Lowland Technology International date; Volume 22(4): 181-192
Internationa; Association of lowland Technology (IALT): ISSN 1344-9656

Research Paper

The Walkability Of Transit Oriented Development (Tod): A Case Study Of Bangkok Metropolitan, Thailand

P. Iamtrakul[1], I. Raungratanaamporn[2], J. Klaylee[3], and S. Chayphong[4]

ARTICLE INFORMATION

Article history:

Received: 01 June, 2020
Received in revised form:
19 September, 2020
Accepted: 13 January, 2021
Published on: 06 March, 2021

Keywords:

Pedestrian
Walkability
Transit Oriented Development
Urban Environment
Mass Transit

ABSTRACT

To cope with the crisis of traffic congestion, Transit Oriented Development (TOD) which promotes moving people rather than cars becomes a powerful tool to be considered to alleviate urban mobility problem. To increase transit patronage, non-motorization travel, revenue increase, and urban diversity with livability enhancement, consideration on creative physical form of urban spaces in proximity to transit station must be evaluated. This study considered all aspects of transit station area within walking distance to attract physical activity and balance transportation by incorporating useful variables on evaluation of walking environment within the TOD. This study selected 10 mass transit (sky train) stations in Bangkok, Thailand to investigate the walkability of transit development, and recommend a suitable development of station area's method that could provide greater accessibility in higher-density settings for non-auto commuting. This could be an explicit policy objective to provide an alternative approach incorporating transportation system with an efficient land use patterns through TOD, with the aim of using the strategic location in the walkability of mass transit stations as an integral part of the existing and future urban development.

1. Introduction

Oftentimes when providing sustainable transportation planning, automobile-based development strategies tends to cause urban sprawl and suburbanization, increase in commuting distances and reduction in land use efficiency (Iamtrakul, P., 2013). However, transit systems promote more efficient resource usage with a variety of benefits, justifying the reason many cities increasingly apply transit-based strategies in solving their urban planning dilemma (Lin, J., and Gau, C. A., 2006). The development of mass transit also plays a key role as an alternative way in alleviating the urban congestion problem with a focus on relieving road congestion and environmental problems (Garrett and Castelazo, 2004). For the case of mega cities in developing world particularly Bangkok, Thailand, one can notice continuing urban growth with almost a stable traffic

[1] Associate Professor, Center for Excellence in Urban Mobility Research and Innovation, Faculty of Architecture and Planning, Thammasat University, Pathumthani 12120, THAILAND, iamtrakul@gmail.com
[2] Instructor, School of Transport Engineer, Suranaree University of Technology, Nakornratchasima 30000, THAILAND, aizuner@gmail.com
[3] Assistant Researcher, Center for Excellence in Urban Mobility Research and Innovation, Faculty of Architecture and Planning, Thammasat University, Pathumthani 12120, THAILAND, klaileejira@gmail.com
[4] Assistant Researcher, Center for Excellence in Urban Mobility Research and Innovation, Faculty of Architecture and Planning,Thammasat University, Pathumthani 12120, THAILAND,s_ararad@hotmail.com
Note: Discussion on this paper is open until September 2021

speed (Iamtrakul et al., 2012). However, with the greatly dispersion of people occasioned by the heavy migration to the city, the original Bangkok Metropolitan to Bangkok Metropolitan Region (BMR) has been renamed to includes 5 adjacent provinces: Nonthaburi, Samutprakan, Pathumthani, Samutsakhon and Nakhonpathom, surrounding it. This existing phenomenon demonstrates the situation of urban sprawl of Bangkok that requires an effective integration of land use and transportation plan to cope with. A number of researches have been conducted to highlight the usefulness of TOD concept as a sustainable urban mobility policy (Ewing, 1997; Thapa and Murayama, 2010). Most of the TOD application is often described in a physical description way of a mixed-use development, with a certain urban density and high-quality walking environment, focused on creating vibrant, rich, and livable urban places with a pedestrian friendly built environment, and a functional connectivity between land uses and the transit stop (Dittmar and Poticha, 2004). Thus, to confirm the usefulness of this concept, this study selected Bangkok metropolitan area as a case study to explore the walkability in TOD distance, in term of satisfaction in accessing the transit stations. The selection of the study area was on the premise that it is the most rapid transition city of its spatial structure with rapid growth rate. Therefore, it required to be allocated an appropriate public transit linkage to accommodate active mobility through different socio-economic environment of human activities together in the diverse context of urban area. In this context, the walkability issue plays an important role as a key indicator to measure the pedestrian accessibility to transit area (Feng et al., 2010). The quantification of potential walkable determinants to built-environment was analyzed in three dimensions of strategic policy and development applicable in enhancing development density around transit station area, diversification of land use (mixed land use development), and improvement of public transport passenger convenience and pedestrian-oriented walkways (Cervero and Kockelman, 1997).

In complying with Transit Oriented Development (TOD) planning, the tradeoffs among three objectives: efficiency, environment and equity must be implemented under limitation of certain characteristics of the built environment in correspondence to travel behaviors of commuters to transit station (Lin and Gau, 2006; Bhattacharjee and Goetz, 2012; Cervero, 2013; Garrett and Castelazo, 2004). However, several factors can influence travel behavior like variety of land use patterns, street networks, and streetscape design features (Estupiñán and Rodríguez, 2008). This study aims to establish a framework or methodology to assist planners in developing guidelines to improve the walking environment of TOD planning. On a basis of enhancing walkability in a more comprehensive manner, the area proximity to the station in metropolitan of Bangkok, Thailand was selected in consistence with sustainability mobility concept. Finally, with the appropriate recommendation on walkability improvement in consistence with different typology of transit station will help in a successful transit planning in term of lively enhanced connectivity to promote ridership.

