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An Analysis of Interaction between Pedestrian Flow and Subjective Impression in Urban Streets

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Synopsis

Pedestrian flow varies depending both on the shape of urban street and on pedestrians' subjective impression. Therefore it could be one of indexes to evaluate quality of urban street. This study visualizes pedestrian flow and makes indexes which express characteristics of the flow. Then we clarify the relation between urban street impression by the visitors and the pedestrian flow as well as other factors such as visitors' social attributes. The results may be useful for construction of better urban streets.

KEYWORDS: pedestrian flow, visualization, flow index, social experiment, subjective impression

1. Introduction

We face aggravation of global environmental problem and aging society. Therefore, we should aim sustainable society and create urban street considering environment with mirthful, rest, and quiet.

To create urban street effectively, we should grasp urban street impression by the visitors and factors to affect them. Urban street space consists of stationary things and moving objects. There are some studies about the influence that each composition gives, but is not yet enough.

This study pays attention to not only stationary things but also moving objects and expresses the pedestrians' traffic quantitatively as vectors (**Figure-1**). In addition, this study clarifies the relation between urban street impression by the visitors and the pedestrian flow as well as other factors such as visitors' social attributes.

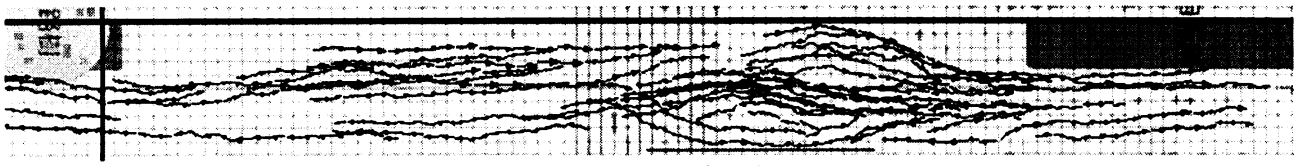

Figure-1 pedestrian flow

2. Outline of this study

In October, 2002, "Midosuji open-terrace social experiment" (placement open terrace on side road, music performance in the terrace and clearance of illegally-parked bicycle) was conducted. During the experiment and after the experiment, two surveys were conducted. One is questionnaire survey to visitors. The other is observation of pedestrians' movement by video cameras.

Based on these two surveys, this study analyzes the relation between urban street impression by the visitors and the pedestrians' movement. **Table-1** shows the outline of the sample, such as survey date, survey hours and street space state.

Table-1 survey date and hours, street space state

date	27-Oct		10-Nov	
hours	13-14	16-17	13-14	16-17
open terrace	○	○	×	×
illegally-parked bicycle	×	×	○	○
number of pedestrians (unit:persons)	2375	3728	2103	3243
characteristics of pedestrian behavior	stand, meandering		straight	

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The way of analysis is summarized in **Figure-2**. First we visualized pedestrian flow and make their indexes. Then discriminant analysis and multiple linear regression analysis are conducted, of which criterion variable is urban street impression is obtained through questionnaire. The explanatory variables are flow indexes, respondent data is obtained through questionnaire, with or without social experiment and survey hours.

