ORIGINAL ARTICLE

Investigation of Factors Affecting the Evaluation of Streetscapes in Japan and China

– An Evaluation of Streetscape based on the Random Forests Method –

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Abstract: Improvements in road sizes, qualities, and quantities are progressing in accordance with car use, while pedestrian space has been neglected. As typical developed and developing countries, Japan and China are facing the same problem in relation to streetscapes. Because streets are city property, it is important for city authorities to plan and conduct qualitative maintenance together with quantitative maintenance. For this reason, clarifying the importance of physical factors on evaluation of streetscapes and their effective operation is necessary. To date, a vast amount of scholarship has been devoted to evaluate streetscapes in Japan and China. However, the physical factors influencing streetscape evaluation have not been the same in all countries. In this study, the target areas of Chengdu, China, and Tokyo, Japan, were selected and a questionnaire was conducted in both places. Breiman's random forests method was used to analyze the data obtained from the survey. It revealed that the three chief factors affecting evaluation of streetscapes were determined as comfort, beauty, and activity. For comfort, streetscape is strongly influenced by landscape and spatial situation in Chengdu. On beauty, the impact of building usage was stronger in Tokyo than in Chengdu. For activity, the activity score of Tokyo was significantly higher than Chengdu, and the congestion of street had the strongest influence for both Tokyo and Chengdu. The fundamental knowledge about the differences and similarities in the evaluation of streetscapes in Japan and China will be a salutary lesson for the streetscape development of China.

Keywords: *evaluation, international questionnaire survey, streetscape, factor analysis, random forest*

1. INTRODUCTION

It is predicted that population, transport demand, and maintenance requirements for urban infrastructure in cities will increase with economic development. In particular, as transport infrastructure is closely connected to urban life, it is important to build an infrastructure that has an appropriate balance between the function and quality of an urban environment. In Asian nations, which have reached high economic growth in recent years, development of urban infrastructure has been progressing rapidly. Particularly in large Chinese cities, the speed of economic growth and infrastructure development has been strikingly impressive and has led to a rapid rise in the number of vehicles. As a result, there has been improvement in the size and quality of roads in accordance with automobile vehicle flow; however, pedestrian space has been neglected. Because roads are city property, it is important for city authorities to plan and conduct qualitative maintenance (with emphasis on landscape) along with quantitative maintenance (with emphasis on efficiency) [1, 2].

The situation is the same in Japan, with high economic growth and a rapid progress in road and street infrastructure.

Chronic congestion is now a feature of Japanese roads. It would be prudent for both Chinese and Japanese cities to conduct both qualitative and quantitative maintenance of their urban infrastructure, although they are in different stages of economic development. Identification of factors that are used to evaluate streetscapes and their effective operation is important for any country. Analyzing physical influencing factors and obtaining useful information on qualitative maintenance are means to achieve these factors.

As a country that ascended to the ranks of developed countries earlier in Asia, Japan has accumulated massive research results in the field of streetscape evaluation than any other Asian nations. In addition, for historical and cultural reasons, Japan and China have a lot of same and similar points in many ways. Therefore, those valuable researches are fortunes not only for Japan but also for China.

However, physical factors that affect streetscape evaluation are not weighted equally in all countries. Differences in culture, ethics, environment, and administration affect the impression of streetscape. As a result, we cannot copy Japan's experiences without any processing. It is important for us to understand the similarities and differences between the target areas under this condition.

In this study, the target areas of Chengdu, China, and Tokyo, Japan, were selected and a questionnaire was conducted in both places. The purpose of our analysis was to explore influencing factors of streetscape in Japanese and Chinese. Multiple linear regression analysis is one of the most popular methods for performing data analysis of questionnaires. However, it cannot construct a model with an interaction effect and nonlinear structure. We adopted the Breiman's random forests [3] method because it can model nonlinear and interaction structures. Moreover, we illustrated some graphical representation evaluation of estimated random forests models. These graphical representations revealed fundamental knowledge about the differences and similarities in the evaluation of streetscapes in Japan and China.

