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Evaluate Ho Chi Minh City Sustainability Using Fuzzy Extent Analysis Method

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ABSTRACT

Sustainable development of cities was among the goals aimed by either country or region since the 1980s. Ho Chi Minh City was ranked as the most rapid urban development in Vietnam, which challenged the accommodation of the necessities for a pleasant life in a city with limited resources, including housing, public infrastructure, a clean environment, security, safety, employment, and other necessities. The purpose of this study was to measure city sustainability by employing fuzzy decision analysis. A systematic review of the literature has provided the theoretical framework for measuring sustainable cities. Further consent on the criteria of a sustainable city in the context of Ho Chi Minh City, Vietnam was confirmed based on the evaluation of thirty experts with academic and practical experience in the field. The research findings provided the measurement model of city sustainability at three levels with three main criteria at 2nd level and twenty sub-criteria at 3rd level. The research results revealed that there is great consent for city performance and priority ranking in terms of the social dimension. However, great conflict in the importance and performance of economic and environmental dimensions has been found. This practically implied the strategies for bridging the gap between the city's actual criteria performance and priority ranking in target city sustainability.

1. INTRODUCTION

Sustainable development is a goal that is aimed by every country and region in the world and sustainable development of cities is not an exception [1-3]. A sustainable city has recently attracted the research community with diversified concepts of green city, digital city, smart city, and livable city. However, the terms only referred to sustainability unidimensionally [4]. A sustainable city must be built and developed based on the adaptation and active participation of three pillars: Economic, social, and environmental development [5]. This concept has been applied worldwide since the 80s to eliminate the bias toward economics when pursuing development goals.

Ho Chi Minh City was ranked as the most rapid urban development with a high rate of rural-to-urban migration [6, 7]. This leads to impressive achievements in the economic pillars, driving national growth [8, 9]. However, the city is also exposed to great challenges in the environment, infrastructure, and society. One of the city's biggest issues was meeting urban people's needs for housing, public infrastructure, a clean environment, safety, employment, and other essentials for a decent life in a metropolis with scarce resources [10, 11]. Moreover, Vietnam has experienced climate change with an increase in average temperature by 0.5℃. Sea-level has raised 20 centimeters over the 50 years [12]. The position of Ho Chi Minh City in an intertropical coastal region with low elevation, northeast of the Mekong Delta and 50 kilometers inland from the South China Sea has resulted in considerable annual changes in climatic and weather extremes [13]. The consequences were negative impacts on the city's sustainability [14].

A sustainable city is an obscured and debatable concept [15].

According to Parris and Kates [16], no unanimous indicator sets of sustainability have been accepted. Lisowski [17] has listed at least 20 different systems of sustainability indicators which have been developed worldwide by institutions, NGOs, and governments. Several reasons have been provided, including but not limited to the vague definition of sustainability, the diversified purpose of its measurement and the confusion about its components. A sustainable city is a multi-dimensional concept with many different measurement criteria, including subjective and objective criteria [18]. Numerous tools for measuring and tracking urban sustainability have been created around the world, taking into account the unique characteristics of cities or areas as well as the needs of their inhabitants [19]. One of the best ways to track and evaluate the progress made toward sustainable development is by using indicators [17]. However, the inclusion of indicators in the measurement model is debatable in the literature. Moreover, it is much dependent on the context because one size does not fit all. This study was conducted to bridge the current gap by providing consent on indicators of sustainable cities in the context of Ho Chi Minh City, Vietnam. It then examined the residents' evaluation of sustainable development dimensions and their indicators with the importance-performance matrix.

In recent academic research, city sustainable evaluation can

be seen as a fuzzy decision-making problem [20]. In this study, the fuzzy extent analysis method (FEAM) is employed for analyzing the city dwellers as an empirical evaluation. The research contributes to the academic and practical aspects in several ways. Firstly, the assessment criteria of a sustainable city in the context of Ho Chi Minh City, Vietnam are operationalized. Secondly, it provides a priority rank of sustainable city criteria under the views of the city dwellers via their evaluation of the criteria importance. Finally, actual city performance of sustainability is evaluated by the residents. The importance and performance parameters are critical for effective and efficient strategies to reach to goal of the city sustainability. Next, this research was structured with the presentation of a literature review in section 2, followed by methodology in section 3. Empirical findings were described and discussed in section 4. Section 5 concluded the research paper.