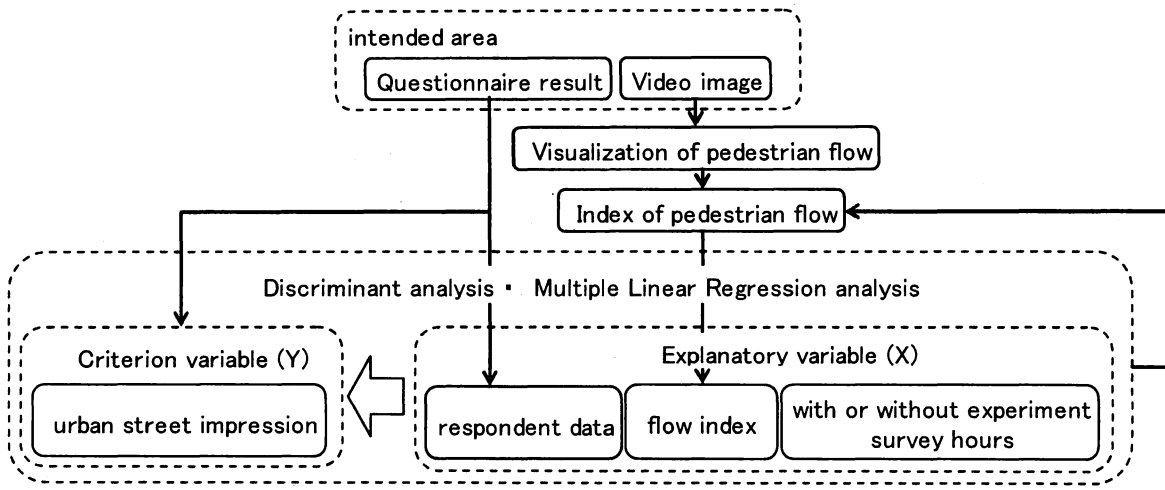


Figure-2 flow of this study

3. Visualization of pedestrian flow and flow indexes

3.1 Visualization of pedestrian flow

Visualizing pedestrian flow helps to grasp characteristics of pedestrian flow. The process of visualization follows (See **Figure-3**):

1) Transform video images into frame images at 0.5-seconds interval.
2) Reading position coordinates of pedestrians on them.
3) Calculation of gait velocity.
4) Description of vector diagram at 0.5-seconds interval.
5) By superposing them, pedestrian flow diagram is obtained.

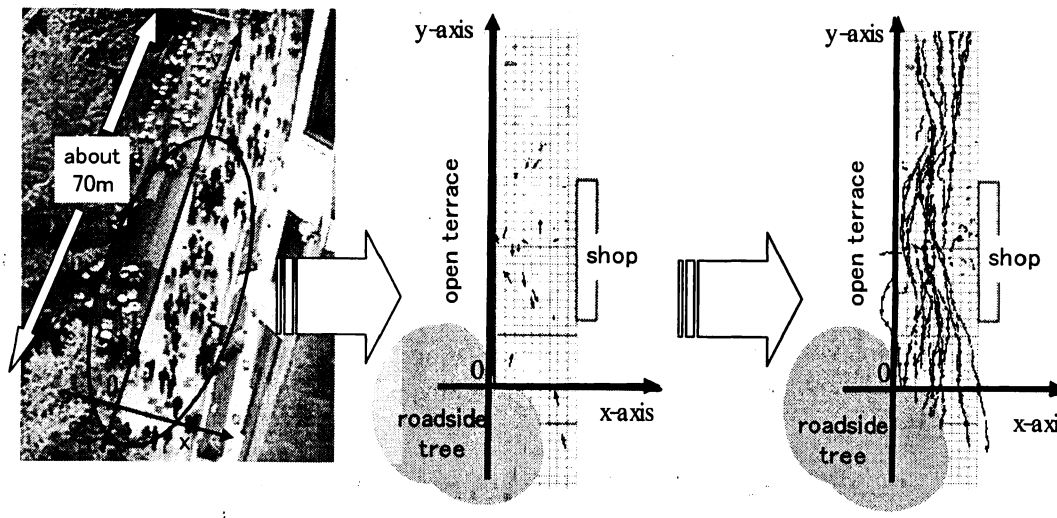


Figure-3 pedestrian flow diagram (27-Oct. 16:01:00-16:01:10)

3.2 Flow indexes

We made the indexes expressing characteristics of flow which are candidates for explanatory variable of the statistical analysis (**Table-2**). This study calls them "flow indexes". To calculate them, we divided 14 Areas in every 5 meter longitudinally on intended space (**Figure-2**).

Regarding "(d) density", area is defined 3 patterns as shown in **Table-3**. And **Figure-2** is color-coded depending on moving direction vectors on 0.5 meters square grids. Shaded parts represent the interspaces between person and person or obstacle. Whether to regard them as personal space changes the useful area. So these 3 areas are defined.