2. LITERATURE REVIEW

A vast amount of scholarship has been devoted to the evaluation of streetscapes in Japan. For example, Kitamura [4] indicated that streetscapes tend to be affected by harmony, activity, and intimacy. Maki et al. [5] assessed the influence of "fatigue" on streetscape evaluation. It has been pointed out that people who get easily tired by fatigue experiments tend to like nostalgic scenery after work, whereas people who do not tire easily tend to dislike urban sceneries and pedestrian traffic. Amano et al. [6] applies covariance structure analysis to evaluate streetscape and points out that "the ease of walking" and "atmosphere" affects the pleasure derived from streetscapes. The desire to return to streetscapes was also considered in his research. By paying attention to disorder/order of streetscapes, Matsumoto [7] evaluated streetscapes using a factor analysis method. As a result, three factors—"passive capacity," "tradition and disorder," and "activity" were derived. Shinohara and Yashiro [8] clarified the influence of uniformity of building height along a street as part of streetscape evaluation. Funakoshi and Tsumita [9] extracted 13 factors for streetscapes, such as "design" and "urbanity," using the semantic differential (SD) method and factor analysis method.

In the People's Republic of China (hereafter referred to as China), Yang et al. [1, 2] evaluated physical influences on comfort and range of activities of a streetscape using cognitive experiments with streetscape images. The width of a sidewalk was shown to have a large effect on streetscape's comfort and range of activities. Moreover, although the "existence of shops" had a positive influence on the range of activities, it gave a negative image to the comfort of streetscapes. Furthermore, it was found that surface of sidewalks had a strong influence on its comfort. Scholars have not yet come up with a physical factor that

affects evaluation of streetscapes in both Japan and China.

However, no attempt has been made to identify factors influencing streetscape evaluation internationally. In this paper, similarities and differences in the relative importance of physical factors affecting the evaluation of streetscape in Japan and China are examined.

3. STUDY DESIGN

3.1 Subject region for questionnaire

Chengdu China and Tokyo Japan were selected as the target areas for this survey. The reasons for selecting these places are as follows. Chengdu is the two-thousand year old provincial capital of Sichuan province. Similar to other cities in China, there has been a rapid increase in the number of vehicles. In the central part, famous places like Wuhou temple, Dufu Thatched Cottage, Qingyang temple, which are dotted with historic sites, have also become into one of the major tourism industry. In such areas, the street maintenance overemphasized only in efficiency has a possibility of altering not only the streetscape but also the street. On that account, development with the landscape consideration is required. Thus, in China, especially Chengdu must perform the street maintenance which noted the street landscape.

In addition, the central part of Chengdu city has a population of approximately 5.3 million, with a population density of 10453 persons per square kilometre [1]. The only city in Japan with an equivalent population to Chengdu is Tokyo (with about 8.96 million people in Tokyo's 23 wards). Tokyo is the capital of Japan and has been termed as the centre of industry and has the largest economy in Japan. It not only features very high population density, but also suffers from chronic traffic congestion. What is more, the forms of transportation infrastructure in urban areas are similar between Tokyo and Chengdu. The road infrastructure of Chengdu is annular with three circular routes. And there is a horizontal main avenue and vertical main road passing through Tianfu square which is located in the centre of Chengdu. Although not perfect, the transportation infrastructure form of Chengdu's central city is similar to the form of Tokyo's Inner Circular Route and Central Circular Route. Besides that, the form of road infrastructure from centre toward the outside in Chengdu is similar to the form of Route 1 (The Tokyo Metropolitan Expressway) and Route 2 (The Tokyo Metropolitan Expressway). In a word, the reason that the similarities in the population and transportation infrastructure form between Chengdu and Tokyo motivated to compare Chengdu and Tokyo.

3.2 Outline of the questionnaire

Among the questionnaire respondents, 100 graduate students were from the Southwest Jiaotong University in Chengdu and 159 undergraduate students were enrolled in the Faculty of Humanities and Environment at Hosei University, Japan. Both surveys were conducted in August 2011. The survey required respondents to think about the most impressive street they knew in their respective cities and fill in the questionnaire accordingly. Impressive main roads, with more than 3 lanes and sidewalks, were also focussed upon. In addition, the questions were graded on a five-grade evaluation scale based on the SD method. Figure 1 shows the content of the questionnaire.

After the questionnaire was created in Japanese and translated in Chinese, it was checked for accuracy of nuance by a native Chinese speaker.

