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The Effect of Built Environment on Walkability in Ho Chi Minh City Center District

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건축 환경이 호치민시 보행편의성에 미치는 영향

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Abstract Walking plays an important role in promoting peoples' health and reducing the increasing pressure of traffic congestion. However, for cities in developing countries located in areas with unfavorable weather, such as hot and humid weather, there is not much research on walking. Therefore, this study focuses on the walkability and the effect of the built environment on walking in the center district of Ho Chi Minh City, Vietnam. The correlation between the built environment and walking frequency of people was analyzed. Besides common elements that have been used in previous studies, other specific factors of the built environment were determined to estimate the walkability index. The results were then compared with the amount of walking obtained from surveys of local people. The result shows that people tend to walk more in the areas with a higher walkability index.

요 약 보행은 사람들의 건강을 증진시키고 증가하는 교통 체증 해소에 중요한 역할을 한다. 기존 보행관련 연구는 유럽, 북미, 동아시아 등에서 진행하였으나, 베트남과 같은 덥고 습한 개발도상국 도시들의 경우, 걷기에 대한 연구가 비교적 많지 않다. 따라서 본 연구는 베트남 호치민시 중심지구의 보행편의성과 건축 환경이 보행에 미치는 영향에 대하여 연구를 진행하였다. 본 연구는 대상지를 이용하는 사람들의 보행 빈도와 건축 환경 사이의 상관관계를 분석하고 있다. 기존 선행 연구에서 일반적으로 사용된 요소 외에도, 본 논문은 보행편의성 지수를 추정하기 위해 도시의 다른 특정한 건축 환경 요소를 사용하였다. 사용된 지표는 주거 밀도, 상업 비율, 혼합 토지이용, 교차로 간격, 블록 크기, 보행로 비율, 천장 유무, 온도 9가지를 사용하였으며, 이러한 지표는 지역 주민들을 대상으로 실시한 조사와 비교 분석을 실시하였다. 분석 결과 사람들은 보행편의성 지수가 높은 지역에서 더 많은 보행을 하는 것으로 분석되었다.

Keywords : Walkability Index, Walking, Built Environment, Ho Chi Minh City, District 1

1. Introduction

Research on the walkability in urban areas is a popular topic. These studies serve all fields of urban issues such as urban design, transportation and people’s health. There are a number of topics that build a walkability index based on built environments, such as Frank's (2005, 2010) [1,2] and Lotfi studies (2011) [3]. For each city, however, the differences in conditions make the distinct walkability.

Ho Chi Minh City is known as a developing city in the tropical climate. Because of the distinction of the

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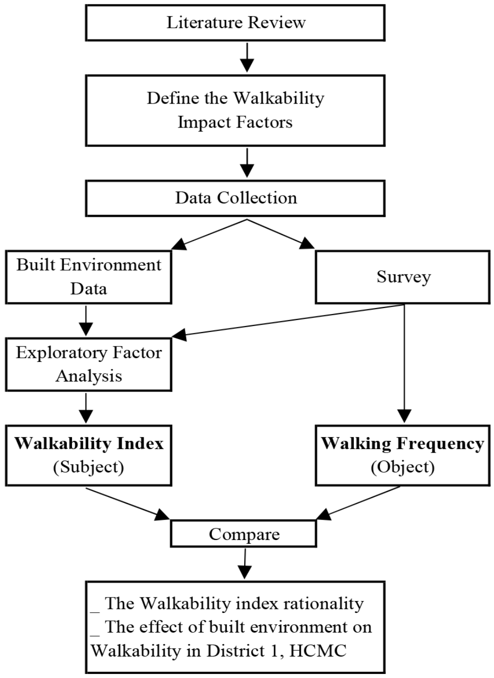

Fig. 1. Flow chart of research methodology

climate, city structure and even the culture and people's habits; the walking condition in this city is different from it in the other cities. This paper follows the theoretical foundations of previous studies, but takes into account some other specific elements that are expected to contribute to the number of walking decisions of local people in the city center. Hypotheses about the effect on the walkability of those factors are analyzed to prove the authenticity. The walkability index later is evaluated by these factors.

