Pedestrian Crossing Location Choice Analysis on Two-way Two-lane Roads based on Questionnaire Survey

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Pedestrian jaywalking behavior has received much attention due to its potential harm. To decrease probability of dangerous jaywalking, it is necessary to clarify the effect of different factors on pedestrian crossing behavior. Therefore, this study aims to clarify the influencing factors of pedestrian crossing location choices using data collected through a questionnaire survey. The survey captured responses from a diverse sample of respondents regarding their preferred choices under different traffic conditions, type of available crosswalk and OD pairs. By using statistical analysis techniques and developing a choice model, the study explored that middle-aged people, pedestrians in a hurry, experienced drivers and those with higher education were more prone to jaywalking. Greater distance from OD to the crosswalk, lower traffic density, unsignalized facilities and brick pavement also encouraged pedestrians to choose to jaywalk.

Key Words : *pedestrians, jaywalking, web questionnaire survey*

1. INTRODUCTION

Pedestrians are important participants in the integrated traffic system. Without protection measures, they are vulnerable and easily involved into traffic crashes. One prevalent issue that poses significant risks to pedestrians is the occurring of jaywalking. According to the statistics of the Traffic Bureau of the National Police Agency[1)] in Japan, 36.6% of traffic crashes fatalities were caused by pedestrian jaywalking. Cantillo et al.[2)] found the highest incidence of fatal traffic crashes happens when pedestrian cross outside of or away from the crossing facilities. To address the challenges posed by jaywalking and mitigate its negative impacts, a comprehensive understanding of the impact of contributing factors and strategies on pedestrian jaywalking behavior is crucial. Though researches and countermeasures have been conducted to promote safe crossings, dangerous jaywalking still exists and causes problems. By analyzing the factors that influence pedestrians' choices when selecting crossing locations and identifying their relative importance, effective strategies that aligns with pedestrians' needs can be developed to promote a pedestrian-friendly traffic environment.

Therefore, the objective of this study is to realize quantitative prediction of pedestrians jaywalking probability by building a pedestrian crossing location choice model about whether to choose jaywalking and examine the comprehensive effects of contributing factors on pedestrians' decision-making process.

2. LITERATURE REVIEW

There are currently many studies about pedestrian jaywalking behavior. Generally, factors affecting pedestrian jaywalking behavior can be classified into four categories, personal characteristics, traffic conditions, road configuration and environmental conditions.

Personal factors have been widely considered in the estimation of pedestrian jaywalking behavior. Al Bargi and Daniel[3)] found that older groups, females, and people carrying baggage prefer to utilize zebra crossings by carrying out observation experiments. Adachi et al.[4)] found pedestrians are more inclined to jaywalk when walking distance can be significantly reduced by jaywalking actions through video survey. Zhang et al.[5)] found that lower educational level and urgent situations can lead to pedestrians' violation

behaviors by conducting questionnaire survey. Guo et al.[6] conducted both video survey and questionnaires, indicating that if the trip is related with work or school pedestrians are more likely to perform illegally. Dhoke and Choudhary[7] referred to previous literature and concluded that pedestrians with positive attitudes towards vehicle yielding behavior are more likely to adopt jaywalking.

Traffic-related characteristics have also been shown to have a large impact on the occurrence of pedestrian jaywalking behavior. Wang et al.[8] found that preference of pedestrian choosing to jaywalk decreases with traffic density increasing. Kumar and Ghosh[9] established a regression model to indicate lower vehicle approaching speed and less pedestrian volume encouraged pedestrians to cross in an illegal manner. The authors also found that pedestrians crossing in a group often has lower chances of taking risk in an increased severity level. Li et al.[10] built a logit regression model and found that law enforcement camera can promote higher vehicle yield rate and thus decrease the probability of serious conflict.

Factors related to road configurations are found to have significant impact on pedestrian jaywalking behavior as well. Guo et al.[11] indicated that the origin and destination of a trip can significantly affect both the choice of jaywalking and types of crossing facilities. Sisiopiku and Akin[12] and Wang et al.[13] found the crosswalk location was the most influential factor for pedestrians deciding to cross at a designated location. Brosseau et al.[14] found that the presence of traffic signal can decrease the probability of dangerous crossings by pedestrians. Mukherjee and Mitra[15] found pavement markings and roadway width are significant site factors that can influence pedestrians' crossing modes while Hasan and Napiah [16] indicated the installation of a fence and barriers can effectively prevent pedestrians from jaywalking.

Environmental condition generally includes factors of weather, travel date and time, and land use. Wang et al.[17] found that heavy rains, high temperature during summer time and other unfavorable weathers will enhance the risks of illegal crossing behaviors by pedestrians. While Liu et al.[18] indicated that the tendency of crossing illegally is higher during weekdays or in the morning of a day due to the lower tolerance of waiting time at the crosswalk. Guo et al.[19] analyzed the impact of land use and found pedestrians tend to violate traffic rules in commercial and residential area but obey the rules in educational area even though the waiting duration is long.

