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MEASURING PEDESTRIANS' SATISFACTION OF URBAN ENVIRONMENT UNDER TRANSIT ORIENTED DEVELOPMENT (TOD): A CASE STUDY OF BANGKOK METROPOLITAN, THAILAND

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ABSTRACT: The problem of continuous increasing of carbon dioxide emissions in line with higher energy demand in Thailand has been called for attention under global warming conditions. In order to tackle with this problem, transportation was found as a major sector in an escalation of energy consumption which is the cause of carbon emission. As a developing country, infrastructure development has always been focused on an increasing of supply side, while less promote on public transportation and almost ignore for nonmotorization. The purpose of this study is to propose the method for measuring factors associated with pattern of walking behavior in connecting to public transportation usage by selecting Bangkok Mass Transit System as a case study. The results demonstrated different dimension of built environment aspects influence on different level of pedestrians' satisfaction. Thus, transportation planners should consider different context of urban area as a key parameter to provide future metropolitan transportation while allocate appropriate strategy and management policy to create walkable urban place to shift in travel mode from vehicles to transit or active transportation.

Keywords: Pedestrian, transit oriented development, urban environment, Bangkok Mass Transit.

INTRODUCTION

Rapid urbanization has created both negative and positive impacts on urban residents, especially uncontrolled urban expansion coupled with inefficient transportation. The negative effects of automobiles on the physical environment and quality of life have become concerns due to the current trend of the global environmental problem of climate change. There is no doubt that the key factors on driven of the climate change for both natural and anthropogenic is including the chain from greenhouse gas (GHG) emissions to atmospheric concentrations. Additionally, it has already recognized that Carbon dioxide (CO_2) was found as the major source of GHG emission and show the largest growth between 1970 and 2004 (Climate Change 2007). This huge amount of consumption has come from energy supply (25.9%), industry (19.4%), transportation (13.1%) and others, while source of CO_2 is mainly from the fossil fuel use.

With the most significant increase of energy consumption, transportation sector leads to the over-utilization of limited natural resources, including energy resources, and emit large volume of greenhouse gases. The consideration of comprehensive action strategies to promote sustainable development by employing efficient use of energy and resources to reduce environmental load could not be longer ignore. Also, one of the proactive approaches is to incorporate between land use and transportation planning profoundly influences on the sustaining urban development. It has been proven that automobile-based development strategies can cause urban sprawl and suburbanization, increasing commuting distances and reducing land use efficiency. On the other hand, transit systems promote more efficient resource usage with a variety of benefits, cities are increasingly applying transit-based strategies to solve the urban planning dilemma (Lin and Gau 2006).

However, when consider the case study of developing world, especially Asia mega city, most of the city has become greatly dispersed with heavy congestion, particularly, outside of the urban is larger than the coverage of mass transit network to accommodate number of trips. The existing phenomena demonstrate the situation of urban sprawl of Bangkok which need for an effective integrating land use and transportation plan

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to cope with (IMAC 2005). However, several researches has been conducted to understand the mechanism of urban growth which was recognized as physical and functional changes due to the transition of rural landscape to urban forms (Ewing 1997; Thapa and Murayama 2010). This study selected Bangkok as a case study to explore about the pedestrians' satisfaction while access mass transit in the urban area. Due to the transition city of its spatial structure which require an allocation of appropriate public transit mode to accommodate urban migration and socio-economic environment of human activities together with their movement in urban area.

To establish an effective urban plan, it should not only guide to the compact settlement with walkable environment but also high population density in proximity to transit area could promote the ridership of transit users. This phenomenon could also help to lead on the reduction per capita infrastructure and distribution costs, and open up opportunities for economies of scale. Bangkok, as a representative of megacities could greatly benefit in term of facilitate the implementation of measures to reduce stress to sustainability. Therefore, city and sustainability could bring into three dimensions of strategic policy of development: enhancing development density to increase transit ridership; diversifying land use (mixed land use development) to improve public transport passenger convenience; and pedestrian-oriented walkways and transfer systems to increase the use of mass-transit (Cervero 1995; Cervero and Kockelman 1997; TGM 2003; Tang and Lo 2008). The effective approach to attract different types of trip purposes within station area is to encourage nonmotorization connectivity in term of modal usage. These behaviors could reflects on their trip-making frequency, distance and time traveled which have been studied its influences by means of several aspects, e.g., a variety of land use patterns, street networks, and streetscape design features (Eestupiñán and Rodríguez 2008). As a consequence, this study aims to establish a framework of methodology to assist planners in development guideline for improve the walking environment for TOD planning on a basis of enhancing walkability in a more comprehensive manner. Based on sustainability concept, a case study of TOD planning in Bangkok can be developed to achieve the objectives of system ridership on an enhancing living-environment quality and maintaining social equity in land development.