This article chooses the city center district as the research area. District 1 has long been considered to be the administrative, social, service and entertainment center of the whole city. Recently, the city center has strongly invested to improve the quality of life. Hence, pedestrian-friendly infrastructure design becomes one of the major issues that planners are concerned about. For that reason, finding the factors that are needed for walking encouragement is essential. This paper focuses on both object and subject research. The research purpose is to search for effecting factors and digitize them through the z-score to estimate the walkability index of each neighborhood in District 1 (object). Walkability reflects how pedestrian-friendly of an area. Walkability takes into account the quality of pedestrian facilities and comfort for walking [4]. Besides, local people are surveyed on their daily walk as well to specify the walking frequency (subject). It is the fact that people tend to walk more in areas with more pleasant walking environments. And the measure of the ease of walking is the walkability index. Thus, the walkability index is claimed to be related to the walking frequency [3]. If the study reflects the reality, the two indicators (object and subject) will be proportional. Therefore, the walkability index, then compared to the walking frequency to validate the accuracy of the method. The flow chart of research methodology is presented in the Figure 1.

2. Survey Literature

In recent years, studies on the effects of environmental factors on walking have attracted a great interest for the researchers from all over the world. In 2005 and later, in 2010, Frank and his colleagues developed a system to measure walkability through four factors: Intersection density, residential density, retail floor ratio and land-use mix [1,2]. Lotfi & Koohsary [3] also based on these four factors for use in walking study in a developing country like India in 2011. In addition, there are a number of studies base on similar factors. These are studies of the relevance between the built environment and walkability of Saelens in 2003 [5]; study on correlates of walking for transportation and recreation of Lee in 2006 [6], and Moudon's Operational Definitions of Walkable Neighborhood, 2006 [7]. Nevertheless, the researches by Lee [6], Moudon [7] and Rodrigue [8] further explored the sidewalk coverage element. Furthermore, the tree canopy is also claimed to be an important factor in the choice of walking, this is evidenced by studies of Lovasi in 2013 [9], Holtan in 2014 [10] and Ulmer in 2016 [11]. By these researchers, one or a combination of certain factors affects the walkability.

The difference in this article is that it sums up and takes into account the unique features of a city in the tropics with its urban structure, culture, traffic conditions, and infrastructure, which are completely different from the cases that above researches aimed at. Considering single factors or a combination of a few factors such as intersection density, residential density, retail floor ratio and land-use mix is not enough to build a walkability index for a city with many different characteristics such as Ho Chi Minh City. More specifically, other elements are tested and included in the walking index calculation. The chosen factors that predicted to affect walkability are verified through the Exploratory Factor Analysis (EFA). Through the above method, factors that do not affect walking ability are eliminated. As such, it is possible to say that this paper essentially builds a walkability index. However, the article adds a certain number of specific elements that were tested through the questionnaire analysis and EFA. The walkability index after qualitative analysis was then tested for accuracy through comparison with the actual walking frequency of the local civilian.

3. Methods

3.1 Walkability Index

Depending on each city conditions and the database, different studies have different factors to build the walkability index [3]. According to some researchers, net residential density, land-use mix, and intersection density have been considered as the main built environment measures relating to walkability [1,5,6]. Net residential density is the ratio of residential units to the land area [2,3]. Intersection density measures the connectivity of the street network. It is represented by the ratio between the numbers of intersections with three or more intersecting streets in a square kilometer. A higher density of intersection corresponds to a more direct path between destinations [2,3]. Land use mix indicates a diversity of land use types in an area. Land use mix values are normalized between 0 and 1, with 0 being single use and 1 indicating a completely even distribution of floor area across the all land uses [2,3]. The diversity of land use plays an important role in promoting the walking [12]. For this study, the land use is classified into five categories, including: residential, retail, entertainment, institutional and others.

$$\text{Land-use mix index} = \frac{\sum_{j=1}^{k} \ln(pj)}{\ln(k)}$$

Where:

Pj: Percent of each land-use type

K: Number of land-use type.

The recent studies have determined that the retail floor ratio is one of the main factors of walkability design [2,3,7]. The retail floor area ratio is the building floor area footprint divided by retail land floor area footprint. The retail floor area ratio is introduced to increase the sensitivity to retail use, which is believed to stimulate pedestrian activity [2,3].

