【カテゴリーⅠ】

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VARIATIONS OF SPATIAL QUALITIES EXPERIENCED IN ROOFTOP GARDEN OF MIX-USED BUILDING IN TOKYO

東京の複合用途建築の屋上庭園において経験される空間の質の変化

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This study examines the aspect of variation of spatial qualities on the user's experience in selected public rooftop gardens (RG) in Tokyo. Firstly, a combined method of fieldwork and simulation was used to describe the physical attributes in different environmental conditions to disclose the variation in RG settings. Secondly, these setting's patterns are interpreted through parameters of experience to reveal the tendency of variation in each parameter. Finally, by connecting setting and experience, the quality factors of RG will emerge as a tangible and intangible relationship between Space Affordance with Usage and Image of Identity.

Keywords: *Spatial quality, Urban public space, User's experience, Rooftop garden, Recreation*
空間の質，都市の公共空間，利用者の経験，屋上庭園，レクリエーション

1.Introduction

1.1.Background and purpose

The design of urban recreation space (URS) in compact cities is a challenging task due to multiple problems of heat island, the limitation of resource and the potential threat to public health[1)]. While roof greening is a widely recognized solution for reducing the environmental effect[i)], in Japan, this green space integrated into the building is bringing the metropolitan lifestyle a new dimension[ii)]. Especially in Tokyo, interests toward the mix-used buildings rooftop garden as a green space available-for-all had proved positive results for the inhabitant well-being[iii)]. This increasing typology of URS intrigues the questions about the quality of such space in an urban setting like Tokyo metropolitan.

Besides, in the author's previous publication[2)], Spatial Quality was defined as a composition between three factors of Usage, Space Affordance and Image of Identity. Also, emerged through a combination of spatial setting and user experience, Spatial Quality is expected to enhance the design of URS in compact cities. However, without illustrating the mechanism of Spatial Quality via the interaction between its factors, the previous research has not yet defined the focal point in the conception of Spatial Quality. Hence, this study aims to understand the interaction between the quality factors via the study of variations in the spatial settings, which affects the user experience.

1.2 Past studies and relevancy

Urban public space consists of a complex relationship between the user and various factors related to physiological, psychological, social and environmental[3)]. Hence, among the researches on urban public space considering the user's parameters, there exist many alternative fields such as environment-behavior, urban space design, human thermal comfort, etc. Among them, the research of Mehta[4)] tends to address many aspects as once through an evaluating framework focusing on the Spatial Quality of urban public space. In this framework, there are five factors rated by users, in which three are considered suitable for the situation of Rooftop Garden (RG) in Tokyo. These factors are defined as Meaningful, Pleasurable and Comfortable[iv)]. Each of these factors is then elaborated through further researches described as follows.

Firstly, in the user-participation, Thiel[5)] defines the experience as a Path going through the overlapping setting of Zone and being interpreted by the user's perceptual system. While Ashihara[6)] proposes the parameters of Boundaries, which are

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the limits between zones and Chen[7] classifies these boundaries as affordances. But Chen's target was on the qualities of the streetscape. Secondly, in the field of environment-behavior, Canter[8] explains the Meaningful aspect of urban space based on the user's Purpose and be driven by their action in space. Gehl[9] then categorizes the actions depends on the user's Opinion on Activity as it is a necessity, an optional or a social activity. Further, an elaborated study from Kiso[10] put on comparison the opinion of the user with their behavior in space. But Kiso's topic was on semiosis. Thirdly, for the Pleasurable aspect in urban design, Lynch[11] explains that the users create the city image through their perception. Carmona[12] then defines the perception of the user via the parameter of View and Almazan[13] seeks to associate this parameter to Opinion on View. Almazan's research, however, was aimed at understanding the user's opinion via a cross-cultural analysis. Lastly, for Comfortable aspect in outdoor space, various researches are addressing the thermal comfort in the outdoor environment using indicators such as WBGT and SET*[v] or the remarkable tool developed by Hoyano related to MRT[14] to predict discomfort situation for future design. However, the direction of this current study aims to integrate the parameter of the user's experience. For that reason, the direction related to thermal adaptation developed by Nikolopoulou[15] in the environmental design field is considered more appropriate. In this direction, thermal satisfaction has been found to differ between users and it is proven to be influenced by their spatial experience. This finding inspired Thorsson[16] to study thermal comfort with human behavior in outdoor activities, but Thorsson's target was to compare the behaviors in different urban public space. Finally, by adopting this direction and the framework of Mehta's[4], the Comfortable aspect in this research will consider two climate criteria as the influence of shading and shelter. These criterias are then interpreted as the Shading toward the sun and the enclosure toward the Wind Flow.

By combining these above parameters defined from the referred researches, this study adopts the framework of evaluating Spatial Quality of urban public space by introducing a combined method of data collection integrating the fieldwork and simulation focusing on the relationship of user-space-environment. By matching the data extracted from each collection method, the variation in the quality of RG will manifest differently through different users. As to say, this study's aim is not to evaluate the design of contemporary URS, but to find beneficial elements of the RG from the viewpoint of the user to contribute to a better design of URS.

2. Method of study

2.1 Framework

The framework is detailed in Fig.1; structure in three steps corresponding to chapters 3,4 and 5. In the first step, the method of data collection will combine the fieldwork by observation and

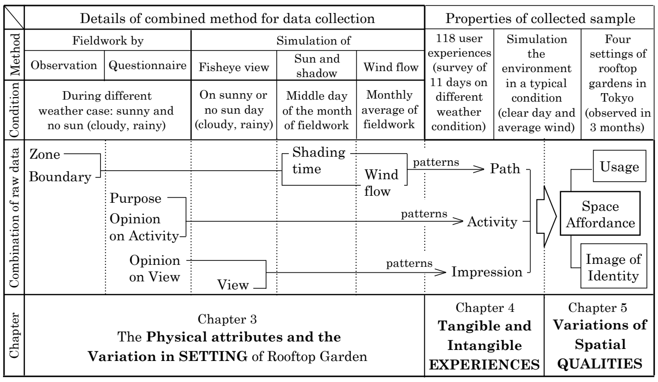


Fig.1 Framework

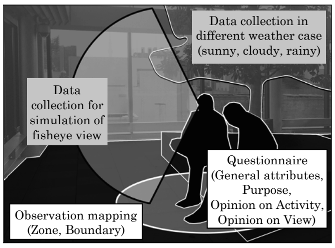


Fig.2 Fieldwork by observation

Table 1a Questionnaire part I: Purpose

Come with: alone, family, friend
Frequentation: often, rarely, first time
Transport: bus/train, bicycle/walk, car
Know this place by: self, other people, media
Intended activity: Passive (eat, sleep, rest, watch nature), Active (play, meet someone, go out)
Impression: activity, access, visibility, atmosphere

Table 1b Questionnaire part II: Opinion

Opinion on Activity	Opinion on View	
Easy to use	Scenery	Panorama
Flexible		Vegetations
Can meet others	Affected by weather	Furnitures
		People outdoor
Optional activity (other than the intended one)	Landscape	Sign, entrance
		Pavement

*User rate criteria based on Libert scale : Great (5), Good (4), So so (3), Poor (2), Bad (1)

