Estimation of Access Mode Choices based on Walkable Environment Index in Bangkok, Thailand

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Abstract: Walkability is thought to be one of the key components in encouraging people for walking to transit stations. Although several indices or methods to measure a walkable environment has been focused more than decades throughout the developed countries, they have recently gained increasing popularity in Asian developing countries. This study intends to investigate how transportation planners and policy makers can understand the current walkable environment around transit stations through two objectives: (1) the development of the walkable environment index (WEI); and (2) the application of WEI to area within 400 meters of given transit stations in Bangkok Metropolitan Region (BMR) as case study using AHP-based approach. Furthermore, this study examines the relationship between walkable environment and transit's access mode choice. Obtaining information will be better for future design to improve the quality transit surrounded environment and suggest appropriate policies to promote transit uses.

Keywords: Walkable environment index; Access mode choices; AHP

1. INTRODUCTION

Many big cities throughout the world are facing serious problem of traffic congestion. The conception of transit-oriented development (TOD), which was firstly introduced by Calthorpe (1993), has gained a popularity as sustain strategy to address such problem by reducing vehicle kilometer traveled (VKT) and promoting transit usage. To achieve this goal, not only do an efficient system and adequate routes require, but also ease, and directness of access to transit stations. In public transport studies, walking is thought to be an important access/egress mode to/from transit station (Wibowo and Olszewski, 2005; Woldeamanuel and Kent, 2016). Previous studies indicated that number of walk trips associate with how pedestrian friendly environment is to walk (Cervero and Duncan, 2003; Frank *et al.*, 2006), while people choose to drive rather than walk in automobile-oriented environment (Handy and Mokhtarian, 2005). Therefore, improper pedestrian environment is potentially barrier to walking and reaching to transit stations which lead to preclude transit uses.

Bangkok Metropolitan Region (BMR) is the urban conglomeration of Bangkok and its vicinity which covers a total area of 7,761.50 square kilometers. Since 1960, transportation infrastructure (e.g., roads, expressway, bridges, etc.) had been planned and constructed without considering the interactions between land use planning, urban growth, and transport. This gradually made Bangkok spread outwards and converted it into an automobile dependent city

(Rujopakarn, 2003). Therefore, rail-based transit system has collaboratively been proposed and planned by transportation planners as well as policy makers to alleviate traffic congestion. Until now, there have been four lines, i.e., BTS Skytrain, MRT Blue Line, Airport Rail Link and MRT Purple Line in service while other lines are now construction.

Walking is the major transit access/egress mode in many cities; however, bus, and paratransit (e.g. motorcycle taxi, songtaew, tuk-tuk, etc.) have been the popular modes to stations in BMR due to uncomfortable and unsafe environment (Prasertsubpakij and Nitivattananon, 2012; Tangphaisankun *et al.*, 2010). The characteristic of street network surrounding each station is probably one of the reason in considering access and egress modes (Chalermpong and Wibowo, 2007). As the major transportation hubs, the percentage of taking bus as access mode was over 50% at Mo Chit, Chatuchak Park, Victory Monument, Hua Lumphong, and On Nut whereas the higher shares of motorcycle taxi were found in areas surrounding Sutthisan, Lat Phrao and Thong Lo stations because of an idiosyncratic street network (Chalermpong and Wibowo, 2007). Recently, poor environment towards pedestrians has been captured in most of the Airport Link stations that was claimed to affect transit ridership (Leopairojana, 2016; Pleongsrithong and Vichiensan, 2016).

The previous studies mentioned above carried out in a demand-side for why a few people walk to stations. However, such a supply-side of environment around stations was less investigation. Therefore, the purpose of this study is to investigate how transportation planners can understand the current walkable environment around the given transit stations. Walkable environment index (WEI) that can capture the elements that affect the transit walkability will be developed. The application of WEI together with the analytical hierarchy process (AHP) will be applied to measure how friendly an area within 400 meters of each given transit station of Airport Rail Link in Bangkok Metropolitan Region (BMR) is to walking. Moreover, this study will examine the relationship between walkable environment and transit's access mode choice.

The rest of this paper is organized as follows. Section 2, an overview of previous studies will be presented. Development process of walkable environment index will be presented in section 3. An application of WEI to case study will be explained in section 4. Section 5, the models are estimated with the sample data. Finally provides the conclusion

2. PREVIOUS RESEACH ON WALKABLE ENVIRONMENT

The transit area of influence to measure walkable environment has been defined in a variety of studies. Most of them indicated that it commonly depends on how far transit users are willingness to walk (Pucher and Dijkstra, 2003). More than 70% of all walk trips is shorter than 1,200 meters in Canada (Millward *et al.*, 2013; Stringham, 1982), while Pucher and Dijkstra (2000) indicated that most people can walk at least 1,600 meters in Europe. Conversely, within 400 meters and 800 meters around transit stations, which represent 5 to 10 minutes' walk area, have become the accepted distance that can have the greatest influence on walk trips in US (Galelo *et al.*, 2014; Lin and Hwang, 2004). More than 50% accounted for walking as access mode to/from station within 1,000 meters and only 3.3% accounted for walking within 0.6 mile to 1.2 mile from stations (Tangphaisankun *et al.*, 2010). However, not only do the shortest distance impact the propensity to walk, but also 3Ds of density, diversity, and design (Cervero and Kockelman, 1997).

Up until now, indices have been developed for quantifying and measuring the walkability of transit stations. Transit Score®, which was created by Front Seat Management, measures how well a location in many cities of American is served by public transit[1] by focusing on the accessibility to stops on the route, the frequency of the route and type of route (Hirsch *et al.*, 2013). Additionally, the scores are available on internet. The transit opportunity index (TOI) introduced by Mamun *et al.* (2013) was a new method for quantifying public transit performance in terms of the level access to transit system and the system's provision of services between origins and destinations. Both measures do not focus on a friendly environment towards pedestrians around transit stations. Peiravian *et al.* (2014) developed a new and easily computable measure of pedestrian friendliness, which is called the pedestrian environment index (PEI). PEI defines as the product of four components representing land-use diversity (based on the concept of entropy), population density, commercial density, and intersection density. However, this index was less attention in terms of pedestrian facilities and safety. Conversely, the pedestrian safety index (PSI) is the evaluation method for assessing pedestrian safety conditions on streets such as traffic barrier, fewer traffic lane, shorter crossing distance, marking crosswalk, lighting, sidewalk, and signal; however, indicators towards transit accessibility have not been included (Asadi-Shekari *et al.*, 2015). Beiler and Phillips (2016) developed the pedestrian corridor improvement index (PCII) which infrastructure, location (accessibility), mobility and safety have been included while the sidewalk availability and quality index (SAQI) and the connectivity index (CI) were proposed by Woldeamanuel and Kent (2016). The metric of crash rate (pedestrian to vehicle) was the highest weighted factor and followed by mixed land use and school zone proximity whereas aesthetics is the lowest. SAQI and CI heavily weigh on availability, quality and connectivity sidewalks to stations but do not design to assess pedestrian safety and land use.

3. DEVLOPMENT OF WALKABLE ENVIRONMENT INDEX

This study proposes to develop the walkable environment index (WEI) to measure the walkability along the way to transit stations. The following steps will be used in the development process: (1) development of criteria and their factors, and (2) estimation of priority weights using AHP.