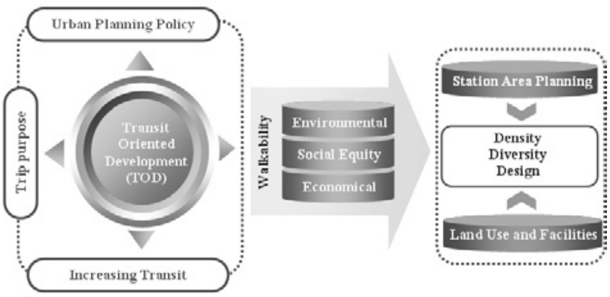


Fig. 1 Enhancing walkability for TOD planning and urban sustainability

OBJECTIVES AND SCOPE OF STUDY

Aforementioned of sustainability concept and the tradeoffs between the TOD planning objectives, this study have three objectives to achieve the goal of TOD planning by focusing on the identification of the particular dimensions of the built environment which enhance walking behavior to transit utilization. The walkability of TOD can be conceptualized as the extent to which characteristics of personal characteristics (socio-demographic & socio-economic) and psychosocial variables of trip makers, built environment may or may not be conducive to residents or commuters within the service area of transit to connect their trip for either leisure, exercise or recreation, to access services, or to travel to work (Fig.1).

1. To explore the condition of physical environment around the station area for further efficiency utilization on the basis of an incorporating of urban planning policy;

2. To draw the relationship of the built environment factor association with pedestrians' satisfaction (such as building use, density, street networks, etc.);

3. To recommend for the planning and policy to sustain the future of walkable environmental in the proximity of transit service area in Bangkok.

CONCEPT OF STUDY

To sustaining the situation of mass transit in Bangkok, the station area development has become vital role for consideration to raise the number of ridership. Despite their limited number, alternative urban forms like transit-oriented developments, new urbanist neighborhoods and walkable communities continue to grow in popularity. Such communities are intended to support more active lifestyles (Cho et.al 2009). To maximize the utilization of urban area for transit oriented development based on the sustainable development towards mitigation of global climate change, there are several factors contributing to the efficient and effective transportation plan for enhancement of the walkability to transit development. This study attempted to assess commuters' walking behavior in terms of several aspects such as users' needs, perception and attitudes on the service.

Furthermore, TOD contains a variety of services required by various types of transit users, e.g. residential, employees, while also linking them through a variety choice of modes in the transit system. However, several satisfaction aspects of neighborhood on the actual conditions of their residents and visitors, particularly those traveling or recreating by bicycle or by walking to the station is necessary to consider for TOD (Lin and Gau 2006; Givoni and Rietveld 2007; Hensher and Rose 2007) . However, the effect of these factors in relation to the demand on walking to transit service is ambiguous. Although there is some ambiguity in the findings from prior research, this study identified three commonalities of interest to the present study. First, a considerable relationship between perceived walkability to transit utilization should exist. Second, the personal attributes as well as built environment are associated, directly and perhaps indirectly, with levels of walkability. This study also provided the methodology to test empirically the mediating effect of perception on walkability of transit users on the relationship among several factors (personal characteristics and built environment factors).

The output from the actual behavior and commuters' preferences could allow for simultaneous creating indirect paths from the built environment to the improvement plan of TOD. Based on this exploratory, the discussion of the factors contributing to the transportation plan for new transit development could be accomplished in terms of several aspects of users' needs, perception and attitude on the accessibility of transit service as depicted in Fig.2.

