Country Report

VIETNAM

Independent semi-annual information on politics, economy and society of a country in transition

No 2 | 2021

Environmental Policy in Vietnam

Phiên bản tiếng Việt từ trang 155

USH
Hanns Seidel Foundation
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN
NHÀ XUẤT BẢN THANH NIÊN

Urban Heat Islands and Implications for Vietnam

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1. Introduction

Urban Heat Islands (UHI) are *the general increase of heat within cities* and are a major issue of the 21st century. The key reason for UHI is the rising replacement of vegetation and water surfaces with built up environments to accommodate cities' increasing population, combined with the related release of human induced heat. This leads to enhanced local temperatures that subtly but profoundly affect human health. Environmental and social challenges resulting from UHI are expected to augment dramatically in the future because they compound with the effects of global warming. This will be a particular challenge for the rapidly growing Southeast Asian and East Asian cities (Aflaki et al. 2017, 132; Steward and Mills 2021; Trihamdani et al. 2017, 526).

In Vietnam's major cities, UHI are increasing abruptly as a consequence of the past decades' massive urbanization. The emerging urban middle population who are often driven by unsustainable lifestyles have requirements for thermal comfort through the operation of energy-intensive air-conditioning devices, these contribute to increase local temperatures at the expense of the major part of the urban population. In Hanoi and HCMC heat stress has imposed adverse health risks to urban citizens, especially vulnerable groups (e.g. young children, old people, low-income groups, etc.). The understanding of and solutions to mitigate UHI effects, however, are very limited among the general public and responsible stakeholders in Vietnam.

This article has a three-fold structure: First it provides an overview of general concepts of UHI. Second, it demonstrates UHI issues in Hanoi and in HCMC. Third, it introduces mitigation solutions, appropriate to the Vietnamese context.

The content is based on the authors' own empirical research resulting from a research project funded by the German government, and an extensive desk review of relevant literature, incorporating academic papers, policy reports and select documents from international development agencies.

2. General Overview of Urban Heat Islands

Urban Heat Islands' formation

UHI represent significantly higher temperatures of the city (or of parts of it) compared to the surrounding areas. Two types of processes are responsible for the heat generation: the effect of solar heat on the earth's surface (solar radiation) and the heat generated from human activities *(anthropogenic heat)* (Steward and Mills 2021).

When the sun shines, *solar radiation* can be reflected or absorbed by earth surfaces. When the sun sets, earth surfaces cool down by releasing the absorbed heat energy back to the atmosphere through:

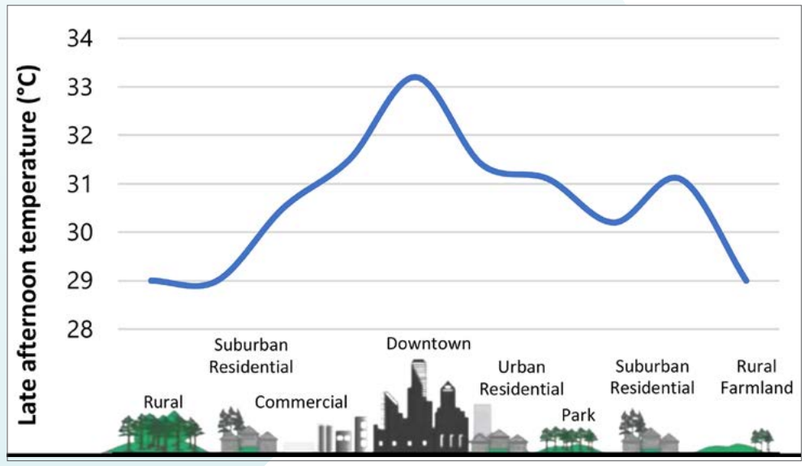
- infra-red radiation (detected as heat above the surface),
- conduction (the heat transferred to the cooler air directly touching the hot surface),
- convection (the heat raised up and moved away in the warmed air),
- evaporation (the heat taken away when energy turns surface liquid into water vapor.

While vegetated and water surfaces reflect more radiation (high albedo) and absorb less solar radiation, constructed surfaces reflect less radiation (low albedo) and absorb more solar radiation. The absorbed heat in urban areas does not rise up high and is not taken away by wind because of the urban morphologies (e.g. narrow spaces between high-rise buildings, thermal properties of buildings, dark surfaces and high rates of surface roughness).