In addition, the other factors that are expected to have a positive or negative effect on people's walkability are put into the study. In the case of the tropical climate of Ho Chi Minh City, the intense sunlight may increase the feeling of discomfort or even adversely affect people health when walking. To be more specific, the average environmental temperature in Ho Chi Minh City is 28 ^{o}C [13] with an average number of sunshine hours ups to 207.175 hours per month [14] and sometime the air temperature recorded ups to 41^{o}C in 2018 [13]. One of the effective solution of the bad weather influence in Ho Chi Minh City is the tree canopy. Tree canopy has been proven to perform well in the sun-drenched task and to improve community relationships and physical activity since it significantly reduces ground and walkway heat

[9,10,11]. For that reason, the study predicts the temperature and tree canopy as two of the environment factors that affect the walkability in the city center. The tree canopy index is defined as the number of trees along the pathways per square kilometer. Temperature index is the average temperature collected from each area. Data on temperature is measured by placing the temperature meters on the sidewalk, 1.5 m height from the ground. The temperature of 105 sites from eleven study areas are recorded from 13h to 15h at the same day.

Beside the mentioned impact factors, sidewalk availability is identified as an element that significantly associated with the attractiveness of non-motorized modes [6,7,8]. However, most studies about walkability recently have ignored it. Therefore, sidewalk coverage is considered in this paper to diversify the impact factors.

As such, there are seven factors that are expected to affect walkability in the research area_District 1. To determine which elements affect the walkability, the authors analyze these eight factors by the EFA method. 138 people who live and work in District 1 were asked about the level of consent for the impact of each given factor on their walkability. As a result of EFA analysis, all seven factors are confirmed to have an impact on walkability. The index of these factors are then synchronized by z-score. A Z-score is a numerical measure of a valuable relationship to the mean in a group of values [15]

$$\text{Z-score} = \frac{x-\mu}{\sigma}$$

Where:

x: Raw score, μ: Average value, σ: Standard deviation.

Walkability index is determined by the sum of the chosen factors' z-score.

Walkability index = z-residential density + z-retail floors ratio + z-mix-land use + z-intersection density + z-sidewalk coverage + z-tree canopy + 2*(-z-temperature).

The z-score of temperature is reversed as these factors negatively affect the walkability. As analyzed, high environmental temperature is the typical of Ho Chi Minh City. Besides, according to the survey result, it is a very high proportion agree that environmental temperature affects the people's walking decision (49.6% said very agree and 34.8% said agree). Therefore, the criterion for temperature is double because of its strong influence on walking.

3.2 Walking Frequency

Walking frequency is a practical reflection of the frequent or non-frequent walking of people in the study area. To investigate the walking frequency of local people, the survey is conducted on 138 people living and working in 11 areas of District 1, Ho Chi Minh City. The respondents include 51.65% of women and 48.44% of men and the average age of the interviewees is 27.34. The walking purpose is divided into 4 main categories: walking to shopping, walking to public transport, walking to school/work and fitness walking. With these main purposes, we asked them how many times they walk for each purpose per week.

Our questionnaire consists of two separate segments. Firstly, as shown at the "Walkability index" section, we asked about the level of agreement on the effects of each factor on their walking choice. The purpose is to determine the impact factors. The second section asks about people walking frequency to compare and verify the accuracy of the walkability index calculation.

4. Case Study

District 1 is the central district of Ho Chi Minh City with an area of 7.73 km^2, which is home to 193.632 people [16] (Figure 2). District 1 is considered as one of the highest living standards district of the City in all aspects. In recent years, pedestrian-friendly improvement has become a major target of the district.

District 1 includes 10 wards. However, because of the unique features of functional subdivision and urban

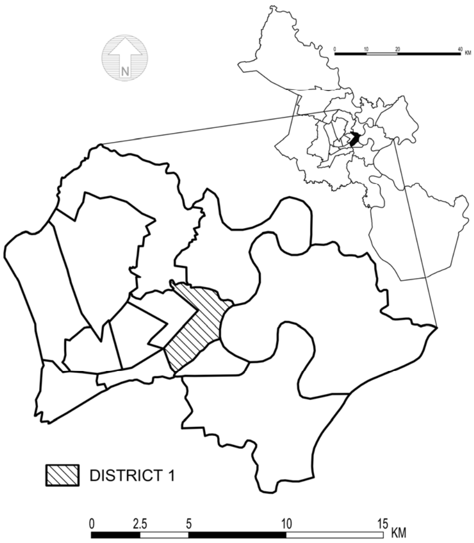

Fig. 2. The Location of Study Area

structure, one of these areas is divided into two separate study areas (area 8 and area 9 in Figure 3 and Figure 4). Therefore, there are total eleven divided study areas.

