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IMPACT OF THE PHYSICAL ENVIRONMENT ON USER BEHAVIORAL PSYCHOLOGY IN URBAN DISTRICT PARK

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Abstract: Urban open spaces (e.g. urban parks) play a pivotal role in improving the quality of life of city dwellers through accommodating various physical and social activities, while further creating social coherence for sustainable development. Due to the shortage of open green spaces in the city, caused by rapid urbanization in developing countries, some big, long-standing urban public spaces such as district parks have been retained, and improved to serve as the main public space for local people. However, such spaces commonly provide outdated, low quality facilities that discourage people from using the park. To satisfy users' needs, local governments have launched campaigns to improve parks based on the ideas of domestic or foreign designers. The purpose of this research is to explore different behaviors of residents in an open space in Da Nang (Vietnam) which can support the future development and improvement of local open space in accordance with environmental behavior theory. User behaviors were identified and categorized based on their activities in the open space, collected using the place-centered behavior mapping method. Results of the statistical analysis revealed that this open space could be divided into three types, each of which had four dimensions: public facilities setting; openness; accessibility; and recreational facilities. The findings showed some aspects that need to be considered during the development process of open space as follows: 1) increasing the quantity and quality of public amenities; 2) separating accessible space and/or buffer space from already used space inside the park, particularly in the entrance zone; 3) providing space adjacent to the lake; and 4) removing obstacles (e.g. walls around the park) to give a clearer view from inside the park to the streets outside and vice versa. Also, the calculation model of evidence-based designs provides input data for re-planning or creating public space/parks to help designers, planners and authorities improve or design better open spaces in the future.

Keywords: Behavior mapping; park environment; environmental behavior; sustainable development; well-being; Da Nang

INTRODUCTION

Urban space has become a controversial issue owing to its failure in serving people (Hester 1984, Jackson 1981). Various studies primarily identified abandoned, vandalized areas and outdated amenities in the space (Francis 1987). Previous studies focused on the quality of open space, and the findings helped raise certain awareness of the community in terms of psychological and economic benefits.

Urban open space has been studied from many aspects including its uses and purposes, and the perceptions of citizens. Whyte's studies proved theories about the significance of a comfortable "sittable" area in open space(Whyte 1980). The relationship between environmental quality and traffic-related issues in street space has also been demonstrated by scholars from around the world including Appleyard (1981), Eubank-Ahrens (1985), Van Andel (1985), Brower, Dockett & Taylor (1983) and (Donald, Gerson, and Lintell 1981, Eubank-Ahrens 1984). Another approach that aimed at the improvement of open space by judgment and redesign is "post occupancy evaluation"(Ozkan et al. 2015). This method was attempts to have direct impact on redesigning and managing open space. That is to say, it is used to deal directly with existing problems in open spaces. Scholars such as Whyte, Cohen, McGinty and Moore successfully used this approach(Ozkan et al. 2015, Francis 2003). Another current method is known as action research, which bases policies and design on direct and continuous feedback obtained through research results(Francis 2003, 1987). In Asia, research on the relationships between physical factors in the spatial environment and user behavior is also of interest to scholars. In particular, Neto et al. (2016) discovered impacts of physical factors on users' impression about public space and proposed the prediction model of desire to stay and rest in these places (Neto et al. 2016). Zeng and Li (2018) investigated the relationships between children's behavior and residential landscape elements (Zeng and Li 2018).

Vietnam is located in Asia, but has a unique society, culture and economy which makes it difficult to use it as the basis for a standard development model for all Asian countries. Many problems and environmental feedback mechanisms are still particular to each country itself and its current state of development (Syamwil 2012). In addition, many studies have shown that the difference in cultures, socio-economic situation and policies affect human behavior, leading to different growth between nations (Kaplan 1985, Foresta 1980, Francis, Cashdan, and Paxson 1984). Furthermore, different groups of people and socioeconomic groups may perceive open space in many different ways (Kaplan 1985, Foresta 1980).

During the course of Vietnam's long history, there has been little evidence about public spaces existing. Where such evidence does exist, public spaces often appear to be places for religious observation or serving activities of the state management apparatus under the feudal or colonial systems (Drummond 2000). During the Economic Renovation Period (from 1986), the concept of open space was formulated, but did not gain great attention. In recent years, however, as a consequence of urbanization, open space has become a heated subject as it is a practical solution for issues resulting from urbanization such as the imbalance between green areas and built-up areas, and this imbalance has exerted adverse impacts on the quality of life(Jim and Chen 2003). Urban open space is currently limited and inadequate in Vietnam (Linh, Erasmi, and Kappas 2009, ALMEC 2010, Dang 2002). The government is proposing public space planning solutions to increase the area of urban open space, such as upgrading existing parks, streets and pseudo-public spaces. However, the park still plays a crucial role in the daily life of Vietnamese people(Loan 2016). However, there are not many parks in urban areas, most of which are district parks that serve daily activities of the people(Loan 2016). The currently proposed solution for open space development in district parks is simply arranging benches, providing children's playgrounds and lawns, putting up artistic statues such as carved stones, and providing huts or fitness equipment to encourage access. The question about the efficiency of these plans remains unclear as much public open space has yet to be used and fully exploited (Loan 2016).

Previous studies

Worldwide open space such as parks and playgrounds was historically criticized as failing to serve users and having unclear purposes (Francis 1987, 2003). Studies over the last few decades that put an emphasis on previously missing aspects of open space quality have provided an insight into the economic, social and psychological benefits of urban open space. Meanwhile, research on public spaces such as district parks (including playgrounds) has been conducted to explore the uses citizens make of and their perspectives towards these spaces. Whyte (1980), noted the importance of design principles in providing open spaces which individuals can find comfortable to stay and rest in (Whyte 1980). Research by Hayward, Rothenberg, & Beasley (1974) compared playgrounds. Whyte's study (1980) examined plazas, and that of Francis, Cashdan, & Paxson (1984) referred to community open space. However, designers still hesitated to apply research findings in practice (Francis 2003). A growing body of research, including that of Cooper-Marcus (1975), and Zeisel (1981) made a direct contribution to the improvement of open space through assessment and re-design (Marcus 1975, Zeisel 1984). Recent studies have focused on the development of open space by recognizing the relationship of users to and benefits of the city park (Brown, Rhodes, and Dade 2018).

Research on physical elements and user's impressions of neighborhood parks was carried out by Tsuchida & Tsymita (2005) and Neto (2016) to investigate the relationship between physical characteristics and user behavior (Neto et al. 2016, Tsuchida and Tsumita 2005). In Vietnam, studies on such relationships have yet to be conducted, as most scholars have just paid attention to theories about space landscape planning on a large scale (Loan 2016). Design theories and suggestions of Vietnamese scholars on developing public space are regarded as the basis for the design and renovation of only some urban open space in Vietnam (Loan 2016, Quang 2018). Public space needs comprehensive development in the areas of politics, economics, society and culture in order to facilitate full and distinctive growth (Loan 2016). A wide range of construction and upgrading projects have been devised in many parts of Vietnam to create green open space for residents, but this is often limited to providing a few lawns or flower gardens or playgrounds with sparse vegetation and some benches(Loan 2016).

The field of environment-behavior studies (EBS) confronts the lack of knowledge of how people and environments interact and the implications of this for open space design. Without it, efforts to improve the built environment through such design were likely to fail, since no outcomes could be reliably predicted (Rapoport 2008). However, it is difficult or even impossible to know when these research outcomes were successful without criteria to assess success. Such success offered no useful lessons for the future, nor any significant contribution to a cumulative body of knowledge for evidence-based design (Rapoport 2008). Among various researchers, only a small group was interested in developing a scientific discipline of environment-behavior relations (EBR) that learnt about the phenomenon through basic study. They believed that the most important thing for improvement was knowledge and the explanatory theory of EBR (Rapoport 2000). Lewin's field theory (1943) held that human behaviors were the result of interaction between people and their surrounding environment. Behavior setting was considered to be a stable connection between action and space that provided a conceptual framework to examine the association of environment and behavior (Barker 1968, Heft 2001).

