this initiative lies the influence of global technology (digital) and energy business. Such initiatives emphasize efficient energy use, the new design of urban must be compact, walkable, waste reduction and similar goals.

However, these initiatives often give low priority to the micro-level aspects, such as sociocultural dynamics of residents, their participation in the planning and infrastructure development processes, or even the compatibility of design with local natural ecosystems. In this context, it can be argued that the ecocities dominated by macro-level drivers primarily serve to perpetuate the interests of global businesses, in particular those involved in technology and energy sectors, such as electric vehicles (EV), solar energy, wind energy, lithium Ion batteries, artificial intelligence and more. This argument echoes earlier theoretical debates that view urbanization processes as integral to capital accumulation. For instance, Harvey (1985) concept of 'spatial fix' can be applied here, suggesting the ecocity represents a form of spatial reorganization designed to accommodate the investments and facilitate the expansion of capital accumulation.

Viewing the integration between ecourbanism and green urbanism as the interaction between macro and micro scale, however, is potentially encountered methodological challenges. This is because green urbanism is driven by diverse and often competing macro agencies. The competition exists not only among players in sectors like electric vehicle (EV) businesses, bit also among government agencies where contradictions frequently arise in the implementation of ecocity policy. Meanwhile at micro scale, the local actors are similarly far from unified.

More critically, the integration between human and non-human entities (e.g., physical or built infrastructures, natural environments, see Delanda, 2006) remains problematic in both ecourbanism and green urbanism. This stems largely from the dominance of discipline-based approach among those involved in ecocity initiatives. In reality, the complexity of 'life-world' problems of urban system exceed the scope of any single discipline. Within academia, whether in the natural or social sciences, the discipline boundaries often foster a 'normal science' paradigm (Kuhn, 1962), creating traditions and norms that resist addressing 'anomalies' outside their discipline scope.

While this study cannot claim to have adopted a fully comprehensive multi-discipline methodology, we strongly advocate for a transdisciplinarity approach (see Nicolescu, 2010) to address the methodological limitation of the macro–micro interactions. By transdisciplinarity, we refer to a research methodology that guides the policy practices to address life-world urban challenge, drawing on knowledge that extends beyond the confines of a single specialized discipline. This approach not only embraces a broader spectrum of disciplines to shape theoretical and methodological understandings of urban systems, but also prioritizing the participation of diverse stakeholders in shaping ecocity initiatives.

5.3 Policy implications

Although the Second-Order CFA presented above suggests that residents' perceptions of economic and environmental factors contribute more significantly to the concept of an ecocity, sociocultural factors are deeply interwoven with both economic and environmental dimensions. Socioeconomic factors can be seen as either a prerequisite for or a mediator between economic and environmental elements in the development of an ecocity.

Moreover, while economic and environmental initiatives are often driven by central governments, local governments typically face budgetary constraints, limiting their capacity to implement such initiatives effectively. Therefore, it is recommended that sociocultural factors be given greater priority in ecocity initiatives. Actions such as capacity building for local governments, promoting environmental and ecosystem literacy, improving residents' health and well-being, fostering participation in urban planning, and encouraging effective leadership can significantly enhance the effectiveness of the transformation toward ecocity goals.

6 Conclusion

For cities like Khon Kaen (the Provincial Urban Centre), which has evolved over more than eight decades, the spatial redesign or retrofitting of urban areas to align with eco-city principles is a challenging task and can easily lead to "greenwashing." The Second-Order CFA of Khon Kaen suggests that economic, sociocultural, and environmental factors have evolved into urban assemblages. The factors constituting the model are not merely the results of an eco-city but represent the "whole"—both human and nonhuman entities of the urban environment—that potentially emerge as new properties from the assemblage. This understanding of the eco-city is compelling, as it goes beyond a technical aspect, embracing the seamless whole of the analogy of organic parts. We need to consider social entities, especially their capacities, and how the constituent factors of the eco-city interact with economics, the environment, or the interactions between human and nonhuman entities.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethics approval was obtained from the Ethics Committee of the Center for Ethics in Human Research at Khon Kaen University. The project Number is HE663211. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

BP: Conceptualization, Investigation, Writing – original draft, Writing – review & editing. RD: Investigation, Validation, Writing – review & editing. KP: Methodology, Software, Writing – original draft. NP: Data curation, Writing – review & editing. PS: Resources, Supervision, Writing – review & editing. SL: Formal analysis, Software, Visualization, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

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