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STREET CHOICE LOGIT MODEL FOR STROLLING VISITORS IN SHOPPING DISTRICT

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Abstract

Streets should be designed as spaces in town where people feel both efficiency for travelling and attractiveness for rambling. By predicting people's distribution and walking around activity in cities, urban planning will become more successful. We investigate a shopping district arround the suburb railway station in Japan, and propose two models for predicting people's activity. The first model is a pedestrians distribution prediction (or postdiction) model by multiple regression analysis using space syntax indices of urban fabric and people's distribution data obtained from the field-survey. The second model is a street choice model uging Logit model. We performed a questionnaire survey on the field and investigated 46 visitors' strolling routes and obtained totally 1211 street choices in thier routes. A utility function, sum of weighted space syntax indices and other indices, is made and the parameters for weights were estimated by maximum likelihood. These models take account of both street networks (Integration Value, distance from the destination) and other spactial compositions (amount of pedestrians, cars and shops, road width, altitude). First model explained the characteristics of the street where a lot of people tend to walk or stay. The parameters of large weight were "near from the station", "wide", "with many stores", and "near to centricity (high Int.V)". Second model clarified differences of weights of street choice parameters between the attributes such as gender, the existence of destinations, number of people, and so on. There are many findings such as followings; males tend to choose the street which has relatively low Int.V, many cars; couples tend to choose the streets which have few pedestrians; people without destination tend to choose the streets which have high Int.V, a lot of pedestrians, narrow width, and few shops; people who move in a group tend to choose the streets which have few cars, many shops, wide width.

Keywords: *street choice, pedestrian distribution, shopping district, strolling visitors*

Theme: *Spatial Cognition and Behaviours*

1. Introduction

In recent years, the importance of realizing cities in which people can live without dependence on cars has been recognized. Therefore, there have been concerns about the need to create user-friendly cities that are equipped with specialized infrastructure. To create such cities, it is necessary that streets in cities are designed to be not only effective pathways for movement but also as attractive spaces that are ideal for a stroll because pedestrians enhance the liveliness of a city. Accordingly, to enable successful urban planning, we need to examine the characteristics of streets on which a large number of people stroll. We propose two models for predicting pedestrian activity. First model is a pedestrian distribution model. This model shows the characteristics of streets where many people stroll. Second model is a street choice model. This model shows the characteristics of street which people tend to choose when they stroll. These models explains pedestrian activity quantitatively. Street choice may be different by people's personal character, therefore we examine the second model by the attribute of the stroller such as genders, ages, and so on. In future, combining these models, it would be possible to estimate the distribution of pedestrians by the estimation of strolling route based on the composition of peoples' age, gender, or occupation.

There are many former related researches about the route choice and strolling behavior in commercial district or shopping center. Gil (2009) clarified that distinct clusters of shopping strategy can be defined in terms of characteristic search trails through a store and that these trails correlated with specific shopper profiles. Tsukaguchi (2002) found that pedestrians' direction of movement changes depending on the angle formed between the street and a straight line drawn between the destination and the present location. Takegami (2006) created a pedestrian route choice model considering the locations of destinations and the direction of movement. Sakurai (2012) formulated a grid street model and estimated the number of pedestrians by using the pedestrian survey data. Sueshige (2007) considered the effects of changes in visual information for pedestrians by a linked QTVR (QuickTime Virtual Reality) simulator. Oiwa (2005) analyzed the dynamics of the behaviors of both shops and visitors by using data from two surveys performed in 1998 and in 2003 in Nagoya. Kawanabe (2012) clarified the effects of spatial compositions for people who use trams. Matsumoto (2011) revealed the relationship between the occurrences of staying and space conditions in an underground shopping arcade, such as advertisements and information displays.

Previous studies in this regard considered two aspects. Some studies focused on spatial connections such as street networks, while the others focused on spatial compositions such as the number of shops and visual elements. However, we assumed that pedestrians perceived both space connections and compositions while strolling. Therefore, this paper suggests two models that consider both space connections and compositions. One is a pedestrian distribution model that explains the relationship between pedestrian distribution and spaces. This model was developed using multiple regression analysis. The other model is a street choice model that explains the influence of elements when people choose a route. This was developed using a Logit model based on routes obtained from a questionnaire survey. We used seven variables in these models. Space connections included the following variables: (1) integration value obtained from the space syntax and (2) the shortest distance to a destination (or a station). Space compositions included the following: (3) number of pedestrians, (4) cars, (5) shops, (6) width of streets, and (7) altitude to obtain the number of pedestrians and cars, we performed a field survey.