In summary, the literature review highlighted various kinds of contributing factors influencing pedestrian jaywalking behavior and put forward different corresponding modeling techniques to study it. However, countermeasures and strategies implemented as a result of previous studies on restraining pedestrians jaywalking phenomenon are still at the variance with the real-life situation. For instance, according to Japan Traffic Regulation Standards[20], pedestrian crossing should be generally spaced at least 100m apart but in real world jaywalking behavior is often observed within this spacing[21]. Considering vehicle and pedestrian travel time, previous studies found 50m of intervals for multiple two-stage crosswalks appropriate[22], without consideration of the possibility of pedestrian taking jaywalking behavior, where corresponding countermeasures on design of crossing facilities hardly took into account pedestrian jaywalking. Thus, it is quite necessary to conduct researches on exploring what factors lead to pedestrians' jaywalking behavior and fill this research gap. The insights derived from this study are intended to be applied practically to optimize the placement of pedestrian crossing facilities, guiding the rational design of crosswalks, ensuring safer road environments.

3. SCENARIO DESIGN AND DATA COLLECTION

(1) Scenario design

Based on the contents above, a set of potential factors influencing pedestrian jaywalking behavior was identified. Though these factors encompassed a wide range of dimensions and each potential factor was carefully examined for its theoretical and practical significance, there are still some research gaps. For instance, the impact of a comparison between the detour distance a pedestrian can tolerate and the distance needed to directly jaywalk toward the direction of destination, and also the placement of crossing facilities need more discussion. And few research has explored the effect of signals on pedestrian choice of jaywalking in terms of spatial concepts. In addition, few studies have examined changes in carriageway paving materials, extending their significance to the study of shared spaces.

Therefore, in order to investigate pedestrians' crossing location choice in different situations and whether these relevant factors have impacts on their choosing to jaywalk, twenty potential factors influencing pedestrian jaywalking behavior are identified and included in the survey and six of them, which are location of origin, location of destination, in a hurry, traffic density, crosswalk type, and roadway pavement, are considered in the traffic scenario design based on the extensive review of literature above. **Table 1** presents the selected influencing factors in this research.

Table 1 Selected influencing factors

Categories	Factors
Personal characteristics	Gender
	Age
	Possession of driver's license
	Driving frequency
	Residential environment
	Parenting situation
	Educational level
	Jaywalking frequency
	Expectation on vehicle yield rate
	Big-five personality traits(Extraversion, Agreeableness, Conscientiousness, Neuroticism, Openness)
	In a hurry
Traffic condition	Traffic density
Road configuration	Location of origin
	Location of destination
	Crosswalk type
	Roadway pavement

*Location of OD are described using distance from the OD to the adjacent boundary of the crosswalk, which are expressed by X_{OC}(m) and X_{DC}(m) respectively

Variables including location of origin with 3 levels (20m, 50m, 70m), location of destination with 4 levels (0m, 20m, 50m, 70m), in a hurry with 2 levels (No, Yes), traffic density with 2 levels (Low, High), combination of crosswalk and roadway pavement with 3 levels (Unsignalized crosswalk with Asphalting paving, Unsignalized crosswalk with Brick paving, Signalized crosswalk with Aspahlt paving), together constitute 144 traffic scenarios. In the case that the road is paved with bricks, the paving of the carriageway and the sidewalk is very similar and more difficult to distinguish than the asphalt paving, for the purpose of evaluating whether visual and intuitive navigations have impact on pedestrians' behavior.

This study only focuses on cases that both origin and destination are located at the same side from the crosswalk, where pedestrians need to detour a certain distance to reach the destination. If the crosswalk is available on the line connecting from origin to destination, at least it is expected that the jaywalking after passing crosswalk would be lower. In addition, the possibility to jaywalk before reaching the crosswalk might be similar to the one if the destination is located just at the curb of the crosswalk. Therefore, the major discussion would be the case when pedestrians are forced to detour if they are in compliance. The distribution of the location of each origin and destination is shown in **Fig.1**.

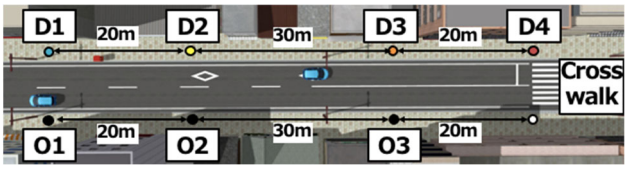


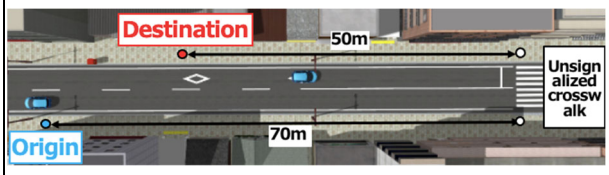
Fig.1 Distribution of the location of each OD



Fig.2 CG-made virtual road environment

Table 2 Question example

You are now going to look at two CG-created pictures: the first one is the overlook view of a road, with one destination and one origin, and the second one is a close-up view. Assume that you are now standing at the origin.





Looking at these pictures, answer the following questions. The distance from where you stand to the unsignalized crosswalk is 70 meters.

Q1: Which action would you take when trying to cross the street to get to the destination?

- Walk to the crosswalk and the cross
- Walk toward the destination and cross when traffic flow breaks off

Q2: Suppose you are in a hurry to get to the destination, which action would you take?