5. Results

5.1 Walkability Index

Walkability index is built on seven factors, including residential density, retail floors ratio, mix-land use, intersection density, sidewalk coverage, tree canopy, temperature. As is mentioned above, before identifying the influence factors, all predicted factors are analyzed by EFA. In order to eliminate independent variables that are not sufficiently reliable, in the EFA analysis, the first step is to run the reliability statistic. The result shows that the Cronbach's Alpha = 0.730, it presents a good result when $0.7 \leq \alpha \leq 0.8$ [17]. The Corrected Item – Total Correlation of all variables is bigger than 0.3, and all of Alpha if item deleted are smaller than Cronbach's Alpha. It demonstrates that the measure is reliable and the variables are satisfactory [18]. Independent variables satisfying the condition are then included in the factor analysis. Before executing the rotation matrix, some values must reach the standard; otherwise, one or more independent variables must be eliminated. With the extraction method of principal components, the varimax rotation and the loading factor are less than 0.5; the next test is performed. The test result shows the KMO = 0.729, satisfies $0.5 \leq KMO \leq 1$ condition [19]. Barlett sig = 0, smaller than 0.05 [20], Eigenvalue >1 and Average Variance Extracted = 69.209%, bigger than standard minimum (50%) [18]. With these results, there is no variable is eliminated. To decide to keep the variables or not in the EFA analysis, the matrix rotation method is then carried out. The outcome indicates that the largest values of the variables cluster into three distinct and separate groups. As such, the EFA test reveals that all factors impact on walkability, no factors are excluded. Data of the chosen factors is then standardized into z-scores. The z-score and the walkability index of each research area are presented in Table 1.

The result has a value range from –9.195 to 5.546. The classification is based on the walkability index of each neighborhood. Low, Medium, and High walkability levels are classified by natural breaks method, a method of manual classification to partition data into classes based on natural groups in the data distribution [20]. With the walkability index of –9.195, -6.558, -6.471, neighborhoods 2, 1, 4 are identified as three areas having weak environmental conditions in walking encouragement. Those areas are classified into low walkability index group. The medium walkability index group includes neighborhoods 11, 3, 6, 5, 8 with the walkability index in order are 0.478, 1.461, 1.667, 2.651 and 3.216. And the neighborhoods 7, 9, 10 are shown to have a high walkability index with scores of 3.357, 3.849 and 5.546 in that order (Figure 3).

$$\text{Z-score} = \frac{x-\mu}{\sigma}$$

Where:

x: Raw score,
μ: Average value
σ: Standard deviation

Table 1. The Z-score of Built Environment Elements and Walkability Index of Neighborhoods

Area	Mix-Land Use		Retail Floors		Residential Density		Trees Canopy	
	Raw Score	Z-score	Raw Score (number/Km^2)	Z-score	Raw Score (people/km2)	Z-score	Raw Score (number/km2)	Z-score
1	0.749	**-0.138**	725	**-1.754**	37166	**0.143**	463	**-0.612**
2	0.592	**-1.843**	1037	**-1.122**	56662	**1.131**	168	**-1.176**
3	0.747	**-0.160**	1743	**0.310**	42251	**0.401**	656	**-0.243**
4	0.650	**-1.213**	1348	**-0.491**	50507	**0.819**	168	**-1.176**
5	0.756	**-0.062**	1594	**0.008**	65304	**1.569**	287	**-0.948**
6	0.870	**1.175**	1749	**0.321**	17099	**-0.874**	1140	**0.682**
7	0.870	**1.175**	1552	**-0.079**	6307	**-1.421**	1821	**1.984**
8	0.767	**0.057**	2129	**1.091**	29787	**-0.231**	626	**-0.300**
9	0.826	**0.698**	1604	**0.028**	6307	**-1.421**	1338	**1.061**
10	0.863	**1.099**	2571	**1.985**	22857	**-0.582**	1028	**0.468**
11	0.689	**-0.790**	1444	**-0.297**	43483	**0.463**	918	**0.258**

