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RESEARCH ARTICLE

The built environment of Japanese shopping streets as visual information on pedestrian vibrancy

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Abstract
Twenty shopping streets in Tokyo, Japan, were analyzed based on pedestrian vibrancy and visual information by assessing physical dimensions, objects, shops and quantity of pedestrians and walking speeds. Field survey recorded 12-h periods of a typical weekday by tracking daily variations between July 3rd to August 3rd, 2017 and October 13th to November 10th, 2018. For analysis, Hierarchical Cluster and Discriminant Analyses were performed using the statistical software, SPSS v.24. The study classifies four clusters of shopping streets accordingly to pedestrian vibrancy as eccentric, with large street dimensions and big retailing shops; strong, with variety of specialized daily life stores, balanced, with lower specialized daily life stores, closer residential area and moderate numbers of flower pots; and weakened, with very few shops, residential predominance and higher numbers of flower pots. Findings indicate that larger street dimensions together with specialization of shops, rather than variety or number, are prone to slow walking speeds and larger numbers of people. Also, it was noticeable the connection of number of flower pots with proximity of residential areas. It could be theorized that pedestrian vibrancy correlates inversely to the proximity of residential areas. The closer residential area is the lowest pedestrian vibrancy would be.

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1. Introduction

1.1. Study objective

The present study aims to classify 20 shopping streets in Tokyo, Japan, by assessing the relationship between pedestrian vibrancy and visual information. This study proposes the assumption that environments with a high presence of physical dimensions, objects, and shops correlate to observable changes in the number of pedestrians and their walking speeds. Additionally, this study expects to fulfill a literature gap by addressing the quantitative presence of physical objects and shops on Japanese shopping streets in relation to walking audit instruments (Ewing and Handy, 2009).

1.2. Pedestrian vibrancy and visual information

The resemblance of public spaces to living organisms can be explained under similar parameters of how alive, active, or vibrant these spaces are in accordance with pedestrian activities. Gehl classified pedestrian activities into the following categories: necessary, which is related to daily commuting or running errands; optional, which is undertaken at one's own will; and social, which is spontaneous and results from optional activities (Gehl, 2011). In accordance with social aspects, many scholars have agreed that streets are common places where people perform daily, functional, and ritual activities; hence, streets are important to the community and nurture social cohesion (Carr et al., 1992; Okabe, 2017). Similarly, Harb related the successful social and economic life of high-density areas, such as city centers or shopping streets, to vibrancy (Harb, 2016).

On the pedestrian scale, the configuration of visual information in built environments can provide the notable distinctiveness of urban contexts (Rapoport, 1990). Visual information plays a vital role in the perception of spatial attractiveness and successfulness (Gehl, 2011; Ewing et al., 2016; Rapoport, 1990). Moreover, visual information is capable of non-verbally communicating environmental meaning by providing "legibility and readability," the ease with which information is perceived and understood (Rapoport, 1990). Thus, the legibility and readability of visual information can influence the walking choices and decisions of people on the basis of the transmitted degree of attractiveness. Rapoport and Hawkes (1970) described visual information as a desirable and vital characteristic when properly utilized at the pedestrian scale. Visual information must not be too simple to sustain pedestrian interest when moving at an average of 1.33 m/s (4.8 km/h) (Rapoport and Hawkes, 1970).

In the context of shopping streets, visual information must consider the existence of objects, physical dimensions, and other critical assets, such as the amount and type of shops. In commercial and mixed-use areas, past observations support the assumption that the typology and quality of visual information, together with commercial typology, can positively or negatively influence pedestrian dynamics (Carmelino et al., 2016).

The literature review of Ewing and Handy (2009) addressed the statistical relation between visual information and pedestrian vibrancy by rating quantitatively subjective qualities, such as imageability, enclosure, human scale, transparency, and complexity (Ewing and Handy, 2009). Although the authors noted several contextual and cultural restraints, the study presented new insights into the future mixed applications of qualitative and quantitative techniques for statistically measuring notable relationships between street environments and pedestrian vibrancy. Similar studies conducted in Asian megacities have statistically supported the remarkable association of pedestrian volume and speed with visual information (Matsumoto et al., 2012; Lee et al., 2017).

1.3. Characteristics of Japanese streets

In traditional Asian cities, streets remain to be the primary organizational component of community cohesion (Sorensen, 2009). According to Okabe (2017), the distribution of roads in most Asian cities, as characterized by the arrangement of narrow alleys and tiny buildings, is in response to the monsoon climate as a means of temperature regulation. This arrangement results in territories without clearly defined borders, which uniquely characterizes the morphology of Asian cities in comparison with western cities (Okabe, 2017). In this regard, the uniqueness of the scale complexity of alleys and roads in Japanese cities satisfies social cohesion through the provision of private–public realms, which is in stark contrast to western cities where the streets' organization mostly relies on junctions with plazas.

Tokyo has been undergoing many meaningful transformations since 1868. At the beginning of the Meiji Restoration, Tokyo had to adapt to its role as the new political center of Japan. Important changes, such as changing the city's name from Edo to Tokyo (the eastern capital), took place to renew contact with Western nations.

Rapid modernization and connectivity to isolated areas of the city resulted in the introduction of a new transportation infrastructure. The new infrastructure, in conjunction with the latest city regulations, such as railways and new zoning types, drove the city to a process of subdivision, thereby generating a unique fragmented patchwork grid. The aftermath of the Second World War also contributed to the introduction of the new infrastructure and zoning principles, which overlapped with remaining ones and thus intensified the urban grain of Tokyo City (Sorensen, 2005; Maki, 2012).