Anthropogenic heat is generated from human activities for example, industrial activities, power plants, residential activities (mechanical cooling, heating, cooking, etc.) or from transportation (motorcycles, cars, etc.). Anthropogenic heat accounts for one third of the heat in urban centres. It depends on the energy use patterns of the urban citizens and may have seasonal cycles (Aflaki et al. 2017).

The effects of solar radiation and anthropogenic heat increase the temperatures of downtown centres compared to the surrounding areas and form UHI (see fig. 1).

Figure 1: Exemplary spatial UHI profile



Source: American Environment Protection Agency 2020

Urban Heat Islands' effects

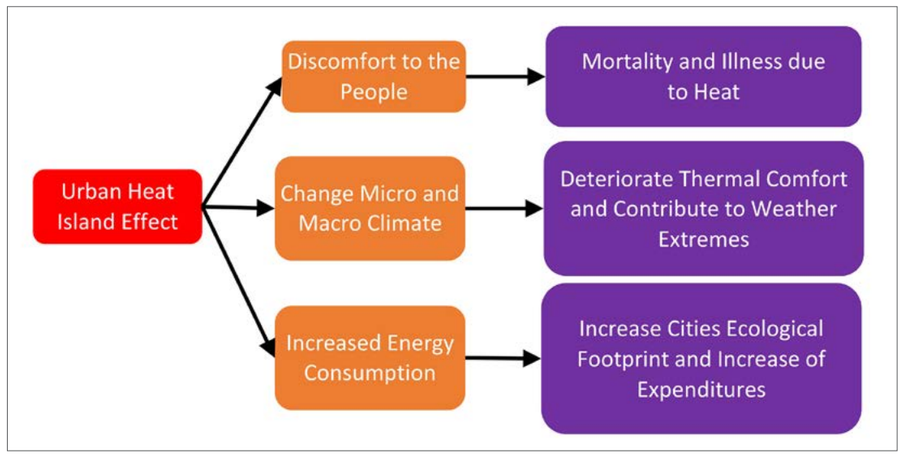
UHI effects generally affect human well-being in regard of the following aspects:

- Health: Exposure to heat is associated with a range of adverse health effects ranging from exacerbation of minor existing conditions to increased risk of hospitalization and death (Heaviside et al. 2017, 4). UHI effects can damage the thermoregulatory system by causing heat stress, cardiovascular stress, thermal exhaustion, heart stroke and cardiorespiratory diseases, thus raising risks in mortality and morbidity among vulnerable groups (Aflaki et al. 2017; He 2019). Low-income groups are more vulnerable to UHI effects as they normally spend longer time in the outdoor heat and might not afford high cooling costs (He 2019).
- Micro and macro climate: UHI, together with global warming, has significantly increased the ambient temperature – the factor increases the concentration of pollutants like rip tropospheric ozone (ground level ozone). UHI deteriorates cities' thermal comfort conditions and indoor environments. The heat concentrated in expanding urban surfaces is also a key player in worsening global warming conditions, changing local ecosystems, micro and macro climate and weather patterns (i.e. wind patterns, humidity alterations, storms, floods) (Aflaki et al. 2017).
- Energy consumption: UHI effects intensify the power and water consumption for cooling purposes in buildings and other structures (Santamouris et al. 2015). There are multiple factors influencing buildings' energy consumption (i.e., Ambient temperature, building characteristics, the electricity appliance usage, etc.), but high ambient temperature levels have the greatest influence on the variation of electricity consumption for cooling needs in the building sector (Aflaki et al. 2017; He 2019; Li et al. 2019).

UHI's driven power need for cooling buildings will have a greater impact in future, due to the rapid growth of the building sector (Heaviside et al. 2017). Compounded with global warming, these impacts will significantly increase cities' ecological footprint and the load on cities' electricity infrastructure (Santamouris et al. 2015). It will also adversely challenge heat-sensitive age groups and lower-income groups.

In general, UHI effects can be briefly noted as presented in fig. 2.

Figure 2: General UHI effects



Source: own design, based on Nuruzzaman 2015

3. Urban Heat Islands in Vietnam: Issues and challenges

UHI studies carried out through remotely sensed images of thermal infrared satellite sensors have revealed that Vietnam's major cities have shown a gradual increase of so-called land surface temperatures (LST) in the past.