- Walk to the crosswalk and the cross
- Walk toward the destination and cross when traffic flow breaks off

In each scenario it provides two choices for pedestrians to cross the road: Walk to the crosswalk and then cross, and Jaywalk. Due to the complexity of the traffic scenarios and limitation of the site variety in the real world, web-based questionnaire surveys are utilized as the data collection method where all scenarios will be described to prompt respondents to place themselves into the situation and answer questions about their crossing preference. Computer Graphics (CG) technique is introduced to create images showing the road environment that the respondents are going to experience. **Fig.2** shows the CG-made virtual road environment.

(2) Questionnaire design

The questionnaire survey collects three parts of information. The first part collects personal information from respondents: gender, age, ownership of driver's license and driving frequency, residential environment, parenting situation, educational level. 144 designated traffic scenarios are randomly and evenly distributed into six groups on the premise of ensuring that every kind of factor is included in each group in the second section. In this part, respondents are provided with image cues containing OD information, traffic condition and road environment created by CG technology, and are asked to make crossing location choices in different situations. An example of one traffic scenario described in the context of questionnaire is shown in **Table 2**. The third part addresses questions on respondents' self-evaluations, expectation on vehicle yielding, and assessment of road environment.

(3) Data collection

The web questionnaire survey was conducted to monitors of a survey company. Respondents surveyed were requested to fill out the questionnaire which takes about ten minutes to answer. Of the 1,500 surveyed respondents, half are male and groups aged younger than 50 years accounts for 50%, representing a wide range of perspectives and experiences. To identify and remove potential bias that could affect the reliability and validity of the results, the following criteria were applied for data screening: (1) data with response time less than two minutes is regarded as invalid and deleted from the datasets; (2)

Table 3 Respondent individual socioeconomic characteristics

Factors	Range	Frequency	Percent	Percent of choosing to jaywalk
Gender	Male	586	49.20%	44.32%
	Female	605	50.80%	38.27%
Age	20~29	130	10.92%	41.92%
	30~39	174	14.61%	41.36%
	40~49	192	16.12%	45.29%
	50~59	225	18.89%	45.99%
	60~69	231	19.40%	39.03%
	70~	239	20.07%	29.94%
Possession of driver's license	Yes	926	77.75%	42.64%
	No	265	22.25%	36.37%
Driving frequency	≥5 times/week	270	29.16%	42.55%
	3~4times/week	134	14.47%	41.70%
	1~2times/week	191	20.63%	46.86%
	1~2times/month	84	9.07%	42.61%
	Occasional	34	3.67%	46.69%
	Seldom or never	213	23.00%	38.95%
Residential environment	Mainly apartments	402	33.75%	40.96%
	Mainly detached houses	384	32.34%	41.55%
	Fields&residences	347	29.14%	40.92%
	Mainly fields	58	4.87%	43.18%
Parenting situation	No child	627	52.64%	41.64%
	Preschooler	49	4.11%	47.28%
	Pupils	41	3.44%	48.07%
	Junior high or older	453	38.04%	39.79%
Educational level	Secondary school	41	3.44%	36.59%
	High school	364	30.56%	37.51%
	Junior college	234	19.65%	38.92%
	University	495	41.56%	44.27%
	Graduate school	57	4.79%	51.75%
Jaywalking frequency	Always	34	2.85%	60.42%
	Usually	156	13.10%	67.12%
	Occasionally	425	35.68%	53.60%
	Rarely	397	33.33%	30.28%
	Never	179	15.03%	10.06%
Expectation on vehicle yield rate	Almost all stop	63	5.29%	31.75%
	Usually stop	421	35.35%	41.68%
	Rarely stop	536	45.00%	42.54%
	Never stop	171	14.36%	39.64%

data with inconsistencies or contradictory responses is excluded to maintain data integrity. After the selection, data from a total of 1,191 questionnaires are certified as valid.

The personal socioeconomic characteristics of the survey sample are summarized in **Table 3**. Of the 1,191 respondents, 49.2% are male. Group aged over 70 years is the largest one which accounts for 20.07%. Within the sample, most of the respondents possess a driver's license and people who drive over five times per week account most. The vast majority live in cities or suburban areas. More than half live without children and near 40% respondents have children who are already adults. Most of respondents' educational levels are undergraduate and high school, which accounts for over 70%. In addition, respondents provided a self-assessment of their own jaywalking behavior, and expressed expectations regarding vehicle yielding behavior. Only a few thinks they always jaywalk and 15.03% claim they never jaywalk. And only 5.29% have belief that vehicles will always reduce speed or stop for them to cross first.

4. ANALYSIS OF PEDESTRIAN CROSSING LOCATION CHOICE

(1) Effect of individual characteristics

Percentage of respondents with different traits choosing to jaywalk is also statistically shown in **Table 3**.

The results show that male pedestrians are more likely to choose to jaywalk, corresponding with the result of previous research. The highest percentage of the middle-aged (40~59 years) chooses to jaywalk, followed by the youth and the lowest percentage of the senior (over 60 years). The possible reason for this may be that when pedestrians of different ages cross the street, their emphasis on safety, convenience, and comfort is different, with youth focusing more on crossing comfort, middle-aged focusing more on convenience, and the elderly considering more about safety.

Attributes related to respondents' driving experience are considered since pedestrians consciously think from the driver's perspective. Results show those with license tend to jaywalk more and among those who hardly drive are more willing to cross in compliance.

