Developing Walkability Index from Walker and Non-Walker Perception

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Abstract: The benefits of walking have recently inspired considerable research on the relationships between pedestrian choices and numerous built environment factors. These relationships are then elaborated using walkability indices for the meso- the micro-levels. Despite important advances in micro-level research, the walkability concept is based chiefly on the perspective of the walker. The views of the potential walker and non-walker are thus given insufficient attention. This paper employs micro-level analysis to bring in the often overlooked non-walker perspective. This perspective can be understood both from the factors enabling as well as barriers inhibiting walking. Therefore, the proposed walkability index may be used as a tool to analyze facilities that not only to serve walkers but those that encourage non-walkers to change their behavior. Changing behavior will be critical to maximizing the benefits associated with walking.

Keywords: Walkability Index, Walker, Non-Walker, Composite Model, Micro-level

1. INTRODUCTION

The growing of urban congestion as well as the global climate change issues have pushed the decision-makers to find more efficient way for transporting people. Several initiatives are then proposed in order to cope with such issues, which are mainly concentrated on the provision of public transportation. As public transportation cannot provide the door-to-door services, the walking plays important roles for supporting the system. Since the walking can essentially be viewed from two dimensions, which are, as a complete mode itself and as a supplementary mode for accessing the other transportation modes, it is expected that creating the good pedestrian environments is part of key success for implementing the public transportation. Therefore, the walking-related research has obtained significant attention not only from academic side but also from decision policy side (e.g., Park et al., 2014).

Although, several pedestrian-related studies have elaborated the effect of built environment on walking behavior (Handy, 2005; Kalakou & Moura, 2014), the quantitative evidence is still remaining inadequate (Park, 2008). Hence, the recent researches has taken place on the assessment of environment attributes in order to provide the friendly environment for pedestrian. Within the framework of walkability concept, the evaluation and assessment methods have been developed from the meso-level to the micro-level. The meso-level uses the aggregation environmental factors for evaluating the walkability of certain area, such as housing density, land use diversity, street patterns, destination accessibility, and distance to transit (Cervero and Kockelman, 1997; Cervero et al., 2009). Since the walking is intrinsically a micro behavior, the micro-level walkability has been proposed for measuring the street-level physical attributes, such as the presence of trees, the width of sidewalks, and the quality of streets (e.g., Ewing and Handy, 2009). The physical attributes are practically compares to the walker perception (Park et al., 2014) or the expert ratings (Kim et al., 2014) to measure the walkability.

This paper discusses not only the walker perspective but also the non-walker perspective, in order to explore the possibility of the mode-shifting. The non-walker perspective can be approached from the barrier point of view as well as from the walkability factor which expectantly influence the decision to walk. Therefore, the proposed walkability index may be used as a tool to priorities the facilities which need to be improved in order not only to serve the existing walker, but also to attract the non-walker to use the pedestrian facilities.

In the following section, the method is described, while in the third section, the walkability index is presented by considering the walker and non-walker perspectives. Finally, in the fourth section, the methodologies, results, and analyses in the paper are summarized.

2. DEVELOPING WALKABILITY INDEX

The main objective of paper is to develop composite walkability index by considering the walker and non-walker perception. The walkability is constructed based on the micro-level analysis. Three different surveys are designed, namely, a walker perception survey based on their experience, non-walker perception survey, and a street survey for gathering the physical indicator that governing the walkability measurement.

Since the micro-level analysis incorporates a smaller unit of measurement, the street-level analysis is considered by measuring the street physical indicator, such as, pedestrian signal coverage, a curb-to-curb roadway, width of sidewalks, number of lane (see Park et al., 2014). In addition, the walking decision is practically influenced by the interaction with the physical environment. The non-walker may perceive the negative environment, which limit their usage to the pedestrian facilities. On contrary, the good experience of walker may encourage the continuous utilization of pedestrian facilities. Therefore, the perception is practically used for predicting the walking behavior (Van dick et al., 2012). The micro-level is possibly obtained a huge attribute combination, which is not practical to be investigated. Therefore, a composite walkability index has a good chance to be implemented (Park et al., 2014).

$$Y = Y^u + Y^n \qquad (1)$$

$$Y^u = c_1 y_1^u + c_2 y_2^u + ... + c_m y_m^u \qquad (2)$$

$$Y^n = d_1 y_1^n + d_2 y_2^n + ... + d_m y_m^n \qquad (3)$$

where :

Y : composite walkability index

Y^u : walkability index from walker perspective

Y^n : walkability index from walking non-walker perspective

y_m^u : walkability index of component-*m* from walker perspective

y_m^n : walkability index of component-*m* from non-walker perspective

c_1, d_1 : relative importance of each walkability components.