In the case of Hanoi, the mean LST increased from 26.4°C in 1996, to 38.8 in 2007 and 42.9°C in 2016 (see fig. 3a) (Tien Nguyen 2020, 182). Whereas in 1996, high LSTs were mostly found in the city centre, in 2007 and increasingly in 2016, high LST areas had greatly expanded towards the western, south-western, and north-western parts of Hanoi. In the case of HCMC, the mean LST increased from 27.1°C in 1996, to 29.5°C in 2007 and 30.1°C in 2016 (see fig. 3b) (Son et al. 2017). Thereby, the expansion of high LST areas clearly followed urban-spatial expansion patterns in both cases during that time-period.

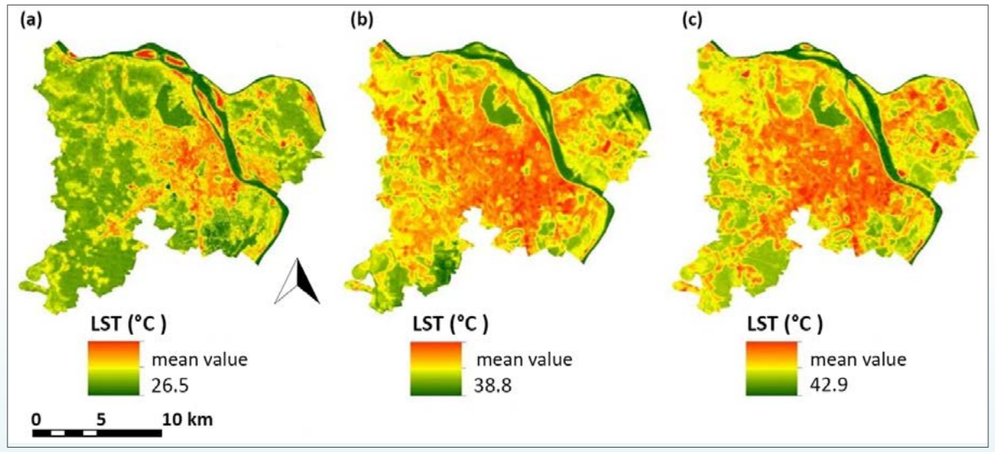
Studies also revealed that the rapid increase of fossil-fueled vehicles such as motorcycles and cars as well as the massively rising use of air conditioners further significantly contribute to increased LST.

In the case of Hanoi, for example, the mean meteorological air temperature (MAT) is predicted to increase by up to 1.8°C during the 2030s (Trihamdani et al. 2017, 8).

Mortality rates caused by UHI effects have been reported to be one of the highest in recent years in Vietnam (Dang et al. 2018, 6).

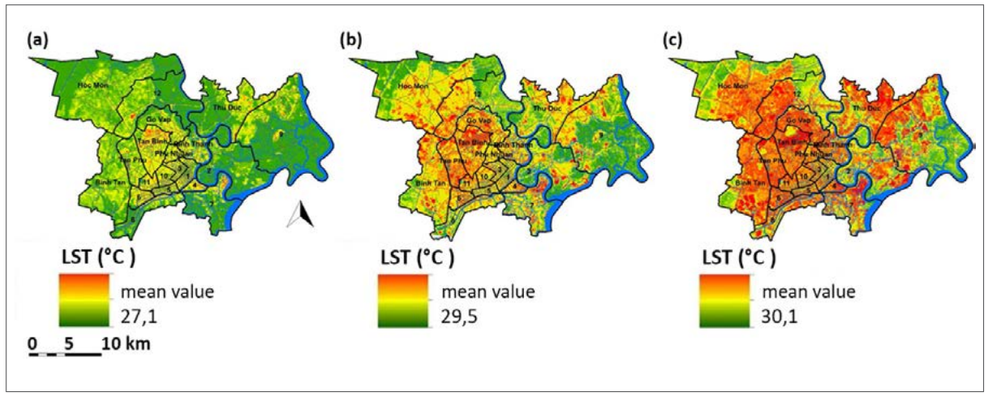
In the case of HCMC, for example, heat increases have caused about 30% of the total mortalities during the period 2010-2013, alone (Dang et al. 2018, 4).