Table 1c Fieldwork schedule

CS	Date	Time	Weather	Sample	
Kitte	Sep 19	11AM - 2PM	Cloudy	14	28
	Aug 6	11AM - 3PM	Sunny	14	
	Oct 22	2PM - 4PM			
Omohara	Oct 5	3PM - 4PM	Cloudy/ Rainy	15	31
	Oct 19	12AM - 1PM			
	Aug 16	1PM - 4PM	Sunny	16	
Ginza Six	Aug 7	11AM - 3PM	Cloudy/ Rainy	15	29
	Oct 17	1PM - 2PM			
	Aug 18	12PM - 3PM	Sunny	14	
	Oct 22	12PM - 2PM			
Isetan	Sep 17	2PM - 3PM	Cloudy/ Rainy	15	30
	Oct 5	11AM - 12AM			
	Oct 19	2PM - 3PM			
	Aug 17	1PM - 2PM	Sunny	15	

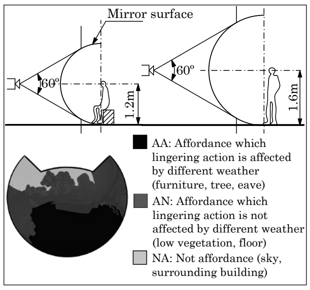


Fig.3a Simulation of fisheye view

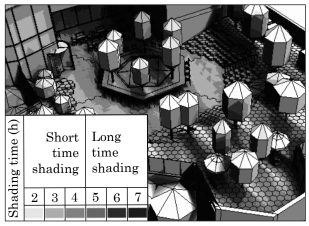


Fig.3b Simulation of sun and shadow

Table 2 Wind data for simulation

Monthy average (source WEADAC)	Velocity	Direction
August	2.3 m/s	South
September	3 m/s	North
October	3.8 m/s	North-Northeast

*Velocity average is calculated following the data of 11:00AM to 5:00PM according to fieldwork period.

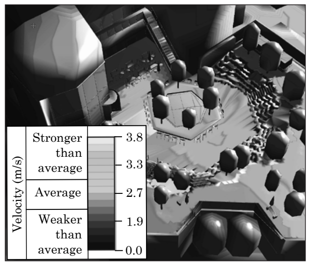
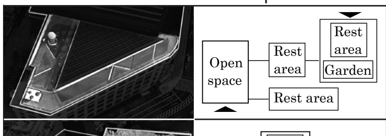


Fig.3c Simulation of wind flow

Table 3 Cases studies of Rooftop Garden from SEGES classification

	**Case 1 - Kitte**: 6th floor of Kitte Japan Post Tower (built 1931, renovated 2012) -1500 m² (50% floor area) -Owner: Japan Post Co., Ltd. -Designer: Mitsubishi Jisho Sekkei Inc. -Program: shops, post office, event hall
	**Case 2 - Omohara**: 6th floor of Tokyu Plaza Omotesando-Harajuku (2012) - 820m² (70% floor area) -Owner: Tokyu Real Estate Co. -Design: NAP Architects, Takenaka Co. -Program: shops, cafe, garden
	**Case 3 - Ginza**: 13th floor of Ginza Six (2017) - 2000m² (60% floor area) -Owner: GINZA SIX Retail Manager Co. -Design: Yoshio Taniguchi, Kajima Co. -Program: offices, theatre, shops, garden
	**Case 4 - Isetan**: 9th floor of Isetan Shinjuku (built 1933, renovated 2013) - 1500m² (60% floor area) -Design : Mitsukoshi Isetan Co., Ltd. -Program: shops, banquet room, garden

questionnaire with the simulation of fisheye view, sun/shadow and wind flow. Also, the condition for data collection is defined for each method and the collected raw data are combined to a specific pattern, as shown in Fig.1. The assembly of these patterns will explain the Physical attributes and the Variations in the Settings of RG of chapter 3. In the second step, each pattern is interpreted as Activity, Path and Impression. These parameters represent the user's Experience and will be categorized as tangible or intangible in chapter 4. In the last step, through a combination of Setting and Experience, the variations of Spatial Qualities will emerge as a tangible and intangible relationship between Space Affordance with Usage and Image of Identity in chapter 5.

2.2 Method of collecting data

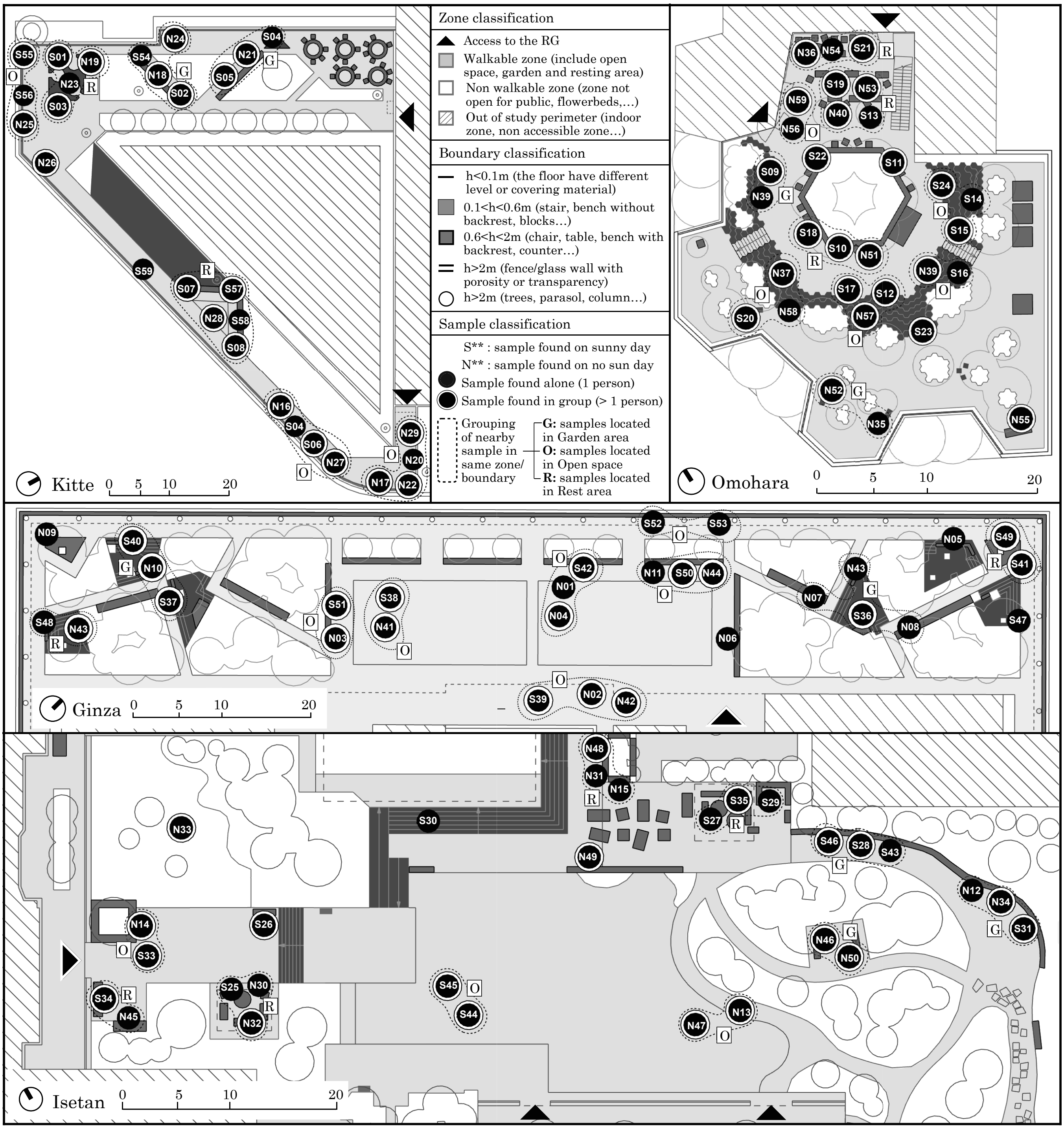
This sub-chapter explains the method for data collection from fieldwork and simulation. In fieldwork, data collected from each sample represents the real situation of the users on-site in specific time and weather. While in simulation, data collected from each sample in variable weather conditions represent the average conditions of RG affecting the user's situation.