According to Maki (2012), a Japanese architect, none of the overlapping grids can be construed as predominant in Tokyo City. The factor that provides the essential characteristic of spaces in Tokyo is deeply rooted in the imagination of the people and implemented as common knowledge (Maki, 2012). Shelton (1992) noted that the organization of grids allows the formation of nodes for activities rather than acting as centers where roads simply meet and merge. Japanese streets channel movements for urban services and are flexible enough to quickly change into "place" when a social event occurs (Shelton, 1992). These terms help communities share common spatial hierarchies from topographical characteristics or existing landmarks. Although Maki considered coincidences in the utilization of words

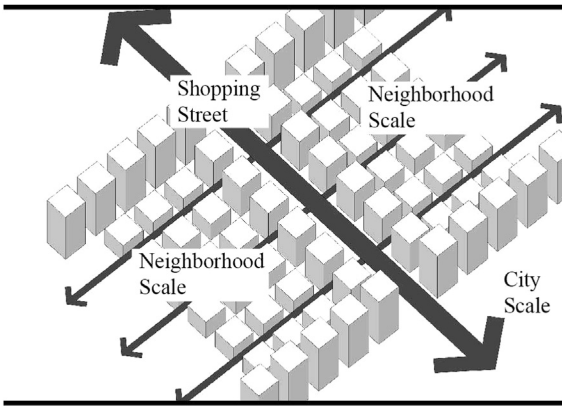

Figure 1 Shopping streets as transition space between city and neighborhood scales.

with other cultures and communities worldwide, he postulated that the term "Oku" is unique when used to refer to Japanese cities.

Complementing Maki's ideas, Okabe (2017) expanded on the concept of Oku and defined it as "deepness" or "space with depth," which indicates a dynamic space that can achieve social cohesion. What makes a city in Japan highly dynamic compared with European cities is the particular networks of narrow alleys, which invite people to go deeper rather than centric (Okabe, 2017). Notably, this complex system of alleys is responsible for the city's scale organization and sustaining the daily socio-spatial events of dwellers.

This deepness in the spatial organization of grids positions shopping streets as a common ground for scale transition of dwellers between city and neighborhood functions (Figure 1).

1.4. Development of Japanese shopping streets

Shopping streets are vital to the livability of any city because they emphasize lifestyle characteristics that are defined by patterns of activity from the social and cultural values of a population leveraged by shopping habits (Harb, 2016; Balsas, 2016).

"Shōtengai" is the arrangement of stores that grew organically along main roads leading to landmarks or another symbolic urban hierarchy present in a town or community, such as temples, shrines, or train stations (Balsas, 2016; Sorensen, 2005).

In the 20th century, Japanese shopping streets met the necessary conditions for development and expansion. Several of them began as small retailers near new neighborhoods, and others began as black markets organized near train stations (Bi-Matsui, 2009). The construction and expansion of train stations after the Second World War increased the number of daily commuters, which considerably influenced the emergence of the majority of modern shopping streets and sprawls (Sorensen, 2005).

Etymologically, the word shōtengai is rooted in the conjunction of three pictograms (one of the three Japanese writing systems known as kanji): 商 (product), 店 (store), and 街 (town, district, and street). Such a conjunction results in the interpretation of shopping street and commercial town or district. The three definitions denote different physical dimensions and organizations from the western point of view. Thus, their meaning must be attached to the sense of the commercial event rather than to the physical setting.

Furthermore, despite its physical boundaries, a shōtengai implies a sense of mutual collaboration and fellowship among store owners by establishing their association, defining their identity, and creating ties with the nearby community. Most of the successful cases managed to cover their streets with seasonal decorations or improve the infrastructure, such as by providing special paving and street lighting. Moreover, they have begun functioning as local community centers that help strengthen social dynamics and nurture community cohesion (Sorensen, 2005).

Sorensen (2009) examined the positive effect that community involvement has on place making and the creation of new shared meanings for public spaces in the area of Yanaka in Arakawa Ward, Tokyo (Sorensen, 2009). The author revealed how self-empowerment of communities can perform a key role in the protection and revitalization of neighborhood streets as shared spaces that are capable of designing and developing new principles regarding urban changes.

1.5. Current condition

The Ministry of Economy, Trade, and Industry (METI) has established policies to vitalize and maintain vibrant shopping street areas in Japan cities (Bi-Matsui, 2009). Initially, these policies subsidized the unification of shopping street associations (SDAs) and allowed them to conduct improvements and renovation projects for shops and street infrastructures. However, these METI policies changed over time. In 1998, the development and implementation of projects were restrained to fall under the direction of central and local governments. All SDAs were affected in different ways through the lack of budget or establishment of new policies from their jurisdiction. Consequently, most SDAs decreased their investing activities in their shopping street projects, which demonstrated hesitation on the part of SDAs and shop owners in following the vitalization policies of METI (Bi-Matsui, 2009). For example, in 2000, METI enacted a new law to protect small shop owners and living conditions in areas where large-scale shops exist. However, the outcome of these efforts was the unplanned extinction of shopping streets in urban areas of Tokyo City. Thus, the current reduced number of shōtengai can be attributed to METI vitalization policies in addition to population displacement to new urban areas and construction of shopping malls nearby.