For governing the relative importance of each walkability components, the walker perception about the priorities improvement action is possibly used, in which it reflects the importance level of pedestrian facilities. In order to get more comprehensive view of walker need, the question is designed based on the pair wise comparison approach.

Table 1 Action priorities for improving pedestrian facilities

Action Priorities	Weight of Importance
Security Facilities	0.20
Facilities for Disabled	0.19
Crossing Facilities	0.16
Width of Side Walk	0.12
Canopy	0.11
Access to Local Stores	0.11
Furniture and Accessories	0.10

As can be seen in Table 1, security facilities are found as the most priority facilities that need to be improved. This condition may be influenced as the rise of criminal issue. Even though this survey is not met the disabled person, the facilities for disabled is positioned as the second important facilities. Actually, this result is quietly surprising, since the issue of facilities for disabled is not growing in the practical forum and in the academic forum, as well. Therefore, this study tried to consider the facilities for disabled in the walkability framework.

In term of non-walker side, the barrier factor to walk is possibly utilized as the relative factors, where the highest factor indicates the most important facilities needs to be improved for encouraging the pedestrian facilities usage. The barrier factor is gained by questioning to the respondent a pair wise comparison between five factors, including travel distance/time, security and safety, weather, comfort, and facilities. The result is indicated by Table 2, in which the security, safety, and weather issues are positioned in the top level as the barrier for using the pedestrian facilities.

Table 2. Barrier factor to walk

Barrier Factors	Weight of Importance
Travel Distance/Time	0.17
Security and Safety	0.22
Weather	0.22
Comfort	0.20
Facilities	0.19

Furthermore, the travel distance/time is interestingly not placed as the main barrier to walk, which is also supported by the non-walker perception about the acceptable walking distance. The perception is attained by asking the non-walker perception about the acceptable walking distance, where the distance perception of non-walker is bigger than the walker experience as it can be seen in the figure below. The walker experience is approximated by calculating the distance between origin and destination of their walking path, which is mentioned in questionnaire. From this result, it can be stated that the top barrier (e.g., security and safety) issue needs to be carefully tackled in order to increase the walking user.