For fieldwork, observation and questionnaire were used to extract information of the users on-site. The raw data of each sample are illustrated in Fig.2. The observation method collects the mapping of the zone where users were found and their behavior along with the existing physical element considered as boundaries. After finding the location where users most frequent, a questionnaire will be conducted in these locations with user agreement to collect data such as their general information[vi], purpose and opinion (Table 1a, 1b). While users complete the online form, their posture and view angle were captured using the photograph. The fieldwork was conducted on four case studies in different weather, such as sunny or no sun (cloudy, rainy) from August to October 2018. And a total of 118 samples were collected with equal distribution on all sites and weather (Table 1c).

For simulation, different software were used to illustrate the typical condition of space where users were found during fieldwork. As for the fisheye view, based on the photo collected from fieldwork, a rendering of each sample's view angle was built via a reversed mirror semi-sphere positioned at human eye level[vii] (Fig.3a). By applying the idea of Ashihara, the following process will remove the above part of the frame of the fisheye, then define the outline of each component identified in the frame for pixel calculation[viii]. As for sun/shadow and wind flow simulation, the locations of 118 collected samples are simulated under typical weather of the fieldwork period. This period, from August to October, is when the weather presents a moderate sun shading and wind velocity. This condition is moderate and could avoid the extreme influence of weather, which is considered most appropriate for outdoor lingering. Hence, the fieldwork questionnaire doesn't cover the range of thermal satisfaction and also the level of simulation is also defined at the level of early-stage environmental modeling. Specifically, for sun and shadow simulation[ix], sun path is chosen on the middle day of the month, within the time interval of 10 am to 5 pm, which corresponds to the observation timeline (see Table 1c). The result provided data of all the shaded zone during the study period and will be classified by long or short shading time (Fig.3b). Parallelly, the wind flow simulation[x] is based on the monthly data taken from WEADAC[xi] (Table 2), where the input of speed and direction was defined as average during the interval from 10 am to 5 pm, also corresponds to observation timeline. The result provided visualized data of airflow and wind speed variations on the sites, which will be considered as stronger or weaker than the average input from WEADAC (Fig.3c). The collected data of all the above simulations will be combined with the data of fieldwork for further analysis.

2.3.Case studies of rooftop garden

This sub-chapter explains the process of selection for case studies of RG in the mix-used building. Since these URS was built mostly by the private firms and had the highest concentration in Tokyo Metropolitan[xii], this research then focuses on this typology classified in an evaluation scheme of the Social and Environmental Green Evaluation System[xiii] Urban Oasis (SEGES). Firstly, these conditions were applied to the list of SEGES selection from 2013 to 2018: being a rooftop garden, locating in the city center, presenting a high ratio of the garden (50% surface of floor area) and having at least three primary areas such as open space, garden and rest area. Secondly, eight selected buildings were visited and a preliminary survey was conducted with its users to confirm the similarity on the level of activity, access, visibility and atmosphere[xiv]. From the preliminary results, four sites are chosen as case studies. Its general information and organization are described in Table 3. For details, Case 1 Kitte is a renovation project focusing on a long promenade with a panoramic view of Tokyo station. This promenade guides users into different portions of the garden and rest area. Case 2 Omohara, on the other hand, is organized around a hexagonal open space and rest area surrounded by the garden. The unique appeal of this RG is the design of stairs around the central area, which is the transition between different areas. Case 3 Ginza is the most recent project of RG with the highest in altitude. The RG has a symmetrical plan concentrating on the open space with lawn and water. On both sides, the gardens are combined with rest area and long promenade around the RG. Case 4 Isetan is the pioneer of public RG in Tokyo, which showcases the landscaping garden distinguishing through seasons. The gardens are organized around a vast lawn space and multiples isolated shaded rest areas. As to mention, these case studies present not only the similarities in general attributes but also have their singularity in the organization between the area of open space, garden and rest area, which is covering various situations for the analysis of variation in this research.



* Plan delimitation is within the perimeter that could be observed permanently during fieldwork.
* Zone classification is based on observation of user's behavior during fieldwork. Boundary classification is related to Fig.5.
* In this figure, picked samples (numbered) is approximately the position of user answering questionnaire during the fieldwork scheduled in Table 1c.
* Grouping sample was defined when there is a frequentation more than one time at an area (during observation and questionnaire).
* Size of the illustrated sample doesn't represent the number of collected answers. It is only to distinguish if the collected sample is from the user being alone or in groups

Fig.4 Mapping Zone-Boundary-Sample

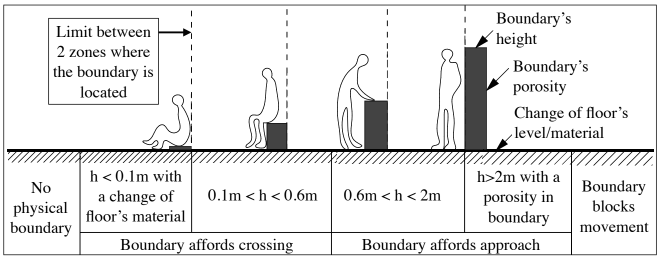


Fig.5 Boundaries features

Table 4a Parameters of Purpose

Samples in weather case	Purpose parameters (motivation to come)	Alone: Yes	Alone: No	Came before: Yes	Came before: No	How to move: Self	How to move: Public	Know this by: Self	Know this by: Others
Sunny	59	15	44	28	31	19	40	24	35
No sun	59	13	46	17	42	18	41	17	42

* In this table, data is collected from the questionnaire of Table 1a.
* The number represent the collected sample in different weathers of all case studies.

Table 5a Parameters of Opinion (A)

Samples in weather case	Opinion on activity parameters	Easy to use: Average	Easy to use: Good	Flexible: Average	Flexible: Good	Optional activities: Average	Optional activities: Good	Can meet others: Average	Can meet others: Good
Sunny	59	11	48	17	42	35	24	33	26
No sun	59	10	49	12	47	27	32	36	23

* In this table, data is collected from the questionnaire of Table 1b.
* The number represent the collected sample in different weathers of all case studies.

Table 4b Pattern of Purpose

Sample 118 (59/59)	Alone	Came before	Transport	Know it by	Patterns of Purpose (motivation to come in different weather case)
S02	○	○	○	○	**P0** No motivation (just happen to be) **7 (5/2)**
N23	○	○	○	○	
S45	○	●	○	○	**P1** One driven motivation **14 (7/7)**
S30	○	○	●	○	
S04	○	○	○	●	
N45	●	○	○	○	
N34	○	●	○	○	
N12	○	○	○	●	
S11	○	●	○	●	**P2** Two driven motivations **21 (14/7)**
S17	●	●	○	○	
S26	○	●	●	○	
S01	○	○	●	●	
N20	●	○	●	○	
N29	○	●	○	●	
N01	○	○	●	●	
N09	●	○	○	●	
N02	●	●	○	○	
S10	○	●	●	●	**P3** Three driven motivations **39 (17/22)**
S27	●	○	●	●	
S38	●	●	○	●	
S09	●	●	●	○	
N18	○	●	●	●	
N11	●	○	●	●	
N24	●	●	○	●	
N07	●	●	●	○	
S03	●	●	●	●	**P4** Four driven motivations **37 (16/21)**
N03	●	●	●	●	

*In this table, ○ and ● are referring to the parameters in Table 4a.
*Picked sample is the first one collected of the samples list from fieldwork which have the pattern.
*Number represent the quantity of collected samples found in each weather case (S/N) respectively.