4. STATISTICAL ANALYSIS

In a questionnaire analysis of this kind, it is not rare to have discussions (Shimokawa et al. [10], Yang et al. [1, 2]) about fitness of a regression model. In recent years, ensemble learning, as a statistical method to rapidly improve the fitness of a model, has been attracting attention. Ensemble learning is a method of combining

multiple models to obtain better predictive performance than it that obtained from any one of the constituent models. In this paper, Breiman's random forests method [3] – one of the most famous ensemble learning methods – is used. The excellent reported model's prediction accuracy was expected to yield fundamental knowledge about differences and similarities in evaluation of urban streetscape development in Japan and China.

4.1 Overview of statistical analysis

The following provides an overview of statistical analysis in this survey.

- 1) To reduce the influence of individual differences in the questionnaire, the normalization of each subject was conducted.

$$x_{ji}^* = (x_{ji} - \bar{x}_i) / s_i$$

, where points assigned in the i th subject's j th item in the questionnaire is x_{ji} , and $\bar{x}_i$ is the mean number of points of the i th subject. Also, s_i represents the standard deviation of the i th subject's points allocations.

- 2) The median response of each questionnaire was calculated and the difference in points between Tokyo and Chengdu was compared using the Mann-Whitney Wilcoxon test.

1) Comprehensive evaluation				
Q1 :	poor	1 - 2 - 3 - 4 - 5	good	
Q2 :	uncomfortable	1 - 2 - 3 - 4 - 5	comfortable	
2) Individual evaluation				
2a) landscape evaluation				
Q3 :	ugly	1 - 2 - 3 - 4 - 5	beautiful	
Q4 :	inharmonious	1 - 2 - 3 - 4 - 5	harmonious	
Q5 :	uninteresting	1 - 2 - 3 - 4 - 5	interesting	
2b) function evaluation				
Q6 :	unapproachable	1 - 2 - 3 - 4 - 5	approachable	
Q7 :	deserted	1 - 2 - 3 - 4 - 5	bustling	
Q8 :	hard to walk	1 - 2 - 3 - 4 - 5	easy to walk	
3) Physical situation				
3a) road situation				
Q9 :	Lot of garbage	1 - 2 - 3 - 4 - 5	no garbage	
Q10 :	many obstacles	1 - 2 - 3 - 4 - 5	no obstacles	
Q11 :	poor road surface	1 - 2 - 3 - 4 - 5	good road surface	
Q12 :	few roadside trees	1 - 2 - 3 - 4 - 5	many roadside trees	
3b) landscape • spatial situation				
Q13 :	isolated	1 - 2 - 3 - 4 - 5	open	
Q14 :	ugly architecture	1 - 2 - 3 - 4 - 5	beautiful architecture	
Q15 :	dense	1 - 2 - 3 - 4 - 5	scattered	
3c) utilization situation				
Q16 :	noisy	1 - 2 - 3 - 4 - 5	quiet	
Q17 :	congested	1 - 2 - 3 - 4 - 5	vacant	
3d) use situation of architecture				
Q18 :	few shops	1 - 2 - 3 - 4 - 5	many shops	
Q19 :	few residential houses	1 - 2 - 3 - 4 - 5	many residential houses	
Q20 :	few office buildings	1 - 2 - 3 - 4 - 5	many office buildings	
Q21 :	few factories	1 - 2 - 3 - 4 - 5	many factories	

Figure 1: Streetscape questionnaire content

- 3) To estimate the evaluation of landscape using factor analysis, a focus was made on physical characteristics of streetscape. To adequately compare Japan and China, the same weightings were given to the questionnaire results from Tokyo and Chengdu.
- 4) The random forests method was used to process the questionnaire results. In addition, variable importance and partial dependencies were analysed to evaluate physical factors that affect evaluation of streetscapes.

4.2 Result

4.2.1 Summary of the result

Normalized questionnaire results for each question were compared using the Wilcoxon test and are shown in Table 1. Items that were significantly higher for Chengdu than for Tokyo are stated in the questions Q9 (lot of garbage-no garbage) Q16 (noisy-quiet) Q17 (congested-vacant) and Q20 (few office buildings-many office buildings). In other words, we can say that Chengdu had a strong tendency toward the right side of the response range in comparison with Tokyo. In regard to the item mentioned in Q9, the tendency may have been influenced by street cleaners' very frequent sweeping of main roads of Chengdu's centre. In regards to the item mentioned in Q16, the tendency may be a result of the presence of noisy advertising vehicles in the commercial area of Tokyo, but rarely in Chengdu, hence making Chengdu residents sensitive to noise. In regard to the item mentioned in Q17, the number of roadways does not necessarily correlate with the width of sidewalks. However, in Chengdu, the sidewalk along the main road is very wide and is not liable

to cause a feeling of congestion.