2. BACKGROUND

Ho Chi Minh City was among the cities with highest population in Vietnam. Nine million peopled was recorded in the census taken every ten years in 2019, sharing over 9% and 50% of the country population and the Southeast region respectively. Ho Chi Minh City is considered as one of the economic, financial, commercial and service centers of the country. The city's economy grew quite quickly, reached 7.72% per year on average in the period 2016-2019, always maintaining the leading position in the economy of the country, contributing more than 22% of GDP and 27% of total national budget. However, the target of sustainable city has not been realized. In fact, sustainable development was defined as a development to meet the needs of both present and future generations [21-23]. The UN 2030 Agenda for Sustainable Development with 17 Sustainable Development Goals (SDGs) was initiated in 2015 to guide nations in developing policies and action plans for sustainable development, and cities are not exceptional [24]. The theme of the ninth World Urban Forum, “Cities 2030, Cities for All” targeted the promotion of sustainable and inclusive development of cities by the year 2030 [10, 25]. Since then, the study of sustainable urbanization has taken on a more complex and in-depth form, indicating the necessity of systematic studies to advance sustainability.

To maintain conventional planning and design practices in line with the updated and revised concept of sustainability, urban planners created a comprehensive set of guidelines for urban planning concepts and strategies [4, 26]. That agenda served as the model for sustainable development in the twenty-first century because it positioned the environment within the context of society and the economy from the viewpoint of human survival [27]. In the early 2000s, the notion of urban sustainability was gradually conceptualized as smart green technological solutions and the way to sustainable urbanization was far from the goal [28, 29].

To date, the urban sustainability notion has become an umbrella concept covering growth, ecological modernization, and social justice, leading to the social–economic–ecological triangle [30]. Urban sustainability research and practice cover a wide range of topics due to its inherent complexity and diversity, including environmental preservation, resource utilization, land use, economic development, resource management, social well-being, living space, climate change, energy conservation, and waste reduction [31]. In short, the concept of a sustainable city was clarified as a place to enable its citizens to satisfy their own needs and enhance their well-being, without compromising others, including the natural world or the lives of other people, even now or in the future [32]. For the equitable benefit and well-being of all current and future citizens, cities should be sustainable economically, socially, and ecologically [33].

The assessment of sustainability relied on the umbrella of the triple bottom line approach, covering social, environmental, and economic dimensions with diverse attributes such as safety and security, housing, education, health care, recreation, transportation, employment, pollution, green spaces, and more [9]. More described sustainable development as a non-declining utility over the long term. Economic and social were the major contributing aspects to the city’s sustainable development due to environmental externalities. Maslow’s theory of the needs pyramid has been integrated into the economic and social dimensions [34, 35]. Economic indicators were the foundation for basic needs before moving to the psychological needs at the social dimension. Maslow [36] demonstrated the unbalance between sustainability and liveability when showing the high-level resource consumption as inputs of liveability, which led to the high rate of waste generation. Maslow [37] was the first to link economic development's process of pollution management, illustrating the possibility of more habitable communities with lower levels of resource use to eliminate environmental decay. The top-down approach to measuring the city’s sustainability can serve as the framework for a set of indicators [38].

To create 21 indicators that describe the environmental, economic, and social features of Mexico's Coatzacoalcos River basin, Calthorpe [39] used the framework of the driving forces, state and response (DSR) philosophy, and multi-attribute decision theory. This objective measurement methodology has been viewed as the gold standard in research because they are believed to reflect the real world and minimize discretion. However, it can only be calculated with the availability of official archives of data. In addition, it was stated that more subjective metrics were required to evaluate the experience itself to describe the population's experience's quality [40]. Subjective evaluation of the indicators has been recently examined in a plethora of studies [41]. Lee et al. [10] have applied the importance-performance matrix with a structural equation model to measure the perceived importance and perceived performance of residents in Shanghai city, China. The findings showed a different level of importance compared to the performance of indicators and sub-indicators in the measurement model of city sustainability.

3. RESEARCH METHOD

After synthesizing the criteria from previous studies, the authors conducted in-depth interviews with thirty experts, who had much experience in the field of sustainability, to final criteria of sustainability in the context of Ho Chi Minh City as indicated in Table 1.