Area	Intersections Number		Temperature		Sidewalk Coverage		Walkability Index
	Raw Score (number/km^2)	Z-score	Raw Score (celsius)	(-) Z-score	Raw Score (km^2)	Z-score	
1	17	**-1.575**	34.283	**-0.651**	0.0443	**-1.321**	**-6.558**
2	18	**-1.546**	34.680	**-1.571**	0.0395	**-1.499**	**-9.195**
3	54	**0.620**	33.913	**0.209**	0.0829	**0.114**	**1.461**
4	36	**-0.426**	34.671	**-1.551**	0.0561	**-0.883**	**-6.471**
5	65	**1.275**	34.143	**-0.325**	0.1191	**1.460**	**2.651**
6	45	**0.091**	34.075	**-0.168**	0.0961	**0.606**	**1.667**
7	42	**-0.089**	33.725	**0.644**	0.0932	**0.497**	**3.357**
8	65	**1.258**	34.000	**0.006**	0.1155	**1.328**	**3.216**
9	60	**0.976**	33.583	**0.973**	0.0949	**0.561**	**3.849**
10	44	**0.036**	33.340	**1.537**	0.0654	**-0.535**	**5.546**
11	33	**-0.621**	33.617	**0.895**	0.0710	**-0.327**	**0.478**

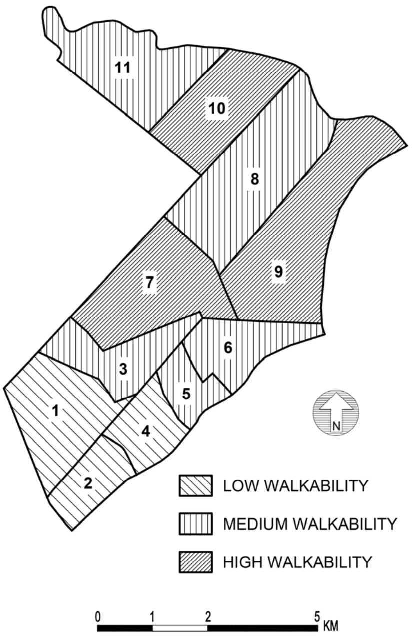

Fig. 3. Walkability Index

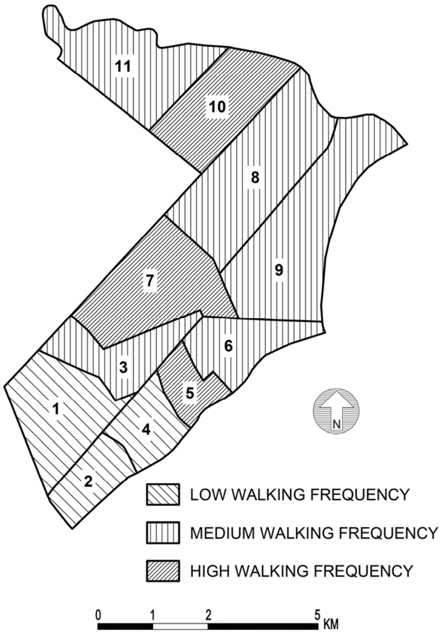

Fig. 4. Walking Frequency

4.2 Walking Frequency

To have the database, the survey is conducted on 138 people in the study areas. The questionnaire asks people about the frequency of walking for each trip purpose every week. The result shows that people living in the neighborhood 2 are "the laziest" to walk, with an average of just 5.1 walking times a week for all trip purposes. The next two positions belong to neighborhoods 1 and 4 with a walking frequency of 5.22 and 6.7 times per week in that order. These three neighborhoods are classified as Low walking frequency. For self-reported walking, walking frequency categories are also classified based on the natural breaks method; includes three levels: Low, Medium and Hight walking frequency. Medium walking frequency group includes 5 areas: area 6 with 7.23 walking times/week, area 11 with average 8.2 walking times/week, areas 8 and 9 with the same result 8.38 walking times/week and area 3 with 8.42 walking times/week. High walking contains neighborhoods 5, 10, 7 with a weekly walking frequency of 8.43, 8.5, 9.46 respectively (Figure 4).