People living in areas with apartment buildings or detached houses are slightly more inclined to utilize crosswalk than those living in rural areas. This may be due to the fact that pedestrians are more pedestrians are more accustomed to obeying traffic rules in urban areas where traffic volumes are higher and facilities are installed better.

Table 4 The results of ANOVA test

Factors	df1	MS	F-value	P-value
Gender	1	10886.540	11.459	<.001
Age	5	7044.302	8.116	<.001
Driver's license	1	8113.258	8.586	.004
Driving frequency	6	2515.988	2.649	.016
Residential environment	3	106.529	.094	.963
Parenting situation	4	1499.795	1.855	.125
Educational level	4	4510.565	4.612	.001
Jaywalking frequency	4	100916.109	204.346	<.001
Expectation on vehicle yield rate	3	2365.417	3.024	.030

People whose youngest child is a preschooler or elementary school student are somewhat more likely to choose to jaywalk than other respondents. This result is inconsistent with the initial hypothesis that "pedestrians with young children in need of education are more likely to cross the street in a disciplined manner", probably because the pedestrians' own age has a greater influence on their choices.

For the impact of education level, it indicates that the more educated the respondents are, the more inclined they are to choose to jaywalk. And the choices respondents make in different situations roughly match their evaluations about how often they jaywalk in their daily lives, where those who claimed they hardly jaywalk are least likely to choose to jaywalk. Among respondents who believe vehicle would always yield, only 31.75% choose to jaywalk while people who think cars rarely or never stop jaywalk most.

In order to assess whether these individual characteristics have a significant impact on making crossing location choices, ANOVA test is used to determine if there exists statistically significant difference among grouping variables. **Table 4** presents the result.

The results indicate that excluding factors of residential environment and parenting situation, whose p-value were found to be greater than 0.05, other factors were significantly related to the probability of pedestrians' choice of jaywalking at a 95% confidence level, implying that there are statistically significant differences in the dependent variable across different groups.

(2) Analysis of Big-five personality traits

Ten-Item Personality Inventory-(TIPI) [23], with a seven-point self-evaluation system describing personal traits from disagree strongly to agree strongly,

Table 5 Description of Big-five personality

Personality	Description
Extraver-sion	1. ____Ectraverted, enthusiastic 6. ____Reserved, quiet
Agreeable-ness	2. ____Cirtical, quarrelsome 7. ____Sympathetic, warm
Conscien-tiousness	3. ____Dependable, self-disciplined 8. ____Disorganized, careless
Neuroticism	4. ____Anxious, easily upset 9. ____Calm, emotionnaly stable
Openness to experiences	5. ____Open to new experiences, complex 10. ____Conventional, uncreative

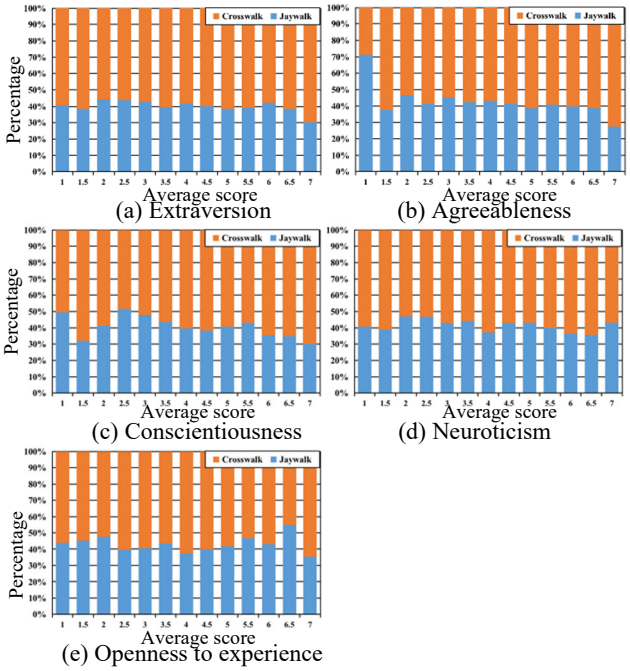


Fig.3 Crossing location choice for pedestrians with different personal big-five traits

was adopted to measure the big-five personality dimensions of respondents, including Extraversion, Agreeableness, Conscientiousness, Neuroticism and Openness to Experiences. **Table 5** shows the two inverse descriptions of each trait and **Fig. 3** shows the percentage of jaywalking pedestrians under different self-evaluated scores with different personal traits.

The results show that for extraversion personality no matter how extraverted or reserved the pedestrians are their percentage of choosing jaywalk fluctuated around 40%. For rating agreeableness, more than 70% who considered themselves as critical chose to jaywalk while only about 30% who evaluated themselves sympathetic chose to jaywalk, with an overall downward trend as the score increasing. The may due to that quarrelsome people are more impulsive, making them behave based on their feelings but not the consequences, so they may not care much about the danger of jaywalking, thus choosing to jaywalk is easier for them compared to sympathetic people. In this scoring system, respondents with higher scores

Table 6 The results of ANOVA test regarding big-five

Factors	df1	MS	F-value	P-value
Extraversion	12	421.768	.433	.948
Agreeableness	12	1711.395	1.877	.045
Conscien-tiousness	12	1888.044	1.924	.033
Neuroticism	12	1105.623	1.089	.370
Openness to experience	12	1174.406	1.189	.294