Objective and significance of study

The international studies mentioned above focus on privately owned public space, as researched by Tsuchida & Tsymita (2005) and Neto (2016), but still have some limitations. For example, their case studies did not always use comparable methods, which restricted designers from applying research findings in different cases or social contexts. Recently, developing countries such as Vietnam have emphasized the development of open space in order to meet higher and more human-driven demands (Loan 2016, Marcotullio 2017, Richards, Passy, and Oh 2017); as Koh (2007) points out, not only is public space a fixed material space with intentionally designed functions, but it is also created by its users (Koh 2007). Meanwhile, in Vietnam, almost no research on the interaction between user behaviors and the environment, especially in public open space, has been conducted. Indeed, approaches to the development and improvement of open space, especially in places that have been recently upgraded, have yet to be made evident and examined in practice.

Whether given measures to the development, upgrading and management of real, open space in Vietnam have affected the activities of residents is still an unsolved question. Meanwhile, theories about open space development in Vietnam, as well as the gap between theory and practice are still vague. Also, there are no definitive technical standards or specific instructions on methodology which provide the basis for planning and design in practice. Thus, this research attempts to fill the knowledge gap in the development of urban open spaces such as large and medium parks in Vietnam by mapping out resident's behaviors in response to the district park's environment. More specifically, this study aims to discover the physical setting characteristics of the district park and users' behaviors and provide correlative evidence for the relationship between environmental factors and classes of activities in this space through suggesting a prediction model of physical elements that are set up and affect user evaluation. This study can help urban designers develop evidence-based designs and minimize the difference between practical effectiveness and expectation of the urban medium and large-scale park development in Vietnam and neighboring countries.

MATERIALS AND METHODS

Object of study

Da Nang is the third largest city in Vietnam, rated second in the PCI (Provincial Competitiveness Index) (2017 Vietnam Chamber of Commerce and Industry) according to the U.S. Agency for International Development (USAID, 2018). With high potential economic growth, Da Nang's population is predicted to double to approximately 2 million by 2030. This research chose 29-3 Park located in Da Nang as a large open space. This district park is located in Thanh Khe district with an area of over 20 hectares and has been established since 1975. It is a district park but is considered as the largest and oldest public open space in Da Nang. The park has various distinct sections for recreational, cultural and sporting activities. Historically the space has been upgraded and renovated several times, most recently in 2014-2015, when free of charge fitness equipment for the elderly was installed; the zoo was retained but upgraded and with some extra species added; games facilities were

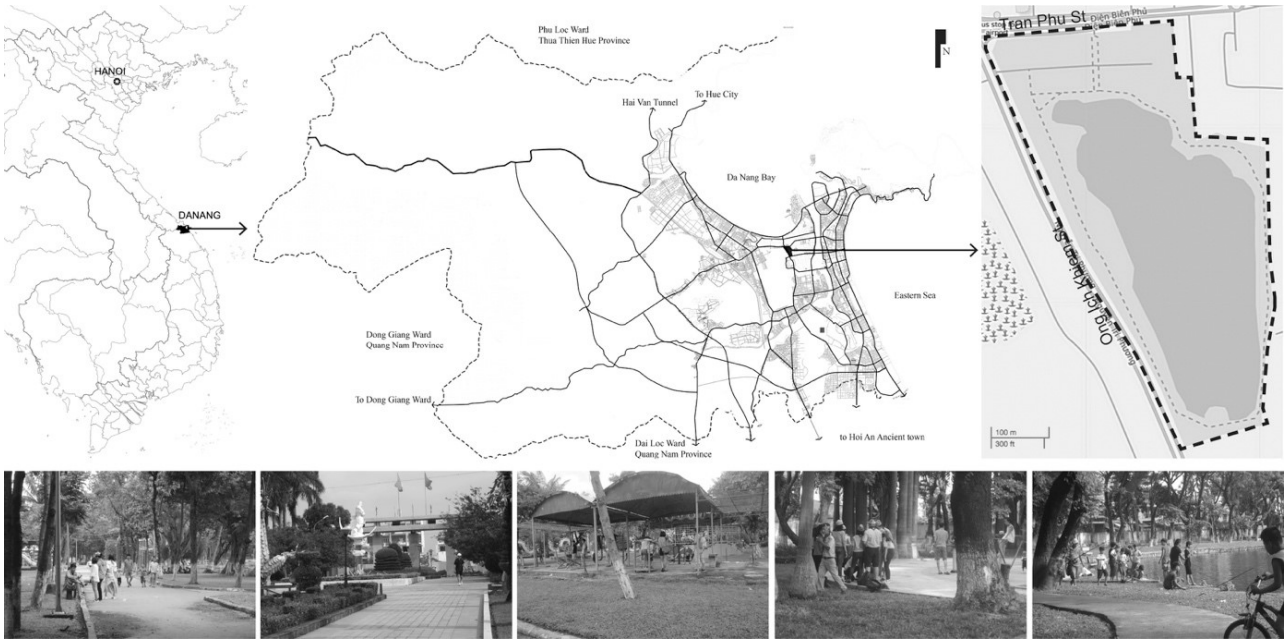


Fig. 1 Location and overview of 29-3 Park

upgraded; exercise grounds were built; and a walking path around the lake was constructed. At the same time, the public restrooms on the site of Dien Bien Phu street were demolished; while the skating rink was knocked down and replaced with a free outdoor skating area. Finally, a new lighting system was added. In contrast with existing green open spaces in Da Nang, 29-3 Park is a public space at the district level full of physical settings for many kinds of human activities, which can be frequented by residents at any time (**Fig. 1**). The question here is whether this renovation satisfies the users' needs or whether the design ideas which were applied elsewhere as proposed by designers can solve problems of unused public open space in developing countries like Vietnam. Despite the as yet unknown effectiveness of this project, the authorities still plan to replicate the 29-3 Park model for developing other district-level parks (Chau 2018). Moreover, in its current form, 29-3 Park plays an important role as a model for other development projects. So along with the usage characteristics mentioned above, the park provides an admirably suitable case for this research.

Outline of investigation

The observation was conducted within 29-3 Park between October 14th and November 11th, 2018, aiming to understand the park's users in terms of their behaviors and interactions with the surrounding environments. To conveniently observe the whole park at the same time, the entire open space was divided into 4 sections based on spatial features and usage features, so that investigators could record as many human activities as possible. Four observers were assigned, and recorded all activities on a paper-based map by using the place-centered behavior mapping method (Whyte 2000) (**Fig. 2**). In addition, all physical elements of the park were investigated and measured, based on the encounter survey method and remote sensing technology, while measuring greenery cover using satellite imaging (Two Landsat 8OLI) (Campbell and Christman 1982) (Ran et al. 2017). The survey was undertaken over four time frames in a day as follows: Morning (6:00 – 10:00), Midday (10:00 – 2:00), Afternoon (2:00 – 6:00) and Evening (6:00 – 8:00). Each time slot was recorded twice; each record lasted 15 minutes and was concurrently done in all areas of the park. Four architecture students from a local university received theoretical and practical training in two pre-survey sessions; before the field survey, they were thoroughly instructed and corrected if they made surveying mistakes. Survey data for two weekdays and two weekend days was collected to guarantee objective factors of the survey. Although there is a different use pattern in various events in this park, people mainly use the park for their daily activities. Therefore, this study focuses on understanding the relationship between users' daily activities and physical environments in the district park and ignores special big events like the Tet holiday in Vietnam. **Figure 3** provides an overall picture of the research process, for better understanding of the investigation and research framework.

Data processing

During the four investigation days, 4539 behavior units were collected in the entire park area. This was divided into 4 sub zones, namely zone 1 to zone 4. User behaviors over the different time slots were recorded and divided into groups. A group of users doing the same activity was treated as one activity unit. Behaviors were identified based on user activities in the personal space/neighboring environment context as defined in behavior setting concept(Hassan, Massoud, and Mansour 2018).