2. Study cases

Previous empirical surveys have shed light on the importance of visual information, especially the spatial furnishing of shopping streets in association with pedestrian speed and volume (Carmelino and Hanazato, 2016) (Figure 2). Matsumoto (2012) suggested that walking speed is expected to be slow in spaces where substantial content and information exist (Matsumoto et al., 2012). Therefore, pedestrians feel attracted. Hence, having a slow walking speed in attractive

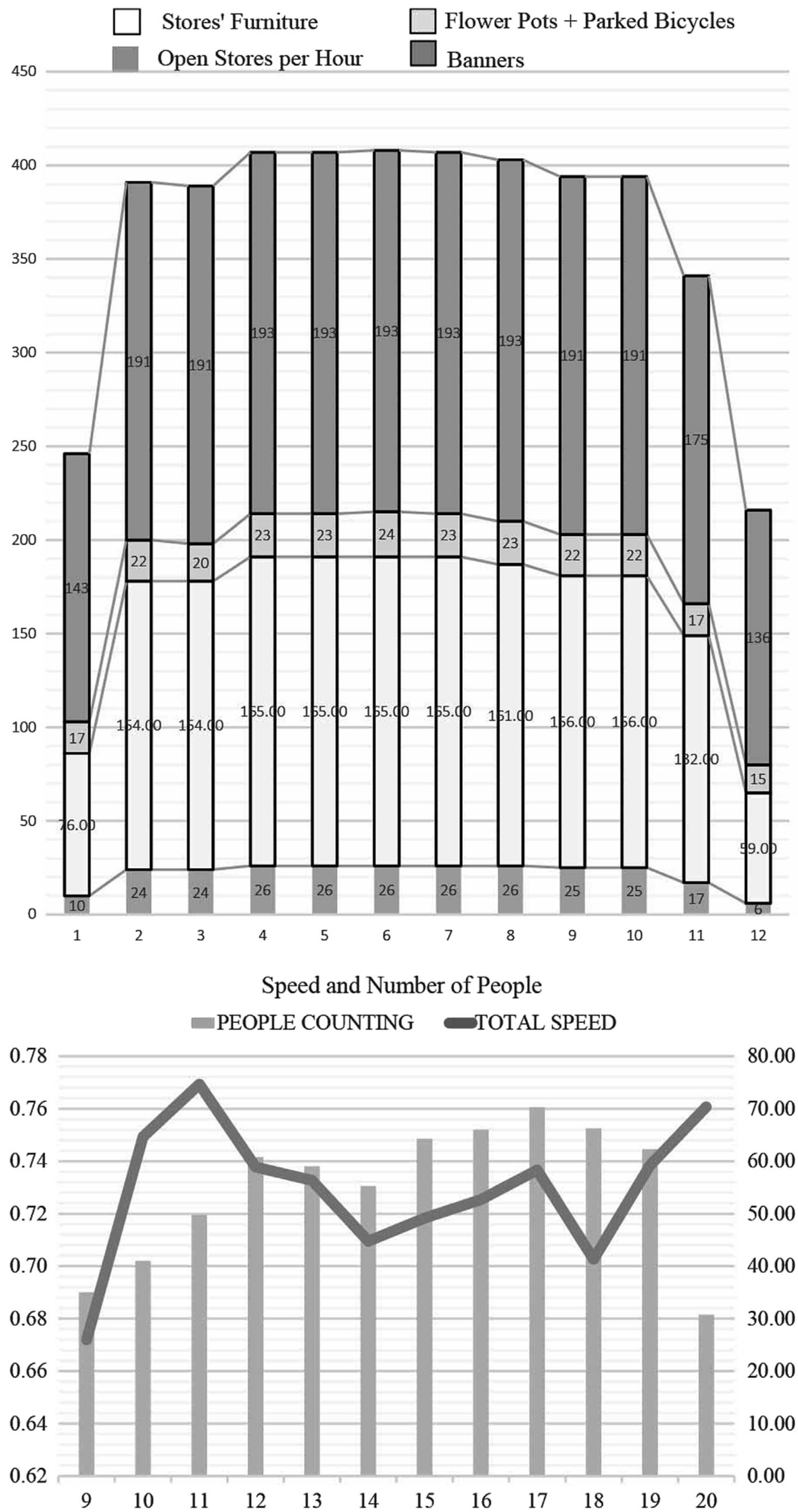

Figure 2 Twelve-hour variation of objects; speed and volume of pedestrians in Pearl Center Shopping Street, Suginami ward.

Figure 3 Study cases of shopping streets in Tokyo, Japan.

Table 1 Variable description.

Category		**Variable**			**Description**
VISUAL INFORMATION	**STREET DIMENSIONS**	Road	Width of Street (m)		Average measure taken from the gap of street between two-sided building fronts
			Walkable Surface of Street (m2)		Walkable area without automobile interruption
		Buildings	Side 1 Height (m)		Average height of one-sided building front in meters
			Side 2 Height (m)		Average height of one-sided building front in meters
			Average Building Height (m)		Average height of side 1 and 2 of building fronts
			Number of Storyes		Average number of storeys from side 1 and 2 of building fronts
			Total number of Stores		Total number of stores from side 1 and 2 of building fronts
	STORES	Total number of Stores			Total number of stores found on the 100-meter surveyed area
		Closed Stores			Number of closed stores per hour
		Open Stores			Number of open stores per hour
		Percentage of Open Stores			Percentage of open stores per hour
		Stores related to Goods			Number per hour of Stores related to Goods Vending
		Stores related to Services			Number per hour of Stores related to Services
		Stores related to Food			Number per hour of Stores related to Food Vending
	OBJECTS	Stores' Street Furniture			Number of street furniture per hour
		Banners			Number of banners per hour
		Flower Pots			Number of flower pots per hour
		Parked Bicycles			Number of parked bicycles per hour
PEDESTRIAN VIBRANCY		Number of Pedestrians			Average number of pedestrians encountered during four 100-meter-walkthroughs
		Speed Behavior by Gender (m/s) and Age Group	Speed of Male Pedestrians	Young (m/s)	Teenager - 30 years old
				Middle aged (m/s)	31 - 60 years old
				Elder (m/s)	60 - elderly
				Average (subtotal 1)	Average speed of male pedestrians in meters per seconds
			Speed of Female Pedestrians	Young (m/s)	Teenager - 30 years old
				Middle aged (m/s)	31 - 60 years old
				Elder (m/s)	60 - elderly
				Average (subtotal 2)	Average speed of female pedestrians in meters per seconds
			Total Average Speed		Total average speed from subtotals 1 and 2

areas is reasonable and can be an indicator of spatial attractiveness.