3.1 Development of Criteria and Alternatives

Based on the literature reviews and guidelines, four criteria, i.e., (1) infrastructures, (2) safety, (3) accessibility and (4) mix of uses with fifteen factors included in walkable environment index are considered as the relevant factors that affect walkability assessment, as shown in Table 1.

The relevant factors that relate to sidewalks such as sidewalk width, surface condition and encroachment were classified to the major category of infrastructures. The widths and surface conditions of sidewalks were included in pedestrians' studies (Hidayat *et al.*, 2011; Shaaban and Muley, 2016; Woldeamanuel and Kent, 2016).

Sidewalks generally vary in the widths depending on the use of each area. However, sidewalks require a minimum width of 1.525 m (AASHTO, 2011). On the other hand, sidewalk encroachment that is illegally intrusion onto sidewalk by mobile stalls selling such as food, fruit, clothing, etc. was less investigated.

[1] https://www.walkscore.com/transit-score-methodology.html

Table 1. Criteria, factors, and definitions

Criteria	Factors	Definitions
Infrastructures	Sidewalk width	Sufficient sidewalk width ≥1.5 m
	Surface condition	Stable, anti-skid smooth, good repair, etc.
	Non-intrusion	Illegal intrusion onto sidewalk
Safety	Crossing facilities	Presences of crossing facilities such as crosswalks, pedestrian signals, etc.
	Pedestrian signs	Presences of pedestrian signs such as pedestrian crosswalk signs, slow watch for pedestrian signs, etc.
	Traffic calming	Presences of traffic calming such as narrowed roads, speed humps, etc.
	Barriers	Presences of barriers such as tree lines, fences, etc.
Accessibility	Network connectivity	Link-to-node ratio < 1.4, ≥1.4
	Sidewalk continuity	Presences of sidewalk on both sides of the roads
	Grid pattern	Number of 4-way intersections
	Coverage walk area	Ped-Shed ratio ≥0.5, < 0.3
Mix of uses	Shopping mall	Presences of shopping malls (Yes, No)
	Education institute	Presences of schools (Yes, No)
	Commercial uses	Density of commercial uses (Urban: 35%, Suburban: 25%)
	Residential uses	Density of residential uses (Urban: 60%, Suburban: 70%)

Many mobile stalls as shown in Figure 1, which are commonly found elsewhere in Thailand, are encroaching into the walking spaces that block and make pedestrian cannot walk down the sidewalk. Unavoidably, pedestrians are walking out on the streets instead.

(a) (b)

Figure 1. Encroaching on sidewalk: (a) mobile stalls and (b) intrusion of private stuffs

More than 40% of traffic accidents occurred in Bangkok involved to pedestrians (Leelakajonjit and Kumpeeranon, 2009). Thus, one of the most important factors for creating and promoting pedestrian-friendly environment is probably safety. Several countermeasures have been proposed in the literatures and guidelines to improve pedestrian safety. For example, pedestrian signal timing was recommended to be adjusted by Canadian Council of Motor Transport Administrators (CCMTA) in order to allow safe crossing by restrictions of mobility because not all pedestrians are easily and safely capable of crossing the road. Furthermore, CCMTA suggested that pedestrian signs are generally used to remind pedestrians about dangerous road and vehicle threats at signalized intersections. Besides several barriers that offered huge opportunities to improve accident statistics need to be installed (Alluri *et al.*, 2013). As known, vehicle speed is likely to be involved in accidents (Malyshkina and Mannering, 2008; Pikūnas *et al.*, 2004). Thus, traffic calming for reducing vehicle speed is proposed as the factor for walkability assessment under the category of safety.

The criteria of accessibility represent the evaluations of how pedestrian network can reach and coverage a variety of specific destination which was measured by four factors including network connectivity, sidewalk continuity, grid pattern, and effective walk area. The number of links (e.g. segment between two intersections) divided by the number of nodes (e.g. intersections) or so-called a link-node ratio is an assessment of network connectivity. The link-node ratio of 1.4 or more is the minimum requirement of a connected network (Ewing, 1996).Sidewalk should present on both sides of street without lapses in continuity. However, both ratios do not reflect a length of each segment between two nodes. Four-way intersections density was used to measure whether it is a grid pattern within buffer zone or not (Boarnet and Crane, 2001). Coverage walk area applied by Gori *et al.* (2014) is calculated based on pedestrian catchment area (PCA) or so-called ped-shed ratios that commonly use to compare the Euclidean walking distance to the actual walking distance based on street network PCA or the ped-shed ratio falls between 0 and 1, with a value closer to 1 indicating a good walking coverage of a total area. Generally, the acceptable threshold to obtain good walking coverage of an area is a PCA of 0.5 or more. Conversely, PCA value lower than 0.3 might correspond to an inaccessible walking area (Gori *et al.*, 2014; Schlossberg, 2006; Schlossberg and Brown, 2004).

The literature suggested that density, land-use diversity and pedestrian-oriented designs encourage non-motorized modes (Cervero and Kockelman, 1997). Furthermore, Chatman (2009) indicated that people tend to walk in densely-developed, transit-served neighborhoods with shops and services. Recently, the conception of TOD has been commonly discussed as strategy for developing sustainable environment by focusing on creating an attractiveness neighborhood with a mixture of residential, employment, shopping and so on (Cervero *et al.*, 2004). In this study, the criteria of mix of uses with four alternatives, i.e., shopping mall, education institute, commercial and residential uses are included in the walkable environment index in order to capture the level of mix of land use activities in each station area. An indicative mix of residential and commercial uses varies depending on each city and station’s location such as city center, urban, suburban, neighborhood, etc. In addition to urban, high-rise (i.e., over 10 storeys) and medium-rise (i.e., between 4 and 10 storeys) residential and commercial uses are predominantly developed whereas low-rise (i.e., up to 3 storeys) residential and commercial uses are predominant development in suburban and neighborhood (Cervero *et al.*, 2004). In this study, the indicative mix of residential and commercial uses for suburban and neighborhood are assigned as in Table 1. Densities of residential and commercial of each buffer zone are added up and divided by buffer area.

3.2 Estimation of Priority Weights using AHP

The multi criteria analysis (MCA) based on the analytical hierarchy process (AHP), which was firstly introduced by Saaty (1980), is applied to determine the priority weights of criteria and their factors that affect walkability assessment through pairwise comparisons. The obtained weights reflect and explain the opinion of the decision maker. The following steps will be used as the AHP development process: (1) development of a decision hierarchy, (2) estimation of priority weights based on pairwise comparison matrices, and (3) consistency check.

Based on Table 1, a hierarchical structure applied to the walkable environment index (WEI) is developed as Figure 2. Walkability assessment is the highest level of the decision hierarchy, then four criteria and fifteen factors as previous stated are the intermediate level and lowest level, respectively.