Items that were scored higher in Tokyo than in Chengdu are given in the following questions Q5 (uninteresting-interesting) Q7 (deserted-bustling) Q10 (many obstacles-no obstacles) Q14 (ugly architecture-beautiful architecture) and Q19 (few residential houses-many residential houses).

4.2.2 Estimation of factors affecting evaluation of streetscapes

By using factor analysis, factors affecting evaluation of streetscapes were estimated. Because the goal of the study was to explore the physical factors affecting the evaluation derived from streetscapes and consider similarities and differences between Tokyo and Chengdu, the same factors were considered for both cities. The data from both Tokyo and Chengdu was analyzed using factor analysis of both comprehensive evaluation items (Q1–Q2) and individual evaluation items (Q3–Q8). In addition, the maximum likelihood estimation was used to estimate the parameters in factor analysis. The minimum number of factors was decided when the p-value of the good-of-fit test became insignificant. Varimax factor rotation was used and the factor score was calculated using the Bartlett method.

Three factors were extracted (p-value = 0.518). The factor loadings are illustrated in Table 2. For the 1st factor, the factor loading of the item given in Q2 (comfortable-uncomfortable) was extremely high and that of the item given in Q1 (good-poor) was the next highest. Therefore, comfort was termed as the 1st factor. The factor loading of the item given in Q7 (deserted-bustling) had a negative

Table 1: Comparison of the items between Tokyo and Chengdu
(■ is represents significant item, *p<0.05, **<0.01, ***<0.001)

	Tokyo	Chengdu	p value
Q1 poor - good	0.612	0.605	0.937
Q2 uncomfortable - comfortable	0.299	0.194	0.243
Q3 ugly - beautiful	0.236	0.332	0.290
Q4 inharmonious - harmonious	0.208	0.104	0.362
Q5 uninteresting - interesting	0.180	-0.152	0.001 **
Q6 unapproachable - approachable	0.076	0.053	0.839
Q7 deserted - bustling	0.891	0.524	0.003 **
Q8 hard to walk - easy to walk	0.115	0.062	0.625
Q9 lot of garbage - no garbage	-0.075	0.428	<0.001 ***
Q10 many obstacles - no obstacles	0.719	0.203	<0.001 ***
Q11 poor road surface- good road surface	-0.010	-0.032	0.831
Q12 few roadside trees - many roadside trees	0.037	-0.035	0.539
Q13 isolated - open	0.493	0.371	0.237
Q14 ugly architecture - beautiful architecture	0.488	0.204	0.009 **
Q15 dense - scattered	-0.647	-0.562	0.439
Q16 noisy - quiet	-0.863	-0.620	0.011 *
Q17 congested - vacant	-0.761	-0.400	0.001 **
Q18 few shops - many shops	0.298	0.217	0.579
Q19 few residential houses - many residential houses	0.153	-0.131	0.012 **
Q20 few office buildings - many office buildings	-1.035	-0.235	<0.001 ***
Q21 few factories - many factories	0.813	0.875	0.637

Table 2: Factor loadings for evaluation of streetscape
(■ expresses the item that the factor loading is bigger than 0.20)

	The 1 st factor (comfort)	The 2 nd factor (beauty)	The 3 rd factor (activity)
Q1 poor - good	0.288	0.133	-0.203
Q2 uncomfortable - comfortable	0.994	0.073	0.050
Q3 ugly - beautiful	0.005	0.963	-0.162
Q4 inharmonious - harmonious	0.064	0.229	0.128
Q5 uninteresting - interesting	-0.004	0.024	0.385
Q7 deserted - bustling	-0.180	-0.010	0.619
Q8 hard to walk - easy to walk	0.005	0.098	-0.240
Q6 unapproachable - approachable	-0.077	-0.122	0.073
Contribution	0.139	0.128	0.09

value, which means “bustle” and “comfort” have a contradictive relationship. This relationship agrees with Yang et al.’s research (2012a, 2012b). For the 2nd factor, the factor loading of the item given in Q3 (ugly-beautiful) was extremely high, and the second highest item was given in Q4 (inharmonious-harmonious). Accordingly, beauty was termed as the 2nd factor. For the 3rd factor, the item given in Q7 (deserted-bustling) had the largest factor loading, and the second largest was given in Q5 (uninteresting-interesting), whereas items such as “hard to walk-easy to walk,” “ugly-beautiful” and “poor-good” had negative values. Therefore, activity was termed as the 3rd factor. The three factors together have a cumulative contribution of 35.7%.