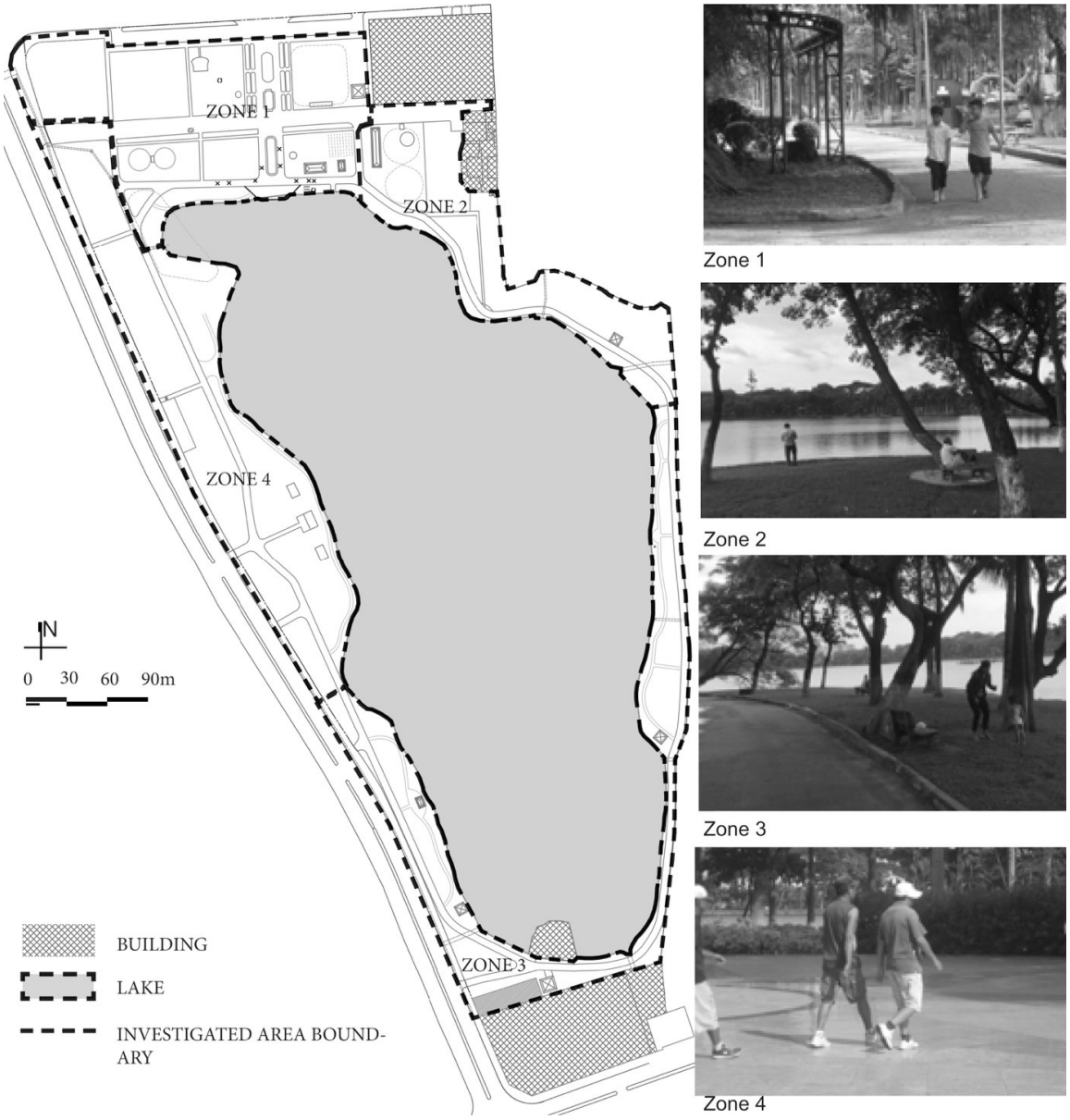


Fig. 2 Investigated Zone Division

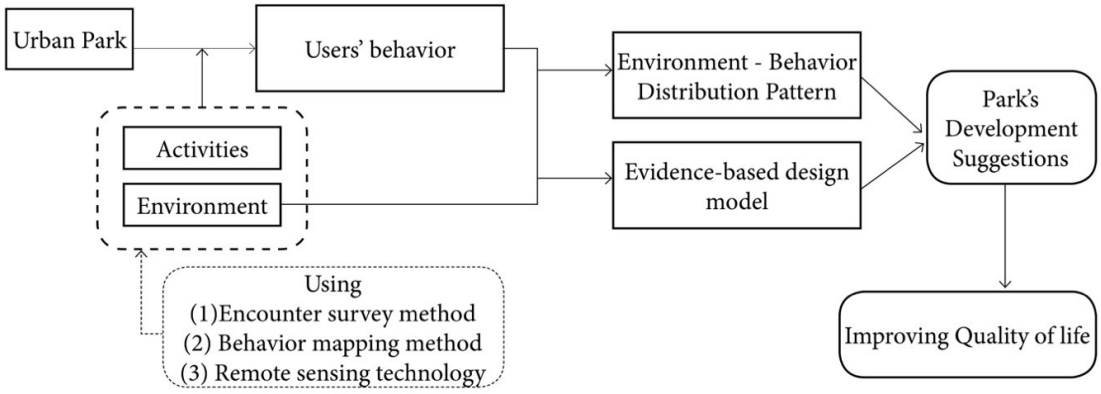
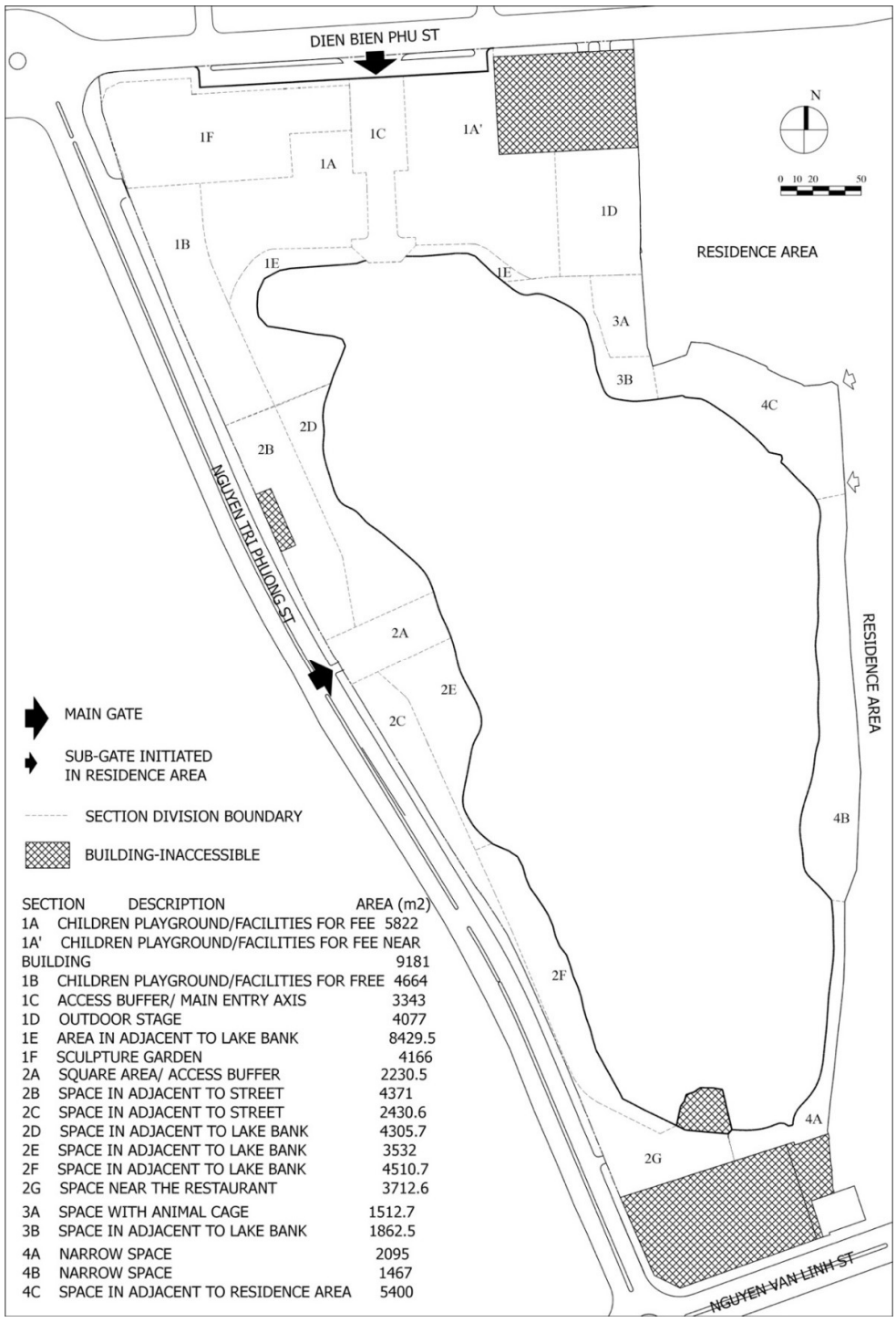


