Video Observation and Analysis of the Pavement Pattern's Visual Impact on Pedestrian Walking Experience in Japanese Low Carbon Society

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Abstract

A combination of individual characteristics, infrastructure, and societal attributes defines the pedestrian walking experience. Walking is a complex phenomenon that should be and could be approached from various fields of scientific research. One of the approaches is within its visual impacts of the walking infrastructure. Increasing number of studies about walking phenomenon shows the importance of walking is being widely recognized as societies strive to implement the low carbon principle. Sidewalks now cover more than 150,000 km in modern Japanese cities. Average Japanese takes 7,168 steps per day. These numbers show how important a walking infrastructure in Japanese urban development.

Walking infrastructure in Japan has been well developed yet varied in its physical appearance especially its pavement pattern. Authors have documented more than 70 different types of pavement pattern in pedestrian areas from several cities in Japan. This research aimed to study the impact of pavement patterns as one of visual stimulations for the pedestrian by observing their walking movement and speed using video sampling and analysis by open source software, and also their awareness to different types of pavement pattern using direct yet non-paper based questionnaire. Totally 93 pedestrians were observed and 71 questionnaire responses were collected. The research then found that there were early indications of visual impact of pavement pattern in the case study which was in the area of Kitakyushu Science and Research Park (KSRP) at Hibikino, Wakamatsu Ward, Kitakyushu City, Japan.

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1. Introduction

During early 20th century, of which was the booming of industrialization, the major utilization of private cars and its solely supporting urban infrastructures such as roads, was started at the United States and then around the world leading to many environmental issues in urban areas. Iamtrakul (Iamtrakul, Satichob & Hokao, 2013, pp. 21-33) stated that Bangkok encounters the disproportion between expansive transport demand and inadequate public transport supply which then creates massive traffic congestion. This condition applies also in any other cities in the developing countries, which then also leads to more serious environmental impact of carbon dioxide emission. Schipper (Schipper, Deakin & McAndrews, 2010) argued that fuel combustion in the transport sector is a major cause of carbon dioxide emission. Increasing numbers of vehicles account for 24% of escalating emissions, half of which are generated in urban transport.

Despite of that, the growth of light duty vehicles in all over the world up to 2050 is projected to keep increasing (World Business Council for Sustainable Development, 2004). According the Ministry of Land, Infrastructure, Transport and Tourism of Japan (Ministry of Land, Infrastructure, Transport and Tourism Japan, 2011), around 50% of the total Carbon-dioxide emissions are from the cities which one third is from the transportation sector only. To deal with this, Japan set up a guideline for low carbon urban development to create more compacted city, minimize travel distance and encourages walking and bicycling.

Japan's initiative to achieve a low carbon society was also based on the fact that despite of the advancement on public transportation in Japanese cities, the level of car-dependency was still high. In 2003, the usage level of cars in other areas outside Tokyo, Nagoya, and Osaka, the level was 84% (Fujimoto, 2008).

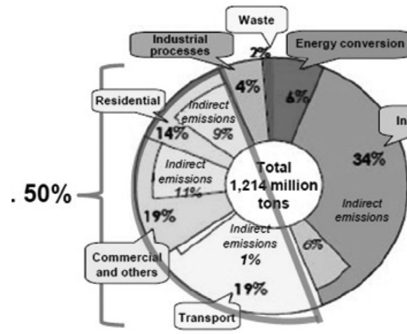

Figure 1. Breakdown of CO^2 Emissions.
(Source: Ministry of Land, Infrastructure, Transport and Tourism Japan, 2011)

Matsumoto (2005) argued that the economic development and the urban sprawl generated the increase of travel demand of which then generated the increase of car or other motorized vehicles usage and later significant volumes of GHG. One of the solutions is to improve the non-motorized transportation modes i.e. walking and cycling.

According to Nuzir (Nuzir & Dewancker, n.d.) in Japanese cities, these kinds of main form of Zero Emission Urban Mobility (ZEUM) are becoming higher priority in the development of low carbon society. The principle for a low carbon society is carbon minimization in all sectors, including the utilization of non-motorized transportation. Japan Government had selected several cities to be Eco Model Cities such as: Obihiro, Shimokawa, Yokohama, Toyama, Kitakyushu, Minamata, Kyoto, Sakai, Iida, Toyota, Miyakojima, Yusuhara, and Chiyoda (Regional Revitalization Bureau, Cabinet Secretariat, Government of Japan, 2009).