Table 5b Pattern of Opinion on Activity

Sample 118 (59/59)	Easy to use	Meet others	Flexible	Optional Activity	Patterns of Opinion (on activity)
S56	○	○	○	○	**OA0** All average **3 (1/2)**
N51	○	○	○	○	
S11	●	○	○	○	**OA1** Rather average **19 (11/8)**
S02	○	●	○	○	
S48	○	○	●	○	
S21	○	○	○	●	
N25	●	○	○	○	
N28	○	●	○	○	
N08	○	○	○	●	
S04	○	●	○	●	**OA2** Moderate **35 (20/15)**
S20	●	○	●	○	
S32	●	●	○	○	
S16	○	●	●	○	
S12	○	○	●	●	
S05	●	○	○	●	
N05	○	●	○	●	
N48	●	●	○	○	
N12	○	●	●	○	
N59	○	○	●	●	
S03	○	●	●	●	**OA3** Rather good **42(19/22)**
S29	●	○	●	●	
S01	●	●	○	●	
N01	○	●	●	●	
N43	●	○	●	●	
N23	●	●	○	●	
N13	●	●	●	○	
S08	●	●	●	●	**OA4** All good **19 (8/11)**
N04	●	●	●	●	

*In this table, the use of ○ and ● is referring to the parameters in Table 5a.
*Picked sample is the first collected of the samples list from fieldwork which have the pattern.
*Number represent the quantity of collected samples found in each weather case (S/N) respectively.

Table 6 Pattern of Shading time

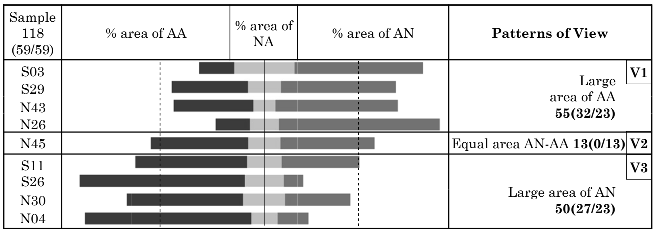
Sample 118 (59/59)	August	September	October	Patterns of Shading time (total shaded hours from 10am to 5pm)
N16(K)	○	○	○	**ST0** No change in short shading time **39 (18/21)**
S10(O)	○	○	○	
N01(G)	○	○	○	
S25(I)	○	○	○	**ST1** Exist change between short and long shading time **31(15/16)**
S02(K)	●	○	○	
S12(O)	●	●	○	
S18(O)	○	●	●	
N55(O)	○	○	●	
N41(G)	●	○	○	
N10(G)	○	●	●	
N12(G)	○	○	●	
N13(I)	●	●	○	
N12(I)	○	○	●	
N03(G)	●	●	●	**ST2** No change in long shading time **48(26/22)**
S12(O)	●	●	●	
S01(K)	●	●	●	
N14(I)	●	●	●	

*In this table, the data resulted from the simulation of Fig.3b. Symbol follows the defined parameters.
○ Short time shading
● Long time shading
*Sample position is used for simulation data. This position is illustrated in Fig.4. The abbreviation K,O,G,I shows that samples are found at Kitte, Omohara, Ginza or Isetan.
*Picked sample is the first one collected from the fieldwork list, it is the sample which is representing the illustrated pattern. The number represents the collected samples found in each weather case (S/N) respectively.

Table 7 Pattern of Wind flow

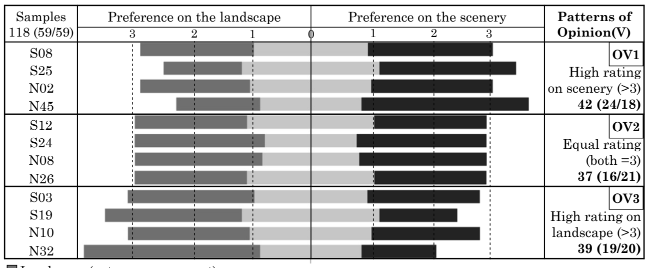
Sample 118 (59/59)	August	September	October	Patterns of Wind flow (monthly average velocity & direction)
N02(G)	○	○	○	**WF0** No change in weak velocity compare to average **12 (4/8)**
S25(I)	○	○	○	
S01(K)	●	●	○	**WF1** Exist change between weak and strong velocity compare to average **98(49/49)**
N16(K)	○	●	○	
S10(O)	●	○	●	
N36(O)	○	○	●	
N42(G)	●	○	○	
S47(G)	●	●	○	
N09(G)	●	○	●	
S49(G)	○	●	●	
N03(G)	○	○	●	
N49(I)	●	○	○	
S28(I)	●	●	○	
N46(I)	●	○	●	
S26(I)	○	●	●	
N34(I)	○	○	●	
S20(O)	●	●	●	**WF2** No change in strong velocity compare to average **8(6/2)**
S52(G)	●	●	●	
S27(I)	●	●	●	

* In this table, the data resulted from the simulation of Fig.3b. Symbol follows the defined parameters.
○ Velocity weaker than the monthly average
● Velocity stronger than the monthly average
* Sample position is used for simulation data. This position is illustrated in Fig.4. The abbreviation K,O,G,I shows the sample is found at Kitte, Omohara, Ginza or Isetan.
* Picked sample is the first collected from the fieldwork list, which is representing the illustrated pattern. The number represents the collected samples found in each weather case (S/N) respectively.



■NA: not affordance (sky, surrounding building)
□AN: Affordance by which lingering action is not affected under different weathers (floor, low vegetation)
■AA: Affordance by which lingering action is affected under different weathers (furniture, tree, eave)
*In this table, the image frame and area is defined in Fig.3a. The number represent the quantity found in each weather case (S/N) respectively. Picked sample represents at least 20% of the related pattern.

Fig.6 Pattern of View



■Landscape (entrance, pavement)
□Affected by weather (furniture, people)
■Scenery (green, panorama)
*In this table, the rating parameters are defined in Table 1b. The number represent the quantity found in each weather case (S/N) respectively. Picked sample represents at least 20% of the related pattern.

Fig.7 Pattern of Opinion on View

3. Physical attributes and variations in settings of RG

Through data collection, 118 samples were collected containing properties related to the user's real situation captured on-site and the average condition simulated. With the actual situation, data samples will be classified and combined in two sets of [Purpose-Opinion on Activity] and [Opinion on View-View]. With the average condition simulated, samples will be classified into sets of [Zone-Boundary] and [Shading time-Windflow]. The details of each set and its corresponded variations are explained as follows.

3.1 Variation of settings by Zone and Boundaries

Through mapping during observation, Zones of RG are classified by their walkability. The three zones are defined as walkable, non-walkable and out of study perimeter. The users were found only in the walkable zone. This zone has three different areas according to user behavior, defined as the open space (playground, lawn space, walkway), the garden (abundance of trees and green) and the rest area (shaded area for sitting). In each area, if the user is found being in specific locations more than once, the locations are considered supported lingering activities and 118 selected samples for further analysis are then chosen in these locations (Fig.4). The lingering activities are supported by the existing physical elements defined in this research as Boundaries. Boundaries are illustrated by their height in Fig.4 and classified by complementary features in Fig.5, such as porosity, material and whether it is affecting the lingering activities by allowing crossing/approach or blocking movement. As an overview, observation on Zone-Boundary of all sites shows a similarity of samples from both weather sunny (S) and no sun (N) in open space(O), garden(G) and rest area(R). However, in the rest area, samples of S and N tend to be found in the nearly same spot but not in the case of the open space and the garden. Concerning each case, samples in Kitte and Omohara tend to be found in a large grouping, while in Ginza and Isetan, it is more scattered in smaller quantities on the whole site.