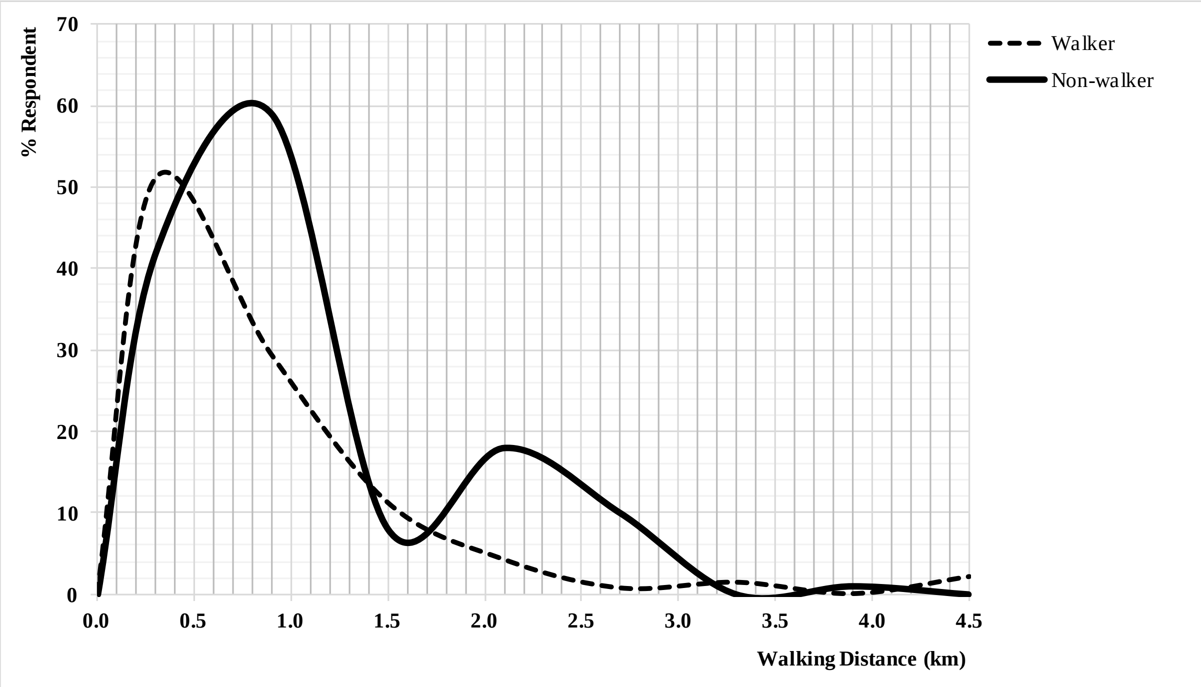

Figure 1. Acceptable walking distance of walker and non-walker

3. WALKABILITY INDEX FROM WALKER AND NON-WALKER PERSPECTIVE

The further step of study is to investigate the walkability index for the pedestrian facilities based on the walker and non-walker perspectives, which is derived from the interview survey. The walkability index is arranged based on the walkability components that reflect the performance of pedestrian facilities. The components are also designed to consider the non-walker consent about the barrier to walk. Hence, the walkability indicator can expectantly be used as a tool to analysis the facilities which need to be improved in order not only to serve the existing walker, but also to encourage the non-walker to use the pedestrian facilities. The components are then determined as, the sense of safety in crossing, existence of others, width of sidewalk, and the buffering from negative impact. The perspective of such components are compared to the physical indicator of pedestrian facilities as it is listed by Park et al. (2014), for instances, width of side walk, percentage of commercial uses, average building width, and etc. The walkability model is then developed based on the assumption there is a linear correlation between the performance perspective and its physical indicator.

The sense of safety in crossing is firstly explored in order to elaborate the walkability from walker and non-walker perspectives. The perspective is elaborated by asking whether the facilities already enable walker to cross safely, which is then compared to physical indicators such as, the pedestrian crossing facility design index, average width of on-street parking, existence of on street parking and existence of traffic calming, as well as the designated school safety zone. The best fit regression model of these components is further showed as follows:

Table 3 Regressions result of sense of safety in crossing

Variables	Walker Perspectives				Non-Walker Perspectives			
	Coeff.	Std. Err.	t	Sig	Coeff.	Std. Err.	t	Sig
Pedestrian Crossing Facility Design Index	0.17	0.07	2.32	0.02	0.19	0.06	3.41	0.00
Constant	2.41	0.20	12.01	0.00	2.50	0.16	15.51	0.00
F Statistic				5.40				11.61
Significance F				0.02				0.00
Pedestrian Crossing Facility Design Index	: pedestrian signals = 5, with hatching patterns = 3, stop sign only = 1							

As can be inferred from the above table, from the walker and non-walker perspectives, the pedestrian crossing facility plays important roles for creating the safety crossing environment, where the crossing facilities with signal is also more preferable by for walker as well as for non-walker.

The existence of other pedestrians, which is closely related to the security issue, is further elaborated. These components are predicted by measuring several physical properties such as, percentage of commercial uses (%), average building width (m), percentage of residential uses (%), average building to building distance (m), and average building height (m). The result shows the different perception between walker and non-walker. The walker has relatively more factors to govern more secure environment, whereas, the security issues are perceived by non-walker with the percentage of commercial uses.