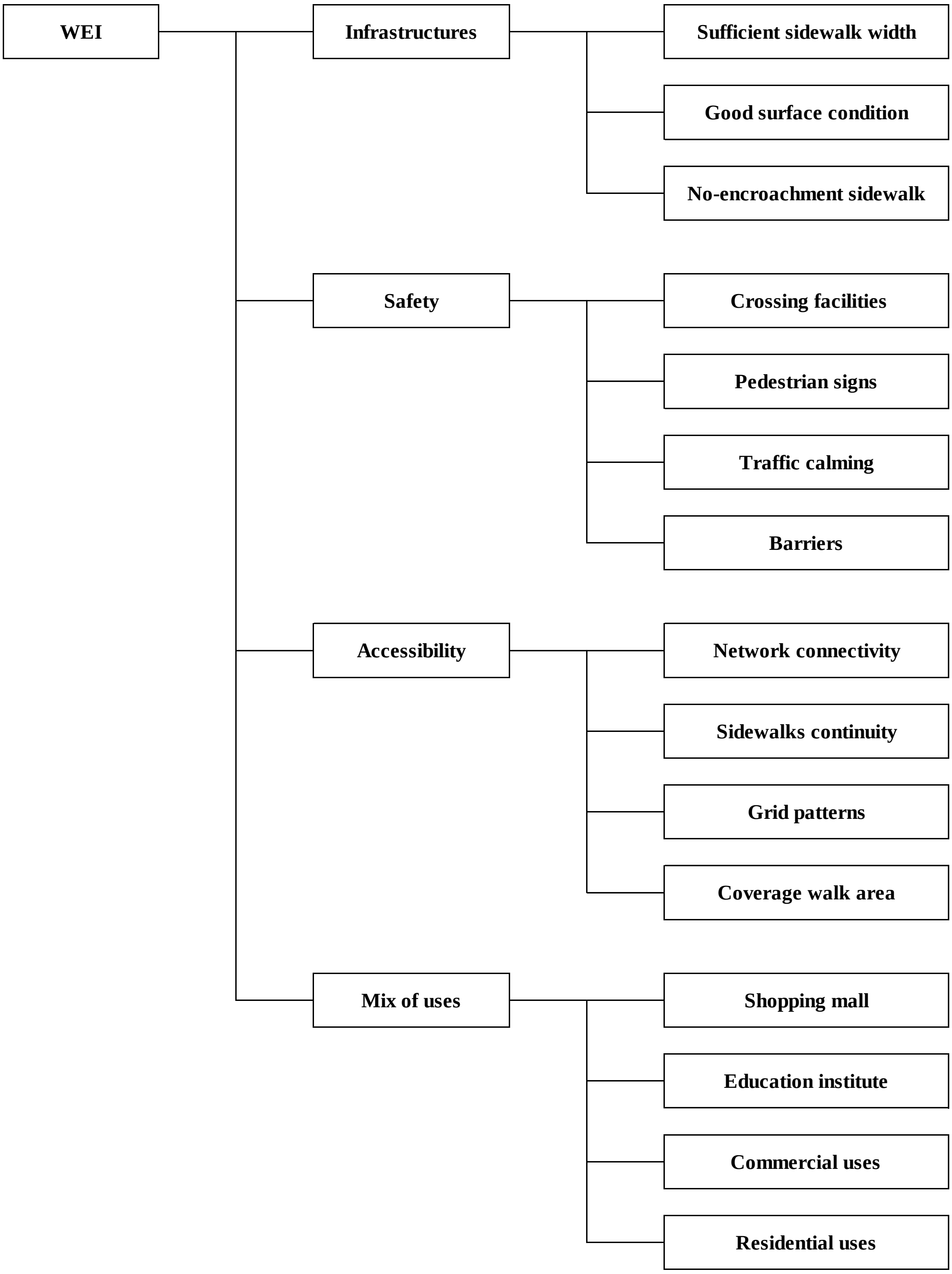


Figure 2. Hierarchical structure to WEI

The priority weights are the estimated values indicating the importance among the elements of the hierarchy. For the prioritization, a decision maker is asked to compare a pair of criteria and factors for all possible pairs using the standard AHP scale of importance from 1 (equal) to 9 (extreme) to perform a pairwise comparison matrix (Saaty, 1980). The comparisons are processed mathematically and priorities are derived.

In this study, four experts in urban and transportation planner were asked to participate. The following sentence is the sample of a pairwise comparison between two criteria of infrastructures and safety: infrastructures including sidewalk width, surface condition and encroachment are more important or less important than safety with crossing facilities, pedestrian signs, traffic calming and presence of barriers. Numerical values on a scale of 1-9 are given as shown in Figure 3.

	More important than								Equal	Less important than								
	9		7		5		3		1		3		5		7		9	
A Infrastructure of sidewalks	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	B Facilities of saftey
A Infrastructure of sidewalks	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	C Accessibility
A Infrastructure of sidewalks	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	D Mixed land use
B Facilities of saftey	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	C Accessibility
B Facilities of saftey	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	D Mixed land use
C Accessibility	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	D Mixed land use

Figure 3. Pairwise comparisons survey

Consistency ratio (*CR*) defined by Saaty (1980) will be used in order to ensure that the results are consistent or need to be improved. If $CR \leq 0.1$ then the pairwise comparison matrix is consistent. On the other hand, if $CR \geq 0.1$ then the matrix should be improved. The *CR* can be computed using equation (1).

consistency ratio: $$CR = \frac{CI}{RI} \quad (1)$$

where CI = consistency index $= \frac{(\lambda_{max} - n)}{(n-1)}$

RI = random consistency index as shown in Table 2 (Saaty, 1980)

λ_{max} = maximum eigenvalue

n = number of criteria/factors for comparisons

Table 2. Values of *RI* in the AHP method

Number of criteria/sub-criteria (n)	3	4	5	6	7	8	9	10
RI	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 3 presents the local, global, and normalized priority weights with $CR \leq 0.1$ for each criterion and factors that were obtained from AHP. The local weights of each criterion and factors are obtained from pairwise comparisons. On the other hand, the global weights are obtained by multiplying the local weights of factors by the global weights of their corresponding criteria. Then, global weights of factors are normalized to bring all values into range 0-1. The results indicate accessibility is the most important criteria in walkability assessment. Among the factors under criteria, crossing facilities are the highest weighed factors and followed by network connectivity and effective walk area. On the other hand, Sidewalk encroachment is the lowest.

Table 3. Local, global, and normalized weights

Criteria/Alternatives	Local weight	Global weight	Normalized weight
Infrastructures	0.0931	0.0931	
Sidewalk width	0.4120	0.0384	0.1670
Good surface condition	0.2607	0.0243	0.0695
No-encroachment sidewalk	0.1527	0.0142	0.0000
Safety	0.2730	0.2730	
Crossing facilities	0.5817	0.1588	1.0000
Presence of barriers	0.0611	0.0167	0.0170
Traffic calming	0.2012	0.0549	0.2816
Pedestrian signs	0.1468	0.0401	0.1788
Accessibility	0.4477	0.4477	
Network connectivity	0.3022	0.1353	0.8377
Sidewalks continuity	0.1941	0.0869	0.5029
Grid pattern	0.1069	0.0478	0.2326
Effective walk area	0.1975	0.0884	0.5133
Mix of uses	0.1020	0.1020	
Shopping mall	0.1480	0.0151	0.0061
Education institute	0.1532	0.0156	0.0097
Commercial uses	0.3188	0.0325	0.1265
Residential uses	0.3590	0.0366	0.1549

4. CASE STUDY APPLICATION

4.1 Study Area and Data Collection

To evaluate walkability to transit station, four stations of Airport Rail Link: (1) Ramkhamhaeng (RKH) station, (2) Hua Mak (HM) station, (3) Ban Thapchang (BTC) station and (4) Lat Krabang (LKB) station were selected as case study application. As stated in the literature review, 400 meters were used to be the representative of the catchment areas of all stations. RKH station is in urban area of Bangkok, while other stations are in suburban area.