Figure 3a: Spatial distribution of LST in Hanoi, retrieved from Landsat data in (a) 1996, (b) 2007, (c) 2016



Source: Tien Nguyen 2020, 183

Figure 3b: Spatial distribution of LST in HCMC, retrieved from Landsat data, in (a) 1996, (b) 2007, (c) 2016



Source: Son et al. 2017, 19

UHI causes in Hanoi and HCMC are two-fold, on one hand, urban land use management systems, in which land is an important local resource, has led to massive conversion of vegetated land into sealed-off surfaces, high densities of urban infrastructures and large-scale residential and industrial complexes (Trihamdani et al. 2017; Son et al. 2017; Dang et al. 2018). On the other hand, anthropogenic heat is increasing from manufacturing activities, residents' rising cooling needs due to changing demands of thermal comfort and the ever-growing share of fossil-fuelled individually owned motorcycles and cars (Doan et al. 2019).

Governments of both cities have recognized the importance of green and water surfaces in the urban landscape through their urban master plans on the one hand and tree planting campaigns on the other hand. Hanoi's master plan (2011) visions to build a green, modern, and cultural city based on its many waterways. A green belt is to be developed between the ring roads number three and four. Hanoi also completed the one million tree program in 2019 and continues to plant even more trees along more than 250 of its roads. HCMC approved a project on public parks and trees promotion for the period of 2021–2030. HCMC's master plan to 2025 (2010) aims at providing an average greenery percentage of 10 m^2 per capita in the core city centre and promoting green spaces along its major rivers and canals.

All this shows that Vietnamese policy makers see the importance of urban green to secure a good quality of urban life for its citizens, in general. Solutions to effectively mitigate UHI effects, however, require systemic and cross-cutting approaches based on multidisciplinary gained scientific evidence.

4. Urban Heat Island Mitigation Strategies for Vietnam

UHI mitigation strategies aim at reducing the formation and impacts of UHI to improve citizens' wellbeing, reduce energy consumption, air pollution and greenhouse gas emission (Aflaki et al. 2017).

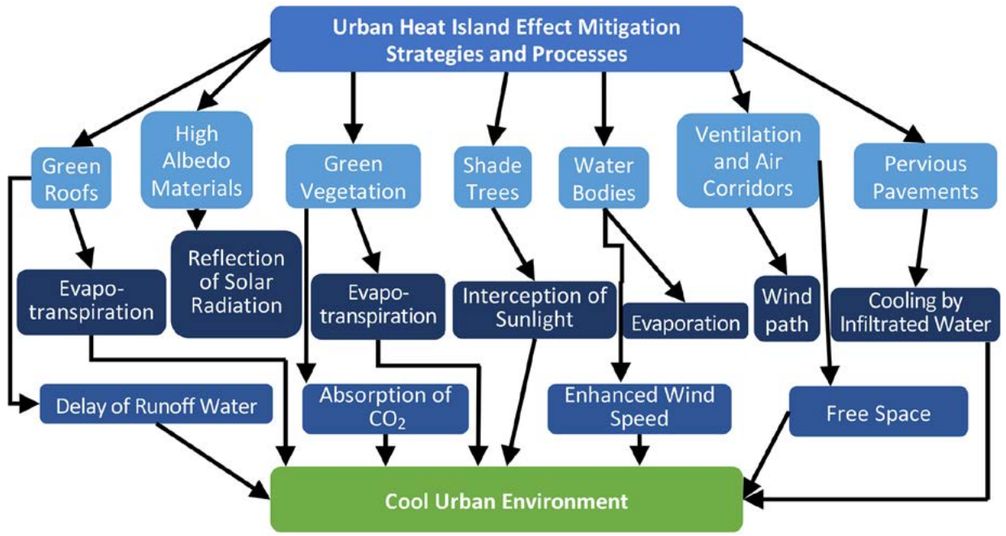
The following suggests five groups of action for Vietnamese policy makers and relevant stakeholders to consider in regard to their UHI mitigation efforts. These condensed recommendations are based on the authors' relevant expertise and on a thorough review of both global and Vietnamese scientific and practical work, with attention to the local context. The categories below focus on interventions, they are interconnected and supplement each other to some extent (See Fig.6).