3.2 Variation of settings by Purpose and Opinion on Activity

Through the questionnaire, data of Purpose and Opinion on Activity are collected. As for Purpose, it is interpreted as the motivation influenced by external factors, as shown in Table 4a. The classification finds that in both weather cases, users are attracted to RG by external factors (more than 50% responds) and this ratio is similar in both cases. The same high ratio appears in the Purpose patterns of Table 4b. There is majority found in P3, P4 (cover more than 60%) with the same pattern appearing in case of S and N. However, it exists another pattern (cover 30%) in other cases of P0, P1, P2 where the variety in each case of S and N is different. These patterns confirm the existence of variations in Purpose. While for Opinion on Activity collected through the questionnaire, the parameters are classified as shown in Table 5a. A high ratio (more than 50%) and a similar rating were found in both weather cases of intended activity while this proportion change in the following parameters. This distinctive pattern with the majority found in OA2 and OA3 even though it exists similar quantity and variety of S and N in most of the case. This result proves the existence of variations in Opinion on Activity.

3.3 Variation of settings by Opinion on View and View

As proven by Gibson[22], visual perception can influence how people recognize affordance and how they adapt their way of being in space. This perception is interpreted as patterns of View and patterns of Opinion on View. As for View, by analyzing the results collected from fisheye view simulation, patterns are classified by a large area of AA, AN or both, as shown in Fig.6. This classification is strongly related to weather cases. In Opinion on View (Fig.7), the questionnaire data are categorized as following a high rating on scenery, on the landscape, or an equal rating on both. The finding shows in Fig.6 an absence of samples S in V2 while the ratio between S and N found not much difference between V1 and V3. While the results in Fig.7 shows no variations in all patterns for both weather cases and a similar ratio is found in each pattern (around 33% in OV1, OV2, OV3). It can prove that the variation between S and N is shown in the pattern of View while it is not visible at this level of analysis in Opinion on View.

3.4 Variation of settings by Shading and Wind flow

Through simulation of sun/shadow (shading) and wind flow, the simulated data are classified into different categories related to the average condition of weather. The details of each pattern of Shading Time and Wind flow are explained in Table 6 and Table 7. In Shading Time (Table 6), even though the pattern of ST2 is superior to others, but the ratio distribution is almost equal (26% to 40%). This finding presents no major predominant in all patterns of all cases study. On the other hand, in Wind Flow (Table 7), the majority is found in WF1 (83%), which has the most variety of patterns. Concerning each case study in WF1, in Kitte and Omohara, the variations are less present compared to the case of Ginza and Isetan. The case of Kitte particularly doesn't exist in patterns of WF0 and WF2, which could be explained by the minimal appearance of shading and windbreak on the site. This variation shows a strong relation to wind flow than to shadow despite mild weather during the fieldwork period. It can be explained by the locations on top of the building of cases study.

4. Tangible and intangible experiences

As Thiel[xv] mentioned in the user-participation research, the user adopts their unique way to understand the physical attributes of space, which results in their own experience. In the direction of POE (post-occupancy evaluation), this chapter focuses on the user's evaluation of their experience, by interpreting the variations of patterns found from the previous chapter.

4.1 Intangible aspect of Activity

RG in the mix-used building provides multiple functional areas which afford lingering, relaxation and encourage users to walk around. Hence, the range of Activity classified in Table 8a shows the quantity of all types with a similarity between S and N. However, in Table 8b, the tendency of Activity, interpreted by crossing the patterns of Purpose (P0 to P4) and Opinion on Activity (OA0 to OA4) shows a different tendency. As an overview, passive Activity, despite the high ratio (near 50% of total samples), has a distribution scattered in most cases of the cross patterns while active Activity concentrates mostly in the case of the majority of A1, A2, A3. Concerning the distribution within the case of the majority, while in A1, S tends toward more passive than in N, in A2 the distribution is nearly equal and in A3 the ratio tends toward N. However, these tendencies are only isolated in the specific case of majority and aren't repeated in the case nearby. This finding could not solidify a regular order in distribution, which explains the intangible aspect of Activity.

4.2 Intangible aspect of Impression

As for the range of Impression described in Table 9a, the parameter of Good impression is in the majority (80%) and is found with nearly equal distribution for S and N. Then, by crossing the patterns of View (V1 to V3) and Opinion on View (OV1 to OV3) in Table 9b, the tendency of Impression shows a broad distribution of this parameter in most of the case. Especially in the case of N, this parameter showing nearly the same quantity, but there is no specific order. Inside the majority case of I1 to I6, this parameter also indicates the highest ratio, but there is no particular order to distinguish between S and N. This finding also explains the intangible aspect of Impression.

4.3 Tangible aspect of Path

The tendency of Path is a combination of patterns of Zone-Boundary and patterns of Shading Time-Wind Flow, as shown in Table 10. Firstly, from the physical features of boundary presenting in each area (open space, garden and rest area), features considering height, texture, enclose and green elements are classified. This range of features results in eight main configurations (PO-PG-PR) with not much difference in quantity between them. The main configuration also has some variants depends on the sample position in each case study. Secondly, the range of Path also follows an order of Shading Time (ST) and Wind Flow (WF) patterns. By connecting the boundary features and patterns of ST/WF, the tendency of Path is revealed in five

Table 8a Range of Activity

Activity range (Purpose & Opinion on Activity relationship)	In sunny weather case (S)			In no sun weather case (N)		
	Passive (P)	Active(A)	Multiple (M=A+P)	Passive (P)	Active(A)	Multiple (M=A+P)
Sample 118 (59/59)	23	15	21	29	12	18

*In this table, the number represent the collected sample

Table 8b Tendency of Activity conditionned by Purpose/Opinion(A)

Tendency of Activity / Patterns of Purpose / Patterns of Opinion on Activity		P0 No motivation (7)			P1 One motivation (14)			P2 Two motivation (21)			P3 Three motivation (39)			P4 Four motivation (37)		
		P	A	M	P	A	M	P	A	M	P	A	M	P	A	M
OA0 All average (3)				(0)			(1)			(0)			(2)			(0)
	S	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
	N	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-
OA1 Rather average (19)				(5)			(2)			(3)			(6)			(3)
	S	3	-	1	-	-	1	-	-	3	1	-	2	-	-	-
	N	1	-	-	1	-	-	-	-	-	3	-	-	1	-	2
OA2 Moderate (35)				(1)			(5)			(4)			(11)			A2 (14)
	S	1	-	-	-	1	3	2	-	1	2	-	2	1	5	2
	N	-	-	-	-	-	1	1	-	-	4	1	2	1	3	2
OA3 Rather good (42)				(1)			(4)			A1 (12)			(10)			A3 (15)
	S	-	-	-	2	-	-	3	3	-	3	2	1	1	3	1
	N	1	-	-	2	-	-	-	3	3	3	-	1	2	4	4
OA4 All good (19)				(0)			(2)			(2)			(10)			(5)
	S	-	-	-	-	-	-	1	-	1	3	-	-	-	-	3
	N	-	-	-	2	-	-	-	-	-	5	-	2	1	1	-

*In this table, Purpose patterns result from Table 4b, Patterns of Opinion on Activity from Table 5b.
*Number in each unit is as follows, using parameters of Table 8a.
*Majority represents more than 10% of total samples collected.