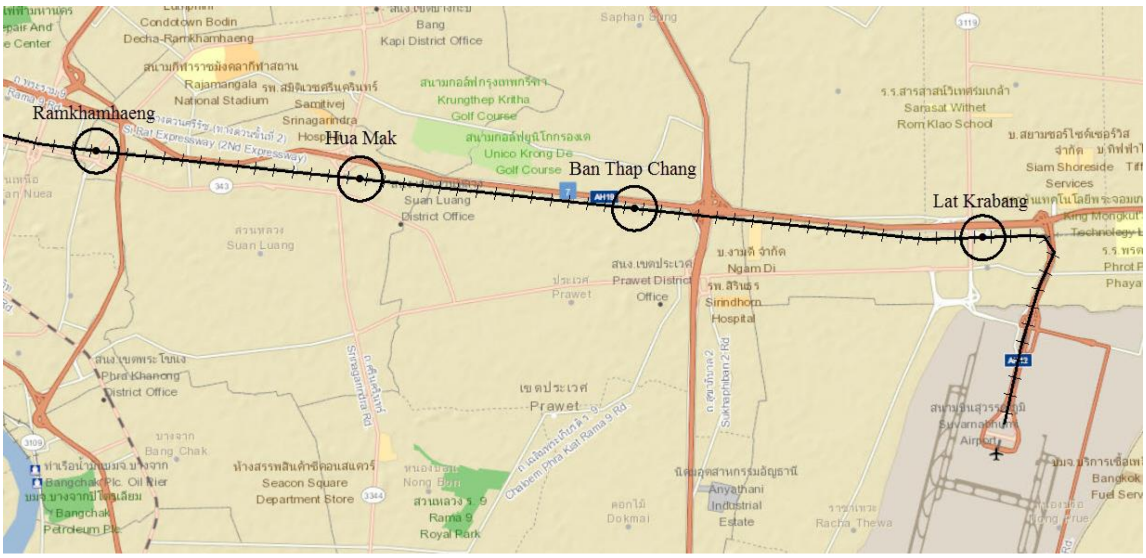
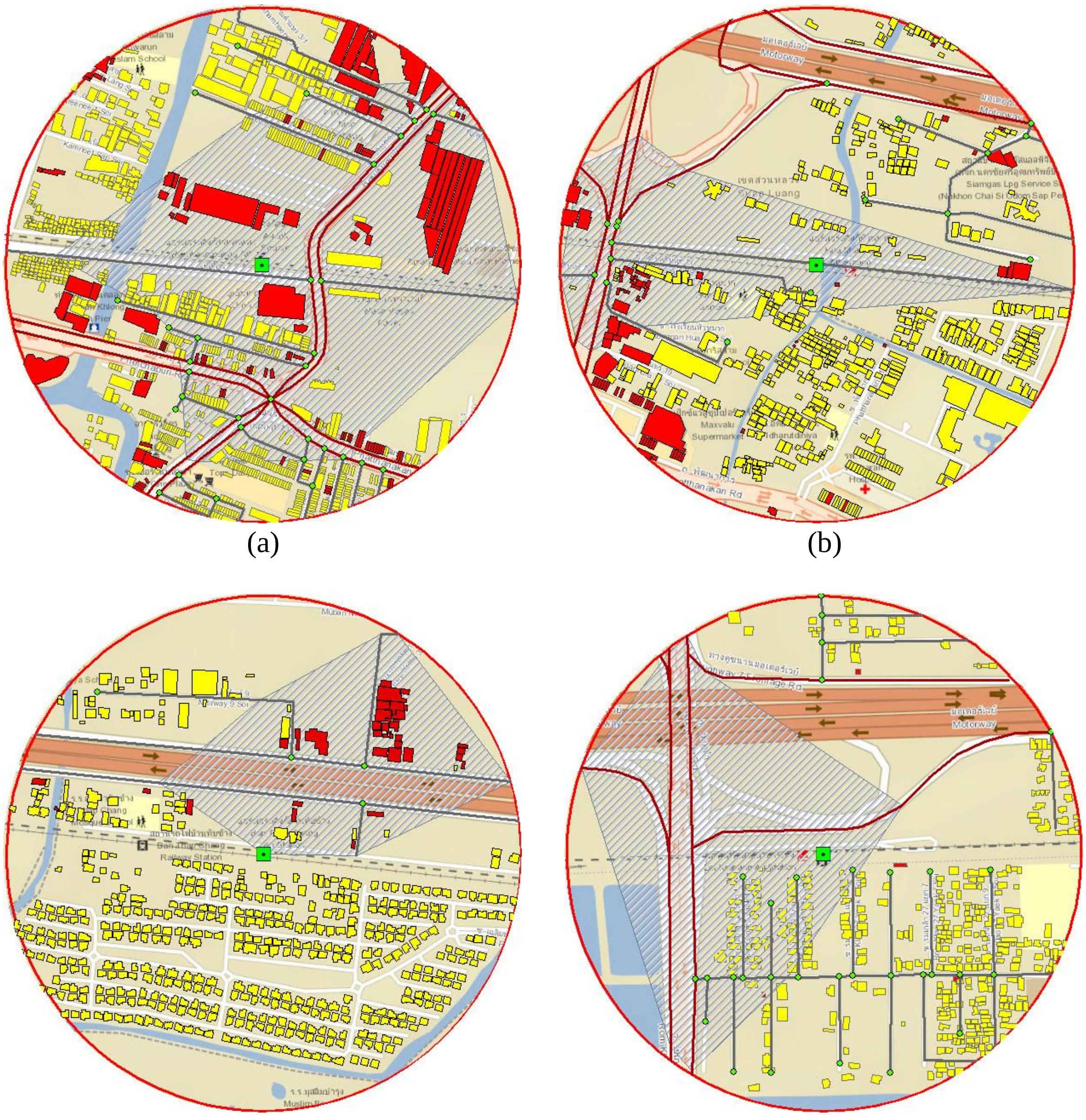


Figure 4. Analysis area: a 400-m buffer zone

Once the target stations were selected and the buffer zones were identified, the data collection in field using variety of methods was started. For example, a measuring wheel measured the widths and lengths of sidewalks, and the dimensions of bad surface conditions and encroachment while presences of crossing facilities, barriers, traffic calming and pedestrian signs were measured using the visual assessment. Other data related to accessibility and mix of uses categories were gathered using an application of GIS. The collected data are presented in Figure 5.



(a) (b)

(c) (d)

Figure 5. Collected data: (a) RKH station, (b) HM station, (c) BTC station, and (d) LKB station

4.2 Outcome of Collected Data for All Factors

After the data was collected, all factors identified in Table 1 were computed the scores regarding the ratios on a scale from 0-1 except presences/absences of shopping malls and education institutes that were assigned the dummy variable of 0 and 1 as presented in Table 4.