2.1. Study area

The area of focus in this study is around the Jiyugaoka Station in the suburbs of Tokyo (Figure 1), around which many shops are distributed. Meanwhile, there are intricate connections between the streets. Therefore, we expect that visitors' strolling routes in this area would be more complicated and different from those on a straight shopping street. It is assumed that visitors who exit the station stroll within this area because a sufficient number of walkers can be considered for the modeling, and it contains a large number of shops, while outside this area, the number of walkers decreases significantly. In this study, we made "a segment map" of the study area, which is prepared by Depthmap. A "segment" indicates the space between two adjacent intersections. The number of segments is 789.

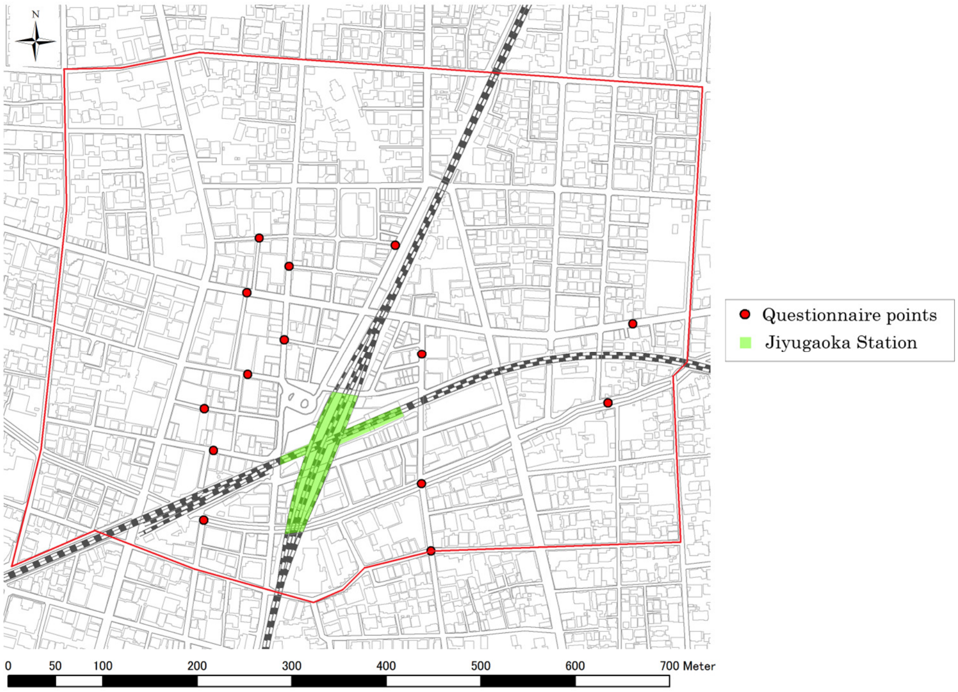

Figure 1: Study area and questionnaire survey points

2.2. Variables of two models

We used seven variables for modeling, namely "number of pedestrians on each segment (PEDESTRIANS)," "number of cars on each segment (CARS)," "number of shops facing each segment (SHOPS)," "height of each node (ALTITUDE)," "width of street (WIDTH)," "integration value (Int.V)," and "distance from a specific place (DISTANCE)" (Table 1). In the distribution model, DISTANCE implies "the distance of each segment from the Jiyugaoka Station." In the street choice model, it means "the distance from the destination."

First, we explain PEDESTRIANS. A field survey was conducted five times on sunny weekday afternoons (14:00–15:00) in October 2012. We charted a survey route that did not include the same streets in the study area. Then, we traveled along that route on a bicycle while recording the route on a video camera mounted on our heads. After the survey, we counted the number of people and cars that we had bypassed on each segment. PEDESTRIANS included people who were walking, stationary, and sitting. CARS included cars, bikes, and vehicles parked on the segment.

Table 1: Evaluating the four growth iterations against the spatial

Variables	Method of data collection
PEDESTRIANS	Field survey
CARS	
SHOPS	Town Pages (NTT yellow pages)
ALTITUDE	Digital map 5m mesh
WIDTH	Measuring result (field survey)
DISTANCE	A program using Dijkstra's algorithm
Int.V	Space Syntax

Next, we explain SHOPS. We obtained 1121 sets of shop data (retail shops and service shops) from Town Pages (Table 2). Then, we counted the number of shops included in each buffer space of the street (Figure 2). Shops facing intersections were included in every segment. This value was called SHOPS.