This number represents the collected samples where the combination of patterns is found (*).
(in S) P A M
(in N) P A M
These number represents each Activity range within the combination of P*xOA* on S/N.

Table 9a Range of Impression

Range of Impression (Opinion on View and View relationship)		Sample (118)
In case of S	Excellent (E)	7
	Good (G)	39
	Average (A)	13
In case of N	Excellent (E)	9
	Good (G)	42
	Average (A)	8

*In this table, the numbers represent the collected samples.

Table 9b Tendency of Impression by View/Opinion(V)

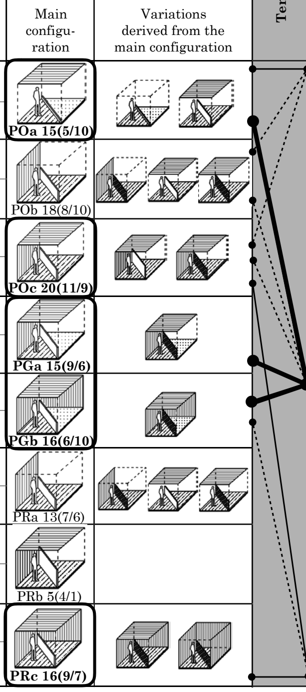
Tendency of Impression / Patterns of View / Patterns of Opinion on View		V1 Large area of AA (55)			V2 Equal area AN-AA (13)			V3 Large area of AN (50)		
		E	G	A	E	G	A	E	G	A
OV1 High rating on Scenery (42)				I1 (18)			(4)			I4 (20)
	S	-	8	2	-	-	-	3	7	4
	N	1	7	-	-	3	1	-	6	-
OV2 Equal rating (37)				I2 (18)			(5)			I5 (14)
	S	2	7	1	-	-	-	2	4	-
	N	2	4	2	1	3	1	4	4	-
OV3 High rating on Landscape (39)				I3 (19)			(4)			I6 (16)
	S	-	9	3	-	-	-	-	4	3
	N	-	7	-	-	4	-	1	4	4

*In this table, Opinion patterns are results from Fig.6. View patterns are results from Fig.7.
*Number in each unit is explained as follows, as parameters of Table 9a.

This number is the collected samples where the combination of patterns is found (*).
(in S) E G A
(in N) E G A
These number show each Activity range within the combination of OV*xV* on S or N.

Table 10 Tendency of Path by Zone/Boundary and pattern of Shading/Wind flow

Range of Path by physical features of boundary in each area	Height: h < 0.1m	Height: 0.1m < h < 0.9m	Height: 0.9m < h < 2m	Texture: Opaque	Texture: Porous	Texture: Change in floor material	Enclose: No enclose	Enclose: 1 side	Enclose: 2 sides	Enclose: 3 sides	*Green: Present	*Green: Non-present	Main configuration	Range of Path by patterns of Shading Time (ST): ST	Range of Path by patterns of Wind flow (WF): WF
Open space (O)	●					●	●					●	POa 15(5/10)	No change in short ST 39	No change in weak WF 12
	●					●		●				●			
		●			●			●			●		POb 18(8/10)		
		●		●				●			●				Exist change between weak and strong WF 98
		●		●					●			●	POc 20(11/9)		
			●		●				●		●			Exist change of short & long ST 31	
Garden (G)		●			●				●		●		PGa 15(9/6)		
		●				●			●		●				
		●			●					●	●		PGb 16(6/10)		
		●				●				●	●				
Rest area (R)		●		●				●			●		PRa 13(7/6)	No change in long ST 48	
		●			●			●				●			
			●	●					●		●		PRb 5(4/1)		
			●		●				●			●			
		●		●						●	●		PRc 16(9/7)		No change in strong WF 7
		●			●					●		●			



* In "Range of Path by physical features boundary":
- The distinction between area is based on observation, user's position in each area is indicated in Fig.4.
- The use of ● symbol indicates if the physical features are appearing in the boundary configuration.
- *Green parameter covers the range of vegetations affecting on the affordance of lingering activity (creating shade, enclose, ornament for viewing).
- The number indicates the quantity of samples of boundary configuration found in different area during fieldwork.

* In "Range of Path by patterns of Shading Time (ST) & Wind flow (WF)":
- Patterns of ST and WF result from the analysis of Table 6 and Table 7. Number represents the collected sample.
- The selected configuration need to cover at least 10% of the relevant pattern.

* In "Tendency of Path":
- The use of ●—● indicates that relationship exists both in ST and WF
- The use of ●···● indicates it exists only in ST or WF.
- The bolder line shows that there exist large samples corresponds to the specific pattern.

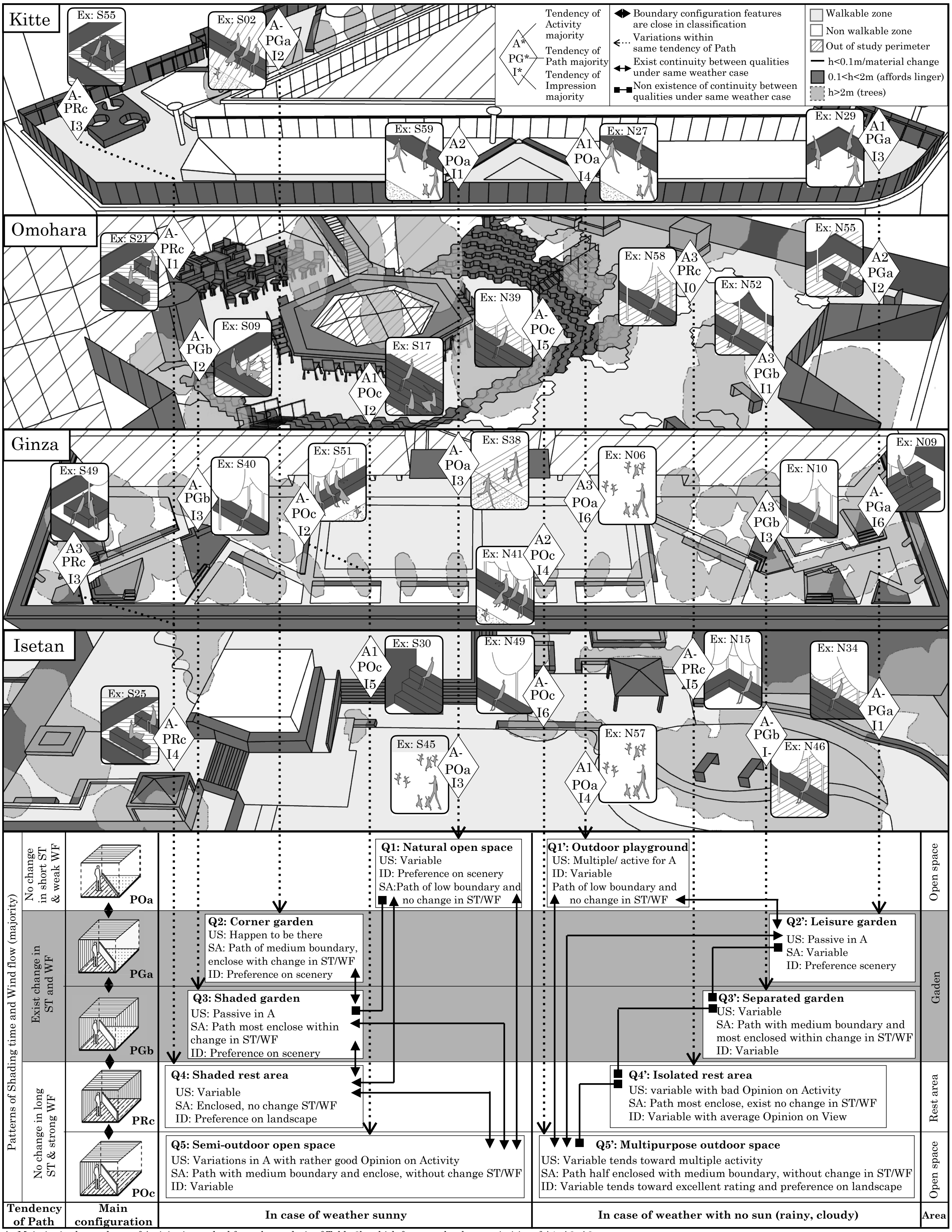
majorities of configurations depends on each of the RG areas, defined as POa, POc, PGa, PGb, PRc. These major configurations exist in all cases, which represents the tangible aspect of Path.