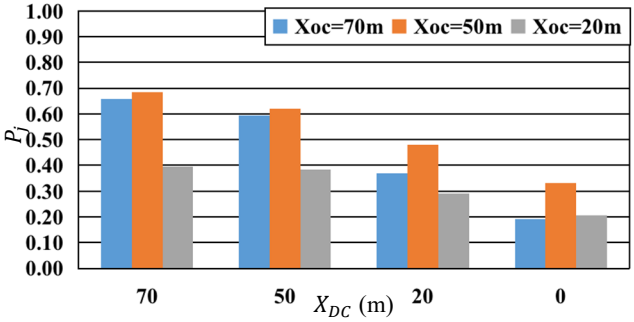


Fig.4 P_j under different X_{OC}

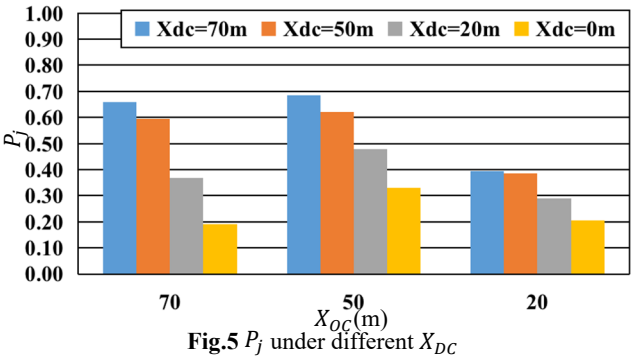


Fig.5 P_j under different X_{DC}

are more rule-compliant and dependable. It is found that the most careless chose to jaywalk at the highest rate while the most self-disciplined chose to utilize crosswalk at the highest rate inversely, which corresponds to the fact that disciplined people are generally more conscious of the impact their actions have on others thus are more inclined not to jaywalk. As for the impact of traits neuroticism and openness, there is no obvious trend towards the impact of their variations on respondents' deciding whether to jaywalk or not.

Similarly, in order to evaluate whether these five traits statistically affect respondents' crossing location choice, ANOVA test was conducted to check the significance of these attributes. **Table 6** shows the results. The results indicate that personalities of agreeableness and conscientiousness were found to be significantly related to the percentage of pedestrians choosing to jaywalk (p-value<0.05) at a 95% confidence level, implying that there are statistically significant differences across different scoring level.

(3) Effect of traffic and road factors

In scenario j, the probability of choosing to jaywalk by respondents in each traffic scenario is calculated by **Eq.(1)**. For 144 designated traffic scenarios, the probability was obtained by counting the number of times respondents chose to jaywalk.

$$P_j = \frac{No.of\ people\ choosing\ jaywalk}{total\ No.of\ people} \quad (1)$$

Control variates was applied to evaluate the effect of each factor considered in the traffic scenario on pedestrians' jaywalking probability. **Fig. 4** shows the general trend of the influence of location of origin, indicating that when the origin is 50 m away from the crosswalk pedestrians are most likely to jaywalk, instead of the assuming longest distance 70m. This may be relative to pedestrians' perception of the yielding behavior by vehicles near the crosswalk area. The interrelationship between pedestrian awareness and vehicle yielding behavior thus needs more discussion in the future research.

Fig. 5 shows that as the distance from the destination to the crosswalk decreases, probability of jaywalking decreases, as pedestrians prefer to jaywalk towards destination to reduce traveling distance when the destination is getting farther from the crosswalk. Though the destination is located at the crosswalk, pedestrians still chose to jaywalk, resulting from their perception that vehicles will slow down when approaching the crosswalk.

The impact of pedestrians' crossing urgency on choosing to jaywalk in relation to trip distance, calculated as a sum distance of X_{OC} and X_{DC} in different scenarios was analyzed and the result was shown in **Fig.6**. It indicates that pedestrians tend to take risks to jaywalk when in a hurry. With the increasing of traveling distance, jaywalking probabilities of both ordinary and urgent conditions increase. **Fig. 7, 8 and 9** present the variation trends of jaywalking probabilities under the influence of traffic density, crosswalk type and roadway pavement respectively. From the results, traffic density impacts pedestrian crossing preference significantly, where pedestrians are less likely to jaywalk if the density is high, no matter how far they need to detour. At signalized crosswalk pedestrians are more willing to utilize crossing facilities since the signal device can prevent them from conflicting with vehicles. When trip distance is less than 100m, this tendency is much more pronounced. This may result from that when trip distance exceeds 100m, it becomes difficult for the respondents to discriminate between the picture cues provided with regard to the crosswalk facilities. And there is no significant difference between two different roadway paving.