2. Literature Review

To sustain the situation of mass transit in Bangkok, alternative urban forms like transit-oriented developments, new urbanist neighborhoods and walkable communities must be applied. Such communities are intended to support more active lifestyles with promotion of transit usage and pedestrian friendliness (Cho et al., 2009). However, to maximize the utilization of urban area for TOD based on the sustainable development towards walkable environment, there are several factors contributing to the efficient and effective transportation plan for enhancement of its ridership, particularly the walkability to transit station area (Cervero, 1995). This study attempted to measure commuters' walking behavior in terms of several aspects such as users' needs, perceptions and attitudes on transit service. The target being to finally fade the demand on automobile especially now most people are highly dependent on car for travel. Achieving this objective requires more understanding about walking environmental planning for the planners, the operators, the public, and other stakeholders (Beirão and Cabral, 2007). Earlier, efforts in stimulating people to walks instead are noticeable in multidimensionality of urban movement such as aesthetic, social benefits reduce chance of urban sprawl, car accidents, obesity and asthma, health problems and environmental problems (Speck, 2015). These considerations affect neighbourhood stability in accordance to maintaining social life, healthiness of community members, quality of physical environment, and creating human interaction (Robinson, 2015). There are similar definitions of walkability given by several scholars, however, those definitions could vary based on its application on contents. Litman T. (2011) provided a definition of walkability which relates to a quality of an urban space or neighbourhood that provides safe, convenient, well-connected, comfortable, permeable and usable walkable facilities for pedestrians. There are two types of pedestrians: (1) *Browsers* – such as tourists, shoppers, workers during lunch breaks or other kind of pedestrians who have times for walking or no need to hurry during walk. This group concerns is the values of pedestrians' quality based on safety and pedestrian's security. Other groups are (2) *Commuters* – this type of pedestrians knows their travel direction, need space for mobility, and time concious. This group of pedestrians' concerns is on moving speed, less congestions and delays (City of Melbourne, 2013).

The set of contributing factors that motivates pedestrians' decision to walk has been seen in numerous literatures. Physical characteristics has rather been more discussed in urban planning and transportation issues (**Fig. 1**). The walking behaviour has been affected by physical feature (urban features, traffic volumes, tree canopy, weather conditions, street width), and urban design qualities (human scale, linkage, complexities, enclosures, legibility). There are two sets of factors affecting individual's reactions, overall walkability and walking behavior with various set of factors influencing pedestrian's decision to walk (Ewings, 2016; Spoon, 2005). The context of walkability analysis could be described in two levels. Macro-scale environmental variables – such as block length and number of intersection (Alfonzo et al, 2008; Rodríguez, D. A. et al., 2006), urban planning issues and transportation planning issues (Semenza, J.C. et al, 2004; Saelens et al., 2003), walking activity and built environmental features (Lee S. and Jeon J., 2004). Next is micro-scale environmental variables – such as visual complexity, uses and activities, microclimate, boundary, seating, planting, public art, fountains, food, vendors, paving, information and sign, and maintenance and amenities (Li, 2015). The following positive factors relates to built environment like attraction from building along both sides of street with distance, land block length, proportion of retail shops, household size, population density in the area – these factors affect the number of pedestrian usage (Singh R., 2016; Ewing et al., 2016).

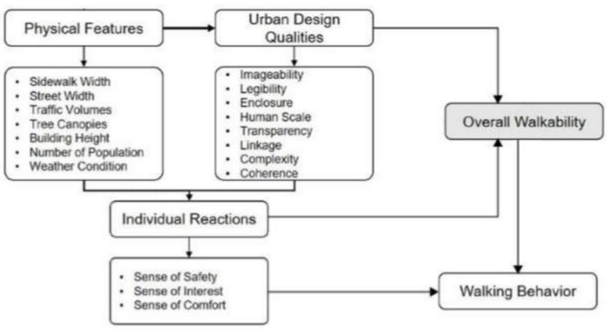

Fig. 1. Relationship between factors that influences walking behavior

A negative effect of pedestrian usage is crowding of pedestrians in walking space. This could likely cause negative effect on commerce, social activities, lacking considerations on some user groups such as children and handicap groups, discourage pedestrians to walks, and causing adverse effect on road safety (Clifton et al., 2013). Moreover, distances between origin and destination would be perceived differently depend on their value for time, vehicle ownership and availability, attitudes and preferences (Clifton et al., 2013), which are based on six components of pedestrian conditions such as safety, security, directness, ease of entry, comfort, and aesthetics (Senevarante P.N. and Morall J.F., 1986). Other studies were conducted on the approach of Willingness-To-Pay (WTP) based on stated preference (SP), which is convenient, conspicuous, comfort, connectivity, particularly conviviality that motivates people to pay for pedestrian improvement (Sinnett, et al., 2011; Lee S. and Jeon J., 2014). For the studies relevant to WTP for pedestrian's improvements, safety improvement was focused in term of perception for likelihood pedestrian injuries, social or neighborhood solidarity, traffic in neighborhood area, age of children, neighborhood characteristics, household income, and problems occurrence on pedestrians' safety (Lee S. and Jeon J., 2004). These variables affect the decision of parents to involve in pedestrian safety in their community (Bishai, et al., 2003).

