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Analysis of the Effects of Walking Environment Components on Pedestrian Satisfaction and Dissatisfaction

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Abstract: Unsatisfactory urban walking environment stresses urban residents, and may cause mental illness and chronic diseases by reducing walking activities. Therefore, establishing a high-quality walking environment that can promote walking activities in urban residents has emerged as an important issue. The walking environment consists of various components, such as trees, stairs, streetlights, benches, signs, fences, and facilities, and it is essential to understand which components and their settings act as satisfiers or dissatisfiers for pedestrians, to create a better quality walking environment. Therefore, this study investigated pedestrian satisfaction and dissatisfaction as a function of various environmental components through a survey using walking environment images. The results revealed that most of the walking environment components except the braille block and treezone exhibited significant correlations with pedestrian satisfaction. Particularly, safety-related component (e.g., adjacent roads, parked cars, traffic cushions, and car separation), and landscape-related components (e.g., trees and green), as well as the material settings of landscape facilities (e.g., wooden fences, benches, stairs, and walkway surfaces) correlated with pedestrian satisfaction. The results of this study can contribute to the extraction of useful features to evaluate pedestrian satisfaction as a function of the walking environment. The research outcome is expected to assist in the effective arrangement of walking environment components and their settings, which will ultimately contribute to significantly satisfactory walking environment and encourage walking activities.

Key words: walking environment, pedestrian satisfaction, chi-square test, mutual information

1. INTRODUCTION

A complex urban environment can affect the mental and physical health of urban residents [1]. Particularly, a poor urban environment has been reported as a factor that contributes to an increase in chronic diseases by reducing the walking activities of urban residents and making them dependent on the use of automobiles [2]. In addition, numerous studies have revealed that compared to nature, urban environment negatively affects mental health, and that walking in an uncomfortable urban environment causes stress in adults with mental illness [3]. Therefore, the

establishment of a high-quality walking environment has emerged as an important issue directly related to the health of modern people.

Walking exhibits advantages, such as reduced vehicle use and transportation costs [4], and is a personal means of transportation that provides equal opportunities to the elderly, children, and women who are vulnerable to transportation [5]. However, the value of walking is underestimated, and transportation plans and policies related to walking are lacking [4], [6], [7]. Factors that affect individual decision-making of walking include not only trip preferences and individual characteristics (e.g., physical ability) of pedestrian but also attributes of the external walking environment (e.g., environmental quality and safety) [8][9]. Although it is difficult to control the personal pedestrian factors that affect walking decision, walking can be encouraged by creating a better external walking environment.

The walking environment consists of various environmental components, such as trees, stairs, streetlights, benches, signs, fences, and facilities. Depending on the settings (e.g., type, shape, and material) of the walking environment components, walking environment may exhibit different effect on the pedestrian [10]; accordingly, it is essential to satisfy the needs of pedestrians, or their dissatisfaction may result in stress. Thus, it is essential to understand the subjective pedestrian experience based on the components of a walking environment.

Therefore, the purpose of this study was to investigate pedestrian satisfaction and dissatisfaction according to various environmental components through a survey using walking environment images, which can be used as meaningful features to evaluate and predict pedestrian satisfaction levels in the walking environment.

2. LITERATURE REVIEW

According to recent studies on the mental health of urban residents, noise pollution, air pollution, and poor urban environment negatively affect the mental health of urban residents [11]–[15]. Furthermore, an increasing number of studies have revealed that urban green spaces and waterfront spaces positively affect mental health [16]–[21]. In addition, several previous studies have employed questionnaires to propose walking environment standards suitable for urban pedestrians [22]–[24]. However, they did not conduct an in-depth analysis that considers various settings (e.g., type, shape, and material) of the physical walking environmental components of a city. To establish a high-quality walking environment that positively affects pedestrians, the effect of each walking environment component and its setting on pedestrians should be investigated.

Recently, MIT Media Lab developed a perceived safety prediction model for walking environment photos by learning the crowdsourced evaluation of various walking environment photos to a machine learning algorithm using an image comparison method based on the of learning the pixels, patterns, and colors of the photos [25]. However, despite the usefulness of this method for the evaluation of walking environment, this model does not consider various walking environment components. Walkscore measured the walkability of streets in the United States and Canada by considering the distances to amenities in 13 categories (e.g., grocery stores, coffee shops, restaurants, bars, movie theaters, schools, parks, libraries, bookstores, fıtness centers, drugstores, hardware stores, and clothing/music stores) [26]; however, this study did not sufficiently consider the walking environment components related to the obstacles, caution area, landscape, and aesthetics. In summary, to effectively construct and improve a walking environment, it is essential to comprehensively understand which walking environment components and their settings act as satisfier or dissatisfier for pedestrians, and the extent of their effects on pedestrian satisfaction/dissatisfaction levels.