Figure 2 provides a comparison of factor scores between Tokyo and Chengdu through a notched box plot of the Wilcoxon test. There is no significant difference between comfort and beauty factor scores between Tokyo and Chengdu (comfort’s p-value = 0.724, beauty’s p-value = 0.929). However, for the activity factor, the factor score in Tokyo was significantly higher than that in Chengdu (in other words, it hints that Tokyo is much more active than Chengdu). In Table 1, it can be seen in Q5 (uninteresting-interesting) and Q7 (deserted-bustling) that the factor loading in Tokyo is significantly higher than that in Chengdu. This is considered to be the cause for differences in factor scores.

Figure 2: The box-whisker plots of factor scores between Tokyo and Chengdu (p-value calculated using the Mann-Whitney Wilcoxon test)

4.2.3 Exploration of physical factors affecting evaluation of streetscape

The three cognitive characteristics (comfort, beauty, and activity) obtained in Section 4.2.2 were used as dependent variables, and the 13 physical factors from items given in Q9–Q21 were made independent variables. The random forests method was applied to the data for both cities on this basis. In this method, the number of trees is selected when the out-of-bag estimator of the error sum of squares is minimum, under a condition where the maximum number of trees is 1000.

The goal of the study was to answer the following questions. (1) What are the physical factors that affect evaluation of streetscapes? (2) Are there differences in the physical factors between Chengdu and Tokyo that affect evaluation of streetscapes? (3) If there are differences, how do the evaluations in Tokyo and Chengdu change according to the changes in physical factors?

Exploration of the factors affecting comfort

The variable importances for comfort are shown in Table 3. Variable importance is a relative statistical value that is given when independent variables (in this case, the physical factors) affect the dependent variable (comfort) under the presumption of the random forests model and the variable importance that affects the dependent variable most is set to 100.

In the Tokyo survey, the highest variable importance was given to the item mentioned in Q18 (few shops-many shops). The same item’s variable importance was 87.9 in the Chengdu survey, which made it clear that it was also important for Chengdu’s streetscape comfort. The variable importance of the item given in Q10 (many obstacles-no obstacles) was 83.3 for Tokyo, which made it second item with respect to variable importance.

In the Chengdu survey, the highest variable importance occurred for the item given in Q15 (dense-scattered) with a variable importance of 55.0 in the Tokyo survey, which is not very high. The variable importances of the items in Q13 (isolated-open) and Q14 (ugly architecture-beautiful architecture) were also high. Therefore, it is suggested

Table 3: Variable importances for comfort

(■ variable importance ≥ 90 , ■ variable importance ≥ 80 , ■ difference of variable importance ≥ 30 , ■ difference of variable importance ≥ 20)

		Tokyo	Chengdu	Tokyo-Chengdu
Q9	lot garbage — no garbage	43.3	52.2	-8.9
Q10	many obstacles — no obstacles	83.3	77.4	5.9
Q11	poor road surface — good road surface	72.9	75.4	-2.5
Q12	few roadside trees — many roadside trees	63.0	80.1	-17.1
Q13	isolated — open	72.7	80.3	-7.6
Q14	ugly architecture — beautiful architecture	53.8	81.9	-28.1
Q15	dense — scattered	55.0	100.0	-45.0
Q16	noisy — quiet	59.0	47.8	11.2
Q17	congested — vacant	51.9	64.7	-12.8
Q18	few shops — many shops	100.0	87.9	12.1
Q19	few residential houses — many residential house	38.0	50.0	-12.0
Q20	few office buildings — many office buildings	62.0	50.9	11.1
Q21	few factories — many factories	74.9	74.4	0.5

that among the physical factors for Chengdu, the comfort of streetscapes was particularly strongly influenced by landscape and spatial situation.