Urban planning system

Effective urban planning should implement interventions that effectively contribute to the cooling of the urban environment. These should consider the city size, shape, construction densities, morphology, etc., in order to enable better ventilation through air corridors, and to allocate larger open vegetation and water surfaces and to increase solar radiation reflection (see also fig. 4).

To do this, Vietnamese urban planning systems require a more integrated approach. Both zoning and detailed planning need to pay attention to the equal distribution of green spaces that supplement the large centralized green belt, as proposed in Hanoi Master Plan 2030. For example, detailed plan implementation needs to be better controlled against the interests in reducing green and open spaces of private developer companies. Widespread violations should be more severely punished. Planning processes need much public participation and consultation by experts and scientists. In general, the implementation of an urban blue-green city development model should be promoted as a method providing the backbone for solving urban and climatic challenges by nature-based solutions.

Figure 4: Examples of UHI mitigation solutions



Source: own design, based on Nuruzzaman 2015

Figure 5: Munich's first green high-rise building: The Arabella26

Source: Schluchtmann Architekten

Sustainable buildings

Buildings cover a very high proportion of the urban built environment and have the potential to play a key role in mitigating UHI effects. Buildings can simply reduce solar heat intake by applying passive design solutions such as constructive shading. Anthropogenic heat can be reduced by the installation of energy efficient equipment (e.g. cooling systems, water, indoor ventilation, etc.).

Cooling in particular is regarded as being a key component in ASEAN countries' transition towards a low carbon future because currently the best available air conditioner (A/Cs) technologies are more than twice as efficient when compared to the market average (International Energy Agency 2019). This untapped potential might be an entry point for Vietnamese Government to review the currently ineffective air conditioner labelling system and raise minimum energy performance standards (MEPS) for this market. At the regulation level, another feasible measure would be to increase the green coverage ratio of each building project (Trihamdani et al. 2017).

Another more nature-based approach is the erection of so-called green buildings. The application of green roofs and of green facades have emerged recently as a solution to reduce solar radiation absorption, which then minimizes the mechanical cooling load and so saves energy resources. The plants' high water-retention capacity and their evapotranspiration can significantly contribute to improving the microclimate of buildings and their surroundings. Green façades can additionally function as a natural air purifier by binding fine dust, forming oxygen, and binding CO2. In this way, green buildings can compensate for the loss of green space in densely populated cities and create new habitats for flora and fauna. Finally, such a green building typology also contributes to the beautification of urban living space as illustrated by an example of a building with a green facade to be developed in Munich, Germany (see fig. 5). However, this solution needs also to consider the cost of investment and maintenance. Several pioneering buildings following the concept of "vertical forest buildings" in Europe, for example, have imposed high expenses for investors and tenants, which might be unaffordable in the Vietnamese context.

Public awareness campaigns

Because anthropogenic induced heat is increasing in Vietnamese cities, a public awareness campaign should be developed that targets the urban citizens. These communication and education strategies would raise public awareness on UHI impacts and encourage citizens to be mindful of their micro-climate as they make their decisions (i.e., planting trees, installing green or white roofs, buying more energy efficient A/Cs, using public transportation, etc.). Economic incentives would be a good tool to trigger behavior change thereby not relying solely on legal regulations. Improving public transportation services is also essential to facilitate public behavior and reduce traffic congestions and emission from private vehicles.

Scientific research

Scientific studies on UHI in Vietnam have proposed promising financially and environmentally beneficial mitigation measures. However, these are mostly based on computational simulations that are only partly applicable (Parsaee et al. 2019). Future research would focus on:

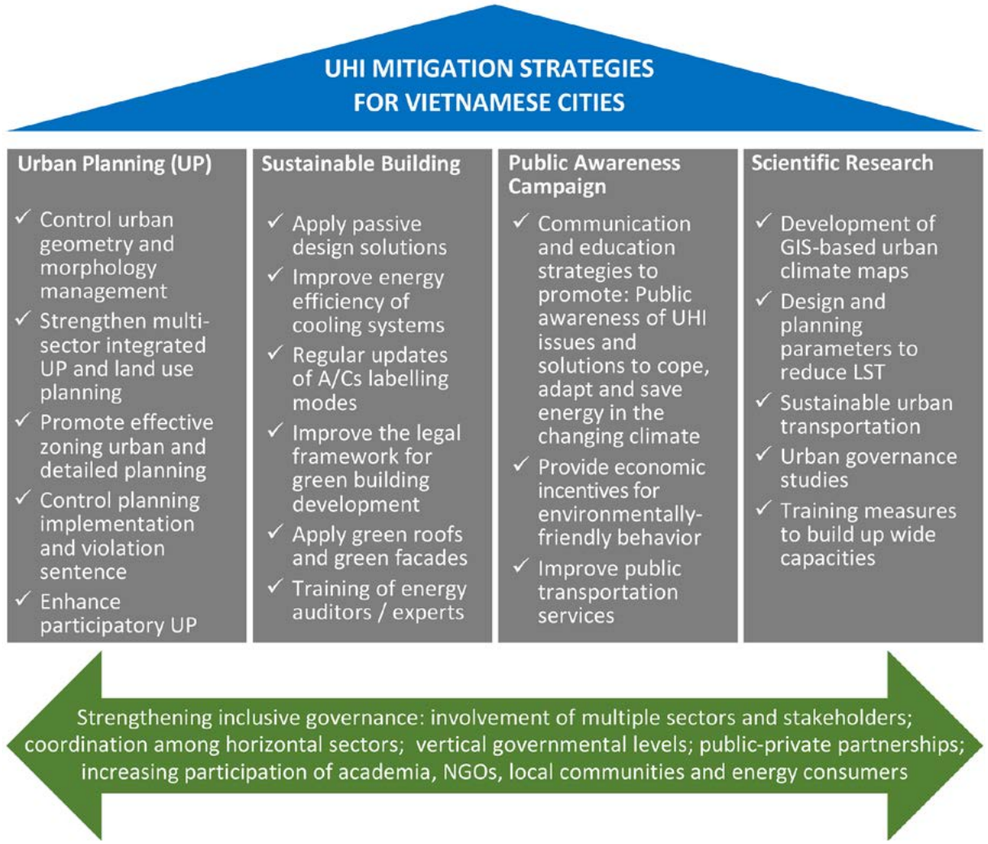
- GIS based mappings of urban climate areas, green areas, natural ventilation corridors, UHI vulnerable communities,
- Parameters for design and planning to reduce cities' land surface temperature,
- Promotion of sustainable urban mobility to reduce related emissions,
- Effective coordination mechanisms among relevant sectors/stakeholders involved in the management and reduction of UHI impact,
- Measures to build-up (implementation) knowledge and (action) capacities.

Inclusive urban governance

Decision-making in Vietnam still happens too much from the top-down and in a sectoral manner. Many regulations already exist in the field but get ignored because they are not adapted to the socio-economic and cultural context and because there are lacking capacities to supervise them. Silo mentalities and institutional fragmentation often hamper much-needed implementation in the multidisciplinary field of sustainability. Therefore, UHI mitigation strategies should involve the responsibilities and interests of multiple sectors and stakeholders and relate to both national and local socio-economic development strategies and plans.

In this way, horizontal coordination among sectors (i.e., urban planning, environmental management, construction, etc.) would be facilitated. New innovative governance mechanisms are also required to promote the vertical dimension from global commitment to local action, e.g. by means of decentralization and new partnerships between state and non-state players. We also require fresh ways to stream scientific evidence into political decision processes.

Figure 6: UHI mitigation strategies for Vietnamese cities



Source: Own design based on various sources

5. Conclusion

Because of solar radiation and anthropogenic heat UHI have posed major challenges globally against the backdrop of ever-increasing urbanization and climate change. This is particularly relevant in the case of rapidly urbanizing Vietnam with its emerging urban middle-income population exhibiting an increasing ecological footprint. Though awareness among Vietnamese policy makers on the relevancea of urban green can be observed, there still seems to be a lack of comprehensive understanding on the complexities of the issue and inter-relations of the factors causing UHI.

This paper advocates to move away from solely implementing technological/spatial solutions and to understand UHI more as a socio-economic, cultural, and political challenge. This requires holistic governance instruments involving multiple sectors and stakeholders. Such a comprehensive approach shall emphasize besides the pursuit of integrated urban planning and sustainable building approaches, the cruciality of raising awareness among the urban citizens and consequently their change towards more environmentally friendly behavior.

All in all, the future backbone for sustainable urban planning should be the promotion of a blue-green infrastructure securing a good quality of life for Vietnam's urban citizens.

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