3. RESEARCH PROCESS

This study conducted a pedestrian survey using various images of the walking environment to investigate the effects of walking environment components on pedestrian satisfaction and dissatisfaction. To this end, a list of walking environment components was constructed by referring to satisfiers and dissatisfiers investigated in previous research and questionnaires [22]–[24]. Thereafter, the correlation between the walking environment components included in each image and the surveyed pedestrian satisfaction/dissatisfaction level was examined using a chi-square test. The chi-square test is a useful statistical method that enables researchers to test hypotheses about variables measured at the nominal level, and can be used to analyze the significance of the satisfaction difference for different situations [27].

Next, the ranking of major guesses for predicting pedestrian satisfaction was confirmed by analyzing the mutual information between each walking environment component and pedestrian satisfaction/dissatisfaction level. A mutual information is a measure of the mutual dependence between two random variables and can be used as a distinguisher that ranks key guesses among variables for classification analysis [28].

To create the image datasets of the walking environment for the questionnaire, public data provided by the AI Hub operated by the National Information Society Agency was employed. This data was produced to construct a general-purpose dataset that can be extended and applied to the development of technologies related to general movement in pedestrian walkways. In this study, 100 images of the walking environment during daytime were selected for the survey, and the images contained benches, soundproof walls, fences, stairs and spaces under repair, facilities and decks, waterfront spaces, and bridges. A minimum of four, a maximum of 18, and an average of nine walking environment components were included in each photo. The survey was conducted for anonymous participants by posting on online bulletin boards in the Google survey form for a month from November 17 to December 17, 2021 (Table 1), and 405 respondents participated in the survey, and each respondent evaluated 20 images. Consequently, 8,100 questionnaire datasets for the 100 images were collected. The contents investigated through the questionnaire were satisfiers and dissatisfiers among the components included in the walking environment images, and the overall pedestrian satisfaction/dissatisfaction level with the walking environment. Satisfiers and dissatisfiers were evaluated subjectively, and pedestrian satisfaction level was evaluated on a three-point-scale score.

Table 1. Summary of the survey

Survey Period	2021.11.17–2021.12.17
Survey Respondents	405 people, each of which evaluated 20 images (Total of 8,100 evaluation datasets)
Questions (Sample)	 1. Are there any factors that make this walking environment comfortable? 2. Are there any factors that make this walking environment uncomfortable? 3. Do you think this walking environment is good for walking?

4. RESULTS AND DISCUSSION

Table 2 shows the list of essential components (and their settings) of the walking environment included in the surveyed images, which are the satisfiers or dissatisfiers derived from previous studies on the criteria of a walking environment [22]–[24]. Based on the survey results, the satisfied and/or dissatisfied settings in each walking environment component mentioned by respondents were listed, and the mean values of the satisfaction scores of the respondents (1: dissatisfaction, 2: overage, 3: satisfaction) were analyzed based on each setting.

Table 2. Descriptive statistics of the survey results

Factor	Component	Settings	N	Mean	SD	Min	Max
Walkway	Surface	0 dirt road	3	1.992	0.374	1.593	2.333
		1 cement	6	1.922	0.521	1.185	2.691
		2 asphalt	18	2.056	0.523	1.074	2.753
		3 block	61	2.250	0.434	1.074	2.938
		4 urethane	12	2.458	0.361	1.889	2.889
	Wooden deck	0 without	89	2.214	0.482	1.074	2.938
		1 with	11	2.202	0.223	1.827	2.543
	Curve	0 straight	58	2.116	0.479	1.074	2.938
		1 curved	32	2.340	0.432	1.284	2.889
		2 openspace	5	2.514	0.189	2.309	2.741
	Braille block	0 without	87	2.212	0.464	1.074	2.938
		1 with	13	2.215	0.452	1.617	2.827
	Bike road	0 without	77	2.192	0.500	1.074	2.938
		1 shared	9	2.300	0.228	2.086	2.691
		2 separated	14	2.272	0.329	1.827	2.802
Safety	Adjacent road	0 without	46	2.455	0.357	1.185	2.938
		1 with	54	2.006	0.439	1.074	2.802
	Crosswalk	0 without	90	2.242	0.467	1.074	2.938
		1 with	10	1.946	0.291	1.556	2.531
	Car separation	0 not separated	7	1.531	0.369	1.074	2.111
		1 separated	93	2.264	0.425	1.074	2.938
	Traffic cushion	0 without	23	1.839	0.480	1.074	2.938
		1 with	77	2.324	0.392	1.185	2.889
	Parked car	0 without	86	2.292	0.409	1.074	2.938
		1 with	8	1.910	0.456	1.309	2.667
		2 invades walkway	6	1.486	0.406	1.074	2.259
	Street light	0 without	74	2.162	0.474	1.074	2.889
		1 with	26	2.358	0.390	1.469	2.938
	Fence	0 without	60	2.234	0.514	1.074	2.938
		1 wood	12	2.471	0.247	1.951	2.889
		2 steel	26	2.081	0.344	1.198	2.864
		3 stone	2	1.753	0.192	1.617	1.889
	Soundproof wall	0 without	91	2.229	0.453	1.074	2.938
		1 wood	3	2.255	0.483	1.889	2.802
		2 steel	1	1.074	-	1.074	1.074
		3 plastic	5	2.126	0.400	1.679	2.580
Obstacle	People	0 without	82	2.175	0.480	1.074	2.938
		1 with	18	2.385	0.308	1.802	2.827
	Moving object	0 without	68	2.258	0.409	1.074	2.889
		1 with	32	2.116	0.548	1.074	2.938
	Static object	0 without	46	2.341	0.406	1.074	2.889
		1 with	54	2.103	0.478	1.074	2.938
Caution area	Stair	0 without	83	2.202	0.462	1.074	2.938
		1 wood	8	2.361	0.134	2.173	2.556
		2 steel	2	1.475	0.009	1.469	1.481
		3 stone	7	2.384	0.553	1.185	2.827
	Manhole	0 without	85	2.229	0.454	1.074	2.938
		1 with	15	2.119	0.497	1.198	2.827
	Tree zone	0 without	73	2.225	0.449	1.074	2.938
		1 with	27	2.180	0.496	1.074	2.827
	Grating	0 without	95	2.214	0.450	1.074	2.938
		1 with	5	2.183	0.687	1.185	2.889
	Repair zone	0 without	92	2.247	0.431	1.074	2.938