Fig. 3 The research framework diagram



SECTION	DESCRIPTION	AREA (m2)
1A	CHILDREN PLAYGROUND/FACILITIES FOR FEE	5822
1A'	CHILDREN PLAYGROUND/FACILITIES FOR FEE NEAR BUILDING	9181
1B	CHILDREN PLAYGROUND/FACILITIES FOR FREE	4664
1C	ACCESS BUFFER/ MAIN ENTRY AXIS	3343
1D	OUTDOOR STAGE	4077
1E	AREA IN ADJACENT TO LAKE BANK	8429.5
1F	SCULPTURE GARDEN	4166
2A	SQUARE AREA/ ACCESS BUFFER	2230.5
2B	SPACE IN ADJACENT TO STREET	4371
2C	SPACE IN ADJACENT TO STREET	2430.6
2D	SPACE IN ADJACENT TO LAKE BANK	4305.7
2E	SPACE IN ADJACENT TO LAKE BANK	3532
2F	SPACE IN ADJACENT TO LAKE BANK	4510.7
2G	SPACE NEAR THE RESTAURANT	3712.6
3A	SPACE WITH ANIMAL CAGE	1512.7
3B	SPACE IN ADJACENT TO LAKE BANK	1862.5
4A	NARROW SPACE	2095
4B	NARROW SPACE	1467
4C	SPACE IN ADJACENT TO RESIDENCE AREA	5400

Fig. 4 Section Division of landscape in 29-3 Park

Because of various complex features of the space and its boundaries, user behaviors may be affected by various environmental factors. Therefore, the behavior setting can be defined by the boundary of space characteristics and space functions. A total of 19 sections were included and specified in **Fig. 3**; Zone 1 was split into 7 sections, Zone 2 had 7 sections, Zone 3 2 sections, and Zone 4 and 3 sections. The division into sectors was based on characteristics of the initial environmental characteristics such as functional aspects of the topographical area within each zone. In addition, further information for each section was described (**Fig. 4**).

The physical environment of each section was measured by the density, defined as the area occupied by physical elements. The area occupied by each physical element was measured based on survey photos - these physical

elements are detailed in the table. Satellite images from Landsat 8 and Google maps (2017) provided details of green cover. The principal component analysis (PCA), a dimension-reduction tool, was applied to reduce a large set of variables to a smaller set that still contains most of the information of the former (Jolliffe 2011). By applying this method, the physical environment of the park emerged and was clarified. A cluster analysis was then conducted to classify different categories of space based on its physical characteristics. Finally, a comparative analysis was conducted between different kinds of space and various behaviors in order to understand the distribution of behaviors within the park environment. Two further correlation and regression analyses, related in terms of dealing with relationships among variables of behaviors units and physical environments in this study, were conducted to measure their linear association (Faul et al. 2009).

Behavior setting and definition

Behavior related to users' physical health, social interaction, and recreation was defined according to their actions within surrounding environments. The behavior categories were established based on behavior setting theory which provides for ecological units where the physical environment and behavior are intrinsically linked (Heft 2001, Schoggen 1989). Based on observation data (e.g. photos and paper-based records), all user behaviors within the park were recorded. Because of the large quantity and variety of activities in the park, visitors' behaviors were thoroughly observed and behaviors that were present in the park carefully set and denominated in order to describe the objective of relevant activities to the surrounding environment. This was based on the theory of proxemics proposed by Hall (Hall 1962; Brown, 2001) (**Fig. 5a**).

RESULTS

Behavior characteristics of users

All user behaviors were collected and classified into 4 main categories which were health-related behaviors, social interaction behaviors, recreational behaviors, and maintenance/service behaviors with an overall total of 15 sub-categories (**Table 1**) (**Fig. 5b**).

As the main focus of the study is on the relationship between user's behaviors and the physical environment, maintenance/service activities carried out by staff such as taking care of plants, cleaning, selling food or beverages, and guarding the park are considered to be out of the scope of the study. Three remaining groups of user behaviors are included in the following analysis.

The frequency of recreational behaviors was dominant over other groups, with a total of 3017 behavior units, while the number of behavior units in the health-related behavior group and social interaction one were 885 and 625 respectively. Accordingly, three of the most popular activities in those behavior groups were respectively listed as follows: jogging with a frequency of 632 occurrences; children playing with 203 occurrences; and fishing with 1098 occurrences. The sections that recorded the highest frequency of user behavior in each zone were 1E (10 kinds of behaviors) with 587 occurrences, 2F (12 kinds of behaviors) with 443 occurrences, 3B (10 kinds of behaviors) with 211 occurrences, and 4B (12 kinds of behaviors) with 358 occurrences.

The results showed that most of the user's activities in the park were for relaxation (e.g. Fishing, Strolling, and Idling), health-related (e.g. Exercising, and Jogging) and social interaction (e.g. Children playing, Chatting, and Couple Dating). This finding also proved the significant role of this open space to daily activities, especially recreational ones, of the residents. Although various studies of urban parks have indicated that the district park was more related to weekend and holiday activities such as picnicking, this finding shows the difference in the context of Vietnamese cities. The possible explanation for this phenomenon is that due to the lack of residential parks in surrounding residential areas, more people participate in this space for their daily activities and relaxation. Moreover, the finding shows the difference of Vietnamese people in using the park.

There are obvious differences between behavior categories and their frequency recorded in various sections. The complex correlation of the environment with behaviors will explain the behavior distribution in a certain area and be discussed in the last part of this paper.

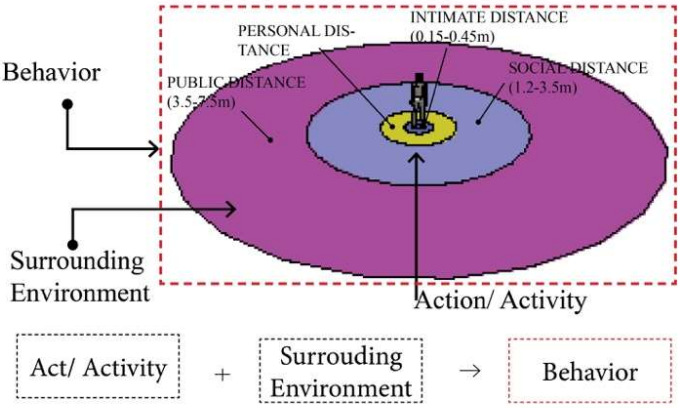
Spatial environment analysis based on physical setting characteristics

Physical Environment characteristics of open space

Features of the physical environment such as amenities, interfaces, the relative boundaries of the space, functional physical elements, shady trees, lawns or pavements were counted and are tabulated in **Table 2**. Data describing the characteristics of this space were analyzed by the Principal Component Analysis using the Xlstat statistical add-in software in Microsoft Excel. The cumulative contribution rate of 83% means if the data is represented from the 1st to the 4rd column (F1 to F4), 83 % of the total variability of the data can still be seen in **Table 3**.