1.1 Background

The old streets in Japanese cities has a narrow width and no sidewalk. Kwon (Kwon, Morichi & Yai, 1997, pp. 853-862) mentioned that 86.5% of the total street in Japan has the width less than 5.5 meters. Fortunately, the new street development has already incorporated the area for walking and cycling as shown in Figure 2 below.

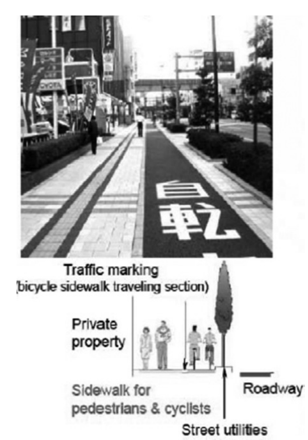

Figure 2. New Sidewalk Development.
(Source: Ministry of Land, Infrastructure, Transport and Tourism Japan, 2011)

Figure 3. Pedestrian Ways in Wakamatsu (1-3), Kyoto (4-6), Tokyo (7-9), and Kurosaki (10-12). (Source: Nuzir, Dewancker, Jing, Nakashima, Lebreton & Rahardi, n.d.)

Besides the technical aspects Nuzir (Nuzir, Dewancker, Jing, Nakashima, Lebreton & Rahardi, n.d.) argued in order to improve the comfort of pedestrian way, one feature that is visibly appearing in the sidewalks of Japanese cities is the pavement pattern. Many variations of pavement pattern can be seen especially in special areas such as commercial, residential, city center/ business, educational, etc.

Authors have documented at least 70 different types of pavement pattern in pedestrian ways from several cities in Japan. Some patterns are very artistic and showing the character of the city, and some others are quite simple yet still attractive. The documented pavement pattern can be classified as follows; regular grid (33%), irregular grid (25%), ornamental (14%), circular (1%), combination of one or two variations above (5%), and without pattern/none, usually covered by asphalt (22%). These variations might play important role in improving the walking experience beside its main function as an aesthetic element.

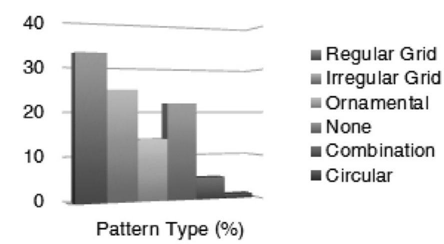

Figure 4. Percentage of Pavement Pattern Variations.

1.2 Previous Studies on Pedestrian Way

Tsukaguchi (Tsukaguchi, Yeh, Vandebona & Ching Hsia, 2010) had concluded that pedestrian walking behavior is a combination of individual characteristics, infrastructure, and societal attributes. For instance, the people`s way of thinking and lifestyle affect the awareness and attitude toward walking and so do the other way around. Therefore, in order to understand the walking behavior, it will need a comprehensive study of the three.

Pazhouhanfar (Pazhouhanfar & Kamal M.S., 2014) had proven that perceived visual characteristics of the environment influence the psychological evaluation of the person-environment interaction. As cited by Azmi (Azmi & Karim, 2012), Shahrol Mohamaddan in his paper titled “Human Walking Behavior

Based on Different Layout Design Using Computer Animation", published by University Malaysia Sarawak in 2010, defined that the walking behavior is how people perform their walking in relation to the time taken for moving from a place to another place, deciding the walking route, avoiding collision from each other and other behaviors during the walking period.

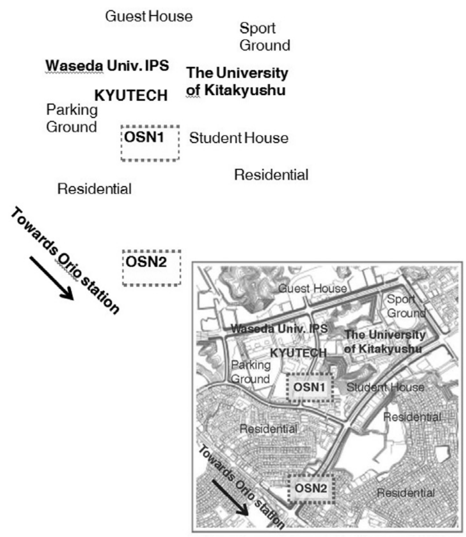

Figure 5. Research Areas in Bold Lines and OSNs.