5.Variation of Spatial Qualities in the rooftop garden

Qualities of URS emerge from the overlapping factors of Setting (chapter 3) together with the factors of Experience (chapter 4). Hence, to study the variations of Spatial Qualities, it is necessary to understand the relationship between these factors of quality. As explained by the previous research[2)], the factors of Experience as Activity, Path and Impression strongly influence the factors of Quality as Usage (US), Space Affordance (SA), Image of Identity (ID), respectively. As found in the previous chapter, only the factor of Path shows a tangible aspect that can be measured and understood through the combination of ST/WF and physical boundaries. For this reason, the Tendency of Path is considered as the base of variations. Hence, the difference in its configurations will indulge in the change of Activity and Impression. Furthermore, as samples represent the situation of four RG case studies in two situations of sunny and no sun, it is relevant to compare between different weathers on the Quality factors. As shown in Fig.8, the emerging spatial variations of qualities can be understood through three layers of relationship.

Firstly, the relationship can be described by the organization of the area by function. As an overview, all case studies contain at least a main Path configuration belonging to each of the areas of Open space (POa, POc), Garden (PGa, PGb) and Rest area (PRc). These Path configurations in different case studies are illustrated in different variants, but they are all related to each other since they all belong to the same Tendency of Path. This finding explains that despite the complexity, these case studies of URS tend to present a standard level of spatial qualities for the users.

Secondly, the relationship is shown by associating the variants of Path in each case study with their relevant factors of Activity and Impression. This relationship between US-SA-ID factors will emerge to describe the variations of spatial quality ranging from Q1 to Q5 in the sunny case and Q1' to Q5' in no sun case. Even though these situations having the same configuration of SA, the variants in weather could indulge different US and ID. For instance, Q1 and Q1' differ each other by the preference on active Activity, making the open space of Q1' being a playground while the preference on the scenery of Opinion on View making



* Majority in the tendency of Activity is resulted from the analysis of Table 8b, which focus on the three majorities of A1, A2, A3
* Majority in the tendency of Impression is resulted from the analysis of Table 9b, which focus on the six majorities of I1, I2, I3, I4, I5, I6
* Majority in the tendency of Path is resulted from the analysis in Table 10, which focus on the five majorities of POa, POc, PGa, PGb, PRc
* Activity/Purpose-Opinion on Activity is interpreted as Usage (US). Path/ Zone-Boundary/ Shading Time - Wind flow is interpreted as Space Affordance (SA). Impression/ View-Opinion on View is interpreted as Image of Identity (ID).
* Quality of RG (Q) is resulted by the combination of US-SA-ID.

Fig.8 Variations in Spatial Qualities of Rooftop Garden the one of Q1 tends toward a green nature open space. Besides, the impact of weather could result in turning the qualities toward more positive or negative. For instance, a shaded rest area in Q4 could be considered as an isolated rest area in Q4' when the presence of many enclosures affecting on the Opinion of View and Opinion of Activity. Or, a semi-outdoor open space in Q5 could be qualified as a multipurpose outdoor space in Q5', with an excellent rating on Impression and more multiple activities.

Finally, the spatial qualities of Q1-Q5 and Q1'-Q5' are not isolated situations, but they all belong to the whole spatial organization of RG and relate to each other. Associated by the similarity in each factor of US-SA-ID, each variation of spatial qualities could have a connection to another, therefore preserve a homogeneous continuation in space or interruption in sequence between spaces. Fig.8 illustrates this potential continuity between these qualities as belonging to the same or different areas between O-G-R. For instance, the natural open space of Q1 has possible to link to the semi-outdoor open space of Q5, which is the case that exists in Ginza. Or the isolated rest area of Q4' could not be connected to the multipurpose outdoor space of Q5' since these spatial qualities present more opposition than similarity. Therefore between these spaces, it exists boundaries blocking vision and movement, as in the case of Isetan. Furthermore, this relationship of continuity between spatial qualities could appear both in sunny and no sun case but also could be different between two weather cases. For instance, Q1 and Q5 in the sunny case and Q1' and Q5' in no sun are always found near each other in all case studies. However, the continuity generated from Q2-Q3-Q4 and Q2'-Q3'-Q4' is different depends on weather and case study. This difference could be explained by the complexity in the configuration and the influence of the weather. This finding suggests the attention on the design of urban open space, which takes into consideration the spatial qualities as an evolutive and interactive situation in which variations have an essential impact on the user's experience.

6. Conclusion

Attempting to study the variations of spatial qualities in RG of the mix-used building in Tokyo, this research aimed to present a comprehensive system to measure the variations of settings of urban recreation space of rooftop gardens affecting on user's experience. The finding shows and explains the different levels of variations in the relationship between user-space-environment, as illustrated as follows. Firstly, the analysis of physical attributes contributes to the variation in settings of RG. Despite the difference due to weather conditions and site location of samples, a common pattern of settings was found in the variation of each parameter set. The result confirms the success of these URS in the role of promoting users to engage with the green environment and enhance the social aspect of the city lifestyle. Secondly, in the analysis of the tangible and intangible aspects of the experience factors, the result demonstrates the importance of Space Affordance based on the tangibility of Path. This quality factor shows a tendency that can be measured and further be predicted as part of a guideline to design urban public space. Thirdly, by combining the tendency of Activity and Impression based on the tendency of Path, qualities of URS emerge as an evolutive and interactive system. This system involves a multidisciplinary research field that will require further analysis. However, a framework related to evaluating this aspect of quality has always been a subject for the research of enhancing urban public space in compact cities. The whole approach shows the benefits and complexities involved in the design of URS, especially in the era of climate change. City governance is still researching on solutions for sustainable development for compact cities. Therefore this theoretical framework will need to be developed to find adaptive solutions that could be applied to the design of urban recreation space. This study has contributed efforts in these aspects.

Finally, the scope of this study is limited to a specific period of fieldwork due to the complexity of changing the weather and also the simple tools for simulation, which were used to find common framework with other factors related to user experience. Whether this result may apply to other locations and situations under different weather conditions, it needs further investigation.