On the first dimension, the negative eigenvalues include factors such as sand/asphalt playgrounds, benches, food/beverage stalls, fountains, parking lots, public toilets, lake view stations, areas for Taichi exercise, refuges, and trash bins, while the positive eigenvalues include walking paths, lawns and shady trees. It is to be noticed that all the above-mentioned factors are involved in public facilities. Therefore, the first horizontal axis describes public facilities of open

(a)



(b)

Standing/ Sitting	on	ground with Taichi exercise gears	Doing Taichi exercises	Health-related behaviors
Running	along	walkpath	Jogging	
Working out	at	outdoor exercise equipments	Doing exercise	
Playing	at	sand/ children playground	Children playing	Social interaction
Sitting + holding hand/kissing	on	the bench/ sward	Couple dating	
Sitting/ lying	at/on	the sward/ outdoor blanket with gears	Camping/ picnic	
Sitting + taking each other	on	the bench/ sward	Chatting	
Walking/standing	at	child playground/walkpath with kids	Walking baby	Recreational behavior
Standing + seeing	at/around	animal cages	Watching animals	
Sitting + seeing/doing nothing	at	bench/sward	Idling	
Walking + seeing	around	walkpath/ sward	Strolling	
Standing	at	lake bank with fishing gears	Fishing	
Laying	on	the bench/ sward	Resting	
Walking/Setting up/ doing	at	park area with uniform and working-stalls	Maintenance	Service/maintenance
Standing/ sitting	behind		Selling	

Fig. 5 Schematic of user's behavior definition and behavior categories; (a) behavior setting definition; (b) behavior categories found.

space. On the second dimension, the eigenvalues indicate all physical environment elements in this open space.

playgrounds and viewing areas. Hence, the second axis represents openness. On the third dimension, there is only one factor, namely "adjacency to street space", as a positive eigenvalue. This third axis refers to the accessibility to the space. The negative eigenvalue on the fourth dimension shows children's game facilities and sport facilities. Thus, the fourth axis describes recreational facilities. In brief, four given axes may show qualities and characteristics of

Sections classification based on physical environment characteristics

The entire open space consists of 19 sections that were classified into 3 groups based on the results of agglomerative hierarchical clustering analysis (**Fig. 6**). Space features are illustrated in **Fig. 7**.

In the first group, there are 7 sections including 1a, 3a, 1a', 1b, 2b, 2c and 2g. This group represents space that is not adjacent to water and has low quality facilities. The second group consists of 10 sections, 4a, 4c, 1e, 4b, 1c, 2d, 2e, 2f, 1f and 3b. This space includes water-adjacent areas with benches, paved/grass covered playgrounds, walking paths near streets or residential areas, and places equipped with fitness equipment and refuges. The final group consists of 2 sections 1d and 2a that describe space with a high density of squares or playgrounds.

Physical environment-behavior relationship

To comprehend the relationship between the environment and behaviors in this space, a comparative analysis was conducted. Instead of comparing different kinds of behaviors in separate sections, we assumed that 13 kinds of user behaviors would be included over 19 sections. The average frequency of each behavior was given at about 7.7%, compared with all behaviors over the entire section. If the frequency of a certain behavior was over 7.7% and it appeared in more than half of the sections, it could be treated as a frequent behavior. Similarly, if the frequency was under 7.7%, the behavior could be treated as an infrequent behavior.

As can be seen on **Fig. 8**, frequent behaviors such as doing Taichi/exercises and watching animals appeared in

Table 1. Occurrence Frequency of Users' behavior

Zone	Section	Health-related behaviors			Social interaction behaviors				Recreational behaviors						Maintenance/ service behaviors		Total
		Doing Taiji exercises	Jogging	Doing exercise	Children playing	Couple dating	Camping/ picnic	Chatting	Walking baby	Watching animals	Idling	Strolling	Fishing	Resting	Maintenance	Selling	
Zone 1	1A	0	80	54	23	13	2	10	49	0	49	110	0	3	2	1	396
	1A'	0	72	17	35	10	1	8	44	9	52	113	0	3	0	0	364
	1B	0	6	1	60	2	0	17	22	0	47	25	0	7	0	0	187
	1C	0	51	3	8	17	0	0	47	0	11	100	7	0	0	1	245
	1D	0	3	0	2	0	1	3	0	24	11	1	0	0	1	0	46
	1E	0	23	0	7	27	5	29	7	0	127	76	282	4	0	0	587
	1F	0	0	15	11	0	0	15	3	0	39	9	0	0	0	1	93
Zone 2	2A	3	6	0	1	1	1	14	4	0	14	25	44	2	0	0	115
	2B	5	7	10	14	6	1	15	11	0	16	23	0	0	0	0	108
	2C	0	43	0	2	7	1	11	5	0	2	26	0	1	0	0	98
	2D	6	25	8	1	29	10	15	23	0	52	79	149	9	0	1	407
	2E	0	12	0	0	17	0	5	5	0	57	27	120	5	0	1	249
	2F	5	67	43	1	15	3	24	20	0	91	49	117	7	0	1	443
	2G	0	15	1	0	0	0	2	0	0	4	2	1	4	0	0	29
Zone 3	3A	0	0	0	0	0	0	0	0	17	0	2	0	0	1	0	20
	3B	0	34	0	7	9	1	6	9	5	33	41	66	0	0	0	211
Zone 4	4A	0	66	1	2	0	0	0	1	0	2	33	192	0	0	0	297
	4B	1	76	40	8	32	1	17	11	0	39	64	55	14	0	0	358
	4C	2	46	38	21	9	2	8	20	0	36	34	65	3	2	0	286
	Total	22	632	231	203	194	29	199	281	55	682	839	1098	62	6	6	4539

group 3, which was overwhelmingly occupied by playgrounds or small squares. In group 2, lake-adjacent space with fundamental amenities mostly allowed residents to go fishing and couples to make a date.

In other dimensions, people rarely performed other activities (except for doing Taichi/ exercises and watching animals) in the empty spaces such as playgrounds or small squares mentioned in group 3.

For space in group 1 that is not adjacent to the water's edge, human activities were limited, owing to low quality and poor recreational facilities, notably the most infrequent behaviors such as couple dating, camping, or sitting and idling. In group 2, most user behaviors occurred in space which provided public fundamental facilities and was adjacent to the water. However, each section provided different kinds of facilities as described in **Fig. 9**. Across the whole group, behaviors were also dispersed, which accordingly leads to the appearance of various infrequent behaviors in the group.

User Behavior and Physical Environment Density Analysis

Environment amenities and interfaces, including the relative boundary of the space, and functional physical elements, such as shady trees, lawns or pavements were counted and measured by their density on each sub-section (**Table 4**). The density of physical environments was defined according to the open space's area or perimeter occupied by physical elements.

To analyze how each element of the physical environment in open space affects the frequency of user behaviors, the physical environment density of each element and behavior was tabulated, as shown in **Table 4** and **Table 1**. As a correlation test for physical elements and behaviors would be applied, any behavior that did not correlate well with physical environment elements was omitted (the correlation index <0.5).

Table 5 shows significant correlation results between physical environment elements and behaviors. There were 11 out of 13 behaviors that had significant correlation with 13 physical environments out of a total of 25. When it comes to the integration of environmental behaviors, except for fixed relationships such as watching animals, visiting the zoo, doing Taichi, or doing exercises and sports, other notable relationships may help to predict the number of user behaviors accordingly.

The frequency of user behaviors is mostly affected by and can be predicted thanks to environmental features. Children's game facilities are correlated with most user activities which consist of jogging, doing exercises, walking babies, and strolling. This may be because the space where children's game facilities were set up encouraged the above-mentioned activities. Moreover, because these facilities were not usually operated, people tend to consider those areas as a common place. It is

Table 2. Physical Environment Characteristics of 29-3 Park

Sections		Children's game facilities	Sand playground fo1r children	Asphalt playground for children	Bench	Food/beverage stall	Fountain	Visual Object	Walk path in adjacent to resident	Walk path	Walk path in adjacent to the Lake	Outdoor Stage	Playground/ View Area	Parking lot	Public Toilet	Dock/ Lake View station	Sport facilities	Small Square	Taichi Exercise Ground	Sward	Shady tree (Shading)	Refuge	The zoo	In adjacent to street space	Trash bin	In adjacent to the lake
Zone 1	a							0	0	1	0	0	1	0	0	0	1	0	1	1	1	0	0	0	1	0
	a'							0	0	1	0	0	1	1	0	0	0	0	0	1	1	0	0	1	1	0
	b							0	0	1	0	0	1	0	1	0	0	0	0	1	1	0	0	1	1	0
	c							1	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0
	d							0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0
	e							0	0	1	1	0	1	0	1	0	0	0	0	1	1	0	0	1	0	0
	f							0	0	1	0	0	1	0	0	1	0	0	1	1	1	0	0	0	1	1
Zone 2	a							0	0	1	0	0	1	1	0	0	0	1	0	1	1	0	0	1	1	1
	b							0	0	1	0	0	1	1	1	0	1	0	0	1	1	0	0	1	1	0
	c							0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0
	d							0	0	1	1	0	1	0	0	0	0	0	1	1	1	1	0	0	1	0
	e							0	0	1	1	0	1	0	0	0	0	0	0	1	1	0	0	0	1	1
	f							0	0	1	1	0	1	0	0	0	0	0	1	1	1	0	0	0	1	1
	g							0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	1
Zone 3	a							0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0
	b							0	0	1	1	0	1	0	1	0	0	0	0	1	1	0	0	0	1	1
Zone 4	a							0	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1
	b							0	1	1	1	0	1	0	1	0	1	0	0	1	1	1	0	1	0	1
	c							0	1	1	1	0	1	0	0	0	1	0	0	1	1	1	0	1	1	1

(1: presence; 0: non-presence

possible to assume that children's game facilities were also related to other activities because their environment supported general users' activities. Walking paths adjacent to the lake are also correlated with couple dating, sitting and idling, and fishing.