3. Methodology

Due to the fact that individual walking behavior is complex phenomenon, this study proposed an approach to assess an in-depth understanding of commuters' perceptions, attitudes, and behaviors. This study is carefully designed to gather both qualitative and quantitative data by considering walkability factors which is depicted in **Table 1**. Qualitative methods are a powerful tool to explore those complexities, thus, this study applied to grasp the individual's own explanations of behaviors and attitudes. While quantitative approaches have the advantage of measuring the reactions of many subjects to a limited set of questions allowing comparison and statistical aggregation of the data set. On the other hand, qualitative methods produce a wealth of detailed data on a small number of individuals (Beirão, G. and Cabral J. S., 2007). The analysis of causes associated to the walkability level is focused on pedestrian satisfaction of walkability around transit stations' area. Data collection was conducted through face to face questionnaire survey, checklist and site survey, as tool for gathering information at the study area within 500 meters of the transit station's service radius of selected three mass transit stations. The pedestrians' satisfaction was analyzed based on the onsite interview sampling. This also includes other participants recruited using non-random methods by asking existing respondents who commuted in each selected station.

This method of analysis could be used to view the association among all built environment characteristics of transit stations along with pedestrian connectivity and quality of service in several aspects. Then, different criteria index could be used for assessment of different level of

Table 1. Criteria for evaluation of different level of walkability

Index of walkability environment	Description	Criteria of Built Environment
Sidewalks and walkway	*Sidewalks* are typically constructed of concrete, raised and located adjacent to curbs or separated from the curb by a linear planting strip. Sidewalk width could be varying but minimum of 5 feet width (clear width) on local residential streets or wider in a special district. *Walkway*: which is contrary to sidewalk, are usually built over existing ground surface separated horizontally by a planting of buffer or ditch. In some case, extruded curbs or barriers had been used to separate a walkway from adjacent street traffic.	A1: Sidewalk width A2: Walking Condition
Tree and planter strip	Residential Zone are clustered to maximize green space. Trails and passageways through natural areas are featured in many parts of town.	B1: Planter strip B2: Trees
Connectivity	Connectivity is measured by the number of street intersections in a neighborhood. A higher value indicates more intersections and more connectivity enabling more direct travel from point-to-point using existing street and pathways.	C1: Block connection C2: Flow and network
Traffic Management	Traffic management techniques focuses on reducing vehicle speed around transit stops and making safety in active transportation mode a choice.	D1: Block size D2: Driveways cross sidewalks
Street Quality	Quality of street had influences towards crash and crime rates reductions. Lower level of street walkability captured by visual quality, physical amenities, maintenance, and safety.	E1: Street width E2: Curbing
Urban characteristics	Density refers to attributes of interest per geographic area, diversity refers to the robustness of land or building use, design refers to the layout of the street, and destination accessibility refers to the availability of destinations places such as stores, or distance to reach public transportation. Additional neighborhood characteristics such as aesthetics and safety also promote walking and often described in walkability.	F1: Density F2: Garage F3: Distance from home to street F4: Surveillance to street
Mixed use and diversity	Mixed use is the degree of mixing of different types of land use or building use in a specific area. A higher value indicates a more even distribution of land between the different types of land use.	G1: Minimum hours of significant activity G2: Job per housing unit G3: Level of mixed use

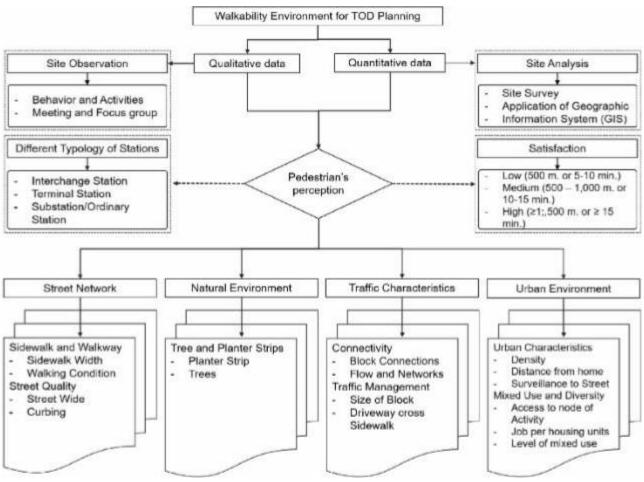

Figure 2. Framework of the study

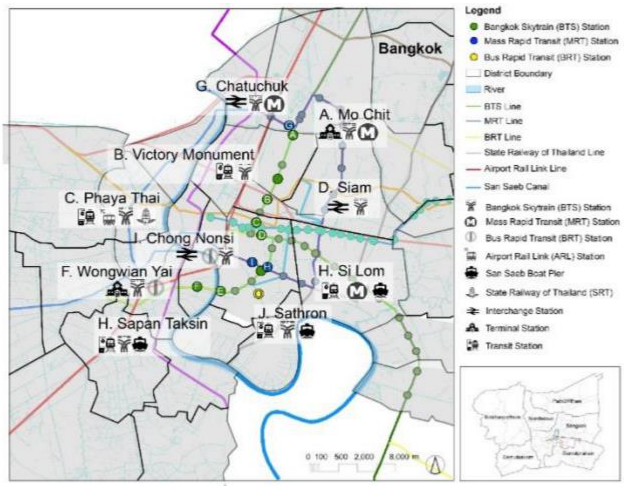

Fig. 3. The study area of selected transit stations in Bangkok Metropolitan, Thailand