Table 4. Methods for scoring factors

Criteria	Factors	Definitions
Infrastructures	Sidewalk width	*Ratio of sufficient width* $= \frac{\text{total length of sidewalk width} \geq 1.5\text{ m}}{\text{total length of road network}}$
	Surface condition	*Ratio of good surface area* $= \frac{\text{total good surface area of sidewalk}}{\text{total surface area of sidewalk}}$
	Non-intrusion	*Ratio of no-intrusion area* $= \frac{\text{total area of no-intrusion onto sidewalk}}{\text{total surface area of sidewalk}}$
Safety	Crossing facilities	*Ratio of presences of crossing facilities* $= \frac{\text{number of crossing facilities at intersections}}{\text{number of intersections}}$
	Pedestrian signs	*Ratio of presences of pedestrian signs* $= \frac{\text{number of pedestrian signs at intersections}}{\text{number of intersections}}$
	Traffic calming	*Ratio of presences of traffic calming* $= \frac{\text{number of traffic calming at intersections}}{\text{number of intersections}}$
	Barriers	*Ratio of presences of barriers* $= \frac{\text{total length of barriers}}{\text{total length of road network}}$
Accessibility	Network connectivity	*Link-to-node ratio* $= \frac{\text{number of links (road segments)}}{\text{number of nodes (intersections)}}$
	Sidewalk continuity	*Ratio of continuity* $= \frac{\text{total length of sidewalk on both sides}}{\text{total length of road network}}$
	Grid pattern	*Ratio of 4-way intersections* $= \frac{\text{number of 4-way intersections}}{\text{number of intersections}}$
	Coverage walk area	*Ped-Shed ratio* $= \frac{\text{actual walking area}}{\text{total buffer area within 400 m}}$
Mix of uses	Shopping mall	*Presences of shopping malls* = Yes (1), No (0)
	Education institute	*Presences of schools* = Yes (1), No (0)
	Commercial uses	*Ratio of commercial uses* $= \frac{\text{total commercial area}}{\text{total buffer area within 400 m}}$
	Residential uses	*Ratio of residential uses* $= \frac{\text{total residential area}}{\text{total buffer area within 400 m}}$

Based on Table 4, the outcomes are presented in Figure 6. Across all four criteria, safety must be assigned the highest priority for improvement. Crossing facilities, pedestrian signs, traffic calming and barriers rarely present for all stations. For the category of infrastructures, the width of sidewalk is not sufficient as requirement especially BTC station and LKB station. Regarding the overall existing sidewalks, good qualities of sidewalks present and sidewalk encroachment is rarely found. Noticeably, RKH station that locates in urban area has somewhat more intrusion onto sidewalks than those stations in suburban area, i.e., HM station, BTC station and LKB station. Among factors in accessibility category, although the network connectivity that measures by link-node ration is more than 1.4 for all stations, coverage walk area is remarkably narrow with predominantly non-grid street patterns. Discontinuity sidewalk system is also captured. Presences of education institutes in the buffer zone are found for all stations, unfortunately, presence of shopping malls is found only urban station of RKH. Besides, commercial uses and residential uses with low density are monitored especially LKB station.

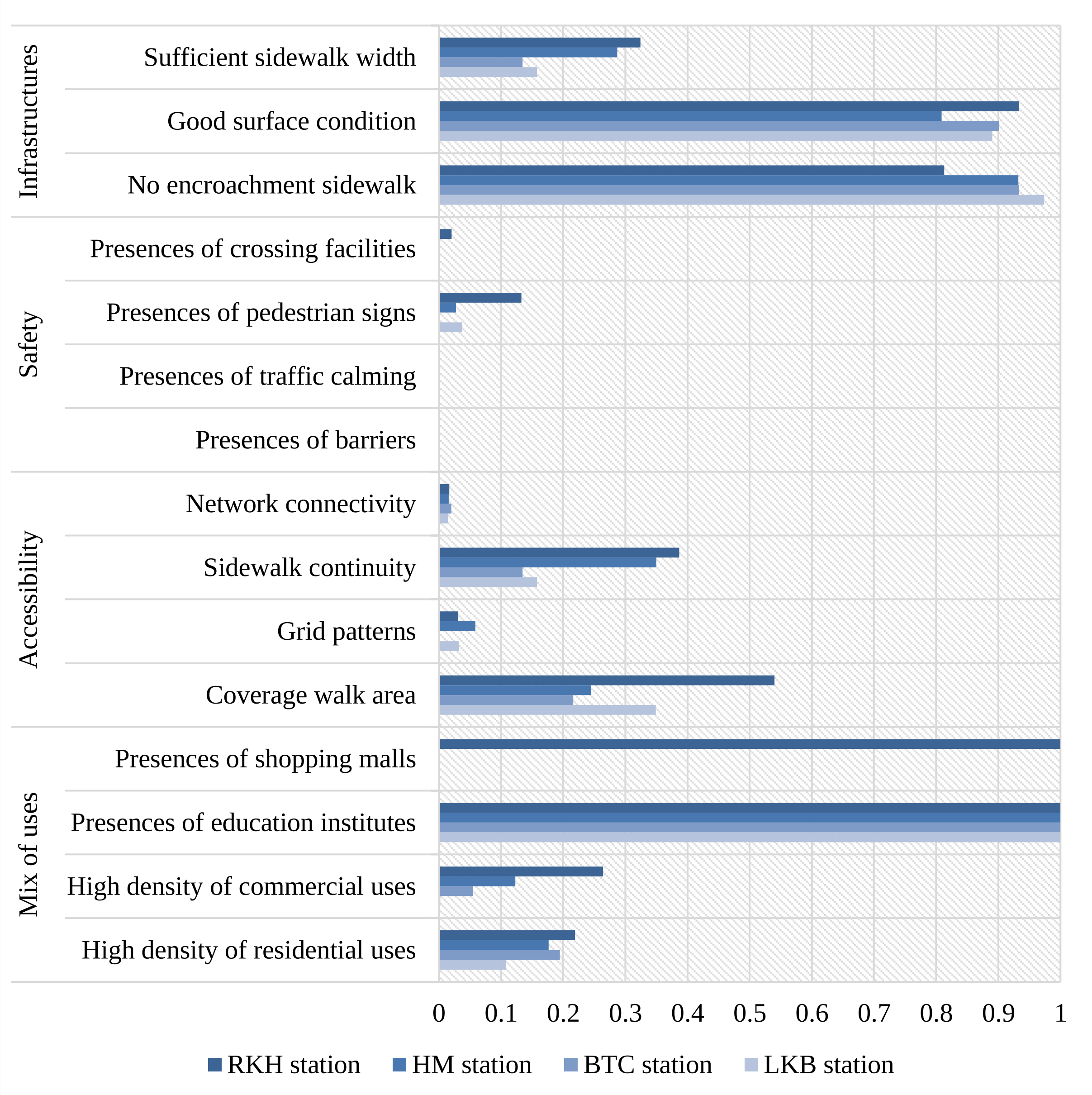


Figure 6. Scores for all factors by stations

4.3 An Application of WEI to Given Stations

Since the application of walkable environment index (WEI) was applied to four stations of Airport rail link, the resulting scores are shown in Figure 7. In addition to WEI, the scores reflect to how friendly areas are to walking and it is, furthermore, capable to identify to which station most in need of improvement. The following categories with equal intervals of 0.2 points are used: 0-0.2 = absent, >0.2-0.4 = poor, >0.4-0.6 = fair, >0.6-0.8 = good, and >0.8-1.0 = very good (Beiler and Phillips, 2016). From Figure 7, although RKH station obtained the highest score, it still falls within the poor category as others, meaning that pedestrian conditions are very poor and improvements are needed.