Accordingly, the most important thing was the accessibility to the water-adjacent places where people can rest or go fishing. Other relationships between user behaviors and environmental features can be found in **Table 5**.

Among 11 environmental factors which were not well correlated with the frequency of users' behaviors, some elements did not really affect users' behaviors because people tended to consider a place either to provide the basic environment elements for their activities (e.g. fountains, visual objects, public toilets, squares, docks/lake view stations, refuges, parking lots, lawns and street or lake adjacent areas) or to consider the environmental factors that appeared almost everywhere in this open space; this led to a non-correlation with user behaviors in the analysis (e.g. shady trees).

The best predictor for jogging was walking path (adjusted $R^2 = 0.447$; $p < 0.001$) by the single regression formula Y = 0.132+14062.5*walking path, where Y is the jogging score. This behavior could also be calculated from children's game facilities but with a less potent model (adjusted R^2=0.222; p< 0.024).

Doing exercise behavior could be predicted by children's game facilities (Adjusted R^2= 0.263; p< 0.014) and Sport facilities (Adjusted R^2=0.286; p< 0.011). The potential predictor for doing exercise can be made by sport facilities through Y = 9.67+74.09*sport facilities, where Y is doing exercise behavior score.

Children playing could also be predicted by the presence of sand playgrounds (Adjusted R^2=0.591; p < 0.0001) through the formula Y= 7.94+2429.57*sand playground, and/or asphalt playgrounds (Adjusted R^2=0.591; p < 0.0001) via the formula Y= 7.944+946.69*asphalt playground, and trash bins (Adjusted R^2=0.301; p< 0.009) with Y= 3.03+10452.678*Trash bin, where Y is Children playing score.

Couple dating could be calculated based on walking paths adjacent to the lake (Adjusted R^2=0.364; p< 0.004) through the formula Y= 4.987+25.153*walking path adjacent to the lake where Y is dating couple behavior score. This behavior could also be estimated by playground/viewing area (Adjusted R^2=0.289; p< 0.010) via formula Y= 4.33+13.98*play/view ground.

Table 3. Score of physical environment elements

	F1	F2	F3	F4
Children's game facilities	-1.16	-1.40	-1.70	**2.09**
Sand playground for Children	**-1.94**	-0.14	-0.11	-0.26
Asphalt playground for Children	**-1.91**	-0.18	-0.12	-0.30
Bench	**-1.97**	-0.11	-0.09	-0.24
Food/beverage stall	**-1.93**	-0.07	-0.10	-0.20
Fountain	**-1.94**	-0.06	-0.09	-0.19
Visual Object	-1.92	0.00	-0.09	-0.13
Walkpath in adjacent to resident area	-0.75	-0.01	1.02	-0.91
Walkpath	**2.03**	0.28	-0.11	1.97
Walkpath in adjacent to the Lake	1.72	1.47	1.52	-0.57
Outdoor Stage	-1.64	-0.83	2.41	1.73
Playground/ View area	4.78	**6.27**	-0.56	0.87
Parking lot	**-1.46**	-0.54	-0.44	0.14
Public Toilet	**-1.97**	-0.11	-0.09	-0.24
Dock/ Lake View station	**-1.96**	-0.10	-0.10	-0.24
Sport facilities	-1.54	-0.87	-1.44	**1.56**
Small Square	-1.65	1.47	-1.10	-1.17
Taichi Exercise Ground	**-1.83**	-0.05	-0.22	-0.19
Sward	**7.83**	-2.06	-2.86	-1.47
Shady tree (Shading)	**11.62**	-1.94	1.41	0.59
Refuge	**-1.81**	-0.09	-0.09	-0.30
The zoo	-1.37	-0.93	0.87	-0.36
In adjacent to street space	1.58	-1.19	**1.71**	-0.96
Trashbin	**-1.97**	-0.11	-0.09	-0.24
In adjacent to the lake	1.17	1.29	0.46	-0.98
Eigenvalue	11.38	2.38	1.20	0.88
Variability (%)	59.89	12.51	6.33	4.64
Cumulative %	59.89	72.40	78.73	83.37

Camping/picnic behavior could be estimated according to Taichi Exercise ground (Adjusted R^2=0.589, p< 0.0001) by Y= 0.74+94.8*Taichi Exercise Ground where Y is Camping/picnic score. Walking babies could be predicted based on children's game facilities (Adjusted R^2=0.421: p< 0.002) by the formula Y= 11.384+70.17*children's game facilities where Y is the walking baby score. In addition, food/beverage stalls (Adjusted R^2=0.210; p< 0.028) and sports facilities (Adjusted R^2=0.214; p< 0.041). Watching animals could be estimated according to the Outdoor Stage (Adjusted R^2=0.554; p< 0.000) by Y= 1.72+22.278*Outdoor Stage, and the zoo (Adjusted R^2=0.215; p< 0.026) by Y= 2.11+14.89*The zoo, where Y is Watching animals score.

Sitting and idling behavior could be predicted based on the bench density (Adjusted R^2=0.267; p< 0.014) though the formula Y= 17.027+23467.96*Bench and Walking path adjacent to the lake (R^2=0.355; p< 0.007)

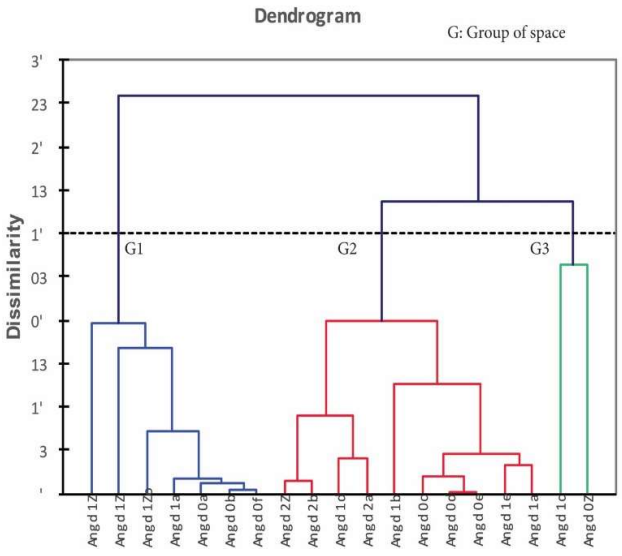


Fig. 6 Clustering sections

Group 1				Group 2				Group 3			
Public Facilities	Openness	Recreational Setting	Accessibility	Public Facilities	Openness	Recreational Setting	Accessibility	Public Facilities	Openness	Recreational Setting	Accessibility
Low	Medium	Medium	Medium	High	Medium	Low	Low	High	High	Medium	High

*. accessed according to score of physical environment elements via principle component analysis