		1 with	8	1.821	0.622	1.074	2.605
Landscape	Tree	0 without	17	1.760	0.420	1.074	2.395
		1 with	83	2.305	0.412	1.074	2.938
	Green	0 without	25	1.998	0.567	1.074	2.938
		1 with	75	2.284	0.397	1.309	2.889
Amenities	Bench	0 without	75	2.156	0.483	1.074	2.889
		1 wood	18	2.404	0.320	1.741	2.938
		2 steel	2	2.759	0.183	2.630	2.889
		3 stone	4	2.241	0.291	1.877	2.580
		4 plastic	1	1.852	-	1.852	1.852
	Facility	0 without	91	2.187	0.461	1.074	2.938
	(e.g., bus station,	1 wood	8	2.448	0.389	1.741	2.889
	bike station)	2 steel	1	2.679	-	2.679	2.679
	Sign	0 without	89	2.226	0.452	1.074	2.938
		1 wood	2	2.611	0.079	2.556	2.667
		2 steel	9	1.995	0.523	1.074	2.691
	Culture space	0 without	94	2.193	0.463	1.074	2.938
		1 square	3	2.486	0.186	2.309	2.679
		2 fitness equipment	3	2.556	0.418	2.086	2.889
Aesthetics	Garbage	0 without	98	2.228	0.450	1.074	2.938
		1 with	2	1.444	0.367	1.185	1.704
	Water space	0 without	92	2.183	0.465	1.074	2.938
		1 with	8	2.554	0.184	2.160	2.753
	Building	0 without	47	2.242	0.433	1.074	2.938
		1 with	53	2.187	0.485	1.074	2.889
	Bridge	0 without	77	2.258	0.454	1.074	2.938
		1 with	9	2.328	0.437	1.370	2.753
		2 under the bridge	14	1.892	0.398	1.309	2.580

The results of the chi-square analysis confirmed that there were correlations between all components of the walking environment and pedestrian satisfaction except the braille block and treezone (Table 3). The chi-square values of the braille block and treezone were less than 9.210, which is the standard value when d.f = 2 and p = 0.01, indicating that braille blocks and tree zones were not correlated with pedestrian satisfaction.

Table 3. Result of chi-square analysis

Factor	Feature	Chi-square	d.f	p
Walkway	Surface	345.588	8	0.000
	Wooden deck	73.383	2	0.000
	Curve	238.007	4	0.000
	Braille block	8.738	2	0.013
	Bicycle road	46.294	4	0.000
Safety	Adjacent road	807.416	2	0.000
	Crosswalk	162.937	2	0.000
	Car separation	643.522	2	0.000
	Traffic cushion	707.725	2	0.000
	Parked car	863.891	4	0.000
	Street light	118.948	2	0.000
	Fence	347.759	6	0.000
	Soundproof wall	347.759	6	0.000
Obstacle	People	109.910	2	0.000
	Moving object	127.007	2	0.000
	Static object	226.096	2	0.000
Caution area	Stair	295.629	6	0.000
	Manhole	24.678	2	0.000