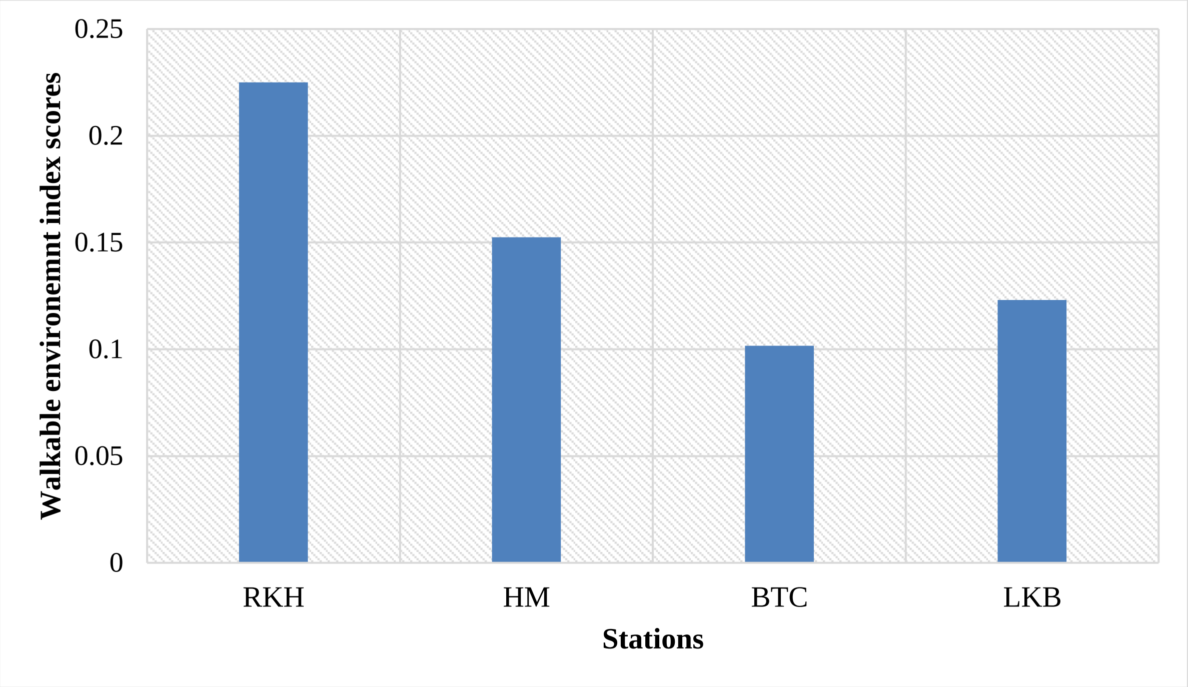


Figure 7. Walkable environment index (maximum index score = 1)

5. RELATIONSHIP BETWEEN WALKABLE ENVIRONMENT INDEX AND ACCESS MODE CHOICE OF WALKING

Over the past decades, built environment influences on travel behavior has been carried out in many studies (Cervero and Kockelman, 1997; Ewing and Cervero, 2001; Ewing and Cervero, 2010; Krizek, 2006; Saelens and Handy, 2008). This part aims to examine the relationship between walkable environment and transit's access mode choice.

5.1 Characteristics of Respondents within Buffer Areas

The general information of the respondents is described using descriptive statistics in Table 5. There are more female respondents than male ones. Noticeably, pedestrians are likely to be students and employees. Home-based work trips are also captured. Low rate of car ownership is found in households that tend to walk.

Table 5. Characteristics of respondents

	Overall	Walk
Gender		
Male	1,049	214
Female	1,414	312
Age		
0-19 years	492	83
20-29 years	1,006	245
30-39 years	587	125
40-49 years	235	45
50-59 years	104	22
>59 years	39	6
Occupation		
Student	887	153
Employee	894	245
Government officer	136	27
Self-business	315	66
Others	231	35
Monthly income		
<10,000 baht	165	12
10,001-15,000 baht	211	41
15,001-20,000 baht	212	46
20,001-25,000 baht	168	25
25,001-35,000 baht	314	80
>35,000 baht	1,393	322
Car ownership		
Yes	1,144	192
No	1,319	334
Trip purpose		
Home-based work trips	821	184
Home-based school trips	461	78
Home-based other trips	963	200
Non-home-based trips	218	64
Total	2,463	526

5.2 Transit Access Modes versus Distance to Station

Figure 8 presents the relationship between access modes and distance to stations within 2 km. As walking distance decreases, most people are willing to walk. Less than 10 % of respondents are willing to walk from the distance longer than 1 km. Only 20 % of the respondents tend to use motorcycle/motorcycle taxi at the distance of 0.7 km, but rate of the use rises to 50 % at the distance of 1.1 km. Car and bus are the same trend as motorcycle/motorcycle taxi and the percentage of motorized modes are not different.