Regarding "(e) difference of direction-dependent", the indexes are the ratio of smaller value to larger value that is calculates direction-dependently the value as showed in Table 2 on the number of vectors and the average of "Vy". These are indexes run from "0" through "1". The closer "1"the value is, the fewer the difference of direction-dependent.

Table-2 flow indexes

characteristic	flow index		
(a) number of pedestrians	number of vectors		stationary vectors (Ns)
			move vectors (Nm)
			all vectors (N)
(b) stand	Ns/Nm		all area
			Av. among the areas
			SD among the areas
(c) direction of movement velocity	longitudinal velocity (Vy)		Av. of all area
			SD ob all area
			Av. among the areas
			SD among the areas
(d) density	density X =N/Nx		Av. among the areas
			SD among the areas
(e) difference of direction-dependent	ratio of direction-dependent (small/large)	number of vectors	all area
			Av. among the areas
			SD among the areas
		Av. of "Vy" in each area	Av. among the areas
			SD among the areas

Figure-2 color-code

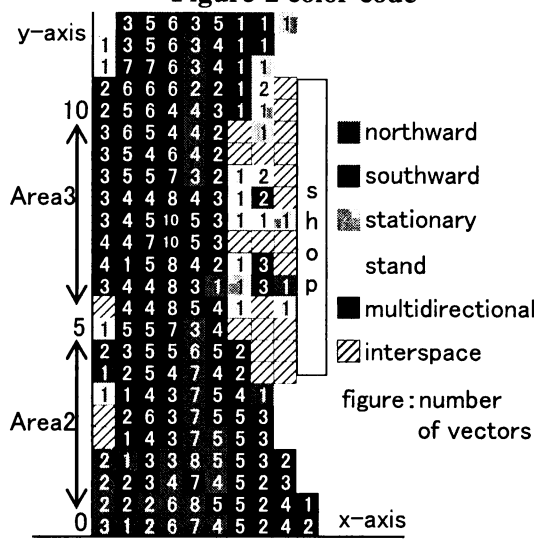
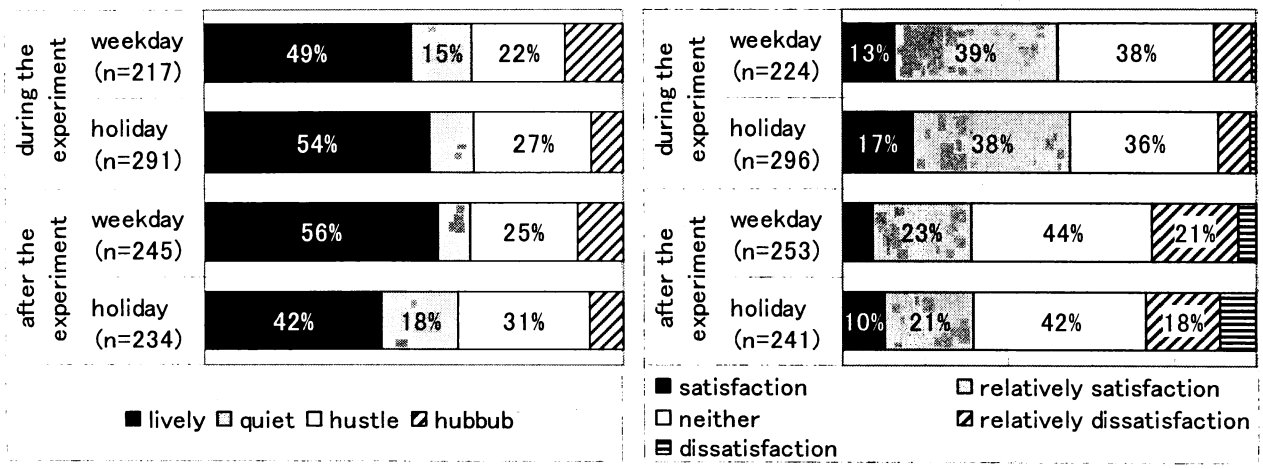


Table-3 definition of area

area	definition	number of grids of area X
area A	transit area	Na
area B	area A + gap between person and person	Nb
area C	area B + gap between person and obstacles	Nc

4. Urban street impression by visitor

Figure-3 shows the questionnaires results. These contains the results of all survey days (during the experiment and weekday are 2days, during the experiment and holiday are 3days, after the experiment and weekday are 2days, after the experiment and holiday are 2days.)