	Tree zone	7.909	2	0.019
	Grating	28.012	2	0.000
	Repair zone	279.180	2	0.000
landscape	Tree	716.580	4	0.000
	Green	301.285	4	0.000
Amenities	Bench	280.939	8	0.000
	Facility	115.755	4	0.000
	Sign	137.711	4	0.000
	Culture space	107.339	4	0.000
Aesthetics	Garbage	217.847	2	0.000
	Water space	167.121	2	0.000
	Building	17.626	2	0.000
	Bridge	281.725	4	0.000

The mutual information analysis results (Figure 1) revealed that the top five walking environment components that affected the pedestrian satisfaction were adjacent road (mutual information = 0.0515), parked car (0.0446), tree (0.0430), traffic cushion (0.0415), and car separation (0.0346). The walking environment components significantly affected the pedestrian satisfaction in the following order: fence (0.0235), walkway surface (0.0216), bench (0.0194), stair (0.0192), green (0.0182), bridge (0.0178), walkway curve (0.0164), soundproof wall (0.0159), static object (0.0142), repair zone (0.0142), garbage (0.0124), crosswalk (0.0111), and water space (0.0109). In contrast, facility (0.0082), sign (0.0082), cultural space (0.0079), street light (0.0074), wooden deck (0.0046), bicycle road (0.0031), grating (0.0017), manhole (0.0015), building (0.0011), tree zone (0.0005), and braille block (0.0005) exhibited a low correlation with the pedestrian satisfaction, all of which were less than 0.01.

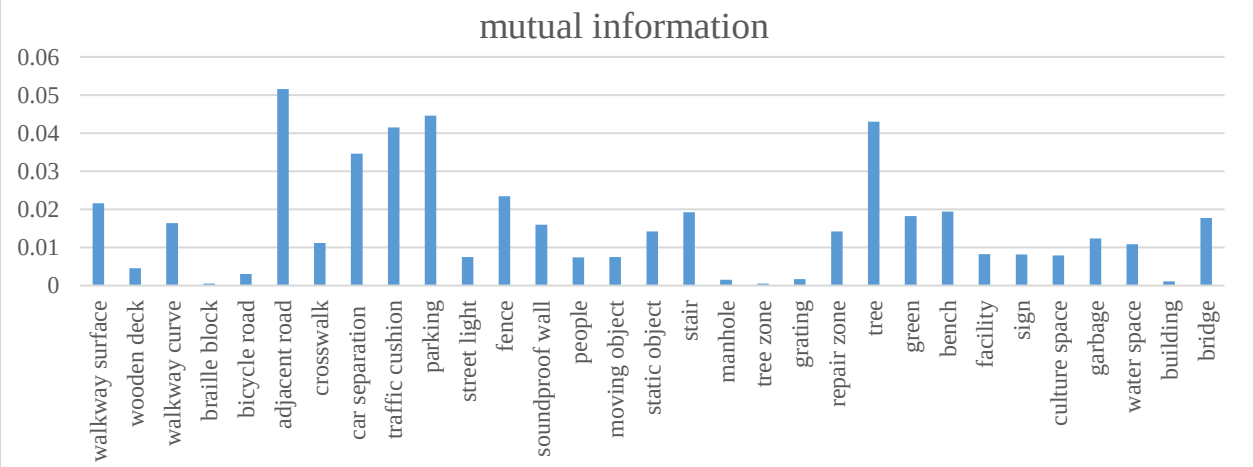

Figure 1. Result of mutual information analysis

The factors that exhibited the most significant effect on pedestrian satisfaction were trees and safety-related components. The evaluation of the difference in pedestrian satisfaction/dissatisfaction scores according to the presence or absence of each component revealed that pedestrians feel a high satisfaction with a walking environment with trees, no adjacent roads, with traffic cushions, separated from the road, and no cars parked nearby. In addition, the components of the walking environment composed of various materials affected pedestrian satisfaction. Particularly, pedestrians feel high satisfaction with environment consisting of wooden fences, soundproof walls, stairs, and walkway surfaces made of blocks and urethane.

5. CONCLUSIONS

In this study, the effect of walking environment components on pedestrian satisfaction/dissatisfaction was analyzed to establish a high-quality walking environment that can promote urban walking. Chi-square analysis confirmed the correlation between pedestrian environment components and pedestrian satisfaction/dissatisfaction scores except the braille block and treezone. In addition, mutual information analysis confirmed the high correlation between safety and landscape-related components. Further, the material settings of components, such as a wooden fence, walkway surface, bench, stair, and soundproof wall, affect pedestrian satisfaction. This research results can be utilized for evaluating pedestrian satisfaction/dissatisfaction according to the walking environment components and building a prediction model for pedestrian satisfaction. This research outcome is expected to ultimately contribute to the development of an efficient walking environment and the improvement of urban walking.

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