Acknowledgment

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Notes

i) In February 2009, the "Report on the environment effects of policies addressing the urban heat island effect" confirmed the solution of green roof as the most economical among local authorities (ヒートアイランド対策の環境影響等に関する調査業務報告書 , 環境省)

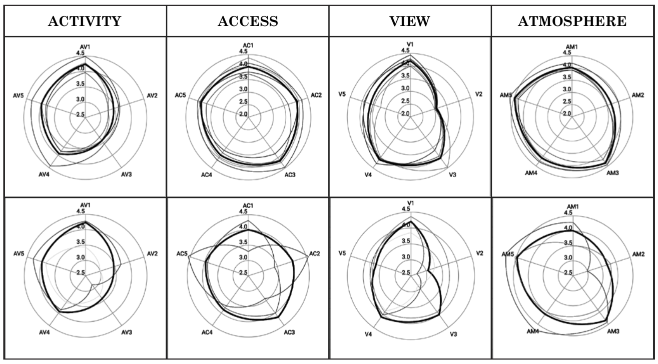
ii) Mix-used building refers to the public function added to private buildings such as office or commercial. In reference 20), Dimmer explains that the creation of the mix-used building in Japan generally came from the necessity to diversify the function of building in central during the nighttime while the most population was displaced to the adjacent town.

iii) In 2014, a report on the proportion of green roof by size and type of building in Japan from 2000-2014 had pointed out that with surface greater than 1000m^2 the medical and welfare facilities shows a growing demand. (平成 26 年全国屋上・壁面緑化施工実績調査の結果報告 , 国土交通省) Furthermore, interested in the benefit of green space toward well-being, the Center for Urban Design and Mental Health established in Tokyo in 2015 have published a few case studies. (Urban Design Mental health 2017;3:4, available at www.urbandesignmentalhealth.com/journal.html

iv) The other two factors are Inclusiveness and Safety, which are considered not relevant for the case study of Rooftop Garden in Japan.

v) The Ministry of Environment's guideline recommends the use of WBGT and SET* as indicators. Available at www.env.go.jp/air/life/heat_island/guidelineH30 (accessed 2019.07.29)

vi) General attributes of each sample consist of sex (male, female), age range (under 35, 35-60, over 60), distance from staying/working place to the RG (less than 15', around 30', over 1h). The questionnaire tried to cover an equal quantity of sex and age. However, most of the samples collected have a longer distance to RG due to their location in city center.



vii) In reference 21), Bourke explained there are enough approximations between this method and the equiangular fisheye projection generated by the software. Hence, this method is suitable for this study.

viii) In reference 6), Ashihara explains that for open space, the design focuses on the exterior architecture, then the part of the sky in rendering is cut off. Additionally, in reference 5), Thiel explains how to capture the view and the pixel calculation in the fisheye method.

ix) This simulation uses Google Sketchup Shadow Analysis plugins to generate shadow every 15 minutes during the defined period. The environment considers only the direct sunlight and clear sky. Models were built considering elements provided shade as higher than 2m (tree, wall, eave) with material allows no transmission and no porosity. In reference 17), Gherri compare this tool with others in the same field and prove that the results are viable for the level required for this study.

x) This simulation uses Autodesk Flow Design plugins to generate air movement, speed and pressure constant on the sites. This software utilizes the CFD techniques consists of the LES turbulence model and the Navier-Stokes equations to simulate airflow. The models were built within its urban settlement, considering windbreak on-site as elements higher than 2m (tree, wall, eave). Following the set up of wind tunnel in the reference 18), all models were made at full scale in the computation domain on a ratio of 4L-3W-3H (length-width-height) and a mesh size resolution of 150%. Wind flow is analyzed in full 3D at transient mode until it reaches the stabilized state to export results. This method provided the general data and not considering the material, porosity and surface of the ground and windbreaker. However, reference 19) compared this software with other tools for CFD simulation and prove that these results are viable for the level of analysis in this study.

xi) WEADAC is a climate system that creates data for 3762 cities worldwide using the data from Meteorological Data System TOP.

xii) In the same report as iii), from 2000-2014, the proportion of green roof by all private facilities represents more than 50% and the proportion of green roofs in Tokyo 23 ward cover around 40% national wide.

xiii) SEGES Urban Oasis selection established in 2013 by the Organization for Landscape and Urban Green Infrastructure to promote sustainable development in cities via promotion of social value through quality green space. This organization is supported by the Ministry of Land, Infrastructure, Transport and Tourism. (『SEGES(シージェス)：都市のオアシス』, 公益財団法人都市緑化機構, 国土交通省)

xiv) Below the results of the preliminary survey on the eight cases of RG in central Tokyo, the four above graphs show the result of four selected cases study and four below graphs shows the others four cases studies which were not selected (Coppice Kichijoji, Tamagawa Takashimaya, Ginza Mitsukoshi, Shinjuku Marui Honkan). The preliminary survey consisted of visiting the site and asking 10-15 users on each site to rate on the level of activity, accessibility, visibility and atmosphere. This preliminary survey was done during June-July 2018.

xv) See reference 5) for the framework related to the user's experience.

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和文要約

本研究は、都市のレクリエーション空間（URS）において、空間の質を決定づける要素の間にある、隠れた関係を理解することを目的としている。既報において示したように、空間の質には２つの主要な特徴がある。まず第一に、それらは「使い方」、「空間のアフォーダンス」、「独自の印象」という３つの要素の組合せによって確立される。第二に、それらは利用者の経験に影響を与える空間の状態を分析することによって理解される。そして本報では、こうした既報で得た知見を発展的に見直し、構築環境や天候が及ぼす利用者への影響を変数とし、それらの差異がもたらす様相を統合する。つまり、本報での試みとは、利用者の経験に関係するそれぞれの変数において、予測可能な様相、予測不可能な様相という弁別的な特徴を明らかにすることを目的とするものである。そして、その成果は、緑地を融合した都市の公共空間の有効性を評価するための、包括的な方法を提示するものと考える。また、その結果は、コンパクト・シティにおいて、人々の健康や社会、環境との関わりを促進する屋外の活動を拡張することにつながり、それは気候変動の時代において不可欠であると考える。

研究対象：
複合的な用途の建物の屋上を対象とする。SEGES の評価方法をもとに、広く一般に公開された緑化空間の成功例として認められている、東京の中心部に位置する４事例を選定した。

研究方法：
・利用者の経験に関する７つの変数で構成された、統合的な枠組みを用いる。これらの変数は、都市の公共空間における利用者の評価に関する様々な既往の研究を吟味して得られたものである。
・フィールドワークとシミュレーションによって得られたデータを組み合わせて分析する。データとして得られた 118 個のサンプルは、フィールドワーク期間中、異なる場所や天候において屋上庭園で観察された、幅広い層の利用者を代表するものである。
・分析の手順は、以下の通りである。
１）まず、利用者の物理的な状態に関する変数として、４つの組合せを分析する。それらは、「ゾーン - 境界」、「目的 - 活動に関する意見」、「視界 - 視界に関する意見」、「日射遮蔽 - 風の流れ」である。そして、各々の組合せにみられるパターンから、URS における物理的な状態の差異を明らかにする。
２）次に、各々のパターンのセットが、「活動」、「行路」、「印象」という、利用者の経験に関する変数として解釈される。その結果が示す傾向から、利用者の経験における予測可能な要因と、予測不可能な要因が識別される。
３）最後に、「行路」の傾向として見出された予測可能な要因が、URS における空間の差異を理解するための基礎となるものとして考察される。

結論：
１）物理的な状態に関する分析では、変数の組合せのすべてにバリエーションがみられた。
２）利用者の経験に関する分析では、「活動」と「印象」が予測不可能な様相として、「行路」が予測可能な様相として解釈されることを示した。
３）物理的な状態と利用者の経験の組合せから、空間の質のバリエーションには、領域の構成に関する傾向に類似性がみられること、「行路」の位置と空間の質の変化に関連がみられること、天候の違いに応じて領域間には空間の質に連続性がみられることを明らかにした。

本研究は、コンパクト・シティの変化に適応するための、利用者の経験や、様々な環境条件に基づく空間の質に関する研究の重要性を示すものである。

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