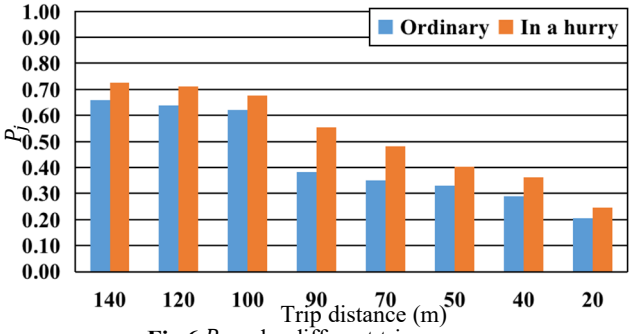


Fig.6 P_j under different trip urgency

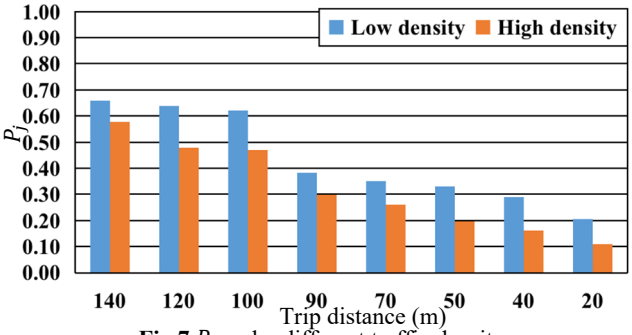


Fig.7 P_j under different traffic density

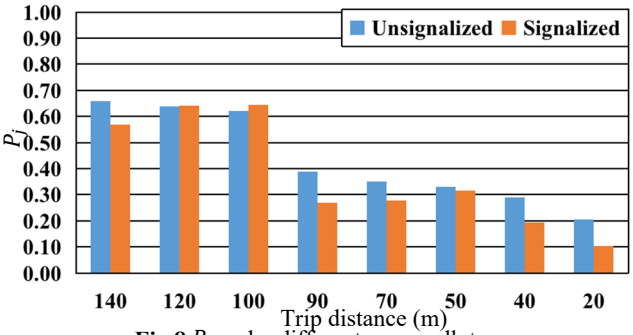


Fig.8 P_j under different crosswalk type

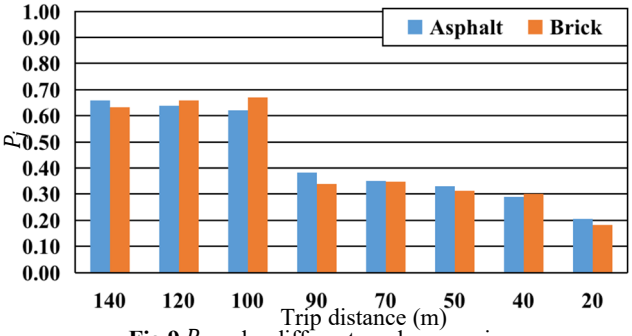


Fig.9 P_j under different roadway paving

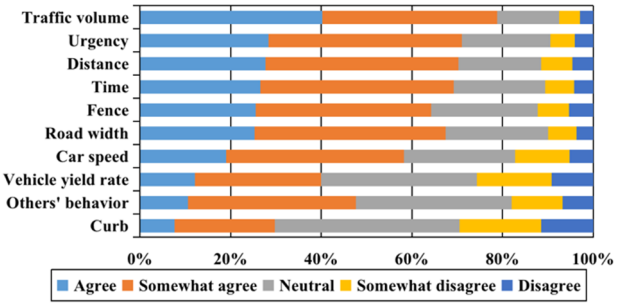


Fig.10 Rating of influencing factors' significance

(4) Evaluation of influencing factors

Respondents' evaluations on the extent to what contributing factors influence their crossing location

choice most are rated and summarized in **Fig. 10**. It is obvious that close to 40% of the respondents agree traffic volume to be an important factor influencing whether they choose to jaywalk. Pedestrians are likely to find longer gaps between vehicles when traffic volume is low, providing a situation that the approaching vehicles do not pose a threat. Meanwhile, more than 25% of respondents think that whether they are in a hurry to cross, the distance they need to detour, the time they need to spend to cross the road, the presence of obstacles between the sidewalk and the roadway, and the width of the road influence their decision, followed by that the speed of approaching vehicles, vehicles' yielding behavior, and whether other pedestrians are jaywalking had a progressively lesser influence on their choice. In addition, fewer people feel that the height of curbs would influence their decision-making.

5. PEDESTRIAN CROSSING LOCATION CHOICE MODEL

(1) Model estimation

In this study, the response variable for modeling pedestrian crossing location choice is binary: walk to the crosswalk and then cross, and jaywalk. Thus, the binary logistic model is developed to predict the probability of choosing jaywalk. In the model, Y=1 denotes pedestrians choose to jaywalk and Y=0 denotes pedestrians choose to use crosswalk. The model form is given by **Eq. (2)**.

$$log\ it\left(\frac{p_i}{1-p_i}\right) = a + b_1x_1 + \cdots + b_ix_i \ldots + b_nx_n \quad (2)$$

Where p_i means the probability that event occurred, which is the function of a vector of independent variable x_i where b_i is the corresponding coefficient of x_i and a is the intercept of the equation.

The condition probability of events occurred is given by **Eq.(3)**.

$$p_i = p(y_i = 1|x_1, x_2, \ldots, x_i, \ldots, x_n) = \frac{exp\ (a + b_1x_1 + \cdots + b_ix_i \ldots + b_nx_n)}{1 + exp\ (a + b_1x_1 + \cdots + b_ix_i \ldots + b_nx_n)} \quad (3)$$

In order to reduce the effect of the large difference in sample data size, both factors of driving frequency and jaywalking frequency were combined into four categories. The correlation analysis was conducted to investigate the relationships between individual characteristics. The results show that correlation between age and parenting situation equals 0.572, which is significant at the 0.01 level. The score test was also used to validate whether these influencing factors were significantly related to pedestrian crossing location choice behavior. The variables were included in the model step by step and factors that were not significant as a 95% confidence level were rejected.