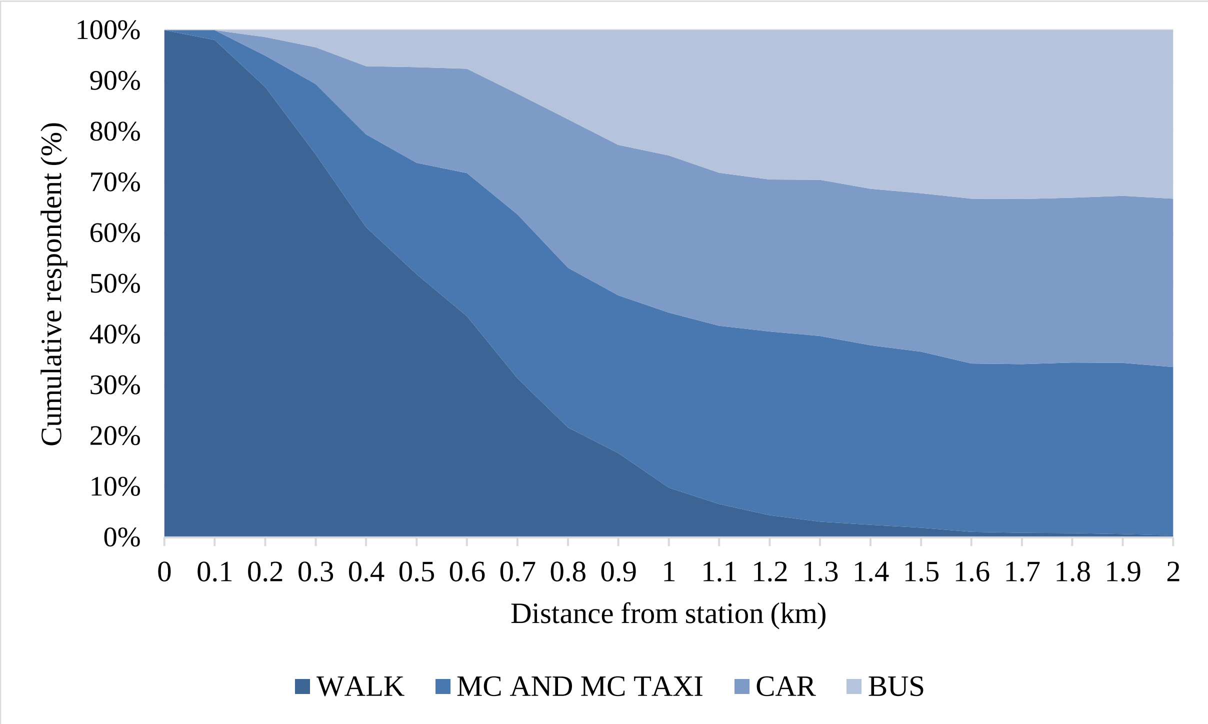


Figure 8. Relationship between access modes and distance from station

5.3 Effect of WEI Scores on Walking to Transit Station as Access Mode Choice

The discrete choice modeling paradigm, in particular the logit model, has been topics for many years, mainly for applications in the field of mode choice studies. After extensive experimentations with different specifications, the model results were chosen based on the theoretical and statistical significance of the estimated parameters.

Table 6 present the estimated results of binary logit model of walk and non-walk access mode choices. Age, occupation, and transfer to other rail transit lines influence access mode choice in this study. Noticeably, most employees tend to walk to stations compared to other occupation, reflecting by positive sign of “employee”. Negative sign of “age” indicates that respondents who younger than 39 years old do not tend to . Besides, transit users who have to transfer to other rail transit lines are not likely to walk. On the other hand, gender, trip purposes, monthly income, and car ownership were also used to derive. Obviously, they are not statistically significant determinants of the propensity to walk in this study. This is probably due to the monthly income among these given stations are not significantly different. Also, there might be collinearity problems between respondent characteristics and station characteristics (Chalermpong and Wibowo, 2007).

Among station variables, the coefficient on the proximity to the transit station has the negative sign with highly statistically significant at 0.01 level, as expected. Holding everything constant, the shorter distance to station increases the probability of walking. Furthermore, the result demonstrates a positive relationship between the probability to walk and WEI index with highly statistically significant at 99 percent confident level. This mean that, holding everything constant, it is expected to see a greater number of walk trips in a buffer zone that has grater walkable environment.

Table 6. Estimation results of access mode choices within 2 km

Variables	Coef.	t-stat	p-value	
Constant	0.149	0.38	0.708	n/s
Respondent's' characteristics				
Age (= 1 if respondents are less than 39 years old)	-0.474	-1.88	0.060	*
Income (=1 if income is higher than 35,000 baht)	0.039	0.38	0.842	n/s
Employee (= 1 if respondents are employee)	0.540	2.82	0.005	***
Transfer (1= if respondents transfer to other lines)	-0.625	-3.08	0.002	***
Station variables				
Distance	-3.280	-15.53	0.000	***
Walkable environment index	16.790	8.97	0.000	***
No. of observation		1,072		
Prob. > chi-squared		0.000		
Log likelihood		-379.05		
Rho-square		0.455		

*** = significant at 1% level

** = significant at 5% level

* = significant at 10% level

n/s = no significant at 10% level

6. CONCLUSION

In order to maintain, improve and promote walkability in catchment area of station, effective improvement plans are needed. This study provides the scientific evidence to demonstrate the feasibility of assessing the walkability to rail transit station within a 400-m buffer zone and investigated its impacts on walking to transit as access mode choice. The data for carried out the walkability assessment are relatively easy and inexpensive to collect.

The index developed and measured whether a passenger accessing to or from the station can easily walk to whatever is there based on the four categories of sidewalk infrastructures, pedestrian safety, sidewalk network accessibility and mixture of land uses. Thus, this approach can be quickly used to identify to which stations are the most and least walkable stations. Furthermore, it is capable to identify a station's need for priority improvements.

Regarding the WEI, the scores of all four stations fall within the poor category, indicating that the walkable conditions somewhat present within a 400-m buffer zone but improvements are required in order to reach the higher categories. Specifically, pedestrian safety and sidewalk network accessibility are prioritized for renovation. However, this study has some limitations by excluding the relevant factors related to disable pedestrian level and the security in term of crimes.

The relationship between walkable environment index and transit's access mode choice was also examined. With the WEI scores for all stations as one of independent variables, higher scores of walkability within the buffer zone tend to increase the transit user's chance of walking to station. On the other hand, with beyond the longer distance, walking as access mode choice does not have the capability to compete with other commute modes.

Recently, focusing on creating pedestrian-friendly environment regarding TOD concepts has just received a great deal of attention in Thailand because it is believed to be the principal component to future urban design, leading people to walk and taking transit over than driving. Therefore, urban and transportation planners can effectively adapt the WEI into the planning process for further promoting pedestrian improvements.

REFERENCES

AASHTO. (2011) *A Policy on Geometric Design of Highways and Streets*. American Association of State Highway and Transportation Officials.

Alluri, P., Haleem, K., Gan, A., Lavasani, M., and Saha, D. (2013). Comprehensive Study to Reduce Pedestrian Crashes in Florida. Florida: Research Center Florida Department of Transportation.

Asadi-Shekari, Z., Moeinaddini, M., and Shah, M. Z. (2015), Pedestrian Safety Index for Evaluting Street Facilities in Urban Areas. *Safety Science*, 74, 1-14.

Beiler, M. R. O. and Phillips, B. (2016), Prioritizing Pedestrian Corridors Using Walkability Performance Metrics and Decision Analysis. *Journal of Urban Planning and Development*, 142(1), 1-12.

Boarnet, M. G. and Crane, R. (2001), The Influence of Land Use on Travel Behavior: Specification and Estimation Strategies. *Transportation Research Part A: Policy and Practice*, 35(9), 823-845.

Calthorpe, P. (1993) *The Next American Metropolis: Ecology, Community, and the American Dream*. Princeton Architectural Press, New York.

Cervero, R. and Duncan, M. (2003), Walking, Bicycling, and Urban Landscapes: Evidence from San Fransico Bay Area. *American Journal of Public Health*, 93(9), 1478-1483.

Cervero, R. and Kockelman, K. M. (1997), Travel Demand and the 3ds: Density, Diversity, and Design. *Transportation Research Part D: Transport and Environment*, 2(3), 199-219.

Cervero, R., Murphy, S., Ferrell, C., Goguts, N., Tsai, Y.-H., Arrington, G. B., Boroski, J., Smith-Heimer, J., Golem, R., Pennger, P., Nakajima, E., Chui, E., Dunphy, R., Myers, M., McKay, S., and Witenstein, N. (2004). *Transit-Oriented Development in the United States: Experiences, Challenges, and Prospects*.Transportation Research Board of the National Academies, Washington, D.C.