The values of the neighborhoods in the low walkability index are much smaller than those of the medium walkability index. It can be said that the distinction between low and medium walkability index is clear. The same phenomenon happens with the low and medium walkability frequency groups obtained from the survey. Both methods show the lowest value in neighborhoods 1, 2, and 4. Area 11, 3, 6, 5, 8 are put into the medium walkability index group, when the medium group of self-reported walking frequency includes areas 6, 11, 3, 9, and 8. There is a relative match when the areas 6, 8, 3 and 11 are classified into the medium group in both methods. However, the value and order of these areas in two groups are not identical. For the high walking frequency group, the survey outcome shows that people in neighborhoods 5, 10, and 7 walk more than people in other areas. Hence, these three areas are listed in the high walking frequency group. This is similar to the High walkability index group when areas 7, 9, and 10 are ranked as the highest value group (Table 2). However, it is easy to recognize that the classification of areas 5 and 9 in two methods do not coincide. Area 5 is classified in a highest group of the walking frequency, but is put in the medium group of the walkability index and vice versa for neighborhood 9 (Table 2). These incongruities may because the article does not figure out all of the factors that impact walkability, or due to errors in calculations and surveys. These reasons led to differences in the Medium and High group of the two approaches. However, in general, the value range of values in the Medium and High groups of both methods are not significant, especially in the case of the walking frequency. The comparison between walkability index and walking frequency is shown in Table 2. From the relative coincidence of the calculated walkability index and the actual walking frequency from local people, it can be concluded that the walkability index built in this study is quite accurate and reliable.

Table 2. Walkability Index and Walking Frequency

Group	Walkability Index		Walking Frequency	
	Area	Index	Index	Area
Low	2	-9.195	5.1	2
	1	-6.558	5.22	1
	4	-6.471	6.7	4
Medium	11	0.478	7.23	6
	3	1.461	8.2	11
	6	1.667	8.38	8
	5	2.651	8.38	9
	8	3.216	8.42	3
High	7	3.357	8.43	5
	9	3.849	8.5	10
	10	5.546	9.46	7

5. Conclusion

By developing the walkability index based on the way that Fank (2005; 2010) [1,2] and Lotfi (2011) [3] have been done before, finding new elements that suit the characteristics of a city such as Ho Chi Minh City shows the greater correlation between environmental factors and the walkability. People in better walking environmental condition areas tend to walk more than the others. It makes sense to claim that the chosen environmental factors affect walkability. These factors include residential density, retail floors ratio, mix-land use, intersection density, sidewalk coverage, tree canopy and temperature. Neighborhoods with a wide variety of land uses, a diversity of retail shops, a crowded place, a large number of crossings, and a huge number of green areas and pavement have a positive impact on walkability. Conversely, high temperature prevents people from walking decisions. Walkability is an important concept in sustainable urban design [22]. From the analysis of the factors affecting walkability, the strategists can rely on that result to identify the strengths and weaknesses in the walking built environment of each area. From there, planners develop appropriate policies and infrastructure that adapt the specific conditions of each locality. With the influence of sidewalk coverage, pedestrians should be given maximum priority with the extended walking space, connected to the network and freed from encroachment. In addition, retail, green space, landscape and land use also provide a better walking environment if properly planned and do not affect walking space. Beside improves the landscape, tree canopy is also a very effective solution for reducing the temperature of the pathway. In addition, improvements in infrastructure and safety at intersections should also be concerned because the suitability and safety of the intersections have a positive effect on the walking environment as well.

In summary, the study result reflects the approximate status of walkability. Nonetheless, as a matter of course, the research also has limitations. Firstly, because of the lack of data, the paper cannot analyze the neighborhoods in more detail with a smaller scale, but simply analyzes based on the administrative boundaries and functional subdivision of the city. Secondly, the values of walkability index and realistic walking frequency do not exactly match. The inaccuracy may come from the lack of factors that influence the walking choices. These missing factors may be block size [7], topography [8], safety [9,22,23] or aesthetic [23], the impact of private vehicles, door-to-door traffic or even housing types, which are not mentioned in this paper. Regarding the result of self-reported walkability, the number of samples is quite small is also the cause of the inaccuracy. In another aspect, the criterion for temperature has a strong impact on walking choice, so it has the coefficient of two. However, that multiplier of temperature factor just comes from the estimation. Besides, the role of other factors in this study is not clearly known. In the other words, the walkability index calculation simply is the sum up the factor index (z-scores) without taking into account the exact coefficient of each factor. Further researches, perhaps should base on more factors with the coefficient of each element to achieve the accuracy. Moreover, in the case of Vietnam, door-to-door traffic using a motorcycle is common. It is considered to influence the selection of the means of passage depending on the purpose of the trip. Therefore, the next studies should further investigate the relationship between the walking frequency for each purpose and the walkability index beside the summed traffic frequency for a more detailed assessment.

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