To determine the significance level and explain the role of each item in the related factor, in the current study, the indices with factor load more than 0.4 were considered. After the extraction of the factors, naming the factors based on their constituent items was done. Furthermore, considering the concept of the items in each factor represented in **Table 4**, 7 extracted factors can be named as follows. The walkability and led to the direction in support of transportation and urban planning based on structural equation model (**Figure 2**). The classification of sample size was distributed equally according to typology of mass transit service. A total of 500 sets of data was collected from 10 mass stations equally and the study area can be depicted in **Fig. 3**.

respectively. This is to examine the provision of sustainable development encouragement to the suitable development of station area which promotes non-auto commuting. Furthermore, this also encourages the suitable development by maximizing the level of potential accessibility on foot for people in the proximity area of the service area of transit station. As a result, commuters could enjoy the service at a local level of the quality of sidewalks and pedestrian facilities used by universal.

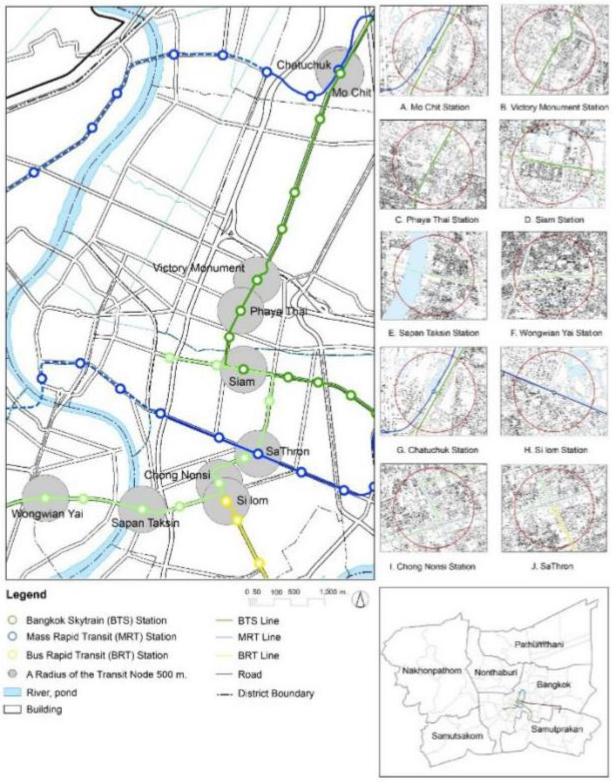

Fig. 4. The characteristic of the area around the station.

4. Data collection

The data collection was designed to request the respondents to evaluate the influence of 10 sites on their different perceptions on variety aspects of TOD characteristics in each station area (**Fig. 4**).

The score ranges from 1 to 3, represents low level of walking (approximately 500 meters or 5 - 10 mins.), medium (500 – 1,000 meters or 10 - 15 mins.), and high (1,500 meters or more or more than 15 mins.), users. The consideration of streetscape design could also enable passengers to transfer or change mode conveniently by making the new system to link with existing network (railway system, bus system, and other transport modes).

Moreover, all study stations could be considered as a modal connectivity location, especially sky train (BTS) and subway (MRT) system, capable of creating mode shift from railway to walk or using other para-transit system.

The characteristics of the area around the stations demonstrates the density of the building, population density, and building uses (housing, commerce, public utilities, public facilities and recreation areas) as illustrated in **Fig. 5**. With Geographic Information System (GIS) application, the spatial data from different sources with its calculated density could reflect the characteristics of building concentration around station area. Based on this powerful aid tool, the structures of data in different layer.

It could be projected into spatially distributed modeling, particularly when working with descriptive data that integrates more than one process. The result of analysis revealed that the association among all influence variables could be evaluated; leading to the direction in support of transportation and urban planning policy.

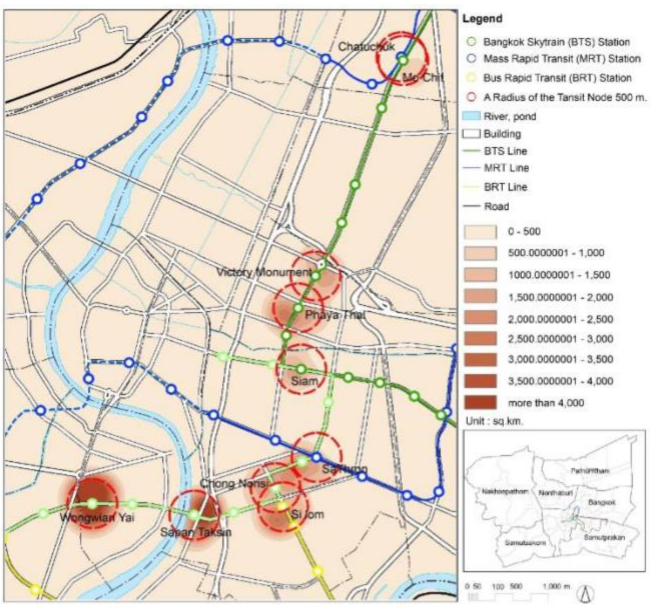

Fig. 5. Building density of the selected stations (study areas)