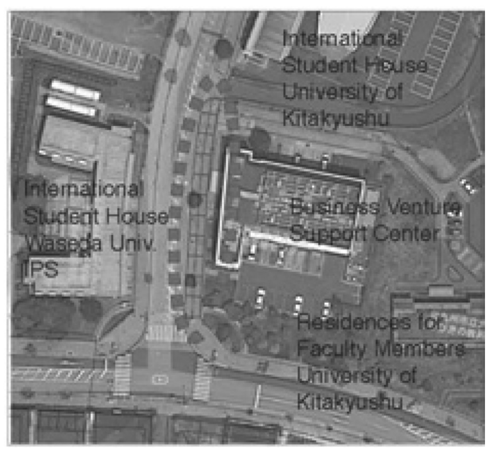

Figure 6. Research Area for OSN1.

Figure 7. Street View and Detail Pattern for OSN1.

2. Methods

Video is now a popular method for contemporary behavioral researches since the presence or usage of video in daily life is increasing throughout the advancement of video feature in smartphones and other electronic devices. Jewitt (2012) explained that video is mainly used for studying the multimodal character of social interaction because it provides a fine-grained multimodal record of an event detailing gaze, expression, body posture, and gesture. Secondarily, a web-based questionnaire was also being used in order to understand the overview of common pedestrian behaviors in the research area. Both methods were being done within the same period of time and conducted within two separated observation groups for each method.

2.1 Scope of Study

In this study, the subjects were the people who are experiencing or have been experiencing walking on the area which within the Kitakyushu Science and Research Park (KSRP) in Hibikino, Kitakyushu. The KSRP was located in Kitakyushu, which is one of the most successful Eco Model Cities that have implemented the principle of sustainable low carbon development. KSRP, established in April 2001, was planned to experiment and exercise environmentally-friendly development especially in creating a low carbon society yet still facing many social, economical, and environmental challenges during its on-going progress (Nuzir & Dewancker, 2014). Furthermore it focused on the pedestrian activities during the weekday, especially in the morning and evening peak hours. These people are referred as the commuter. Furthermore individual commuter was also specifically targeted in order to reduce and limit external influences.

There were two observation spots which has similar physical characteristic yet differ in the variations of the pavement pattern.

From these observation spots, video sampling was taken. Observation Spot Number 1 (OSN1) was a 50 meters long pedestrian way with the width of 3.5 meters. Meanwhile Observation Spot Number 2 (OSN2) was also a 50 meters long pedestrian way but with wider width which is 4.5 meters.

The pavement pattern in OSN1 was classified as regular grid for its variation. Meanwhile pattern in OSN2 was classified as irregular grid. Individual dimension pavement unit in OSN1 has bigger surface size than in OSN2.

Pavements on OSN2 are consisted of three colours: red, black, and white. Although it has smaller dimension of unit, its unique combination with the colour variation has made pavement pattern in OSN2 more visually attractive than OSN1 and at the same time more recognizable as a pattern. Therefore authors presumed that OSN2 would represent the pedestrian way with stronger visual impact and OSN1 would represent the lesser.

Figure 8. Research Area for OSN2.

Figure 9. Street View and Detail Pattern for OSN2.

Figure 10. Video Camera Recording and Questionnaire.

Both locations are located in the vicinity of a junction. Vehicular traffic on OSN1 was less crowded than on OSN2 yet on the other hand pedestrian way on OSN2 is separated by 2.5 meters green area from the main road. Therefore the influence from the traffic is considered minimum.

Video sampling and questionnaire distribution were conducted from June 2nd – July 9th, 2014. Totally 93 pedestrians were observed and 71 questionnaire responses were collected. They were mainly university students and the elderly.

2.2 Procedures

2.2.1 Video Sampling

Video sampling was used to record the pedestrian activities of which to be analyzed using video analysis software. Authors used Digital Video Camera Recorder for recording on mini DV cassettes and also equipped with a Tripod for stabilization. Then the content of the cassettes were transferred into PC using Apple's iMovie application via High-Definition Multimedia Interface (HDMI) interface.