Next, they evaluated the criteria by using the fuzzy extent analysis method (FEAM). This method used a range of values rather than a single fixed value or number to solve problems. Because it could be challenging for people to convey their opinions clearly, this was a more realistic scenario. The following are the FEAM's steps [20, 42-46]:

Table 1. Criteria of sustainable city

	Dimensions
SOC	**Social dimension**
SOC1	Safety and security in the city
SOC2	Quality of housing conditions and necessary amenities
SOC3	Quality of healthcare facilities and services
SOC4	Quality of educational facilities and services
SOC5	Adequacy of recreational and sports facilities
SOC6	Convenient locations of retail shops and restaurants
SOC7	Public transportation system and access to places in the city
SOC8	Control of traffic congestion
EVN	**Environmental dimension**
ENV1	Control of air pollution
ENV2	Control of noise pollution
ENV3	Control of water pollution
ENV4	Management of waste
ENV5	Preservation of natural areas
ENV6	Adequacy of green and open spaces
ENV7	Maintenance of streets and buildings
ECO	**Economic dimension**
ECO1	Monthly income adequacy
ECO2	Cost of living affordability
ECO3	Adequacy of affordable houses
ECO4	Economic performance of the city
ECO5	Employment opportunities

Let $Z = \{z_1, z_2, \ldots, z_n\}$ be an object set, and $V = \{v_1, v_2, \ldots, v_m\}$ be an object set, and an objective set.

The extent analysis values for each goal's item are then determined and shown as follows:

$\tilde{M}_{g_i}^{j}$, where i=1, 2, ..., n; j=1, 2,…, m.

Step 1: Find the priority weights

The value of fuzzy extended analysis synthetic on the i^{th} is expressed as:

$$S_i = \left(\sum_{i=1}^{m} a_i, \sum_{i=1}^{m} b_i, \sum_{i=1}^{m} c_i\right) \otimes \left(\frac{1}{\sum_{i=1}^{n} c_i}, \frac{1}{\sum_{i=1}^{n} b_i}, \frac{1}{\sum_{i=1}^{n} a_i}\right) \quad (1)$$

Step 2: Comparing degrees of possibility: The degree of possibility of $N_2 \geq N_1$ is expressed as follows:

$$V(N_2 \geq N_1) = \begin{cases} 1 & \text{if } b_2 \geq b_1 \\ 0 & \text{if } a_1 \geq c_2 \\ \dfrac{a_1 - c_2}{(b_2 - c_2) - (b_1 - a_1)} & \text{otherwise} \end{cases} \quad (2)$$

Step 3: Calculate the weight vector:

Assume that

$$d'(B_i) = \min V(T_i \geq T_k) \quad (3)$$

for k=1, 2,…, n; $k \neq i$.

Then, the weight vector is given by:

$$W' = (d'(B_1), d'(B_2), ..., d'(B_n))^T \quad (4)$$

where,

B_i (i=1,2,…, n) are n elements.

Step 4: Calculate the normalized weight vector:

$$W = (d(B_1), d(B_2), ..., d(B_n))^T \quad (5)$$

Step 5. Ranking of the criteria of sustainable Ho Chi Minh city. After having criteria weights, their ranking of them was known.

4. RESULTS AND DISCUSSION

City performance (CP) and evaluation of the residents on priority ranking (PR) of the indicators and sub-indicators under the umbrella index of the sustainable city have been calculated based on FEAM. The research results in Table 2 implied a three-level model of a sustainable city. The 2nd level includes three main criteria.

The respondents confirmed that the environmental aspect was the most significant aspect of a sustainable city (0.4597), followed by the social dimension (0.3845). The economic dimension (0.1558) was ranked as the least important.

According to people's perceptions of Ho Chi Minh City's performance, the city did best on the economic dimension (0.4795), followed by the social dimension (0.3202). The environmental dimension (0.2003) was the worst performance.

The findings showed a great consent for city performance and priority ranking in terms of the social dimension. However, a conflict performance picture of economic and environmental aspects was found. Ho Chi Minh City's economy always takes a driving role in the national economy in terms of its size and high growth rates [9]. However, the trade-off between economic growth and environmental quality is inevitable. Wang [47] found that energy consumption and carbon emissions were associated with economic growth. In the context of Ho Chi Minh City, Vietnam, the environment is the priority of a sustainable city under the views of city dwellers.