5. Results of Analysis

According to variety of trips made by the respondents, there are three priorities of destination which was ranked accordingly. Based on the existing 89 stations currently in operation (BTS, ARL, BRT, MRT and MRT Purple Line), Siam Station is the highest ranked destination upon the respondent's decision, follow by Mo Chit Station and Victory Monument, respectively. Those three locations are surrounded with variety of attractions in the walkable distance to the station (500 m.). Siam station for an instance is located in CBD of Bangkok surrounded by shopping stores, university, schools, while Mo Chit station is located nearby a central market, regarded as a terminal station for BTS by Thais and tourists. On the other hand, Victory Monument station is located nearby administration offices, commercial buildings, and public transit system (bus and van). Thus, urban connectivity issues become important in this area necessitating proactive steps as evidence in the efforts from governments and private operators, particularly in transportation projects.

This phenomenon revealed that Bangkok Metropolitan Area had a major node of attraction located in central park, where the spatial locations of trips are accumulated in BMA rather than widespread to other suburban areas. Based on this exploratory analysis, the understanding of the factors contributing to the utilization of transit nodes could be accomplished under the consideration in terms of users' characteristics which reflects their commuting needs, perceptions and attitudes towards the accessibility of transit service. Due to TOD features, a variety of services are being required by various types of transit users, e.g. residential, employees, which also links them through the transit system. Satisfaction on aspects of proximity area of transit station to the actual conditions could be examined through their residents and visitors, particularly those traveling or recreating by bicycle or by walking to the station. However, the effect of these factors in relation to the demand on walking to transit service is ambiguous. This study identified two commonalities of interest to the present study. First, a considerable relationship between behavior on walkability to transit utilization among multi aspects of commuters' socio-economic.

Second, the attributes are associated, directly and perhaps indirectly, with levels of satisfaction on the walkability, illustrated in term of the physical attributes of the TOD sites. This study also provided the methodology to demonstrate perception on walkability of transit users on different characteristics of TOD in terms of built environment (level of mix used, urban density, connectivity, sidewalk condition etc.). The output from this step could allow for simultaneous creation of indirect paths from the perception of built environment to the improvement plan of TOD.

5.1. Social and economic characteristics and walking

From the result of analysis in **Table 2**, the socioeconomic characteristics combined with the use of mass transit by walking on foot shows that commuters on daily basis are mostly females (44.76 percent) which is greater than males (40.69 percent). As for the level of education, it was found that bachelor degrees holders preferred to travel on foot to access public transport services more than any other educational level, with over 26.00 percent almost every day. As for the occupation, it was found that the most popular occupation who prefer to access public transportation on foot is government workers (32.20%), followed by students (32.00%) and office workers (22.80%). Most of them have the frequency almost on every day traveling up to 47.98 percent. For the income aspect, those who have income ranging from 15,001-20,000 baht prefer traveling on foot to access public transport services.

The frequency of traveling almost on daily basis is 9.60 percent, followed by income of 10,001-15,000 baht (8.20 percent) and 20,001-30,000 baht (5.80 percent). On considerating ownership of vehicles, it was found that the samples who own personal cars are those that mostly travelled by foot to public transport almost every day (22.00 percent), while those without vehicles in their possession preferred to travel about 2-3 days a week. This may reflect that car ownership does not have influence on the frequency of travel and the use of public transport for daily travel.

5.2 Level of Satisfaction on walking to transit station

This study assessed the satisfaction of the respondents regarding to the physical conditions nearby the stations. The results in **Table 3** showed that most of the respondents are satisfied with the physical conditions in moderate level. The input factors influence on walking to access public transportation through structural equation modelling for testing the research hypothesis consist of accessibility, connectivity, available of facilities and quality of physical environment for walks.

The appropriateness of these inputs for analysis was tested for a normal distribution of variables by considering the skewness values between -3 and +3 which represent the normal distribution.

Table 3. Details of inputs factors

Factors		Mean	Std. Deviation	Skewness		Kurtosis	
		Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Availability factors (3.39)							
A1	Availability and quality of walkway conditions to connect to other modes	3.46	0.82	0.16	0.11	-0.48	0.22
A2	Availability and quality of walkway conditions for sharing with bike lanes	3.33	0.70	0.17	0.11	-0.13	0.22
A3	Availability and quality of walkway conditions for level of pedestrian security	3.29	0.71	0.21	0.11	-0.09	0.22
A4	Space availability of effective walkway width	3.49	0.72	0.23	0.11	-0.24	0.22
Facility factors (2.57)							
B1	Ease for baggage, children and elderly	2.51	0.68	0.74	0.11	0.41	0.22
B2	Number of parking spaces per building	2.67	0.66	0.56	0.11	-0.02	0.22
B3	Degree to parking spaces with pricing and regulated for efficiency	2.52	0.61	0.83	0.11	0.26	0.22
Connectivity factors (3.18)							
C1	Stations are accessible by high quality public transit	3.25	0.58	-0.11	0.11	-0.48	0.22
C2	Ease for access by other public transports	3.06	0.68	-0.08	0.11	-0.84	0.22
C3	Degree of connected roads&paths and allow direct travel between destinations	3.24	0.79	0.10	0.11	-0.53	0.22
Accessibility factors (2.91)							
D1	Availability and quality of walkway conditions for crosswalk	3.05	0.72	0.48	0.11	0.32	0.22
D2	Accessible within a reasonable travel time (e.g., 30 minutes)	2.77	0.68	0.25	0.11	-0.74	0.22