Each sampling was originally recorded for one hour duration at the same camera position and angle within two periods a day which are between 8-11 AM. and between 4-7 PM. The original movie files then were divided to show each individual pedestrian activity and compressed into small sized

video clips for further analysis.
The video was taken from observation spots that met certain criteria such as:

- non-visible, which means that the camera and camera person should not be seen by the pedestrian in order not to raise curiosity that could change their walking behaviour,
- upper/top point of view, which means that the video should be taken from a place above the research area to have clear view for analysis,
- roofed spot, which means that due to bad condition of the weather, the camera must be protected under a roofed area,
- pedestrian way with different variations of pavement pattern,
- high numbers of pedestrian,
- and permissible, which means that the observation spot and also the research area should be a public or semi-public area that requires less or none of permission for entry.

2.2.2 Questionnaire

This questionnaire was intended firstly to briefly measure the usage of the targeted pedestrian areas. Then, to understand the general overview of common pedestrian's behaviors in the research area. And lastly, it was to know how much people notice and remember the pattern of the pedestrian pavement when walking.

The questionnaire was conducted by direct interview by using tablet PC's interface to access the questionnaire and record the response. This was intended to avoid using papers as the conventional questionnaire to practice environmentally-friendly action. The questionnaire could also be accessed online using Google platform within the following web-link: https://docs.google.com/forms/d/1l730_LBSUmF0cvlk3v4z7d-3nq7eOC22bMPp1iLZu17c/viewform (no longer accepting response).

The questionnaire was consisted of 12 questions of which were divided into three parts. The first part consisted of five questions was intended to identify the respondent.

10/9/2014 Pavement Pattern Questionnaire

Edit this form

Pavement Pattern Questionnaire

This questionnaire is intended firstly to briefly measure the usage of the targeted pedestrian area. Then to understand the general overview of common pedestrian's behaviors in the research area. And lastly to know how much people notice and remember the pattern of the pedestrian pavement when walking.

This questionnaire is a part of research project titled: Behavioral Study on Zero Emission Urban Commuting System in JAPAN. Contact person is Fitri Alhmad Nusir (email: [illegible]), doctor student from Laboratory of Prof. Bart Dewancker, Department of Architecture, Graduate School of Environmental Engineering, The University of Kitakyushu.

This questionnaire is targeting only the people who are experiencing or have been experiencing WALKING on the research area.

* Required

Research Area: Kitakyushu Science and Research Park (Gakkentoshi), HIBIKINO

Have you been walking on this area, marked in red? If yes, please proceed to the questions.

https://docs.google.com/forms/d/1l730_LBSUmF0cvlk3v4z7d3nq7eOC22bMPp1iLZu17c/viewform 1/6

Figure 11. First Page of the Web Questionnaire.

Figure 12. Kinovea Interface on Windows OS.

The second part consisted of four questions was to understand the purposes and basic behaviours of the respondent. Then the last part was to test the memory of the pedestrian towards the pavement pattern variations.

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Figure 13. Movement of Pedestrian, Shown in Blue.

2.3 Data Analysis

2.3.1 Video Sampling

Open source video analysis software named Kinovea (www.kinovea.org) was used to analyze the video clips taken from the video sampling. In total there were 93 video clips being analyzed.

Figure 12 showed the Kinovea's software interface when running the analysis process. The analysis resulted the movement line by tracking each pedestrian`s walk and also the walking duration from when entering and when exiting the research area, as shown in Figure 12 and then the software also could generate a spreadsheet database from the movement line tracking of which a chart could be generated from for further movement analysis. The chart was a direct projection from the real view of video camera recorder containing values of x and y coordinates of video pixel percent second of time.

At the end a recapitulation of spreadsheet database was finalized for each OSN1 and OSN2. Firstly as seen on Figure 16, the chart showed the movement lines from OSN1 which represented only 17 clips from total 72 clips, overlaid with the guidance lines of the pedestrian area many clips were considered insufficient after being analyzed because the pedestrian received other influences such as cyclists, other pedestrians, etc. And also on OSN1 due to the perspective video angle that was resulting misleading pixel coordinates and confusing start-end points, authors decided to include only the movement lines which were started from the far side of the video angle from the chart, it could be seen that the movement lines in OSN1 were distributed evenly if not centered in all over the pedestrian area. Average walking duration in OSN1 was 34.3 seconds.

As for OSN2, video analysis showed rather different result compared to OSN1, as seen from Figure 17. The chart showed polarization of the movement lines, either to the right

X (pixel)	Y (pixel)	T (h:m:s:dc)
0	0	0:00:00:00
15	-11	0:00:04:70
82	-72	0:00:15:81
183	-168	0:00:22:62
387	-391	0:00:30:43
611	-629	0:00:36:33

Table 1. Pixel Coordinates (x,y) - Time (T).