For Almazan and Tsukamoto (2007), the content and display of visual information in Japanese commercial contexts are the primarily asset in defining identity by a notion of "complexity" in contrast to the more "functional" Western approach (Almazan and Tsukamoto, 2007).

Following these arguments, this research compares shopping streets with unique conditions to comprehend the manner through which physical dimensions, objects, shops, and human variables contribute to their differentiation.

An onsite exploratory assessment was conducted to identify 79 shopping streets between April and May 2017 on the basis of the observed volume and walking speed and amount of spatial furnishing in the following wards: Ota, Setagaya, Kita Edogawa, Suginami, Chuo, Chiyoda, Toshima, Bunkyo, and Arakawa. Then, the field survey selected the following 20 study cases between July and August 2017: Shintomi Shoeikai and Chuo Dori (Chuo-ward), Irisan Shoutenkai and Milpa (Ota-ward), Boro Ichi and Shimokitazawa Minami Guchi (Setagaya-ward), Minami Koiwa Showa Dori and Hirai Shin Wakai (Edogawa-ward), Akabane Ichiban Gai

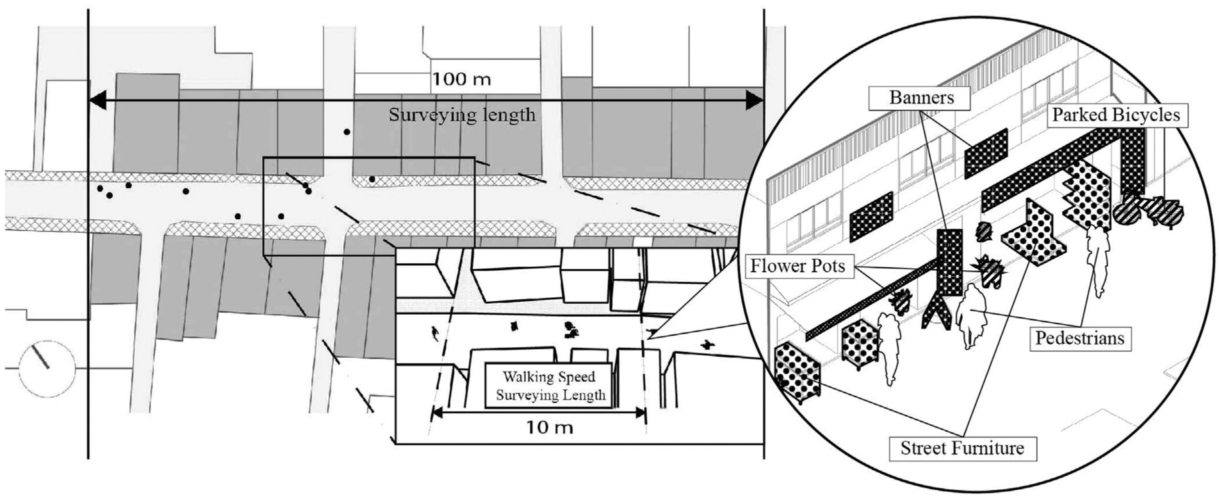

Figure 4 Counting of Pedestrians and objects.

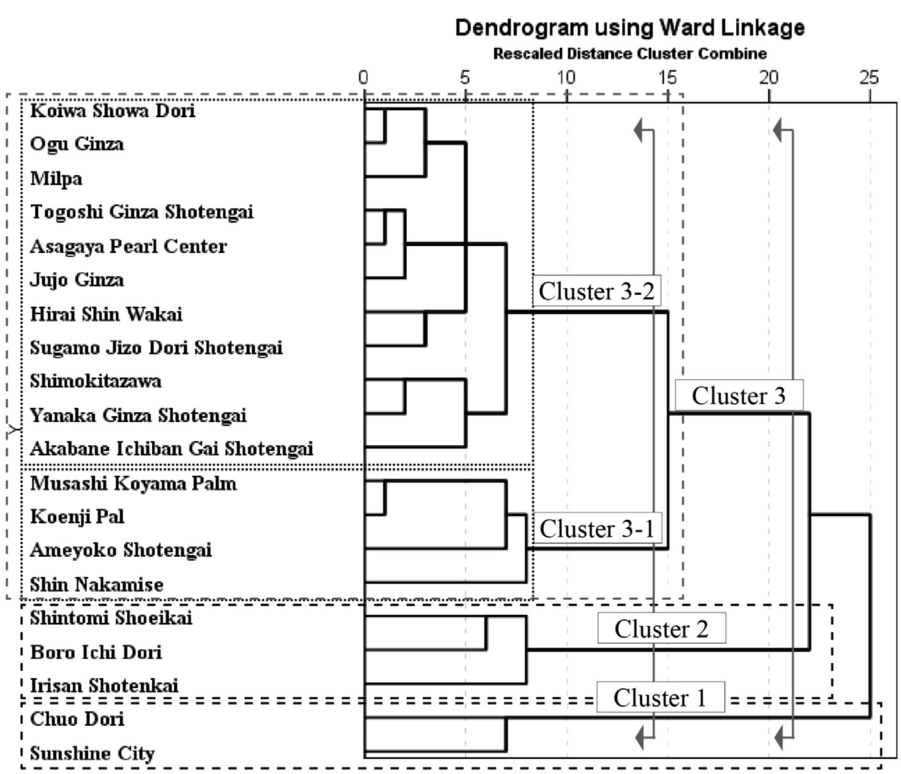

Figure 5 Clustering dendrogram of study cases.