Because of its terrain, which includes low elevated coastal zones throughout the more than 3,000 km of coastline, Vietnam is among the countries most significantly affected by this hazardous development and is not an exception [48, 49]. Future sea level rise threatens coastal regions all around the world, placing their infrastructure, ecosystems, and other significant economic and environmental assets in jeopardy. [50]. The two densely-populated main delta regions of the Red River (Ha Noi city) and the Mekong (Ho Chi Minh City) are particularly affected. According to Nguyen [48], a 1-meter sea level rise may cause up to 20,000 km^2 of the Mekong River delta and 5,000 km^2 of the Red River delta to flood. Eckert, and Waibel [51] have implied the risk of flooding caused by sea level rise for low-elevation coastal areas around the world, including Vietnam. Sea level rise could negatively affect up to three times compared to previously forecast damage, and even wipe out some coastal cities. The metropolis of Hanoi and Ho Chi Minh City, being situated within the delta regions, will not only be endangered by sea level rise itself but may also experience a massive migration pressure of climate change refugees from the surrounding areas.

Further evaluation of sub-indicators at level three of the city sustainability index provided empirical evidence on the contrast between importance and performance. For instance, in the social dimension, traffic congestion was ranked first as the most important but was evaluated as the worst control (the

worst performance). This finding has practical meaning in identifying the prominent problem of traffic congestion and transportation-related environmental pollution [52-55]. A similar story can be found with the sub-indicators of the environmental dimension. Maintenance of streets and buildings was lastly ranked in terms of performance despite its first demand. Relating to the economic dimension, city dwellers highly judged the economic performance of the city. However, their problem was the cost of living affordability. The Spatial Cost of Living Index (SCOLI) compiled by the General Statistics Office of Vietnam for 63 provinces and cities based on surveys and comparison of prices of 11 essential commodities showed confirmed the second rank of Ho Chi Minh City (99.05%). In terms of education expenses, Ho Chi Minh City was the top expensive.

Table 2. Research results

	Dimensions	Weight		Rank	
		PR	CP	PR	CP
SOC	Social dimension	0.3845	0.3202	2	2
SOC1	Safety and security in the city	0.1523	0.2363	3	1
SOC2	Quality of housing conditions and necessary amenities	0.0730	0.1377	6	4
SOC3	Quality of healthcare facilities and services	0.0860	0.1495	5	3
SOC4	Quality of educational facilities and services	0.0868	0.2032	4	2
SOC5	Adequacy of recreational and sports facilities	0.0477	0.0833	7	6
SOC6	Convenient locations of retail shops and restaurants	0.0379	0.0969	8	5
SOC7	Public transportation system and access to places in the city	0.1932	0.0524	2	7
SOC8	Control of traffic congestion	0.3230	0.0405	1	8
ENV	**Environmental dimension**	**0.4597**	**0.2003**	**1**	**3**
ENV1	Control of air pollution	0.1875	0.2257	3	1
ENV2	Control of noise pollution	0.1361	0.1868	4	2
ENV3	Control of water pollution	0.1110	0.1765	5	3
ENV4	Management of waste	0.1965	0.1481	2	4
ENV5	Preservation of natural areas	0.0321	0.1135	7	5
ENV6	Adequacy of green and open spaces	0.0867	0.0979	6	6
ENV7	Maintenance of streets and buildings	0.2501	0.0514	1	7
ECO	**Economic dimension**	**0.1558**	**0.4795**	**3**	**1**
ECO1	Monthly income adequacy	0.0874	0.2912	5	2
ECO2	Cost of living affordability	0.3557	0.0625	1	5
ECO3	Adequacy of affordable houses	0.1078	0.1114	4	4
ECO4	Economic performance of the city	0.1886	0.3377	3	1
ECO5	Employment opportunities	0.2605	0.1972	2	3

5. CONCLUSIONS

This study has applied the fuzzy extent analysis method (FEAM) to evaluate the performance and importance of city sustainability based on the responses from the city dwellers. Research findings have determined the priorities of criteria and sub-criteria in the sustainable city model. In addition, the actual performance of these indicators has been calculated. The research findings have provided empirical evidence for ranking index for city sustainability in terms of both actual performance and priority ranking of indicators under the lenses of the city dwellers. They are useful for policy implications in bridging the gap between actual performance and the perceived importance of the indicators toward city sustainability. More specfically, the performance of "maintenance of streets and building" was evaluated as the worst in environment domain despite of its 1st priority ranking. The problem mainly related to condominium apartment common interest development. It's also the phenomenon in developing countries. Therefore, we suggest the promotion of home owner association in addition to the local state governance so that this partnership can push the effectiveness of the urban micro-governance, lead to the performance improvement of this environmental criterium.

However, the generalization of this study has been challenged, given its stragegy of relying on the data of experts'interviews. Therefore, larger survey with the city residents as participants should be done in future to get the findings more generalized.

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