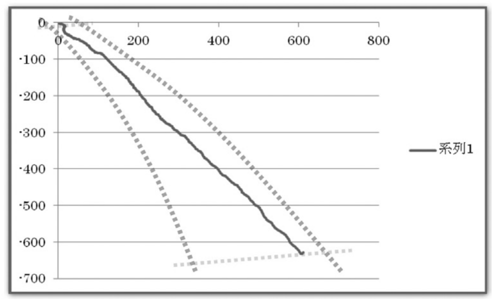

Figure 14. Example of Chart from the Database, Dotted Lines additionally added to Show the Area. Axes contain values of x and y coordinates of video pixel percent second of time.

Figure 15. The Movement Track on the Pedestrian Area.

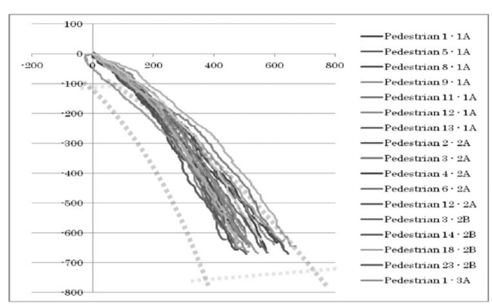

Figure 16. The Movement Track on OSN1
Axes contain values of x and y coordinates of video pixel per centisecond of time.

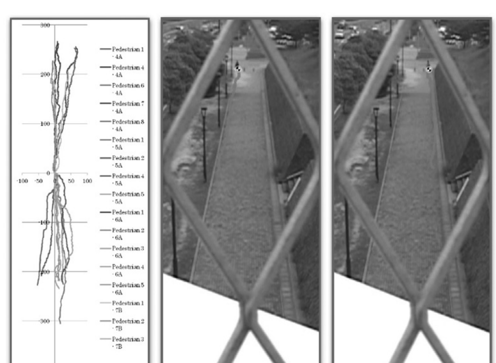

Figure 17. The Movement Track on OSN2
Axes contain values of x and y coordinates of video pixel per centisecond of time.

or to the left, either to the top or to the bottom, of the video angle. The meaning of this result was then comprehended after comparing it with the movement lines tracked on the video clips. The movement lines were actually clearly divided into the two sides of the pedestrian area. The average walking duration was 52.4 seconds, slower than duration in OSN1.

2.3.2 Questionnaire

The questionnaire recorded 71 responses of which 43 (60.6%) were 20-29 years old. They were presumably the university students. Furthermore 44 respondents (61.9%) live in Hibikino which includes the research area and the surrounding.

Nearly all the respondents currently walk within the research area in daily basis which means more than three days per week. 16 people (22.5%) walk from 100 meters to 300 meters a time and 34 people (47.8%) walk even more than 500 meters a time. Then when being asked the reason for walking within the research area, 46 respondents (64.7%) answered school/university/conference. All these results justified that the respondents were indeed the daily commuters of KSRP which is an educational designated area.

The next question was to understand about their basic activities when walking. For this question, the respondents were asked to choose minimum two answers from the available options and were also able to add their own answer if necessary. The options were: doing conversation by phone, looking at the surrounding, looking at your smartphone, looking down to the pavement/ground, and other (possible to submit their own answer). There were 127 answers and the top two answers were 43.3% looking at the surrounding and 20% looking down to the pavement/ground. These two answers are both related to visual environment.

And as for the last part of the questionnaire, authors were trying firstly to assess which pedestrian area in the KSRP of which mostly being utilized by the commuters. Authors divided the pedestrian areas into nine separated zones as shown on Figure 16 below. Respondents were asked to submit all zones that they have been walking on it regularly. They could also submit more than one zone as their answer.

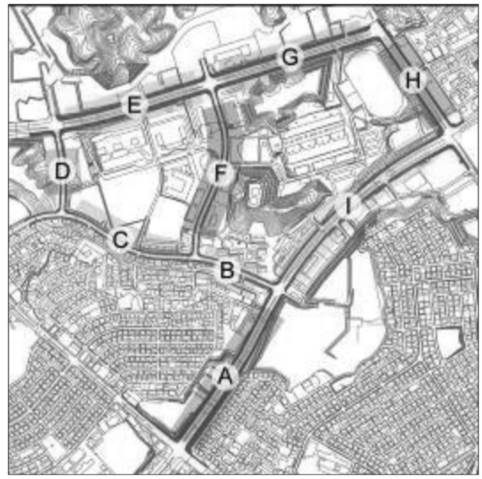

Figure 18. The Pedestrian Zones of the KSRP.