Fig. 7 Characteristics of three typical space groups in 29-3 park

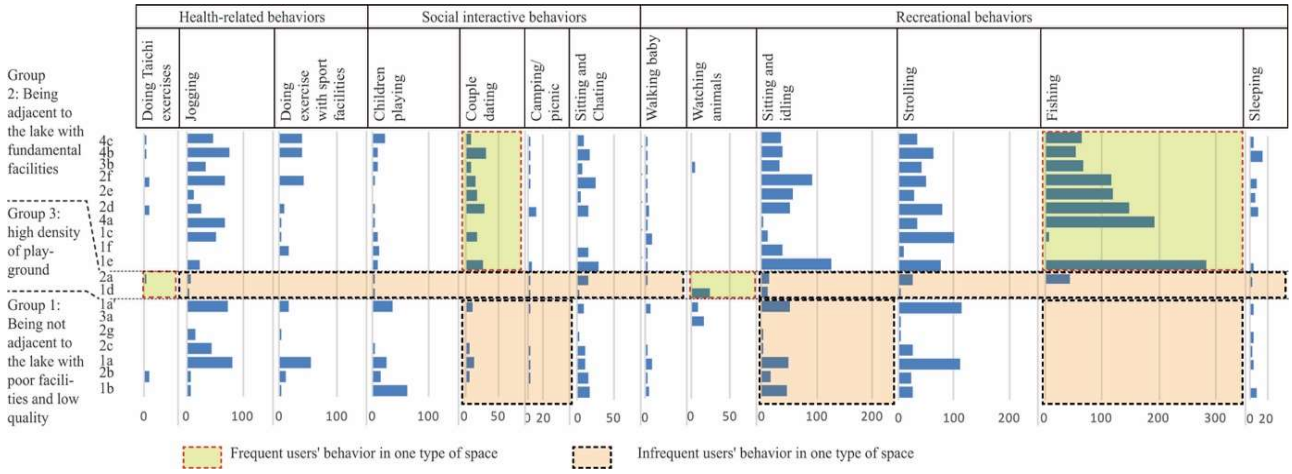


Fig. 8 Distribution of users' behaviors

by the formula Y= 20.32+75*Walking path adjacent to the lake, where Y is the sitting and idling score.

Strolling was also estimated based on walking path (Adjusted R^2=0.369; p< 0.003) through the formula Y = 5.41+16446.5*walking path where Y is Strolling behavior score. It is also calculated based on Children's game facilities (Adjusted R^2=0.34; p< 0.005).

The final behavior that the element of walking path adjacent to the lake could be affected by fishing (Adjusted R^2=0.769; p < 0.0001) and it could be predicted by the equation Y= 1.02+273.37*walking path adjacent to the lake where Y is the fishing behavior score.

DISCUSSION

In this research, activities in an open space have been investigated. Its findings reveal that the open space plays a pivotal role in providing a place for recreational

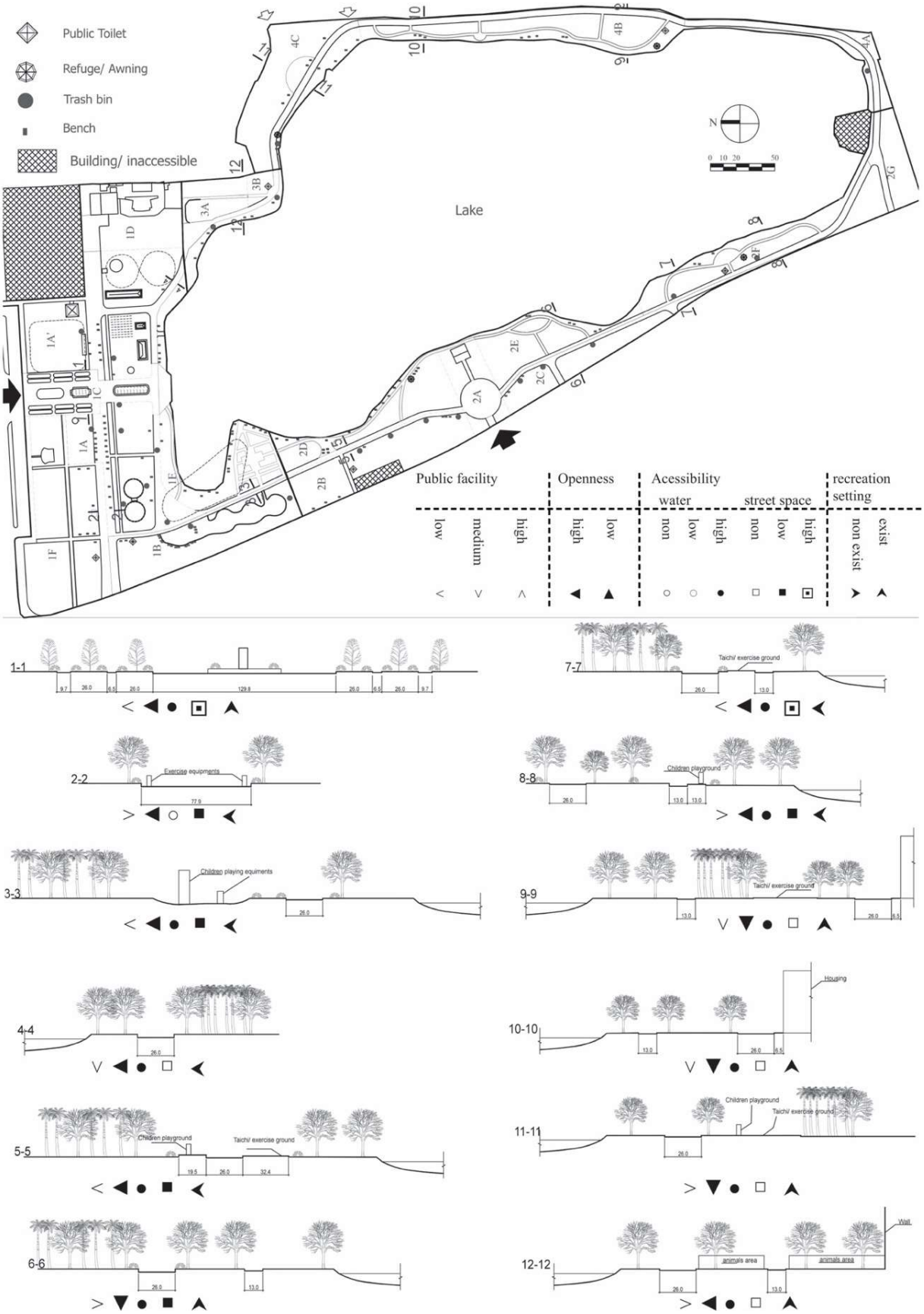


Fig. 9 Characteristics of each typical section in 29-3 open space.

Table 4. Physical Environment Characteristic density

Sections		Zone 1						Zone 2							Zone 3		Zone 4		
		a	a'	b	c	d	e	f	a	b	c	d	e	f	g	a	b	a	b	c
In adjacent to the lake*		0	0	0	0	0	0	.65	.15	0	0	0	.42	.45	.14	0	.43	.44	.44	0
Trash bin		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
In adjacent to street space*		0	.14	.39	.13	.24	.32	0	.16	.3	.2	0	0	0	.14	.32	0	.55	.44	0
The zoo		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Refuge		0	0	0	0	0	0	0	0	0	.04	.04	0	0	0	0	0	0	.04	0
Shady tree (Shading)		.4	.65	.63	.4	.45	.9	.95	.1	.97	.96	.55	.9	.99	.9	1	.98	.95	.97	.4
Sward		.41	.38	0.8	0	0	.16	.6	.19	.84	.98	.91	.92	.92	.77	.22	.44	.54	.34	.41
Taichi Exercise Ground		.02	0	0	0	0	0	.01	0	0	0	.07	0	.05	0	0	0	0	0	.02
Small Square		0	0	0	0	0	0	0	.95	0	0	0	0	0	0	0	0	0	0	0
Sport facilities		.6	0	0	0	0	0	0	0	.04	0	0	0	0	0	0	0	0	0	.6
Dock/ Lake View station		0	0	0	0	0	0	.01	0	0	0	0	0	0	0	0	0	0	0	0
Public Toilet		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parking lot		0	.32	0	0	0	0	0	.08	.04	0	0	0	0	0	0	0	0	0	0
Playground/ View area		.01	0	0	.96	0	.51	1	.61	.29	0	.8	1	1	0	0	.48	0	1	.01
Outdoor Stage		0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Walk path in adjacent to the Lake*		0	0	0	0	0	.74	0	0	0	0	.42	.42	.47	0	0	.48	.53	.53	0
Walk path		.4	0.3	.1	.6	.1	.3	.2	0	.1	.2	.2	.2	.3	.1	.1	.4	.5	.3	.4
Walk path in adjacent to resident area*		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.5	.49	0
Visual Object		0	0	0	.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fountain		0	0	0	.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Food/beverage stall		0	0	.01	.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bench		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asphalt playground for children		0	0	.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sand playground fo1r chilren		0	0	.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Children's game facilities		.62	.31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.62

(*the density measured by the length of this item per its total perimeter)

activities which positively affect human life. Although streets are where most daily activities of residents occur(Drummond 2000, Drummond and Lien 2008), open spaces with sparse amenities still attract certain social activities, which may difficult to find a location for in other open spaces in urban areas. The important thing is how to maximize the number of user's activities or the organization of those activities in this space during the process of renovation and design. It was found that environmental behaviors in this study could be classified into three types, namely Group 1, Group 2 and Group 3.