Going by general characteristics of import factors (**Table 3**), it was found that *Availability factors* has the highest average value in the assessment ($\bar{x}$ = 3.39). Within this factor, the sub-factors that have the highest average value are space availability of sidewalk ($\bar{x}$ =3.49), followed by availability and quality of walkway conditions connecting the public transport modes ($\bar{x}$ =3.46). The second highest value is *Connectivity factors* ($\bar{x}$ = 3.19), with the sub-factor representing the degree of accessibility by high quality public transit or good quality of feeder system ($\bar{x}$ =3.25), follow by the degree of connected roads and paths that allows direct travel between destinations ($\bar{x}$ =3.24). The third main factor is the *Accessibility factor* ($\bar{x}$ =2.91), with the highest average sub-factor of availability and quality of walkway conditions for crosswalk: zebra crossing ($\bar{x}$ =3.05), followed by the level of access within an acceptable journey time (30 minutes) ($\bar{x}$ =2.77). From the details of these inputs, it can be seen the factors that plays an important role for traveling on foot is built environment of walkway characteristics. This is the significant effect on the connectivity level to public transportation which can be prioritized from the *Availability factors*, followed by the *Connectivity factors*, *Accessibility factors* and *Facility factors*.

Table 2. Social and economic characteristics of respondents

Factor			Walk Within Service Area of Mass Transit System					P-value
			1 day per week or less	2-3 days per week	4-5 days per week	Almost every day	Total	
Gender	Male	N	52	107	13	118	290	0.267
		%	17.93	36.90	4.48	40.69	1	
	Female	N	44	60	12	94	210	
		%	20.95	28.57	5.71	44.76	1	
Education	Secondary school	N	8	6	4	26	44	0.041
		%	18.18	13.64	9.09	59.09	1	
	Vocation	N	26	56	4	40	126	
		%	20.63	44.44	3.17	31.75	1	
	Undergraduate	N	54	90	14	130	288	
		%	18.80	31.30	4.90	45.10	1	
	Graduate	N	8	15	3	15	41	
		%	19.51	36.59	7.32	36.59	1	
	Other	N	0	0	0	1	1	
		%	0.00	0.00	0.00	100.00	1	
Occupation	Student	N	27	43	11	79	160	0.000
		%	16.88	26.88	6.88	49.38	1	
	Government officer	N	24	65	2	70	161	
		%	14.91	40.37	1.24	43.48	1	
	Business person	N	24	44	5	41	114	
		%	21.05	38.60	4.39	35.96	1	
	Housewife	N	6	4	2	5	17	
		%	35.29	23.53	11.76	29.41	1	
	Retired	N	0	0	0	5	5	
		%	0.00	0.00	0.00	100.00	1	
	Self-employed	N	15	11	5	12	43	
		%	34.88	25.58	11.63	27.91	1	
Income level (baht)	Less than 10,000	N	29	42	12	56	139	0.013
		%	20.86	30.22	8.63	40.29	1	
	10,001-15,000	N	13	31	6	41	91	
		%	14.29	34.07	6.59	45.05	1	
	15,001-20,000	N	36	69	1	48	154	
		%	23.38	44.81	0.65	31.17	1	
	20,001-30,000	N	7	14	4	29	54	
		%	12.96	25.93	7.41	53.70	1	
	30,001-40,000	N	9	9	2	9	29	
		%	31.03	31.03	6.90	31.03	1	
	40,001-50,000	N	0	2	0	8	10	
		%	0.00	20.00	0.00	80.00	1	
	More than 50,000	N	2	0	0	3	5	
		%	40.00	0.00	0.00	60.00	1	
	Others	N	0	0	0	18	18	
		%	0.00	0.00	0.00	100.00	1	
	Yes	N	54	64	13	110	241	0.000
		%	22.41	26.56	5.39	45.64	1	
	No	N	42	103	12	80	237	0.000
		%	17.72	43.46	5.06	33.76	1	

However, in order to test the hypothesis for in-depth analysis, all aforementioned factors were brought into the structural model in order to examine the relationship between observation variables and latent variables. The confidence value of all factors was equated to 0.745 (KMO and Bartlett's Testa) and the analysis results is demonstrated in **Fig. 6.**

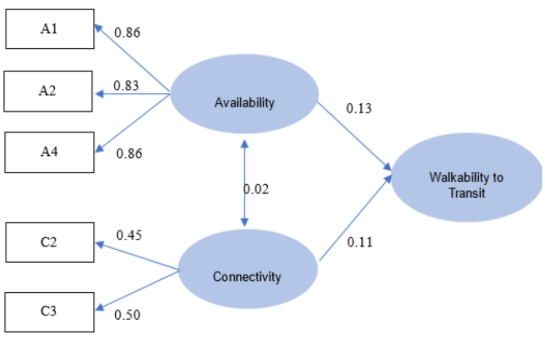

Fig. 6. Hypothesis testing results

From the determination of variables and assumptions of the study, analysis of the relationship of availability, facilities, connectivity, and accessibility factor which affects the walkability to transit system was done. During selection of the factors to input into the model, it was found that only 2 main factors can be entered into the model. There are 5 observation variables which are; 1) A1 = Availability and quality of walkway conditions to connect to other modes, 2), A2 Availability and quality of walkway conditions for sharing with bike lanes, 3) A4 = Space availability of effective walkway width, 4) C2 = Ease for access by other public transports, 5) C3 = Degree of connected roads and paths and allow direct travel between destinations. There are also 2 latent variables which consists of 1) Availability factor and, 2) Connectivity factors. The results of the analysis in **Table 4** showed

that there is a statistically significant correlation of *Availability factor* with the promotion of pedestrian access to transit services.