Table 2 Clustering table of average values from 20 study cases.

			CLUSTER 1	**CLUSTER 2**	CLUSTER 3-1	CLUSTER 3-2	**CLUSTER 3**
VISUAL INFORMATION	STREET DIMENSIONS	Width of Street (m)	16.17	7.25	7.47	6.86	7.16
		Walkable Surface of the Street (m2)	1964.05	565.00	619.01	694.98	656.99
		Side 2 Height (m)	25.35	11.24	5.89	6.58	6.24
		Side 1 Height (m)	23.90	9.67	5.63	6.79	6.21
		Average Building Height (m)	24.63	10.46	5.76	6.69	6.22
		Average Number of Storyes	8.05	4.16	2.30	2.67	2.49
	SHOPS	Total number of Stores	21.50	11.00	36.00	29.45	32.73
		Stores related to Goods	10.00	2.67	18.00	13.18	15.59
		Stores related to Services	2.50	3.67	6.25	5.64	5.94
		Stores related to Food	9.00	4.67	11.75	10.64	11.19
		Number of Closed Stores	4.00	6.22	7.46	7.77	7.61
		Number of Open Stores	17.50	4.78	28.04	21.69	24.87
		Percentage of Open Stores	0.81	0.56	0.78	0.75	0.76
	OBJECTS	Number of Stores' Street Furniture	40.04	4.92	182.96	100.22	141.59
		Number of Flower Pots	3.50	51.67	5.50	19.90	12.70
		Number of Parked Bicycles	0.00	6.94	8.00	18.14	13.07
		Number of Banners	155.04	33.83	191.00	165.03	178.02
PEDESTRIAN VIBRANCY		Estimated Number of People per Store	16.74	1.27	4.56	3.01	3.79
		Average Number of Pedestrians	250.42	5.76	116.98	55.12	86.05
		Male Young Walking Speed (m/s)	1.19	1.47	1.22	1.40	1.31
		Middle Aged Male Walking Speed (m/s)	1.19	1.49	1.19	1.37	1.28
		Male Elder Walking Speed (m/s)	1.05	1.16	1.09	1.24	1.16
		Males Walking Speed (Average - m/s)	1.14	1.49	1.17	1.34	1.25
		Female Young Walking Speed (m/s)	1.14	1.47	1.14	1.31	1.22
		Female Middle Aged walking speed (m/s)	1.12	1.31	1.09		1.18
		Female Elder Walking Speed (m/s)	1.03	1.11	1.04	1.18	1.11
		Females Walking Speed (Average - m/s)	1.10	1.40	1.09	1.25	1.17
		Total Average Walking Speed (m/s)	1.12	1.45	1.13	1.30	1.21

Table 3 Mean and standard deviation.

	N	Mean	Std. Deviation
Width of Street (m)	132.000	6.556	0.602
Walkable Surface of Street (m2)	156.000	629.387	86.329
Average Building Height (m)	180.000	6.440	1.454
Stores related to Goods	180.000	14.467	4.924
Stores related to Services	180.000	5.800	3.340
Stores related to Food	180.000	10.933	4.767
Closed Stores per Hour	135.000	3.185	2.754
Open Stores per Hour	180.000	23.383	9.482
Stores' Furniture	170.000	106.259	53.472
Flower Pots	146.000	9.610	6.209
Parked Bicycles	150.000	10.460	7.464
Banners	165.000	170.394	41.504
Average Number of Pedestrians	176.000	68.811	41.118
Total Average walking speed (m/s)	173.000	1.265	0.109

Table 4 Outliers summary.

Unweighted Cases		*N*	Percent
Valid		129	72
Excluded	Missing or out-of-range group codes	0	0.0
	At least one missing discriminating variable	51	28.3
	Both missing or out-of-range group codes and at least one missing discriminating variable	0	0.0
	Total	51	28.3
Total		180	100

and Jujo Ginza (Kita-ward), Togoshi Ginza and Musashi Koyama Palm (Shinagawa-ward), Asagaya Pearl Center and Koenji Pal (Suginami-ward), Ameyoko and Shin Nakamise (Taito-ward), Yanaka Ginza and Ogu Ginza (Arakawa-ward), and Sugamo Jizo Dori and Sunshine City (Toshima) (Figure 3).

In most of the studied cases, the interruption of pedestrian flow by car transit was classified as nonexistent or seldom and mainly regulated for the stocking of stores during specific hours on shopping streets predominantly surrounded by residential areas. The two cases in Chuo-ward, namely, Shintomi Shoekai and Chuo Dori, were the only instances with regular car transit, but they have exceptions. Both cases have a low presence of residential areas and present a clear transit delimitation for pedestrians and cars. Chuo Dori also has a five-hour car transit prohibition from 12 p.m. to 5 p.m.

3. Research methodology

The field survey recorded 12-h periods of a typical weekday (from 9:00–21:00 h) by tracking the daily variations and gathering a sample size of 240 data points from July 3 to August 3, 2017, and from October 13 to November 10, 2018. The counting process used 28 variables divided into the following categories (Table 1): (a) street dimensions, (b) stores, (c) objects, and (d) pedestrian vibrancy. The first group, "street dimensions," refers to the height of each side building front and the average value, the width of the street, the walkable surface, and the average number of floors. The second group, "stores," is composed of the number of open and closed stores per hour, the percentage of open stores, and the stores related to services, goods, and food vending. The third group, "objects," denotes the stores' furniture and the number of flower pots, parked bicycles, and banners. The fourth group, "pedestrian vibrancy," is composed of the number of pedestrians and their walking speeds recorded every hour. The field survey classified pedestrians according to gender (male/female) and age groups (young, middle-aged, and old).