Figure 3 expresses the partial dependencies for the items which had a variable importance of more than 90 in either Tokyo and Chengdu, or when the absolute value of the difference between Tokyo and Chengdu was larger than 30. The full green line represents Chengdu and the dashed red line represents Tokyo. The horizontal blue line is the datum of 0. The lug in green at top of the graph represents the observed values in Chengdu and red lug at the bottom expresses those observed in Tokyo. The degree of partial dependence indicates how independent variable (i.e., the physical factor) affects the dependent variable (i.e., comfort) under presumptions of the random forests model (see the appendix). Figure 3(a) shows that the degree of partial dependence of item in Q15 (dense-scattered) with comfort tends to increase when it becomes more scattered in Chengdu. In contrast, in Tokyo, although a downward tendency is expected at the right end of the graph, because there are few lugs, it is possible that there is over-fitting. From Figure 3(b) the following can be observed. Considering the item in Q18 (few shops-many shops), comfort tends to decrease with an increase in the quantity of shops in both Tokyo and Chengdu. Here, although the sharp reduction at the right side of the graph

in Chengdu is expected, because the number of lug is only 1, there is a possibility of over-fitting. For that reason, it is considered that the change should not be interpreted.

Therefore, it is suggested that the existence of shops should strongly influence the evaluation of comfort in both Tokyo and Chengdu and comfort should decrease if the quantity of shops increases. Furthermore, the tendency observed in Chengdu states that more scattered the streetscape are, the better the comfort becomes.

Exploration of the factors affecting beauty

The variable importances for beauty are shown in Table 4. The highest variable importance was given to the item given in Q15 (dense-scattered) for both Tokyo and Chengdu. The variable importances of items given in Q19 (few residential houses-many residential houses), Q20 (few office buildings-many office buildings), and Q17 (congested-vacant) were high. The variable importance of the item given in Q21 (few factories-many factories) for Tokyo was 32.2 points higher than that for Chengdu. Therefore, the influence of building use on beauty is bigger in Tokyo than Chengdu. In contrast, the effect of item in Q15 (dense-scattered) in Chengdu is striking. The variable importance of the item in Q12 (few roadside trees-many roadside trees) for Tokyo was 33.2 points higher than that for Chengdu.

Figure 4 shows the degrees of partial dependence on items where the variable importance was more than 90 for either Tokyo and Chengdu or where the absolute value of the difference between the variable importances for Tokyo and Chengdu was larger than 30. Figure 4(a) shows that with respect to item [Q12: few roadside trees-many roadside trees], beauty tended to increase with an increase in the quantity of roadside trees for Tokyo, while there was no pronounced increase tendency for Chengdu. This may be due to the fact that in Chengdu, roadside trees are planted along almost all main roads but in Tokyo this only occurs sometimes. In relation to the item in Q15 (dense-scattered), beauty tended to reduce rapidly when density

Figure 3: The partial dependencies on the comfort (red: Tokyo, green: Chengdu)

Table 4: Variable importances for beauty

(■ variable importance ≥ 90 , ■ variable importance ≥ 80 , ■ difference of variable importance ≥ 30 , ■ difference of variable importance ≥ 20)

		Tokyo	Chengdu	Tokyo-Chengdu
Q9	lot garbage — no garbage	56.5	50.6	5.9
Q10	many obstacles — no obstacles	57.4	56.2	1.2
Q11	poor road surface — good road surface	68.9	43.7	25.2
Q12	few roadside trees — many roadside trees	71.9	38.7	33.2
Q13	isolated — open	63.3	38.0	25.3
Q14	ugly architecture — beautiful architecture	78.7	51.6	27.1
Q15	dense — scattered	100.0	100.0	0.0
Q16	noisy — quiet	64.5	35.0	29.5
Q17	congested — vacant	82.4	58.9	23.5
Q18	few shops — many shops	53.2	46.7	6.5
Q19	few residential houses — many residential house	99.4	49.5	49.9
Q20	few office buildings — many office buildings	89.6	48.2	41.4
Q21	few factories — many factories	74.8	42.6	32.2

became lower for both Tokyo and Chengdu. In Figure 4(b), it can be seen that the reduction was more dramatic in Tokyo than in Chengdu. In this survey, the focus was on the main roads in urban areas. In such areas, roads with a scattered impression may have an ugly appearance. For the item in Q19 (few residential houses-many residential houses), beauty tended to reduce with an increase in the