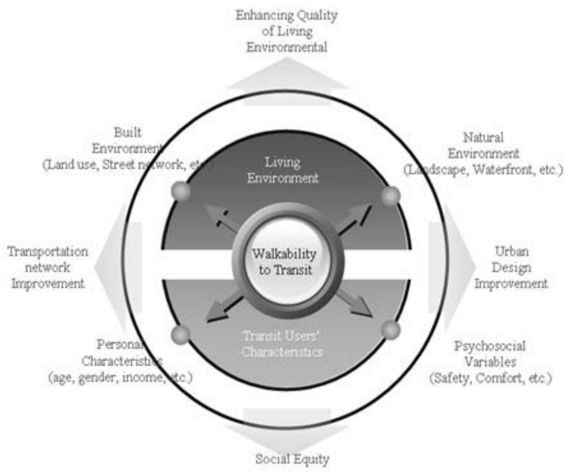


Fig. 2 Conceptual framework of the study

METHODOLOGY

The walking behavior is complex phenomenon which a deep understanding of people's perceptions, attitudes and behavior are required. The qualitative approach is a powerful tool to explore those complexities, since they allow a grasp of the individual's own explanations of behavior and attitudes. As well as quantitative approaches have an advantage of measuring the reactions of many subjects to a limited set of questions allowing the comparison and statistical aggregation of the data. On the other hand, qualitative methods produce a wealth of detailed data on a small number of individuals (Beirão and Cabral 2007). Thus, this study classified the cause factors which are associated to the walkability level into 4 parts according to the questionnaire that includes;

- Personal Characteristics: age, gender, income, education, car ownership, etc.;
- Psychosocial Variables: safety, comfort, convenient, etc.;
- Built environment: land use (mix used, compactness), street network (directness, interconnected), housing type, infrastructure, etc.;
- Natural environment: landscape, water body, park, etc.

Based on this methodology, data collection will be conducted by adopt the questionnaire survey, checklist and site survey as tool for gathering information. The survey was performed at the study area by covering 500 meters of the transit station's service radius of selected three mass transit stations (Siam, Mo-chit and Victory Monument). The pedestrians' satisfaction can be analyzed based on the onsite interview of 500 sets of respondents. This also includes other participants who will be recruited using non-random methods by identifying streets within the study areas, or by asking existing respondents. The selected stations in this study can be demonstrated as shown in Table 1.

The result of analysis is useful to elaborate the association among all built environment characteristics of transit stations along with pedestrian connectivity and quality of service in several aspects which could be evaluated and lead to the direction in support of transportation and urban planning policy. Furthermore, this study will also employ the ability of GIS to integrate spatial data from different sources with the calculated of its reflecting of the dimensions of built environment that are most closely associated with walkability and public transit use.

Table 1 Typology of selected stations (study area)

Station	Typology			Connected with Other modes					
	Interchange	Terminal	Substation	BTS	BRT	MRTA	Water Transport	Rail Transport	Airport Rail link
Siam	x			x					
Mo-Chit		x				x			
Victory Monument			x	x					
Chong-Nonsi	x				x				
Wongwien Yai		x						x	
Phayathai			x					x	x
Silom	x			x					
BRT Sathorn		x		x					
Saphantaksin			x				x		
Chatuchak	x			x					

Based on this powerful aid tool, the structures of data in different layer could be viewed into spatially informations. The visualization of the result could be useful and more comprehensible and understandable format for different levels of users or concerned stakeholder (Saaty 1980). Not only the perception of commuters who reach station by walking could be measured based on the linkert scale approach, the different idea to promote walkability around transit station area could be prioritized by using analytical hierarchy process (AHP) technique. AHP is one of multicriteria decision making method to determine the ratio scale from pair wise comparison (Saaty 1990). The comparison on different measurement of urban to support TOD could be weighted from different groups of stakeholders who work for transit planning. Different target group could be examined their subjective opinion and their preference to allow final comparison among different TOD policy and ranking the importance of planning and policy.

RESULTS OF ANALYSES

Socio-Economic Characteristics of Commuters

Due to a number of factors other than land-use environment can also have a profound impact on future commuting behavior. This study was designed to collect the data from both commuters and the experts. The first group of analysis was conducted based on the interview survey of 500 respondents which can be categorized into 2 parts: socioeconomic characteristics and preferences on walking within service areas of transit stations. The commuters' survey results for the former part can be explained. The majority of commuters who use mass transit are the government officers (32.0%) and students (32.2%) with the education of undergraduate level (57.6%).