Group 3 attracts almost no activities. That is, although these spaces in this group are equipped with amenities of open spaces such as squares, huts, flower gardens, and good quality pavement, the high level of openness and accessibility turns out to be the culprit discouraging user's activities. The reason behind could be the low privacy level which discourages activities.

Table 5. Correlations of behavior occurrence frequency and physical elements

	Children's game facilities	Sand playground	Asphalt play ground	Bench	Food/beverage stall	Walkpath	Walkpath in adjacent to the Lake	Outdoor Stage	Playground/ View area	Sport facilities	Taichi Exercise Ground	The zoo	Trashbin
Doing Taichi/ zen	-0.19	-0.14	-0.14	0.34	-0.18	-0.21	0.16	-0.14	0.35	-0.11	0.70	-0.14	-0.12
Jogging	0.52	-0.23	-0.23	0.09	0.08	0.69	0.31	-0.26	0.04	0.39	0.15	-0.28	0.03
Doing exercise	0.55	-0.15	-0.15	0.35	-0.17	0.17	0.13	-0.17	0.19	0.57	0.33	-0.17	0.00
Children playing	0.36	0.78	0.78	0.23	0.20	-0.10	-0.28	-0.14	-0.33	0.20	-0.17	-0.17	0.58
Couple dating	0.06	-0.19	-0.19	0.40	0.09	0.39	0.63	-0.24	0.57	0.06	0.41	-0.24	-0.23
Camping/ picnic	0.02	-0.15	-0.15	0.39	-0.20	0.02	0.44	-0.05	0.24	0.04	0.78	-0.15	-0.12
Walking baby	0.67	0.11	0.11	0.30	0.50	0.49	-0.19	-0.22	0.04	0.51	0.23	-0.22	0.19
Watching animals	0.01	-0.10	-0.10	-0.36	-0.13	-0.26	-0.29	0.76	-0.40	-0.11	-0.19	0.51	-0.23
Sitting and idling	0.14	0.08	0.08	0.55	-0.15	0.10	0.60	-0.18	0.39	0.09	0.36	-0.27	0.04
Strolling	0.61	-0.13	-0.13	0.29	0.32	0.64	0.19	-0.29	0.18	0.43	0.27	-0.28	0.04
Fishing	-0.24	-0.17	-0.17	0.25	-0.20	0.27	0.88	-0.17	0.29	-0.18	0.27	-0.17	-0.11

Also, accessibility to the park may be seen as a buffer zone, precluding outsiders' access in many ways such as by using motorcycles, bicycles or walking. Because of this buffer zone effect for such approaches, users may find other spaces for their activities instead of entering the park. However, as small squares or well paved common playgrounds are inevitably open space, some activities like doing Taichi/exercises which require space, have the highest frequency, while some activities that require larger space as watching animals, or birds, often take place in this space.

In Group 2, most activities often take place in lake-adjacent areas that have public facilities such as benches, trash bins, vegetation and visual objects, or has the medium level of openness, noticeably the high frequency of couple dating and fishing. However, this space has a low accessibility level and no recreational setting such as game facilities for fee, and no fitness equipment. As can be seen, despite the low quality of public functions and the low level of accessibility, most activities still take place in this space. In addition, the suitability of the openness factor in the space also needs consideration in order to prepare for the process of developing public space for private activities like couple dating. Meanwhile, natural or artificial water bodies are necessarily mentioned in the design of open space for human activities as water is an important factor for people (Alexander 1977).

In Group 1, almost no activities take place frequently as the space of this group is neither adjacent to the water nor of good quality, nor well-organized. This space is simply a vacant place or lawn without public facilities. Recreational amenities such as paid-for game facilities and fitness equipment were set up here, but almost no one uses them very often. More importantly, such space practically has no activities like sitting & idling or couple dating.

The current situation of open space in 29-3 Park reveals that apart from improving the quality of amenities set up for public spaces such as benches, trash bins, vegetation and well paved paths, the development or renovation of open space needs to take openness and privacy into consideration. The entrance zone/gate also needs to separate such accessible space as parking lots from buffer zones between the street and inside space. The maximal development of water-adjacent space opens more avenues for people to get closer to water. Also, research findings proved whether the removal of the boundary between the inner part of the park and surrounding street space is necessary as the current spatial border of 29-3 Park is formed by the high degree of disparity between inside and outside spaces that leads to a lack of activities in street-adjacent space.

Thus, the increased interaction between open space and street space would encourage many more activities, while thoroughly exploiting unused spaces.

The results of user's behaviors and physical environment density provided a calculation model for evidence-based designs. The positive correlation between activities in the space and physical environment density plays a role as a reference value for input data of the design and renovation process, and activities that occur in the space can be used to explain the density of various elements/ facilities.

Although the findings possibly provide information for the design and renovation of open spaces such as parks in Vietnam and other urban areas of developing countries with the same social context, this research still has some

limitations. The survey time should be extended to a whole day to discover all activities in this space, including negative activities at night. Also, activities need to be surveyed over different seasons and events (such as lunar new year) to explore the change in activities in different time frames. Moreover, this investigation does not examine contextual aspects of the park such as location of the study area in the context of the city, transportation models, and other surrounding social factors that influence the behavior pattern of the park. Future studies should consider the above-mentioned points and consider the relationship between behaviors and the environment under differing climates, cultures, user profiles and affordability. The behavior mapping method needs improvement by using Google-based GPS to minimize errors when data is collected. Measurement of indicators as green trees, lawns and other objects through Google and Landsat images with low resolution was carried out, but time was wasted in collecting data. IKONOS (1m) images with higher resolution will facilitate data collection for faster and more precise calculation of the density of physical settings. Also, the redesign and renovation of this space requires the collection of feedback from professionals, experts, administrators and users, and this will help to prepare input data for subsequent studies in the future. Such research can provide in-depth insight into the environmental quality of open spaces within users' impressions. In addition, it is necessary to investigate impact factors in the vicinity of this park such as land-use factors or usage characteristics of street open spaces and its amenities.

CONCLUSIONS

Although the Vietnamese government is seeking to increase urban open space areas and to attract more users by various ways, such as improving or creating open spaces (e.g. streets, riversides, or lakes), how to possibly improve or create an open space that can attract human activities is still an unanswered question. In this paper, the relationship between the physical environment and user behavior has been explored systematically, contributing a theoretical basis for creating a successful and user-friendly park. Although there are pseudo public spaces developed in Vietnamese cities such as commercial malls, the urban park still plays a crucial role as a unique and irreplaceable space for recreational activities, health related activities and social activities of residents. The design and development or improvement of urban parks should consider three main functions serving recreational purposes, health-related activities and social interaction. In order to thoroughly exploit the possibilities to make the park more attractive, it is necessary to improve the quality and quantity of public amenities; to separate accessible space/buffer zone from used space near the entrance zone/gate into the park; to ensure privacy in the space; to provide walking paths to approach the water surfaces; and remove obstacles (e.g. walls around the park) to give a clearer view from the interior of the park to the streets outside and vice versa. Finally, the calculation model for evidence-based designs that provides input data for re-planning/ organization of public spaces/parks is suggested in accordance with the area density of the corresponding physical environment to human activities. In addition, the frequency of user behaviors can be adjusted based on the ratio of the physical environment in each section, which would help designers, planners, and authorities to improve or design open spaces in the future. Finally, user's behavioral and psychological needs should be seriously considered in an objective, scientific and comprehensive way during the process of designing, planning, and developing urban parks and urban open spaces.

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