quantity of residential houses in Tokyo. For Chengdu, an increasing trend near zero can be observed, which means that even if the quantity of residential houses decreases, the level of beauty will not change, and the level of beauty will rise with an increase in the quantity of residential houses. The reason may be that in Tokyo, many residential areas along the main road are similar to those at downtown, while in Chengdu, even if residential areas are along the main road, they can be of high quality. To sum up, the different partial independencies may be affected by the different residential situations in Tokyo and Chengdu. In Tokyo, although the partial independence of the item in Q20 (few office buildings-many office buildings) tends to decrease rapidly toward the right side of the graph, it is appropriate to regard this as overfitting because there is almost no lug. Apart from that occurrence, no remarkable change can be observed. For partial independence of the item in Q21 (few factories-many factories), beauty tended to decrease when the quantity of factories became larger for both Tokyo and Chengdu. The reduction tendency was marked high for Tokyo than for Chengdu.

Exploration of the factors affecting activity

The variable importances for activity are shown in Table 5. The highest variable importance was given to the item in Q17 (congestion-vacant) for both Tokyo and Chengdu. The other physical factors hardly affected activity.

Figure 5 shows degrees of partial dependence on items where the variable importance was more than 90 for either Tokyo and Chengdu, or where the absolute value of the difference between the variable importances for Tokyo and Chengdu was larger than 30. For the item given in Q17 (congestion-vacant), a rapid downward tendency was shown as the road became vacant for both Tokyo and Chengdu. The value of partial independence was higher for Tokyo than for Chengdu. Figure 2(c) shows that activity for Tokyo is significantly higher than Chengdu. Therefore, it can be inferred that the magnitude of item in Q17 (congestion-vacant) led to difference in activity.

Figure 4: The partial dependencies on the beauty (red: Tokyo, green: Chengdu)

Table 5: Variable importances for activity

(■ variable importance ≥ 90 , ■ variable importance ≥ 80 , ■ difference of variable importance ≥ 30 , ■ difference of variable importance ≥ 20)

		Tokyo	Chengdu	Tokyo-Chengdu
Q9	lot garbage - no garbage	54.2	46.4	7.8
Q10	many obstacles - no obstacles	49.7	35.7	14.0
Q11	poor road surface — good road surface	18.2	25.7	-7.5
Q12	few roadside trees- many roadside trees	23.2	52.7	-29.5
Q13	isolated - open	20.6	31.4	-10.8
Q14	ugly architecture - beautiful architecture	22.4	30.6	-8.2
Q15	dense - scattered	59.0	52.8	6.2
Q16	noisy - quiet	51.8	53.7	-1.9
Q17	congested - vacant	100.0	100.0	0.0
Q18	few shops - many shops	58.2	29.4	28.8
Q19	few residential houses - many residential house	22.7	33.6	-10.9
Q20	few office buildings - many office buildings	20.7	48.2	-27.5
Q21	few factories - many factories	26.0	52.7	-26.7

Figure 5: The partial dependencies on the activity (red: Tokyo, green: Chengdu)

5. CONCLUSION

In this paper, using a questionnaire, the effect of similarities and differences in the importance of physical factors on the evaluation of urban main road streetscapes in both Japan and China was explored. The study areas were chosen to be Tokyo in Japan and Chengdu in China, as they were considered similar enough and could be compared. The results are summarized as follows:

1. The three chief factors affecting perception of streetscapes were determined as comfort, beauty, and activity. These factors were also extracted in the experiments by Kitamura [4] and the same trend has been apparent in other researches.
2. Out of the three factors, the activity score of Tokyo was significantly higher than Chengdu.
3. The number of shops strongly influenced the evaluation of comfort for both Tokyo and Chengdu. Comfort plummeted in areas with many shops. Density had a strong effect on comfort in Chengdu, low density increases comfort. It was suggested that for Chengdu, comfort of streetscapes is strongly influenced by landscape and spatial situation.
4. For beauty, the density had the strongest influence in both Tokyo and Chengdu, beauty reduced heavily at

great scattering. An increase in the quantity of houses decreased the level of beauty in Tokyo but increased in Chengdu. The impact of building usage on beauty was stronger in Tokyo than in Chengdu.

5. For activity, the congestion of streets had the strongest influence for both Tokyo and Chengdu, with decreasing activity, streets become vacant.