Chalermpong, S. and Wibowo, S. S. (2007), Transit Station Access Trips and Factors Affecting Propensity to Walk to Transit Stations in Bangkok, Thailand. *Journal of the Eastern Asia Society for Transportation Studies*, 7, 1806-1819.

Chatman, D. G. (2009), Residential Choice, the Built Environment, and Nonwork Travel: Evidence Using New Data and Methods. *Environment and Planning A*, 41(5), 1072-1089.

Ewing, R. (1996) *Best Development Practices; Doing the Right Thing and Making Money at the Same Time*. American Planning Association, Chicago, IL.

Ewing, R. and Cervero, R. (2001). Travel and the Built Environment: A Synthesis. *Transportation Research Record: Journal of the Transportation Research Board, 1780*, 87-114.

Ewing, R. and Cervero, R. (2010), Travel and the Built Environment: A Meta-Analysis. *Journal of the American Planning Association*, 76(3), 265-294.

Frank, L. D., Sallis, J. F., Conway, T. L., Chapman, J. E., Saelens, B., E, and Bachman, W. (2006), Many Pathways from Land Use to Health: Associations between Neighborhood Walkability and Active Transportation, Body Mass Index, and Air Quality. *Journal of the American Planning Association*, 72(1), 75-87.

Galelo, A., Ribeiro, A., and Martinez, L. M. (2014), Measuring and Evaluating the Impacts of Tod Measures - Searching for Evidence of Tod Characteristics in Azambuja Train Line. *Procedia - Social and Behavioral Sciences*, 111, 899-908.

Gori, S., Nigro, M., and Petrelli, M. (2014). Walkability Indicators for Pedestrian-Friendly Design. *Transportation Research Record: Journal of the Transportation Research Board, 2464*, 38-45.

Handy, S. L. and Mokhtarian, P. L. (2005), Which Comes First, the Neighborhood or the Walking?. *Access Magazine*, 26, 16-21.
Hidayat, N., Choocharukul, K., and Kishi, K. (2011), Pedestrian Level of Service Model Incorporating Pedestrian Perception for Sidewalk with Vendor Activities. *Journal of the Eastern Asia Society for Transportation Studies*, 9, 1012-1023.
Hirsch, J. A., Moore, K. A., Evenson, K. R., and Diez Roux, A. V. (2013), Walk Score® and Transit Score® and Walking in the Multi-Ethnic Study of Atherosclerosis. *American Journal of Preventive Medicine*, 45(2), 158-166.
Krizek, K. J. (2006). Lifestyles, Residential Location Decisions, and Pedestrian and Transit Activity. *Transportation Research Record: Journal of the Transportation Research Board, 1971*, 171-178.
Leelakajonjit, A. and Kumpeeranon, P. (2009). *Pedestrian Safety at Signalized Intersection in Bangkok.* Paper presented at the The 8th International Conference of Eastern Asia Society for Transportation Studies.
Leopairojana, S. K. (2016), Mass Transit Station Environments and Accessibility Improvements: Lessons Learned from Ban Thab Chang Airport Rail Link Station, Bangkok. *Academic Journal : Faculty of Architecture, Khon Kaen University*, 15(1), 153-172.
Lin, J.-J. and Hwang, C.-H. (2004), Analysis of Property Prices before and after the Opening of the Taipei Subway System. *The Annals of Regional Science*, 36(4), 687-704.
Malyshkina, N. V. and Mannering, F. (2008). Effect of Increases in Speed Limits on Severities of Injuries in Accidents. *Transportation Research Record: Journal of the Transportation Research Board, 2083*, 122-127.
Mamun, S. A., Lownes, N. E., Osleeb, J. P., and Bertolaccini, K. (2013), A Method to Define Public Transit Opportunity Space. *Journal of Transport Geography*, 28, 144-154.
Millward, H., Spinney, J., and Scott, D. (2013), Active-Transport Walking Behavior: Destinations, Durations, Distances. *Journal of Transport Geography*, 28, 101-110.
Peiravian, F., Derrible, S., and Ijaz, F. (2014), Development and Application of the Pedestrian Environment Index (Pei). *Journal of Transport Geography*, 39, 73-84.
Pikūnas, A., Pumputis , V., and Sadauskas, V. (2004), The Influence of Vehicles Speed on Accident Rates and Their Consequences. *Transport*, 19(1), 15-25.
Pleongsrithong, J. and Vichiensan, V. (2016). *Accessibility Boundary to Ban Thap Chang Sstation and Lat Krabang Station.* Paper presented at the The 21st National Convention on Civil Engineering Songkhla.
Prasertsubpakij, D. and Nitivattananon, V. (2012), Evaluating Accessibility to Bangkok Metro Systems Using Multi-Dimensional Criteria across Users Groups. *IATSS Research*, 36, 56-65.
Pucher, J. and Dijkstra, L. (2000), Making Walking and Cycling Safer: Lessons from Europe. *Transportation Quarterly*, 54, 25-50.
Pucher, J. and Dijkstra, L. (2003), Promoting Safe Walking and Cycling to Improve Public Health: Lessons from the Netherlands and Germany. *American Journal of Public Health*, 93(9), 1509-1516.
Rujopakarn, W. (2003), Bangkok Transport System Development: What Went Wrong? *Journal of the Eastern Asia Society for Transportation Studies*, 5(1), 3302-3315.
Saaty, T. L. (1980) *The Analytic Hierarchy Process.* McGraw-Hill, New York.
Saelens, B., E and Handy, S. L. (2008), Built Environment Correlates of Walking: A Review. *Medicine & Science in Sports and Exercise*, 40(7), 550-566.

Schlossberg, M. (2006). Tiger to Audit Instruments: Measuring Neighborhood Walkability with Street Data Based on Geographic Information Systems. *Transportation Research Record: Journal of the Transportation Research Board, 1982,* 48-56.

Schlossberg, M. and Brown, N. (2004). Comparing Transit-Oriented Development Sites by Walkability Indicators. *Transportation Research Record: Journal of the Transportation Research Board, 1887*, 34-42.

Shaaban, K. and Muley, D. (2016). Exploring the Suitability of a Survey Instrument to Measure the Walkability of Streets in Doha. In D.-K. Kim, J. Jung & J. Seo (Eds.), *Advances in Civil, Architectural, Structural and Constructional Engineering* (pp. 157-160). London: CRC Press.

Stringham, M. (1982), Travel Behavior Associated with Land Uses Adjacent to Rapid Transit Stations. *Institute of Transportation Engineers*, 52(4), 16-18.

Tangphaisankun, A., Nakamura, F., and Okamura, T. (2010), Influences of Paratransit as a Feeder of Mass Transit System in Developing Countries Based on Commuter Satisfaction. *Journal of the Eastern Asia Society for Transportation Studies*, 8, 1341-1356.

Wibowo, S. S. and Olszewski, P. S. (2005), Modeling Walking Accessibility to Public Transport Terminals: Case Study of Singapore Mass Rapid Transit. *Journal of the Eastern Asia Society for Transportation Studies,* 6, 147-156.

Woldeamanuel, M. and Kent, A. (2016), Measuring Walk Access to Transit in Terms of Sidewalk Availability, Quality, and Connectivity. *Journal of Urban Planning and Development*, 142(2), 1-13.