Samples for the categories "stores" and "objects" were collected every hour from walk-throughs along 100 m of each shopping street. The counting of "pedestrian vibrancy" included every passer-by encountered along four passes by using a tally counter, and a hand chronometer was used to capture the walking speeds in two 10-meter-long sections of the street (Figure 4).

Hierarchical cluster and discriminant analyses were performed using the statistical software SPSS v.24 to analyze the data. Hierarchical cluster analysis is an algorithmic process that groups comparable samples by their similarities, and the results are commonly expressed visually in a dendrogram. Hierarchical cluster analysis was used to process the average values ($n = 20$) of the 28 variables of each street by using Euclidean distance as the measurement interval and Ward's approach as the cluster method.

The discriminant analysis was utilized to arrange the variables within discriminant functions and evaluate how well they explain the model according to their statistical weights expressed via Wilk's lambda.

The input for the discriminant analysis eliminated variables that are mathematical functions of others to ensure an optimal grouping separation of the clusters' centroids. For example, the variables called goods, service stores, and food stores were used instead of the variable total number of stores, considering that their summation is equal to it.

4. Results

The interpretation of the scoring distances in the hierarchical cluster analysis from major to minor in the dendrogram illustrated that the shopping streets are mainly clustered into three major groups: Clusters 1, 2, and 3 (Figure 5). The analysis also identified two well-clustered subgroups within Cluster 3, namely, Clusters 3-1 and 3-2.

Cluster 1 is formed by Chuo Dori (Chuo-ward) and Sunshine City (Toshima-ward). Cluster 2 is composed of Shintomi Shoeikai (Chuo-ward), Irisan Shoutenkai (Ota-ward), and Boro Ichi (Setagaya-ward). Cluster 3-1 consists of Musashi Koyama Palm (Shinagawa-ward), Koenji Pal

Table 5 Tests of equality of group means.

	Wilks' Lambda	*F*	df1	df2	Sig.
Stores related to Goods	0.68	22.89	1.00	48.00	0.000
Stores related to Services	0.45	58.30	1.00	48.00	0.000
Stores related to Food	0.85	8.63	1.00	48.00	0.005
Open Stores per Hour	0.47	54.47	1.00	48.00	0.000
Width of Street (m)	1.00	0.06	1.00	48.00	0.803
Walkable Surface of Street (m2)	0.99	0.54	1.00	48.00	0.466
Average Building Height (m)	0.64	26.95	1.00	48.00	0.000
Stores' Furniture	0.88	6.63	1.00	48.00	0.013
Flower Pots	0.66	24.23	1.00	48.00	0.000
Parked Bicycles	0.97	1.31	1.00	48.00	0.258
Banners	0.74	17.04	1.00	48.00	0.000
Average Number of Pedestrians	0.30	110.80	1.00	48.00	0.000
Total Average walking speed (m/s)	0.64	26.57	1.00	48.00	0.000
Closed Stores per Hour	0.94	2.84	1.00	48.00	0.098

(Suginami-ward), and Ameyoko and Shin Nakamise (Taito-ward). Cluster 3-2 comprises Minami Koiwa Showa Dori (Edogawa-ward), Ogu Ginza and Yanaka Ginza (Arakawa-ward), Sugamo Jizo Dori (Toshima), Milpa (Ota-ward), Togoshi Ginza (Shinagawa-ward), Asagaya Pearl Center (Suginami-ward), Akabane Ichiban Gai and Jujo Ginza (Kita-ward), Hirai Shin Wakai (Edogawa-ward), and Shimokitazawa Minami Guchi (Setagaya-ward).

The clustering table (Table 2) indicates that Cluster 1 has the largest street width (16.17 m), building height (24.63 m), walkable area (1964.05 m^2), and number of people (250.42). The table also shows the slowest walking speeds from all collected samples (1.12 m/s).

By contrast, Cluster 2 has the fastest walking speed (1.45 m/s). Notably, the number of closed shops (6.22) far surpasses that of open businesses (4.78).

The scoring values of Clusters 3-1 and 3-2 are closely correlated to each other in comparison with Clusters 1 and 2. Despite the similarities, Cluster 3-1 exhibits a larger amount of street furniture (182.96), banners (191), and stores (36) and mainly doubles the number of pedestrians (116.98) compared with Cluster 3-2 (55.12). Cluster 3-2 has the largest number of parked bicycles (18.14) and flower pots (19.90) registered.

Table 3 displays the mean and standard deviation values of the variables from Clusters 3-1 and 3-2 to be used in the discriminant analysis after the removal of outliers. The statistical tool processed 14 variables from the corresponding clusters with an outcome of $n = 129$ valid samples out of the 180 total population, representing 71.7% (Table 4). The "Street Dimensions" category consists of width of the street, average building height, and walkable surface of street. The "Stores" category is composed of stores related

Table 7 Wilks' Lambda.

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	0.033	144.479	11	0.000

Table 8 Functions at group centroids.

2 Clusters Membership	Function 1
Cluster 3-1	− 7.345
Cluster 3-2	3.784

Unstandardized canonical discriminant functions evaluated at group means.

Table 9 Classification results[a].

2 Clusters Membership			Predicted Group Membership		Total
			Cluster 3-1	Cluster 3-2	
Original	Count	Cluster 3-1	34	14	48
		Cluster 3-2	24	108	132
	%	Cluster 3-1	70.8	29.2	100.0
		Cluster 3-2	18.2	81.8	100.0

[a]78.9% of original grouped cases correctly classified.