The factor that has the highest correlation value is space availability of sidewalk (Estimate = 3.486). Next is availability and quality of walkway conditions for sidewalk (Estimate = 3.464), followed by availability and quality of walkway conditions for sharing with bike lanes (Estimate = 3.334). In terms of *Connectivity factor*, there is a correlation with the promotion of walking in order to access transit services with statistically significance as well. This can be noticed from the sub-factors that have the highest correlation value which is effortlessness to be accessed by other public transportations (Estimate = 2.706), next is degree of connected roads & paths which allows direct travel between destinations (Estimate = 2.520). Based on this relationship, it can be established that in the development and improvement to promote travel in transit service areas, the factors that have an effect on the choice of traveling on foot to access the service should be considered in order to maintain good quality of service or improvements for better quality. Furthermore, the condition of the pedestrian connection system that connects to the other public transport modes, especially pedestrian paths, bicycles, and pavements must be in suitable conditions for public use. Importantly, the development of the connection system of roads and sidewalks must be safe for all users, so that commuters can enjoy the service conveniently.

Table 4. The relationship of factors that affect walking to access transit

Factor	Estimate	S.E.	C.R.	P
A4	3.486	0.032	108.219	***
A2	3.334	0.031	106.348	***
A1	3.464	0.036	94.912	***
C3	2.520	0.027	92.596	***
C2	2.706	0.030	82.641	***

Remarks:
S.E. = Standard Error
C.R. = Critical Ratio
A1 = Availability and quality of walkway conditions to connect to other modes
A2 = Availability and quality of walkway conditions for sharing with bike lanes
A4 = Space availability of effective walkway width
C2 = Ease for baggage, children and elderly
C3 = Degree of connected roads and paths that allows direct travel between destinations
***Significant at level 0.001

With the result of this analysis, the relationship of factors that affect walkability to use transit was examined and tested on the influence of variables in Structural Equation Model. This statistical technique is useful to test and identify the logical relationship of the assumptions through its estimation value. From the results of the consistency testing of the model under the established hypothesis, the result of the model can be summarized through the consideration of 4 criteria listed below and illustrated in **Table 5:**

1) ***Chi-Square*** *Statistics* is the index used to check the consistency between the model and the empirical data. Overall, it was found that the consistency of the factors must be greater than 0.05, interestingly, the model is equal to 0.188, therefore, considered to pass the criteria.

2) ***RMSEA*** is a measure of the difference per unit of free degrees. It demonstrated that the consistency of the factors must be less than 0.05. However, the result in the model is equal to 0.029, which is considered to pass the criteria.

3) ***Comparative Fit Index (CFI)*** represents normed causes with a value between 0 and 1. It is revealed that the consistency of the factors must be greater than 0.95. This analysis showed the calculated result of the model is 0.997, which is considered to pass the criteria.

4) ***Normed Chi-Square or Relative Chi-Square*** is demonstrated by the chi-square value divided by degrees of freedom. The consistency of the factors must be less than 2.0, interestingly, the model is equal to 1.430, which is considered to pass the criteria.

Table 6. Model consistency tests

CFI	RMSEA	CMIN/DF	NFI	Chi square
0.997 (>0.95)	0.029 (<0.05)	1.430 (<2)	0.736 (>0.95)	0.188 (>0.05)

6. Conclusions and Recommendations

From the statistical test, it can be concluded that the hypothesis is consistent with the data. However, this can be used to explain the relationship among influencing factors on walkability according to the assumptions. Results from the study showed that the satisfaction of physical improvements are in moderate to high level i.e. (2.57-3.39), while some significant factors such as street width improvement, and better connectivity are in high level. However, it should be noted that case of high quality of improvement stated in this research had been implemented, and the demand level or satisfaction level of respondents will promote more walkability to transit station in Bangkok. This policy message could be interpreted as a management of physical attribute improvement. Moreover, characteristics of respondents who had their origins within 500-meter from station, requires mostly maintenance of good quality of physical environment to reach the station. This can be considered in detail from the *Availability factor*, followed by the *Connectivity factors*, *Accessibility factors* and *Facility factors* etc.

Notwithstanding, other design aspects should be also taken into consideration to promote supportive services and facilitate users' safety, convenient and comfortable while using transit such as connectivity to other modes, etc. More so, the station area design in the proximity area of walkable distance should encourage denser, mixed-use development in transit oriented, with reasonable options for walking and bicycling to work, and with non-auto commuting. So as to enjoy the quality of built environment in attainment purpose of suitable location of intermodal. Finally, to promote active mobility, the interlinkage must be efficiently designed to incorporate mass transit services to land use design and planning in order to allow all commuters access to the station without social and economic difficulties.