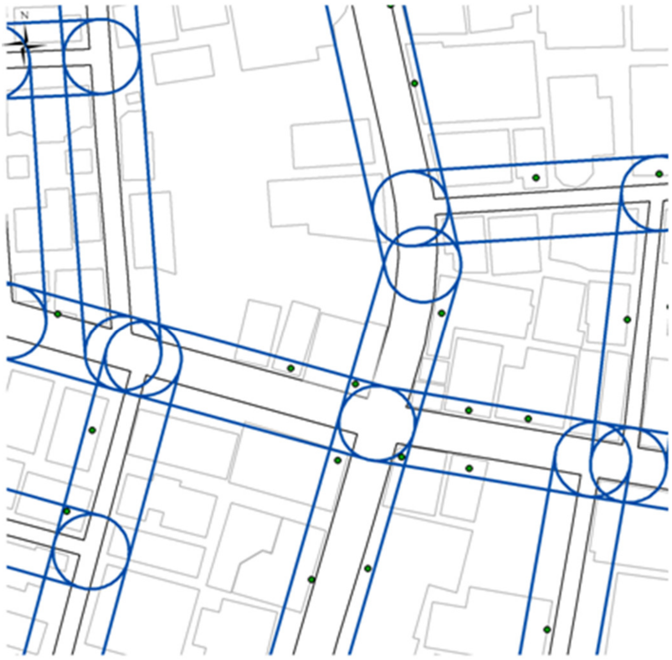

Figure 2: Shops included in buffer spaces

Table 2: Number of each of the main shop-types

Retail shops				Service shops					Total
Commodity	Fashion	General goods	Food	Restaurant	Café	Beauty salon	Beauty parlor	School	
44	244	131	77	268	35	92	123	107	1121

Then, we explain ALTITUDE. "Digital map 5m mesh" is a point data. First, we made segment map of study area. Then we got the closest point data from nodes (start points and end points of each segment). Finally, we calculated the mean value between them. We used these values as ALTITUDE.

Finally, we explain Int.V. We prepared an axial map to cover a 2-km radius from the Jiyugaoka Station. Then, we calculated the Axial Analysis (radius = 3, 5, 7, 9, n), Angular Analysis (radius = 1, 2, 3, 4, 5, n), and Segment Analysis (metric radius = 150, 300, 450, 600, 750, 900, 1050 m).

Figure 3 shows the values of these variables.