Table 6 Eigenvalues.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	28.949[a]	100.0	100.0	0.983

[a]First 1 canonical discriminant functions were used in the analysis.

Table 10 Structure matrix.

	Function 1
Banners[a]	– 0.388
Average Number of Pedestrians	– 0.282
Stores related to Services	– 0.205
Open Stores per Hour	– 0.198
Average Building Height (m)	0.139
Total Average walking speed (m/s)	0.138
Flower Pots	0.132
Stores related to Goods	– 0.128
Stores related to Food	– 0.079
Stores' Furniture	– 0.069
Closed Stores per Hour[a]	– 0.045
Parked Bicycles	0.031
Width of Street (m)	0.007
Walkable Surface of Street (m2)[a]	– 0.004

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions Variables ordered by absolute size of correlation within function.

[a]This variable not used in the analysis.

to goods, stores related to services, stores related to food, and open and closed stores per hour. The "Objects" category is composed of stores' furniture, banners, flower pots, and parked bicycles. The "Pedestrian Vibrancy" category includes average number of pedestrians and total average walking speed.

The analysis revealed that the following variables failed the significance threshold and Wilk's lambda score: width of street, walkable surface of street, parked bicycles, and closed stores per hour (Table 5).

Accordingly, a discriminant function is significantly defined by explaining 100% of the variance with a canonical correlation of $R^2 = 0.97$ (Table 6), Wilk's lambda $(\Lambda) = 0.03$, $X^2(11) = 144.48$, and $p = 0.05$ (Table 7). The procedure showed that Cluster 3-1 has a discriminant score of – 7345 with 70.8% of classified cases; Cluster 3-2 has a 378 rating with 81.8% of classified cases (Tables 8 and 9). Banners were unable to successfully pool during the within-group correlation and were excluded by the procedure (Table 10).

The outcome of the discriminant analysis revealed that nine variables out of the initial 14 are the most significant in differentiating Clusters 3-1 and 3-2. The "Stores" category is composed of stores related to goods, stores related to services, stores related to food, and open stores per hour. The "Objects" category includes stores' furniture, banners, and flower pots. The "Pedestrian Vibrancy" category is composed of average number of pedestrians and total average walking speed.

5. Findings

The study successfully classified four clusters according to the field survey by comparing the observations to the outcome of the hierarchical cluster analysis. Subsequently, discriminant analysis was conducted to assess further the weight variations of variables between Clusters 3-1 and 3-2.

First, Cluster 1 scored the maximum values for the variables related to street dimensions and the lowest values for walking speeds over the other clusters. This cluster has wide roads and height dimensions corresponding to a boulevard-type of street enclosing a high vibrancy of outside passers-by. Hence, this cluster achieved a long scaling distance in the hierarchical cluster analysis and was classified as an eccentric cluster. The type of commerce in this cluster considerably relies on product branding and entertainment rather than variety or number of shops when related to the slow walking speeds as an attraction indicator. Notably, this type of vibrancy is sustained mainly by non-locals depending solely on the schedule of the commercial activity because of the absence of residential areas. The streets in this cluster, namely, Chuo Dori and Sunshine City, followed new guidelines in their conception as major city streets in a different context compared with the rest of the studied streets.

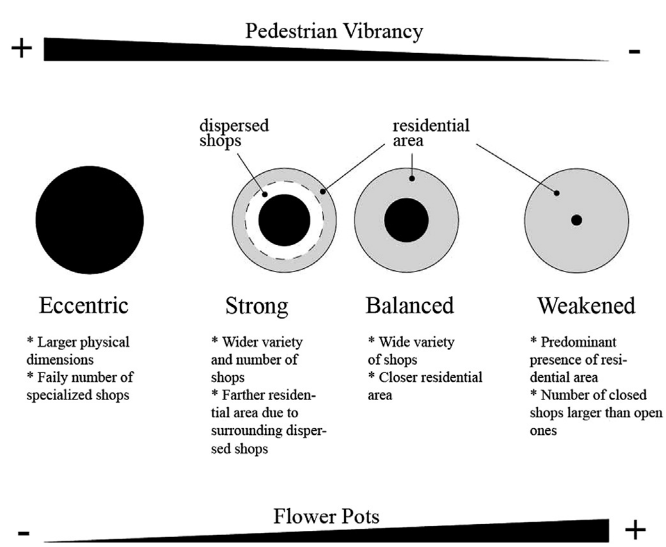

Figure 6 Clustering classification.

Second, the car transit prohibition exerted considerable effects on pedestrian vibrancy as registered in their amount and walking speed. In Chuo Dori, the number of passers-by changed from 140.25 at 11 a.m. to 259.75 at 12 p.m. and from 312.75 at 5 p.m. to 180 at 6 p.m., with walking speeds of 1.17–0.99 and 1.04–1.11 m/s, respectively. These management decisions that appraise walkability benefit stores in this kind of roads because of the constant arrival of outsiders.

Third, Cluster 2 was also classified as an eccentric case but for other reasons. Among the four clusters, Cluster 2 had the fewest shops, parked bicycles, and banners, the largest number of flower pots, and the fastest walking speeds. The predominance of housing and office infrastructure was also observed. This situation suggests that the weakening of the commercial activity has led the streets in this cluster into a primary role of neighborhood interconnection. These streets are highly vulnerable because of their considerable distance to major transportation hubs and the emergence of large retail stores redefining the nodes of activities in the area. Consequently, the stores in these streets are similar to permanently closed ones and in a condition that is unable to trigger pedestrian vibrancy.

Fourth, Clusters 3-1 and 3-2 featured the widest variety of daily life shops, more proportionated street dimensions (height, width, and area), and a more balanced number of pedestrians and walking speeds among all clusters. These clusters are close to transportation hubs and residential areas and have a moderate degree of pedestrian vibrancy compared with Clusters 1 and 2.