Acknowledgements

This study was supported by the Global environmental leaders' education program for designing a low-carbon world (GEL), Hiroshima University, Japan. The authors also wish to express their profound gratitude to the Office of Transport and Traffic Policy and Planning (OTP) and Bangkok Metropolitan Administration (BMA), for providing the necessary data about transportation planning in Bangkok. This research unit is supported by the Faculty of Architecture and Planning Research Fund, Thammasat University. It is also supported partially by the Center of Excellence in Urban Mobility research and Innovation, Thammasat University.

References

Alfonzo, Mariela & Boarnet, Marlon & Day, Kristen & Mcmillan, Tracy & Anderson, Craig. (2008). The Relationship of Neighbourhood Built Environment Features and Adult Parents' Walking. Journal of Urban Design. 13. 29-51. 10.1080/13574800701803456.

Ankum, P., Koga, K., Segeren, W.A. and Luijendeijk, J. (1988). Lessons from 1200 years impoldering in the Netherlands. Proc. Int. Symposium on Shallow Sea and Lowland, Institute of Lowland Technology, Saga Univ. Saga: 102-108.

Beirão, G. and Cabral, J., S. (2007). Understanding attitudes towards public transport and private car: A qualitative study, Transport Policy 2007, 14, 478-489.

Bhattacharjee, S., Goetz, A.R., 2012. Impact of light rail on traffic congestion in Denver. J. Transport Geogr. 22, 262–270.

Bishai, D., Mahoney, P., DeFrancesco, S., Guyer, B., & Gielen, A. C. (2003). How willing are parents to improve pedestrian safety in their community? *Journal of Epidemiology & Community Health*, *57*(12), 951-955.

Cervero, R. Mixed land-uses and commuting: evidence from the American housing survey, Transportation Research Part A, 1995, Vol.30, No. 5, 361-377.

Cervero, R., Kockelman, K., Travel demand and the 3Ds: density, diversity, and design. Transportation Research D 2 (3), 1997, 199–219.

Cervero, R., 2013. Transit-Oriented Development transit-oriented development (TOD) and Land Use land use. In: Transportation Technologies for Sustainability. Springer, pp. 947–958.

Cho, G. Rodriguez, D. and Khattak, A.J, The role of the built environment in explaining relationships between perceived and actual pedestrian and bicyclist safety, Accident Analysis and Prevention, 2009, 41, 692-702.

Clifton, K. J., Singleton, P. A., Muhs, C. D., Schneider, R. J., & Lagerwey, P. (2013). Improving the Representation of the Pedestrian Environment in Travel Demand Models, Phase I.

City of Melbourne (2013) The Effects of Pedestrian Delay and Overcrowding on our Street & the Rationale for Shorter Blocks and Through Block Links.

Dittmar, H., Poticha, S., 2004. Defining Transit-Oriented Development: The New Regional Building Block. In: Dittmar, H., Ohland, G. (Eds.), The New Transit Town: Best Practices in Transit-Oriented Development, pp. 19–40.

Estupiñán, N. and Rodríguez, D. (2008). The relationship between urban form and station boardings for Bogota's BRT, Transportation Research Part A, 2008, 42, 296-306.

Ewing R., 1997, Is Los Angeles-Style sprawl desirable? Journal of the American Planning Association, 63 (1), 107-126.

Ewing, R., Hajrasouliha, A., Neckerman, K. M., Purciel-Hill, M., & Greene, W. (2016). Streetscape features related to pedestrian activity. *Journal of Planning Education and Research*, *36*(1), 5-15.

Feng, J., Glass, T.A., Curriero, F.C., Stewart, W.F., Schwartz, B.S., 2010. The built environment and obesity: a systematic review of the epidemiologic evidence. Health Place.16 (2), 175–190.

Garret, T.A, Castelazo, M. D. 2004. Light rail transit in America: Policy issue and prospects for Economic Development. Federal Reserve Bank of St, Louis, MO.Working Paper.

Iamtrakul, P. and Hokao, K. (2012), The Study of Urbanization Patterns and their Impacts on Road Safety, Lowland Technology International (LTI), 14, No.2, pp. 60-69,

Iamtrakul, P. (2013), The Association of Transportation And Land Use Planning Towards Sustainable Urban Energy Planning, 1st Asia Future Conference 2013, Asia in the world-Potentials of Regional Cooperation, 8-10 March 2013. Bangkok, Thailand.

Li, X. (2015). Study of Environmental Variables Affecting Walkability: Learning From Main Street in Downtown Fort Worth.

Lin, J., and Gau, C. A. (2006) TOD Planning model to review the regulation of allowable development densities around subway stations, Landuse Policy 23, 2006, 353-360.

Litman T. (2011). Evaluating Transportation Economic Development Impacts. Understanding How Transport Policy and Planning Decisions Affect Employment, Incomes, Productivity, Competitiveness, Property Values and Tax Revenues. Retrieved on May 10, 2020 form https://www.vtpi.org/econ_dev.pdf.

Robinson, J. C. (2015). *Amenities, walkability, and neighborhood stability: A mixed methods analysis*. University of Pennsylvania.

Rodríguez, D. A., Merlin, L., Prato, C. G., Conway, T. L., Cohen, D., Elder, J. P., Evenson, K. R., McKenzie, T. L., Pickrel, J. L., & Veblen-Mortenson, S. (2015). Influence of the built environment on pedestrian route choices of adolescent girls. Environment and behavior, 47(4),359–394.