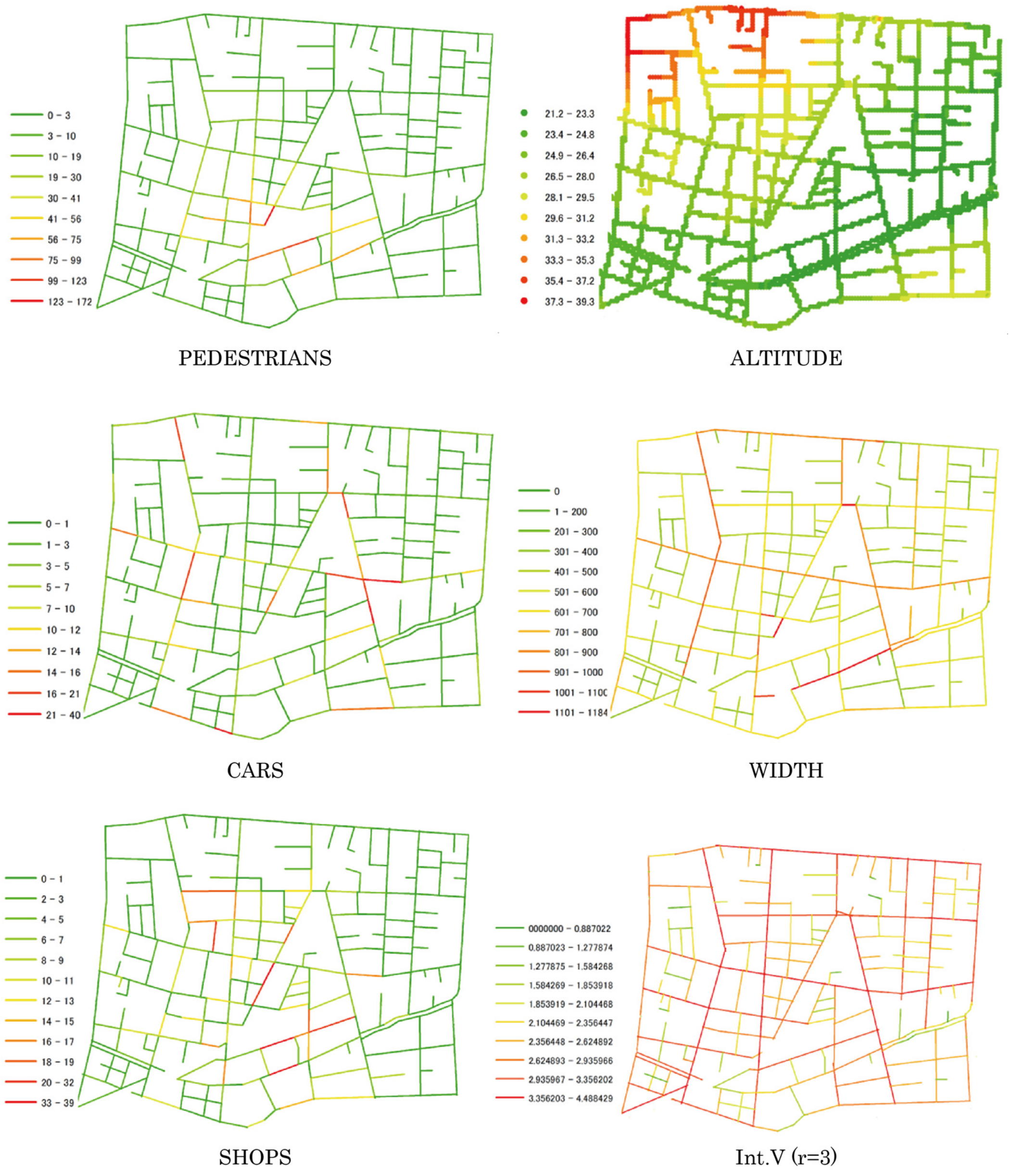

Figure 3: the values of each variables

3. Pedestrian distribution model

First, we evaluated the correlation between the predictor variables (Table 3). Then, we removed CARS and conducted multiple regression analysis using SHOPS, WIDTH, ALTITUDE, DISTANCE, and each Int.V. If the t-value or p-value was inadequate, we removed misfit variables and performed the modeling again. The results differed with respect to the integration value (Table 4). As a result, the model employing Int.V (Axial Analysis radius = 3) showed the best result because R-value, R^2-value and adjusted R^2-value are the highest of all Int.V and standard error is the lowest. The model formula is

$$\text{PEDESTRIANS} = 3.133 \times \text{Int.V} + 0.663 \times \text{SHOPS} + 0.048 \times \text{WIDTH} - 0.110 \times \text{DISTANCE (from station)} + 17.309 \quad (1)$$

The multiple correlation coefficient was 0.705, and the contribution ratio was 0.498. The power of each predictor variable for the pedestrians' distribution is in the order DISTANCE > WIDTH > SHOPS > Int.V. Therefore, "near the station," "wide width," "many shops," and "high Int.V" (established at the center) represent the characteristics of streets where pedestrians are distributed. Table 5 explains the details of the distribution model.

Table 3: Correlation between predictor variables

	SHOPS	WIDTH	CARS	ALTITUDE
SHOPS	0.199**	0.432**	−0.060	−0.374**
WIDTH		0.444**	−0.003	−0.099
CARS			−0.078	−0.100
ALTITUDE				0.090

Table 4: Distribution models using each value of Int.V

Int.V	R-value	R^2-value	Adjusted R^2-value	Standard error (SE)
Axial R3	0.705	0.498	0.489	19.712
Axial R5	0.702	0.493	0.481	19.860
Axial R7	0.701	0.491	0.479	19.896
Axial R9	0.701	0.491	0.479	19.891
Axial Rn	0.701	0.492	0.480	19.884
Angular_R1	0.698	0.487	0.475	19.978
Angular_R2	0.697	0.486	0.474	19.992
Angular_R3	0.697	0.486	0.474	19.989
Angular_R4	0.698	0.487	0.474	19.983
Angular_R5	0.698	0.487	0.474	19.982
Angular_Rn	0.697	0.486	0.474	19.985
Metric_150m	0.698	0.488	0.476	19.962
Metric_300m	0.698	0.488	0.475	19.964
Metric_450m	0.703	0.494	0.482	19.833
Metric_600m	0.705	0.497	0.485	19.777
Metric_750m	0.703	0.494	0.482	19.844
Metric_900m	0.704	0.491	0.479	19.894
Metric_1050m	0.705	0.488	0.476	19.961