APPENDIX: RANDOM FORESTS METHOD

A.1 Outline of random forests

The random forests method is one of ensemble method proposed by Breiman[3]. This model is constructed based on combines the B decision trees. Each tree is constructed using a bootstrap samples. In regression problem, the random forest model $f_{RF}(\mathbf{x})$ for estimation of output y , is given by

$$f_{RF}(\mathbf{x}) = \frac{1}{B} \sum_{b=1}^B T_b(\mathbf{x}; \boldsymbol{\theta}_b) \quad (\text{A.1})$$

where $\mathbf{x}$ is P predictor variable $\mathbf{x} = (x_1, x_2, \dots, x_P)^T$, and $\boldsymbol{\theta}_b$ is a parameter vector (partitioning variables, and splitting points) of b th tree. The algorithm of constructing trees $T_b(\mathbf{x}; \boldsymbol{\theta}_b)$ is applied growth process in CART algorithm, under randomly selected $m (< P)$ variables at each node to consider for splitting. Given a training set $L = \{\mathbf{x}_n, y_n\}$, $n = 1, \dots, N$, the random forest procedure is described in Algorithm A.1.

A.2 Variable importance

The random forests model is constructed so many trees that they are useless for interpretation. In interpretation of estimated random forests model, a descriptive statistics that is often of interest is the variable importance of the respective predictor variables. The variable importance uses the OOB samples to construct a different variable importance measure, apparently to measure the prediction

Algorithm.A.1:The random forest algorithm for regression problem

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- 0 **Input :** B : the number of tree in the forest. m : the number of random predictor variable to select (default $P/3$)
 - 1 **For** $b=1, \dots, B$
 - a: Generate a bootstrap sample L_b^* of size N by sampling with replacement from the training set L . The nonbootstrap samples for iteration b is called Out-Of-Bag (OOB) samples L_b^{OOB} .
 - b: Grow a tree model $T_b(\mathbf{x}; \hat{\boldsymbol{\theta}}_b)$ using the bootstrap samples L_b^* , randomly selecting at each node in the tree m variables to consider for splitting, until the minimum node size $n_{\min}$.
 - 2 **Next** b
 - 3 **Output:** the estimated random forest model is given by

$$\hat{f}_{\text{RF}}(\mathbf{x}) = \frac{1}{B} \sum_{b=1}^B T_b(\mathbf{x}; \hat{\boldsymbol{\theta}}_b).$$
-

strength of each variable. When the b th tree is grown, the OOB samples are passed down the tree, and the prediction accuracy is recorded. Then the values for the p th variable are randomly permuted in the OOB samples, and the accuracy is again computed. The decrease in accuracy as a result of this permuting is averaged over all trees, and is used as a measure of the importance of variable x_p (Hastie et al. [11]).

A.3 Partial dependence

For two or more predictor variables, we are difficult to graphical evaluate influences of predictor variables to the random forests model. A useful alternative can sometimes be to view a collection of plots, each one of which shows the partial dependence of the approximation $f_{\text{RF}}(\mathbf{x})$ on a selected small subset of the predictor variables (Friedman [12]).

Consider l ($l < P$) variable $\mathbf{x}_S$, indexed by $S \subset \{1, 2, \dots, P\}$. Let C be the complement set, with $S \cup C = \{1, 2, \dots, P\}$. Then, estimated random forest model in principle depend on variables in both subsets $f_{\text{RF}}(\mathbf{x}) = f_{\text{RF}}(\mathbf{x}_S, \mathbf{x}_C)$. The partial dependence of $f_{\text{RF}}(\mathbf{x})$ on $\mathbf{x}_S$ is defined as

$$f_S(\mathbf{x}_S) = E_{\mathbf{x}_C} f_{\text{RF}}(\mathbf{x}_S, \mathbf{x}_C).$$

Given a training set $L = \{\mathbf{x}_n, y_n\}$, $n = 1, \dots, N$, the partial dependence function for subset variables $\mathbf{x}_S$ is estimated by

$$\bar{f}_S(\mathbf{x}_S) = \frac{1}{N} \sum_{n=1}^N \hat{f}_{\text{RF}}(\mathbf{x}_S, \mathbf{x}_{C,i}),$$

where $\{\mathbf{x}_{C,1}, \mathbf{x}_{C,2}, \dots, \mathbf{x}_{C,N}\}$ are the observations of $\mathbf{x}_C$ (Hastie et al. [11]).

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