3-(a) impression of street space **3-(b) satisfaction of street space**

Figure-3 questionnaires results

5. Effect factors analysis about subjective impression of street space: Discriminant analysis

On questionnaire responses about subjective impression of street space we focused only "lively" and "hustle" that wear major opinions. Then we adopted discriminant analysis to create the models to estimate "lively" or "hustle".

To clear effects of pedestrian flow, analysis was conducted on the following two steps:

Analysis 1: Explanatory variable are respondent data, with or without social experiment and survey hours.
Model made from analysis 1 is called model 1.

Analysis 2: Explanatory variable are those of analysis 1 and a flow index.
(A flow index is added one at a time in turn in explanatory variable.)
Models made from analysis 2 are called model 2-A model2-B ... to mark *off each* flow index.

5.1 Effects of other than flow indexes.

Table-4 shows the result of analysis 1. Discriminant hitting ratio was 89.1%. Correlation ratio was 0.644. The result means street space impression greatly relate with these explanatory variables.

Table-4 Effects of other than flow indexes (model 1)

item	category	coefficient	range
gender	male	0.37	0.37
	female	—	
age	10–20	—	21.67
	20–30	3.02	
	30–40	-3.21	
	40–60	2.81	
	60–	-18.44	
residence	internal Osaka city	2.43	6.15
	internal Osaka pref.	6.15	
	external Osaka pref.	—	
image factor	pedestrian and bicycle	-3.68	8.54
	car	-8.54	
	other	—	
reason of street usage ※multiple answer	roadside trees	4.34	
	smooth	0.96	
	destination	2.65	
	avoidance of confidence	5.30	
	other	0.52	
purpose of visit ※multiple answer	shopping	0.32	
	eating and drinking	0.01	
	window shopping	-1.75	
	work	-6.34	
	other	3.02	
means of visit	railway	-4.05	13.58
	walk	-10.45	
	bicycle	3.13	
	car	-8.70	
	no answer	—	
frequency of visit	more than 3 times a week	2.96	5.69
	1 or 2 times a week	-2.24	
	1 or 2 times a month	-2.73	
	1 or 2 times a year	0.19	
	no answer	—	
social experiment	during	1.35	1.35
	after	—	
hours	13–14	-2.14	2.14
	16–17	—	

sample size	discriminant hitting ratio	correlation ratio
55	89.10%	0.64

5.2 Effects of flow indexes

Table-5 shows the results of analysis 2. The discriminate coefficients in **Table-5** focus only that of the flow indexes. Because there are few difference between the result of 'analysis 1' and those of 'analysis 2' on the discriminate coefficients of out of the flow indexes. This difference was maximum 1.7. And signs of plus and minus of these coefficients didn't shift.

Accuracy was the same with the results when every flow index was added. Discriminant hitting ratio was 92.7%. Correlation ratio was 0.654.

Table-5 shows the following;

The higher density, the more "hustle" visitors are impressed.

The faster average velocity, the more "lively" visitors are impressed.

The smaller the differences of "Vy" of direction-dependent, the more "lively" visitors are impressed.

Table-5 Effects of flow indexes (model 2-A～C)

model	item		coefficient ($\times 10^{-1}$)
			-5 0 5
2-A	Vy	Av. Among the areas	2.79
2-B	density C		-1.05
2-C	ratio of direction-dependent (Av.of "Vy")		3.64
sample size	discriminant hitting ratio		correlation ratio
55	92.70%		0.654

6. Effect factors analysis about degree of satisfaction of street space: multiple linear regression analysis

On questionnaire response about satisfaction of street space, we quantify "dissatisfaction" as "1", "satisfaction" as "5." Namely, qualitative data is treated as quantitative data that vary continuously. Then we adopted multiple linear regression analysis to grasp effect factors to the degree of satisfaction of street space.