Table 7 The results of crossing location choice model

Factors		Coeff-cient	Sig.
Constant		-1.106	<.001
Age		-.003	<.001
X_{OC} (m)		.021	<.001
X_{DC} (m)		.023	<.001
Dummy variables			
	Driving frequency (base: No license)		<.001
	Seldom	-.015	.732
	A few times per month	.270	<.001
	Several times per week	.105	.008
	Education (base: Secondary school)		<.001
	High school	-.221	.008
	Junior college	-.108	.201
	University	-.120	.142
	Graduate school	.155	.121
	Jaywalking frequency (base: Usually)		<.001
	Sometimes	-.565	<.001
	Occasionally	-1.700	<.001
	Never	-3.165	<.001
	Expectation on vehicles (base: Always stop)		<.001
	Usually stop	.329	<.001
	Rarely stop	.388	<.001
	Never stop	.404	<.001
	In a hurry (Hurry:1, otherwise:0)	.532	<.001
	Traffic density (High:1, low:0)	-.597	<.001
	Crosswalk type (Signalized:1, Unsignalized:0)	-.245	<.001
	Roadway pavement (Brick:1, Asphalt:0)	.079	.020
R^2		.331	
Overall percent		72.7%	

Eventually, excluding possession of driver's license, parenting situation, residential environment and traits of extraversion, neuroticism and openness, other remaining fourteen explanatory variables, three of which are continuous variables (age, X_{oc}, X_{dc}) and others are categorical variables, were considered in this model. Some of the categorical variables have more than two levels, so for these variables, dummy variables were created. Based on the questionnaire survey, the binary logistic model was constructed. The statistical software (IBM SPSS Statistics 29.0) was used to implement the process. The modeling results are shown in **Table 7**. At last, at the 95% confidence level, eleven factors were found to be significant.

(2) Discussion

A negative coefficient indicates the older the pedestrians the lower probability of their choosing to jaywalk. Compared to people without license, pedestrians driving frequently are more likely to jaywalk. The impacts of the group where pedestrians seldom drive are not significant probably because these pedestrians are about as familiar with the driver's mindset as those without a driver's license. Regarding pedestrians with different educational backgrounds, the results indicate that pedestrians with high school education are less likely to jaywalk compared to people who are certificated with secondary school education. All three types of pedestrians' daily jaywalking frequency influence pedestrians' preference significantly with the category usually jaywalk as the basis. Pedestrians' expectation on vehicle yielding behavior is significantly associated with their choices, whereas the vehicle yielding frequency decreases, the probability of pedestrians choosing jaywalking increases. The reason for this result, which is contrary to our usual belief that pedestrians are more likely to jaywalk when they think approaching vehicles will slow down, may be that pedestrians trust their own behavior more than their trust in vehicles to ensure the safety of their crossing.

Traffic- and road-related factors are also found to be significantly associated with pedestrian jaywalking choice. According to the modeling results, both factors of distance from origin and destination to the crosswalk are positively related to pedestrian jaywalking behavior, indicating that with the increase of distance pedestrians are more likely to jaywalk. Pedestrians in a hurry are inclined to choose to jaywalk. One possible reason may be that pedestrians in a hurry can tolerate shorter detour distance, they are more inclined to cross the road quickly. The negative coefficient of variable traffic density indicates that pedestrians presented in road with more vehicles are less likely to jaywalk. Pedestrians are also less likely to jaywalk when the nearby crossing facility is a signalized crosswalk. In the meanwhile, roadway pavement also impacts pedestrian choice, where brick pavement, which is similar to the sidewalk pavement, can influence pedestrians to jaywalk. This shows that it is more conducive to discouraging pedestrian jaywalking when the paving of the carriageway and sidewalk can be clearly identified. Therefore, the improvements of crossing facilities and road layout could help reduce jaywalking behavior and create a safer road environment for pedestrians.

6. CONCLUSION AND FUTURE WORKS

The findings of this study contribute valuable insights into pedestrian crossing behavior and factors influencing the propensity for pedestrian jaywalking. The results revealed that these factors play a crucial role in pedestrians determining crossing location. Specifically, age was found to have a significant impact on crossing behavior, with middle-aged pedestrians being more prone to jaywalking. A higher likelihood of jaywalking by crossing pedestrians in a hurry was observed. Pedestrians with driving experience are more likely to choose to jaywalk than those without driving experience. In a high-density environment, pedestrians crossed more carefully and were less likely to jaywalk. Additionally, the distance from OD to the crosswalk was positively associated with the likelihood of jaywalking, emphasizing the importance of providing convenient and well-placed crossing facilities. The crosswalk type and roadway paving were also found to influence pedestrian crossing choices.

This research contributes to a better understanding of the factors influencing pedestrian crossing location choice behavior and highlight the significance of a multifaceted approach to pedestrian safety, through which effective strategies and interventions to improve pedestrian crossing safety can be developed.

For future work, other important contributing factors such as the speed of approaching vehicles and the pedestrian flow can be considered further. And this study summarizes only two options for pedestrian crossing locations while the actual situation is much more complex, so future research could be more comprehensive in this regard. Moreover, more crosswalks with different geometric conditions are needed to be selected to evaluate pedestrian jaywalking behavior.