Lastly, the discriminant analysis revealed an inversed relationship between higher number of flower pots and lower presence of pedestrian vibrancy compared with Cluster 3-1. The shopping streets in Cluster 3-2 can be considerably influenced by the place decision-making of neighboring local communities, but further research is required for a strong assertion.

6. Conclusions

In summary, the present study classified 20 shopping streets in Tokyo, Japan, from a quantitative perspective of the relationship between visual information and pedestrian vibrancy and in consideration of physical dimensions, number of stores and objects to people agglomeration, and walking velocity. Flower pots were regarded as the most important variable from the "Objects" category and had an inverse relationship with pedestrian vibrancy.

The four clusters were classified as follows: Cluster 1 as eccentric, with prevailing large street dimensions and retailing shops; Cluster 3-1 as strong, with wide and numerous specialized daily life stores; Cluster 3-2 as balanced, with few specialized daily life stores that are close to the residential area and a moderate number of flower pots; and Cluster 2 as weak, with few shops, residential predominance, and the largest number of flower pots (Figure 6).

The findings of this study helped clarify that a high level of pedestrian vibrancy is linked to the presence of many exclusive shopping streets, where the large dimensions of buildings and streets can enclose and maintain a large number of passers-by. Pedestrian vibrancy showed a tendency to be highly related to shops specialized in goods and food vending.

Notably, a direct connection was observed between the number of flower pots and residential areas. Although additional research and analysis are required, pedestrian vibrancy is inversely correlated to the proximity of residential areas. The closer the residential area is, the lower the pedestrian vibrancy is.

Moreover, this study cannot assume that high pedestrian vibrancy is synonymous to a thriving shopping street. Depending on non-local pedestrians can be a deceiving sign of artificial vibrancy. The study considered that a high degree of vibrancy must be resilient by nature, supported by locals, and boosted by outsiders as evidenced in Clusters 3-1 and 3-2. SDAs can promote the active involvement of local dwellers contributing to the creation of enduring communities by improving decision making in shopping streets. As observed by Sorensen (2009) in Yanaka, community involvement brings positive reactions in street life and can support the protection and revitalization of shopping streets that face weak pedestrian vibrancy.

A limitation of the study is the lack of extensive periods in the surveys during the evaluation of methodological approaches from related literature. Implementing 12-h period surveys on every street is essential to understand the substantial effects of value deviations from the variables during a day. Designing a proper methodology and determining the most suitable statistical tools for the data analysis concerning built environments and pedestrians are also necessary.

References

Almazan, J., Tsukamoto, Y., 2007. Tokyo public space networks at the intersection of the commercial and the domestic realms (part II) study on urban content space. J. Asian Archit. Build. Eng. 6 (1), 143-150.

Balsas, C., 2016. Japanese shopping arcades, pinpointing vivacity amidst obsolescence. Town Plan. Rev. 87 (2), 205–232.

Bi-Matsui, T., 2009. Consensus building in shopping district associations and downtown commercial re-vitalization in Japan. Berkeley Plan. J. 22 (1).

Carmelino, G., Hanazato, T., 2016. Mapping of Semi-Fixed Elements and Pedestrian Behaviors as Indicators of Attractive Urban Environments. Tsukuba Global Science Week 2016 Art and Design Session Proceedings, 73-76.

Carmelino, G., Kaijima, M., Hanazato, T., 2016. New strategies for the spatial Re-configuration of railway stations surroundings. Spaces Flows: Int. J. Urban Extra Urban Stud. 7 (3).

Carr, S., Francis, M., Rivlin, L.G., Stone, A.M., 1992. Public Space. Cambridge University Press.

Ewing, R., Hajrasouliha, A., Neckerman, K.M., Purciel-Hill, M., Greene, W., 2016. Streetscape features related to pedestrian activity. J. Plan. Educ. Res. 36 (1), 5-15.

Ewing, R., Handy, S., 2009. Measuring the unmeasurable: urban design qualities related to walkability. J. Urban Des. 14 (1), 65-84.

Gehl, J., 2011. Life Between Buildings: Using Public Space. Island Press.

Harb, D.F., 2016. Examining the Vibrancy of Urban Commercial Streets in Doha (Master's thesis).

Lee, S., Sung, H., Woo, A., 2017. The spatial variations of relationship between built environment and pedestrian volume: focused on the 2009 Seoul pedestrian flow survey in Korea. J. Asian Archit. Build. Eng. 16 (1), 147-154.

Maki, F., 2012. Nurturing Dreams: Collected Essays on Architecture and the City. MIT Press.

Matsumoto, N., Sakuragi, K., Higashi, M., Ito, M., 2012. Study on the relationship between walking speed and streetscape attractiveness. J. Archit. Plan. (Trans. AIJ) 77 (678).

Okabe, A., 2017. Dynamic spaces with subjective depth. The public space in monsoon Asia. Kult-ur 4 (7), 151–164.

Rapoport, A., Hawkes, R., 1970. The perception of urban complexity. J. Am. Inst. Plan. 36 (2), 106–111.

Rapoport, A., 1990. The Meaning of the Built Environment: A Nonverbal Communication Approach. University of Arizona Press.

Shelton, B., 1992. Rethinking our images of the Japanese city. Aust. Plan. 30 (3), 131–135.

Sorensen, A., 2005. The Making of Urban Japan: Cities and Planning from Edo to the Twenty First Century. Routledge.

Sorensen, A., 2009. Neighborhood streets as meaningful spaces: claiming rights to shared spaces in Tokyo. City Soc. 21 (2), 207–229.