Table 5: Details of the distribution model

	Non-Standardizing Coefficient		Standardizing Coefficient		P-value	Collinearity	
	B	SE	Beta	t-value		Tolerance	VIF
Constant	17.309	5.99		2.889	0.004		
Int.V	3.133	1.632	0.080	1.920	0.056	0.964	1.038
SHOPS	0.663	0.237	0.126	2.792	0.006	0.831	1.204
WIDTH	0.048	0.006	0.336	7.903	0.000	0.932	1.073
DISTANCE	−0.110	0.010	−0.499	−11.250	0.000	0.859	1.164

4. Street choice model

4.1. Questionnaire survey on the strolling route

We carried out a questionnaire survey to examine the routes taken by pedestrians in Jiyugaoka. Figure 1 shows the 14 points at which the survey was conducted. At each point, we interviewed five persons. In this way, we obtained routes for 70 persons. Table 6 shows the questionnaire items. The pedestrians answered these questions and drew their routes on the A2-size map. We distinguished their street choices into the following categories: “headed toward their destination” and “having no set destination.” In this study, we used 46 persons’ routes (1211 street choices), which started from the Jiyugaoka Station. After this survey, we classified the respondents’ street choices into “toward destinations,” “non-destinations,” “male,” “female,” “couple,” “alone,” and “group.” Table 7 shows the number of street choices and the rambling ratio for each of these categories. The rambling ratio is the ratio of “the number of street choices for which destinations are not defined” to “the total number of street choices.” The rambling ratio of “female” is lower than other categories (“male” and “couple”). Also, the rambling ratio of “alone” is lower than that of “group.”

Table 6: Questionnaire items

Items	Choices						
Gender	Male	Female					
Age	Teens	Twenties	Thirties	Forties	Fifties	Sixties	Other
Purpose	Shopping	Lunch	Rambling	Business	Get home	Other	
Transportation mode	On foot	bicycle	bus	train	Car		
Travel time	30 min	30 min	1 h	1.5 h	2 h		
Frequency	Once	Twice	Third times	Other			
Stationary time	Free answer						
Relationships	Friend	Parent	Couple	Other			
Route	Free answer						

Table 7: Number of choices and rambling ratio for each attribute

Attribution	Definition	Number of choices	Rambling ratio
All	All street choices	1211	34%
Toward destination (TD)	Heading for destination	799	0%
Non-destination (ND)	Undefined destinations	412	100%
Male	Only male (alone, group)	230	40%
Female	Only female (alone, group)	825	30%
Couple	Male and female group	156	46%
Alone	Street choices for a lone person	129	30%
Group	Street choices for a group	780	36%

4.2. Logit model

In order to estimate the street choices mathematically, we built the prediction model based on Logit model of microeconomics. V_{in} indicates the "utility" when an individual "n" chooses "i" from "A_n" choices. "Utility" is the same as desirability which a subject "i" has. It is assumed that each individual considered both space connections and compositions and then chose a street whose utility is the maximum. In this case, V_{in} represents the sum of the products X_{ink} (K pieces of elements) and constant θ_k (parameter).

$$V_{in} = \Theta X_{in} = \sum_{k=1}^{K} \theta_k X_{ink} \qquad (i \in A_n) \tag{2}$$

$\Theta = [\theta_1 \ldots \theta_K]$ is an unknown parameter vector, and $X_{in} = [X_1 \ldots X_K]$ is a characteristic vector (choice "i" of individual "n"). In this study, we set the utility function V_{in} as follows:

$$V_{in} = \theta_1 X_I + \theta_2 X_P + \theta_3 X_S + \theta_4 X_R + \theta_5 X_V + \theta_6 X_E + \theta_7 X_D \tag{3}$$

Each predictor variable is defined as follows:

X_I : Int.V (r = 3)
X_P : PEDESTRIANS
X_S : SHOPS
X_R : WIDTH
X_V : CARS
X_E : ALTITUDE
X_D : DISTANCE (from the destination)

Then, formula (4) represents the probability that an individual "n" chooses subject "i."

$$P_{in} = \frac{e^{V_{in}}}{\sum_{j \in A_n} e^{V_{jn}}} \qquad (i \in A_n) \tag{4}$$

Next, we formulate the likelihood function. We regard the number of individuals as N and consider the chosen results as δ_{in}. Then, the joint probability is given as follows:

$$P_{1n}^{\delta_{1n}} P_{2n}^{\delta_{2n}} P_{3n}^{\delta_{3n}} \ldots P_{1n}^{\delta_{1n}} \ldots P_{Jn}^{\delta_{Jn}} = \prod_{i \in A_n} P_{in}^{\delta_{in}} \tag{5}$$

$$L^* = \prod_{n=1}^{N} \prod_{i \in A_n} P_{in}^{\delta_{in}} \tag{6}$$

Accordingly, formula (6) represents the likelihood function L^*. We estimate parameter θ_{k}, which maximizes the likelihood function, by using the method of steepest descent. This is a street choice model obtained by using the multinominal logit model.