Analysis was executed on the two steps as is the case of discriminant analysis showed in chapter4. In addition, we checked significance of each variable based on F-value. The variable that F-value was under 1 was eliminated.

6.1 Effect factor of other than flow indexes.

Table-6 shows the result of analysis 1. Determination coefficient was 0.438. Variance analysis result was a significance level of 5%.

Table-6 Effects of other than flow indexes (model 1)

item	category	coefficient	F-value	T-value	P-value
residence	internal Osaka pref.	**0.82**	**5.94**	**2.44**	**0.02**
image factor	open terrace	-0.77	1.52	1.23	0.22
	pedestrian and bicycle	**-1.22**	**5.51**	**2.35**	**0.02**
	car	-2.00	7.31	2.70	0.01
reason of street usage ※multiple answer	smooth	-0.86	2.66	1.63	0.11
	roadside trees	-0.95	4.01	2.00	0.05
purpose of visit ※multiple answer	shopping	-0.92	7.92	2.82	0.01
	eating and drinking	-0.54	2.79	1.67	0.10
	window shopping	1.08	3.04	1.74	0.09
means of visit	railway	**1.70**	**4.88**	**2.21**	**0.03**
	walk	1.61	3.48	1.87	0.07
	bicycle	1.79	3.91	1.98	0.05
	car	1.18	1.76	1.33	0.19
frequency of visit	more than 3 times a week	**1.33**	**5.71**	**2.39**	**0.02**
	1 or 2 times a month	0.43	1.89	1.38	0.17
	1 or 2 times a year	0.88	3.18	1.78	0.08
social experiment	during	0.65	3.93	1.98	0.05
sample size	Determination coefficient	Variance analysis result			
67	0.438	significance level of 5%			

significance level of 5% significance level of 10%

6.2 Effect factor of flow indexes

Table-7 shows the results of analysis 2. The partial regression coefficients in **Table-5** focus only that of the flow indexes. The difference between the result of 'analysis 1' and those of 'analysis 2' on the partial regression coefficients of out of the flow indexes was maximum 0.40. And signs of plus and minus didn't shift.

The accuracy was difference depending on a flow index was added. Determination coefficient was 0.454 ~0.462. Variance analysis result was a significance level of 5% or 1%.

Table-7 shows the following;

The higher density, the lower visitors' satisfaction level is.

The faster average velocity, the higher visitors' satisfaction level is.

The smaller the differences of "Vy" of direction-dependent, the higher visitors' satisfaction level is.

The smaller the differences of the number of vectors of direction-dependent, the lower visitors' satisfaction level is.

Table-7 Effects of flow indexes (model 2-A~H)

model	item			coefficient ($\times 10^{-2}$) -5 0 5
2-A	Vy		Av. of all area	2.02
2-B			Av. among the areas	1.72
2-C	density A			-2.63
2-D	density B			-2.63
2-E	density C			-2.71
2-F	ratio of direction-dependent	number of vectors		-1.67
2-G		Av. of "Vy" in each area		2.04
2-H			SD among the areas	-2.00
sample size		Determination coefficient		Variance analysis result
67		0.454~0.462		significance level of 5% or 1%

7. Concluding Remarks

We visualized pedestrian flow as vectors and made the indexes express characteristics of the flow. And we confirmed these indexes are contributing factors explain urban street impression by the visitors.

This study analyzed the holiday data clarified that the factor enhancing street space impression are higher velocity and lower density on the crowded space like holiday data.

Further investigation is needed the following:

1) Analyzing the weekday data and survey results of other spaces.
2) Making the indexes express "eddy", "swell" and more characteristics of flow.
3) Confirming the nonlinearity between urban street impression by the visitors and the pedestrian flow.

Reference

1) Yusuke ISHII, Yasuo HINO, and Takashi UCHIDA : A Basic Study on the Quantitative Analysis of the Prosperity of the Central Area - A Case Study of "Midosuji Open-Terrace Social Experiment" in Osaka -, Proceedings of Infrastructure Planning, Vol. 27, 2003 (CD-ROM). (in Japanese).