Table 4. Regressions result of the existence of others

Variables	Walker Perspectives				Non-Walker Perspectives			
	Coeff.	Std. Err.	t	Sig	Coeff.	Std. Err.	t	Sig
Percentage of Commercial Uses (%)	-2.92	1.05	-2.79	0.01	-0.63	0.32	-1.97	0.05
Average Building Width (m)	-0.04	0.01	-2.63	0.01	-	-	-	-
Percentage of Residential Uses (%)	3.91	1.74	2.24	0.03	-	-	-	-
Avg. Building-to-Building Distance (m)	-0.28	0.14	-2.03	0.04	-	-	-	-
Avg. Building Height (m)	-0.30	0.12	-2.51	0.01	-	-	-	-
Constant	8.66	1.81	4.80	0.00	3.60	0.20	17.93	0.00
F Statistic				2.29				3.88
Significance F				0.05				0.05

The width of sidewalk is then investigated. Practically the pedestrian width is constructed by three components, namely, total width, obstacle that reduce the usage of total width, and the effective width. This study thus elaborated how the perception of walker and non-walker to the width by considering those components. By comparing the perception of walker and non-walker to the physical indicator, it is interesting to find that the walker more considers the effective width rather than the non-walker. On contrary, the non-walker put the attention to the total width. This result may be explained by the different walker experience and non-walker perception. Based on their experiences, the walker understands the walk space is strongly related to the effective width. Meanwhile, the non-walker practically perceived the walking space is related to the total width.

Table 5. Regressions result of width walkability component

Variables	Walker Perspectives				Non-Walker Perspectives			
	Coeff.	**Std. Err.**	**t**	**Sig**	**Coeff.**	**Std. Err.**	**t**	**Sig**
Effective Width of Walking Zone (m)	0.42	0.12	3.35	0.00	-	-	-	-
Total Width of Walking Zone (m)	-	-	-	-	0.21	0.10	2.11	0.04
Constant	2.70	0.17	16.08	0.00	2.73	0.25	10.85	0.00
F Statistic				11.20				4.44
Significance F				0.00				0.04

The buffering from the environment negative impact is further explored. This component is related to performance of pedestrian facilities to avoid walker from negative environmental exposure, such as, rain and sunlight. The physical indicator (e.g., percentage sidewalk with visual nuisance, average number of street trees / 150 m) is compared to the walker experience and non-walker perception. The result is showed in the table below, where both walker and non-walker consider number of tree in the side walk for buffering them from the negative impact.

Table 6. Regressions result of sense of buffering from negative impact

Variables	Walker Perspectives				Non-Walker Perspectives			
	Coeff.	**Std. Err.**	**t**	**Sig**	**Coeff.**	**Std. Err.**	**t**	**Sig**
Avg. Number of Street Trees / 150 m	0.001	0.001	1.084	0.280	0.002	0.001	1.862	0.065
Constant	2.826	0.126	22.461	0.000	2.748	0.118	23.274	0.000
F Statistic				1.18				3.47
Significance F				0.28				0.06

In addition, the visual attractiveness is regarded as the components that construct the walkability perception. The relation of perspective and physical condition of pedestrian facilities is then described in the table below.

Table 7 Regressions result of visual attractiveness component

Variables	Walker Perspectives				Non-Walker Perspectives			
	Coeff.	**Std. Err.**	**t**	**Sig**	**Coeff.**	**Std. Err.**	**t**	**Sig**
Avg. Amount of Street furniture	0.04	0.02	2.29	0.02	0.35	0.12	2.88	0.00
Avg. Width of Landscape Strip	0.01	0.00	2.47	0.01	-0.04	0.01	-3.30	0.00
% of Walking-Conducive Commercial	-	-	-	-	-0.44	0.14	-3.07	0.00
% of Sidewalk with Visual Nuisance	-	-	-	-	3.47	1.18	2.93	0.00
Constant	2.93	0.11	27.65	0.00	2.07	0.71	2.90	0.00
F Statistic				5.24				3.28
Significance F				0.01				0.01

In the interview surveys, the issue relating to the facilities for disabled and the easy access to local store are raised. Therefore, both issues are considered as a walking component for pedestrian user. The easy access to local stores is then explored, where the local stores are defined into two different types, there are permanent stores and local street vendors. The walker perception relating to the easy access to local store is positively correlated with the street vendors.

Table 8. Regressions result of the easy access to local stores component

Variables	Walker Perspectives			
	Coeff.	Std. Err.	t	Sig
Percentage of Commercial Uses	-0.87	0.26	-3.37	0.00
Percentage of Street Vendors	0.10	0.05	2.05	0.04
Constant	3.27	0.15	21.52	0.00
F Statistic				6.22
Significance F				0.00

Furthermore, this study elaborates the walkability by considering the disabled person. The existence of tactile pavement and warning pavement as well as the width of side walk are regarded as the indicator for measuring the walkability by taking into account the requirements of the disable person.