4.3. Estimated parameters for each attribute

We made nine logit models and estimated the weight parameter of street choices with respect to the nine attributes of the strolling people and their destination. Table 8 shows the estimated parameters and hit ratio. The hit ratio is the ratio of "the total number of choices" to "the number of choices for which the joint probability evaluated by the street choice model is maximum."

$$\text{Hit ratio (\%)} = \frac{\text{number of choices for which the joint probability is maximum}}{\text{number of all the choices}} \times 100 \tag{7}$$

The hit ratio is 67% to 94%, and these models would be appropriate. DISTANCE (from the destination) produces a negative effect. Therefore, all pedestrians tend to choose streets that are near their destinations. People whose destinations are not defined tend to take "fewer shops and narrow" streets. Males prefer streets that "are distant from the center (low Int.V) and have fewer shops." Couples tend to take streets that "are distant from the center (low Int.V) and have fewer pedestrians," and people in groups tend to choose streets that have "fewer cars." The hit ratio of the model considering all choice is the lowest because this model ignores the difference between respondent attributes.

Table 8 Each estimated parameter and hit ratio

Attribution	Int.V	PEDESTRIANS	SHOPS	WIDTH	CARS	ALTITUDE	DISTANCE	Hitting ratio (%)
All	0.469	0.005	0.024	0.002	0.006	0.296	−0.024	67
Toward destinations	0.180	0.009	0.040	0.002	0.055	0.609	−0.038	89
Non-destinations	0.664	0.031	−0.073	−0.005	0.077	0.320	0.000	77
Males	−0.340	0.011	−0.026	0.001	0.140	0.538	−0.044	92
Females	0.511	0.007	0.038	0.002	0.040	0.578	−0.039	80
Couples	−0.059	−0.024	0.056	0.002	0.076	1.802	−0.046	94
Alone	0.487	0.012	0.035	0.001	0.069	0.344	−0.037	89
Group	0.552	0.000	0.082	0.003	−0.047	0.503	−0.033	77

4.4. Standardization of parameters

The parameters PEDESTRIANS, SHOPS, WIDTH, and CARS take both positive and negative values, and regularities are not visible. Also, they cannot be compared because predictor variables have different units. Therefore, we standardized these parameters (Table 9) and showed them on a radar chart (Figure 4, Figure 5, and Figure 6). This chart enables visual comparisons of the parameters. When we standardized the parameters, we regarded “all attribution parameters” as the mean value and divided the deviations into the remainders between “each estimated parameter” and “the mean value.” If the standardized value is 0, then the value is same as mean value, and if the value is above 0 the index has positive influence on street choice, and vice versa. Then, we focused on the largest and smallest values in each element. For example, the largest value of Int.V is 0.525 (Non-destinations), and the smallest value is -2.179 (Males). Therefore people who don’t have destinations are affected positive influence and males are affected negative influence by Int.V.

Table 9: Each standardized parameter

Attribution	Int.V	PEDESTRIANS	SHOPS	WIDTH	CARS
Toward destinations	−0.777	0.267	0.312	0.178	0.871
Non-destinations	0.525	1.599	−1.833	−2.509	1.275
Males	−2.179	0.394	−0.938	−0.350	2.390
Females	0.114	0.149	0.262	0.000	0.604
Couples	−1.422	−1.735	0.601	0.259	1.248
Alone	0.048	0.464	0.200	−0.047	1.131
Group	0.225	−0.275	1.099	0.351	−0.941