The results showed all the nine zones of the pedestrian area has been fairly utilized by the daily commuters. Yet from the 193 answers collected, the top three were zone F (27.5%), zone I (17.6%), and zone A (16.6%) respectively. This result has proved that the two observation spots, OSN1 and OSN2, were indeed the most utilized pedestrian ways in the KSRP area.

After determining the utilization of the pedestrian areas, authors tried also to conduct visual assessment to test the memory of the pedestrian towards the pavement pattern. The respondents were shown two pictures of pavement pattern as seen on Figure 7 named as Picture Nr. 1 and on Figure 9 named as Picture Nr. 2. Then, they were asked to point out which pedestrian zones that contain of have those two patterns on the walkway.

For Picture Nr. 1 representing the pattern on OSN1, the respondents who answered correctly were 34.5% and as for Picture Nr. 2 representing the pattern on OSN2, there were 58.4% of correct answers. See Table 2 for the complete results. Direct conclusion from this was the pattern on OSN2 is more memorable and better perceived by the pedestrian than the one on OSN1. Another results showed that from the respondents who look at the surrounding when walking, not specifically looking down to the pavement, 72% for OSN1 and 51.5% for OSN2, chose the correct answer. This might lead to a conclusion that the pedestrians who are not directly related or visually attached to the pavement pattern, they still could memorize and identify the pavement pattern once they have been experiencing walking on the paved area.

Pattern Picture	A	B	C	D	E	F	G	H	I
Picture Nr. 1 (correct answer: F)	11	22	21	4	1	39	3	2	1
Picture Nr. 2 (correct answers: A and I)	39	7	1	4	7	7	11	10	27

Table 2. Result of The Pavement Pattern Memory. Numbers in bold show highest result.

3. Conclusions

By conducting video observation of daily commuters and comparing, the results of Kinovea's video analysis software from the two observation spots, OSN1 and OSN2, which were in a special function (education) designated area, authors concluded that pavement pattern with irregular arrangement and colour combination i.e. OSN2 is more likely to be influencing their routine walking experience. This was indicated from the movement tracks comparison showing that the pedestrians in OSN2 follow certain movement track to adapt to the pavement pattern. And also in OSN2 the pedestrians would take longer time i.e. 52.4 seconds, presumably because of experiencing visual comfort from the pavement pattern.

In order to verify the result of video observation, a questionnaire was conducted. From the questionnaire it was learned that the most basic activities conducted by the pedestrians were related to the visual environment including the attention towards pavement pattern. There was also indication that even the pedestrians who are not directly related and visually attached to the pavement pattern, they still could memorize and identify the pavement pattern. This might indicate that pavement pattern is visually easy to memorize.

From the result of video analysis and questionnaire, authors concluded that there are indications of visual impact of pavement pattern on pedestrian walking experience. However since the study focused only to the pedestrians which are daily commuters, the behavior of visitor type pedestrians are excluded from the conclusion of this study. Another limitation is concerned with the selection of case study area which is an educational designated area. The result might be different when being conducted to a commercial area for example, or to a multipurpose area due to a different routines and much more complex external influences. In regards to sample size, there were 93 pedestrians were observed and their movements were recorded as video clips. However many clips were considered insufficient after being analyzed because the pedestrian received other influences such as cyclists, other pedestrians, etc. and also due to the perspective video angle that was resulting misleading pixel coordinates and confusing start-end points. As for the questionnaire, 71 responses were recorded of which nearly all the respondents still currently walk within the research area in daily basis. However, these numbers of pedestrians and respondents do not simply correlate one to another. Therefore the actual sample size could be the sum of the pedestrians and the respondents, although there might be some overlaps. Furthermore, in order to increase the appropriateness of the sample size, authors acknowledge the need to increase or a least double the number of the subject and also to reduce the insufficient samples.The method of video observation and analysis using open source software has given many benefits for this study yet it still faces many challenges such as the need of bigger database of video sampling from more case studies. And also the determination of camera angle was important to avoid misleading tracking information. However the final goal is to know the pedestrian's preference so that urban design and planning would be more effective in improving the walking environment. Therefore authors are determined to find solution for the research problems and further the study.

Acknowledgement

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