ACKNOWLEDGMENTS: This research is supported by Kajima Foundation.

REFERENCES

1) National Police Agency: Annual report by Traffic Accident Statistics in 2022.
2) Cantillo, V., Arellana, J., Rolong, M. (2015). Modelling pedestrian crossing behavior in urban roads: A latent variable approach. Transportation Research Part F, 32, 56-67.
3) AL Bargi, W. A. & Daniel B. D. (2020). Modelling pedestrians' utilization of crossing facilities along urban streets. Case Study on Transport Policy 8, 593-598.
4) Adachi, K., Suzuki, K., Okada, Y., Ito, H. (2021). Empirical analysis of jaywalking behavior on two-stage crosswalk. JSTE Journal of Traffic Engineering, Vol.3, No.2（Special Issur A）, pp. A_102-A_109.
5) Zhang, W., Wang, K., Wang, L., Feng, Z., Du, Y. (2016). Exploring factors affecting pedestrians' red-light running

behaviors at intersections in China. Accident Analysis and Prevention, 96, 71-78.
6) Guo, H., Zhao, F., Wang, W., Zhou, Y., Zhang, Y., Wets, G. (2014). Modeling the perceptions and preferences of pedestrians on crossing facilities. Discrete Dynamics in Nature and Society, Volume 2014, Article ID 949475, 8 pages.
7) Dhoke, A., Choudhary, P. (2023). Is there a relationship between time pressure and pedestrian non-compliance? A systematic review. Transportation Research Part F: Psychology and Behavior, 93, 68-69.
8) Kumar, A., Ghosh, I. (2022). Non-compliance behavior of pedestrians and the associated conflicts at signalized intersections in India. Safety Science, Volume 147, 105604.
9) Wang, Y., Shen, B., Wu, H., Wang, C., Su, Q., Chen, W. (2021). Modeling illegal pedestrian crossing behaviors at unmarked mid-block roadway based on extended decision field theory. Physica A 562, 125327.
10) Li, H., Zhang, Z., Sze, N. N., Hu, H., Ding, H. (2021). Safety effects of law enforcement cameras at non-signalized crosswalks: A case study in China. Accident Analysis and Prevention, 156, 106124.
11) Guo, H., Wang, W., Guo, W., Jiang, X., Bubb, H. (2012). Reliability analysis of pedestrian safety crossing in urban traffic environment. Safety Science, 50, 968-973.
12) Sisiopiku, V.P., Akin, D. (2003). Pedestrian behaviors at and perceptions towards various pedestrian facilities: an examination based on observation and survey data. Transportation Research Part F: Traffic Psychology and Behavior, Volume 6, Issue 4, 249-274.
13) Wang, Y., Shen, B., Wu, H., Wang, C., Su, Q., Chen, W. (2021). Modeling illegal pedestrian crossing behaviors at unmarked mid-block roadway based on extended decision field theory. Physica A 562, 125327.
14) Brosseau, M., Zangenehpour, S., Saunier, N., & Miranda-Moreno, L. (2013). The impact of waiting time and other factors on dangerous pedestrian crossings and violations at signalized intersections: A case study in Montreal. Transportation Research Part F: Traffic Psychology and Behavior, 21, 159–172.
15) Mukherjee, D., Mitra, S. (2020). A comprehensive study on factors influencing pedestrian signal violation behavior: Experience from Kolkata City, India. Safety Science, Volume 124, 104610.
16) Hasan, R., Napiah, M. (2017). The perception of Malaysian pedestrians toward the use of footbridges. Traffic Injury Prevention, Volume 19, Issue 3, 292-297.
17) Wang, J., Huang, H., Xu, P., Xie, S., & Wong, S. C. (2020). Random parameter probit models to analyze pedestrian red-light violations and injury severity in pedestrian-motor vehicle crashes at signalized crossings. JOURNAL OF TRANSPORTATION SAFETY & SECURITY, 12(6), 818–837.
18) Liu, Y., Alsaleh, R., & Sayed, T. (2022). Modeling Pedestrian Temporal Violations at Signalized Crosswalks: A Random Intercept Parametric Survival Model. Transportation Research Record, 2676(6), 707–720.
19) Guo, H., Gao, Z., Yang, X., & Jiang, X. (2011). Modeling pedestrian violation behavior at signalized crosswalks in China: A hazards-based duration approach. Traffic Injury Prevention, 12(1), 96–103.
20) Japan Traffic Regulation Standards (2021): National Police Agency：Traffic Regulation Benchmarks.
21) 中島 孝規, 井料 美帆：バーチャルリアリティ実験による歩行者の横断位置選択行動分析，交通工学論文集，Vol.9, No.2, pp. A_253-A_262, 2023.
22) Adachi, K., Suzuki, K. (2022). Analysis of the appropriate intervals for two-stage crosswalks considering driver's yielding behaviors, Journal of Japan Society of Civil Engineers, Ser. D3 (Infrastructure Planning and Management), Vol. 78, No. 1, 1-12, 2022.
23) Gosling, S.D., Rentfrow, P.J., Swann Jr. W.B. (2003). A very brief measure of the Big-Five personality domains. Journal of Research in Personality. 37(6), 504-528.

(Received October 13, 2023)