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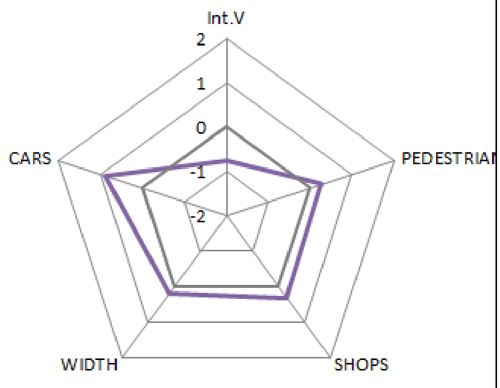
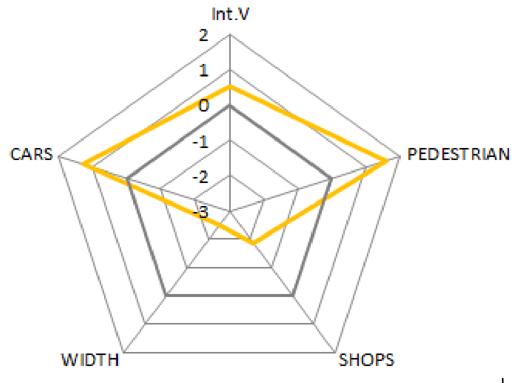
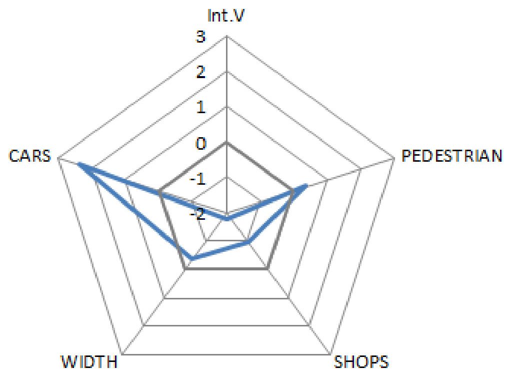
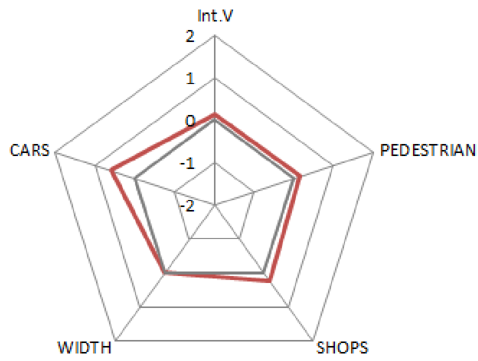
<tr><td colspan="2">
</td><td colspan="2">
</td></tr>
<tr><td>Positive</td><td>Negative</td><td>Positive</td><td>Negative</td></tr>
<tr><td colspan="2">Nothing</td><td>PEDESTRIANS、 Int.V</td><td>SHOPS, WIDTH</td></tr>
</table>

Figure 4: Trends for the existence of destination

Figure 4 explains the difference in the trends of street choices depending on the presence of destinations. People whose destinations are defined are not affected by any elements, and they would choose the streets that are the closest to their destination. Therefore, it is assumed that street choices made by persons whose destinations are defined depend on the location of their destination. On the contrary, people whose destinations are undefined are affected by many elements (PEDESTRIANS, Int.V, SHOPS, CARS, and WIDTH). On one hand, they tend to choose streets on which "pedestrians are more distributed and are closer to the center (have a high Int.V)." On the other hand, they tend to choose streets that "have fewer shops and narrower widths." Although it is assumed that people whose destinations are undefined are affected by many elements, they are not affected equally. It depends on their context or what kind of person they are. We also need to take account of the definition of "destinations" more studiously. Even if they don't have "specific" destinations, they might have "indeterminate" destinations. For example, when someone is strolling without any destinations and he is hungry, he might have "indeterminate" destinations (restaurant or cafe). So it is assumed that estimating their route choice would be very complicated. On the contrary, it would be possible that estimating route choice of people whose destinations are defined if we comprehend the places where tend to become destinations.

<table>
<tr><th colspan="2">Male</th><th colspan="2">Female</th></tr>
<tr><td colspan="2">
</td><td colspan="2">
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<table>
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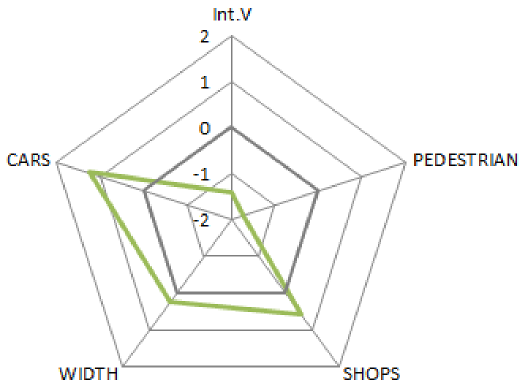
<tr><td colspan="2">
</td></tr>
<tr><td>Positive</td><td>Negative</td></tr>
<tr><td>Nothing</td><td>PEDESTRIANS</td></tr>
</table>

Figure 5: Trends for different genders

Figure 5 explains the difference in the trends of street choices depending on pedestrians' gender. Males are affected by CARS (positive) and Int.V (negative), and couples are affected by PEDESTRIANS (negative). Males tend to choose streets that have even more cars, while couples prefer streets that have fewer persons. The shape of the radar chart indicates that the shape of females' is balanced and that of males' is biased. There are two reasons behind this observation. First, there are many females in Jiyugaoka and female respondents outnumbered males or couples. Therefore, the parameters would be the same as "the mean value." The other is that the rambling ratio for females is lower than that for other gender attributes. Therefore, the street choices would become similar to those obtained for "toward destination."