Table 9. Regressions result of social inclusion component

Variables	Walker Perspectives			
	Coeff.	Std. Err.	t	Sig
Total width of walking zone (m)	0.30	0.14	2.15	0.03
Constant	1.70	0.35	4.85	0.00
F Statistic				4.63
Significance F				0.03

Table above show the regression result of social inclusion components, where the walker regarded the width as the important factor for measuring the walkability index for disabled person. The interesting result can also be seen in term of the existence of tactile and warning tile that is not considered as part of disabled facilities. This finding is possibly explained by facts that the function of facilities has not been known by Indonesian people. The key components construct the walkability perception from walker and non-walker is then summarized as follows:

Table 10. Key components constructing the walkability perception

Walkability Component	Physical Indicators	
	Walker	Non-Walker
Sense of Safety in Crossing	x_1: Pedestrian Crossing Facility Design Index	
The existence of other pedestrians	x_2: Percentage of Commercial Uses (%) x_3: Average Building Width (m) x_4: Percentage of Residential Uses (%) x_5: Avg. Building-to-Building Distance (m) x_6: Avg. Building Height (m)	x_2 : Percentage of Commercial Uses (%)
The width of side walk	x_7 : Effective Width of Walking Zone (m)	x_8: Total Width of Walking Zone (m)
The buffering from negative impact	x_9 : Avg. Number of Street Trees / 150 m	
The visual attractiveness	x_{10} : Avg. Amount of Street furniture x_{11} : Avg. Width of Landscape Strip	x_{10}: Avg. Amount of Street furniture x_{11} : Avg. Width of Landscape Strip x_{12}: % of Walking-Conducive Commercial x_{11} : Avg. Width of Landscape Strip

Walkability Component	Physical Indicators	
	Walker	Non-Walker
		x_{13}: % of Sidewalk with Visual Nuisance
The easy access to local stores	x_2: Percentage of Commercial Uses x_{14}: Percentage of Street Vendors	
The social inclusion	x_8: Total width of Walking Zone (m)	

Putting together the walkability components, which have already been explored, the composite model for measuring the walkability from walker and non-walker perspective can be described as follows:

$$
\begin{aligned}
&Y = Y^u + Y^n \\
&Y^u = 0.16(0.17x_1 + 2.41) + 0.20(-2.92x_2 - 0.04x_3 + 3.91x_4 - 0.28x_5 - 0.30x_6 + 8.66) \\
&\quad + 0.11(0.42x_6 + 2.7) + 0.12(0.001x_9 + 2.82) + 0.10(0.04x_{10} + 0.01x_{11} + 2.93) \\
&\quad + 0.11(-0.87x_2 + 0.10x_{14} + 3.27) + 0.19(0.30x_8 + 1.7) \\
&Y^n = 0.09(0.19x_1 + 2.50) + 0.10(-0.63x_2 + 3.60) + 0.17(0.21x_8 + 2.73) \\
&\quad + 0.19(0.002x_9 + 2.75) + 0.16(0.35x_{10} - 0.04x_{11} - 0.44x_{12} - 3.47x_{13})
\end{aligned}
$$

From this model, it can be inferred that the non-walker has a relatively different key component that build their walkability perception. This key then should be carefully taken into account in order to promote the walking behavior. For instance, in spite of the walker more consent to the effective width (i.e., x_7), the improvement of total width (i.e., x_8), is still required for increasing the walkability perception of non-walker. In addition, the facilities which are considered by both walker and non-walker should obtained the well consideration, such as, the crossing facilities, the number of trees as well as the street furniture.

4. CONCLUSION

This paper presents the walkability index model by considering the walker and non-walker perception. As different with the preceding research that mostly pay attention to the walker perception, the proposed model takes into account the non-walker perception for measuring the walkability index. The result shows that the non-walker has a different key component which construct the walkability perception. Since the walking decision is also influenced by the built environmental of factors, the proposed walkability index is potentially to be utilized for analyzing the required pedestrian facilities not only to serve the walker, but also to encourage the non-walker for using the facilities.

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