Many of males came to Jiyugaoka on business and their destinations (their offices) are located along the streets which has many cars. So they tend to choose streets that have more cars. And they left Jiyugaoka after completing their mission. They set a high value on efficiency and take secluded shortest path. So they choose streets that have lower Int.V. Males stay in Jiyugaoka shorter than females, so we must consider "time limit" of the strolling route.

Couple came to Jiyugaoka to spend time for sharing their time. There are many hideaway shops or cafes for them. So they tend to choose streets that have fewer pedestrians to go there.

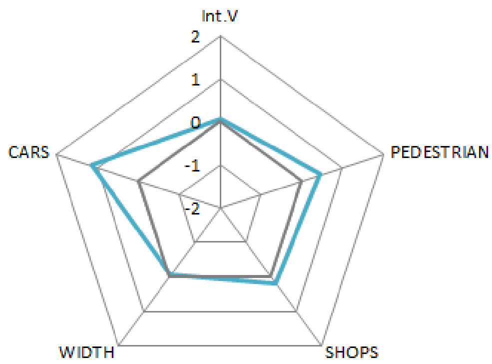
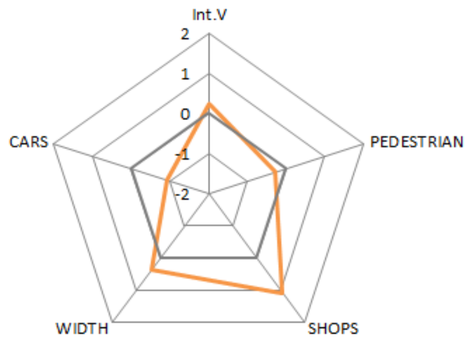
<table>
<tr><th colspan="2">Alone</th><th colspan="2">Group</th></tr>
<tr><td colspan="2">
</td><td colspan="2">
</td></tr>
<tr><td>Positive</td><td>Negative</td><td>Positive</td><td>Negative</td></tr>
<tr><td colspan="2">Nothing</td><td>SHOPS, WIDTH</td><td>CARS</td></tr>
</table>

Figure 6: Trends for the number of respondents

Figure 6 explains the differences in the trends of street choices on the basis of the number of pedestrians. People in groups are affected by SHOPS, WIDTH (positive), and CARS (negative). Individual persons are not affected by any element, while persons in groups tend to choose streets that have "more shops, less cars, and larger widths." The rambling ratio of "alone" is lower than that of "group" and alone people tend to leave Jiyugaoka after completing their mission. Therefore, an individual's street choice would be similar to that of "toward destination."

Many of people in groups are mothers who are with their children. Therefore they tend to choose wider streets which have fewer cars. In jiyugaoka, many mothers are strolling with their friends and children

5. Conclusion

In this study, we proposed a distribution model and a street choice model that considered both space connections and compositions. We developed a pedestrian distribution model that explained the characteristics of streets along which the density of pedestrians is high. It also clarified the weightof each element. People are distributed on the streets that "are closer to the station," "wider," "have more shops," and "are closer to the center (have a higher Int.V)." The street choice model explains the differences in the trends of street choices on the basis of pedestrians' attributes. The street choice of people who have their destinations strongly depends on the location of them. And that of people who don't have destinations is affected by the number of pedestrians and shops, street width, and Int.V. The rule of street choice of people who don't have destinations would depend on their character (for example, gender, age, amount of time they have and so on.) Males tend to choose streets which have many cars and low Int.V. We thought that their destinations (office) tend to be located along the street which have many cars and they use alleys to get there faster. Couple tend to choose streets which have fewer pedestrians. People in group tend to choose wide streets which has many shops and fewer cars. We thought they would like safe streets. Females and Alone people are not affected any elements.

As states above, we found the differences between people's attribution when they stroll. But this result may be applied in only Jiyugaoka. So we hope to conduct further studies in other cities to conduct a more generalized analysis of the mechanisms related to persons' walking patterns.

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