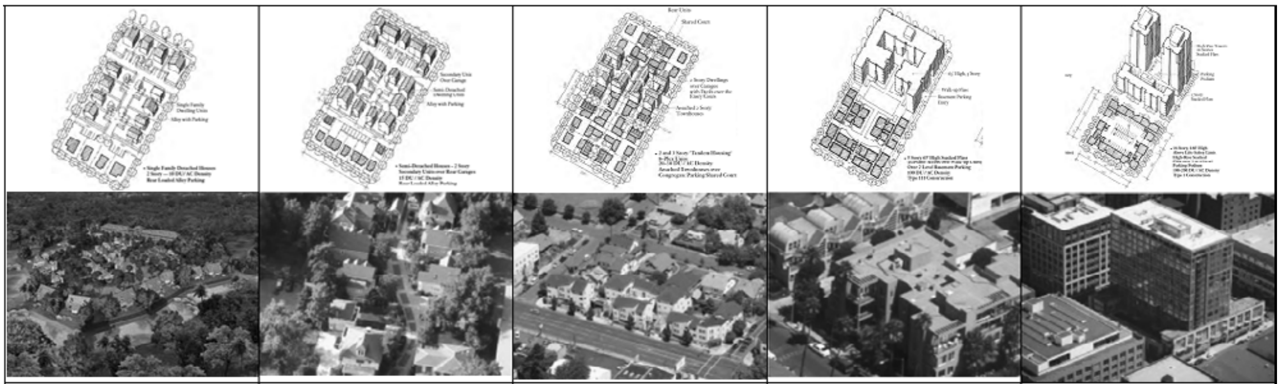
It is not surprising that the survey revealed the high number on the ages during 21-30 years (30.2%) and 41-50 years (32.4%). Additionally, the family size of Bangkokians is about 3-4 persons per family (couple and children, 32.0%) which reflects the collective behavior on social aspects. They may prefer to travel by their own vehicles (passenger car, 46.3%) rather than travel by public transportation or mass transit. Most of them have been living in the townhouse/commercial building (44.6%) as of their residential type with the parking space included (87.8%). This reflects the contributing factors which induce Bangkok people prefer to travel by private vehicle with more convenient while the public transportation provides less accessibility in term of connections. The more compact and intermixed an urban environment is more prefer to pedestrian due to the shorter the distances between destinations.

Pedestrians' Satisfaction on Built Environment around Mass Transit Station

Furthermore, this study was also designed to ask the respondents to evaluate the influence of sites on their level of distance which they were willing to walk under different street conditions of the different aspects of proximity of station area as depicted in Fig.3 to Fig.9. The score was range from 1 to 3 and represent low level of walking (approximately 500 meters or 5-10 min), medium (500 - 1000 meters or 10-15 min) and high (1,500 meters or more or more than 15 min), respectively. Figure 3 also shows that although better facility for sidewalk provides sufficient space for pedestrian flow with cover way, green amenity with tree

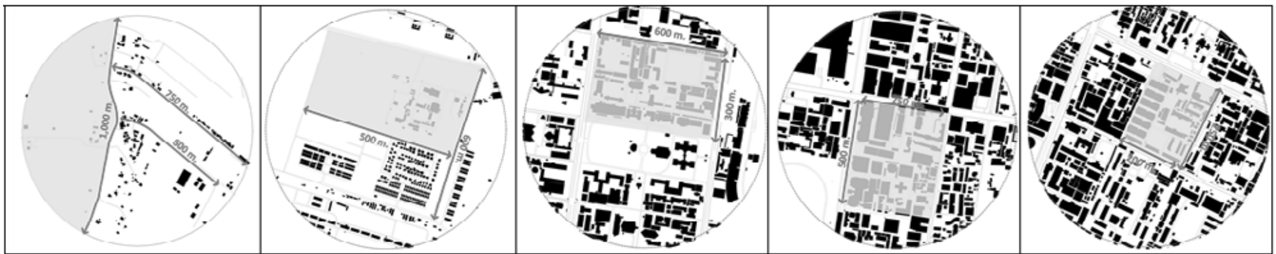
Blocks are driveway loaded. Garages set back, no cars block sidewalks. Some or many driveways cross sidewalks with cross slopes	Some blocks are alley loaded. Few driveways or overhead wires in street corridor. No driveways cross sidewalks with cross slopes.	Many blocks are alley loaded. Few driveways and no driveways cross any portion of sidewalks with cross slopes.	Most blocks are alley loaded. No driveways or overhead wires in most street. Alleys have Accessory Dwelling Units or other means for surveillance.	Most blocks are alley loaded. No driveways or overhead wires in most street. Alleys have Accessory Dwelling Units or other means of surveillance.
Mean (Max=3)				
1.38	1.68	1.93	2.31	2.50

Fig. 3 Sidewalks and walkways



3 to 5 du/a or more. Garages seen from street but do not dominate. Homes 16 or more meter from street. Moderate surveillance.	5 to 10 du/a or more. No Garages seen from street. Homes are 3-9 meter from street. Good surveillance to street.	10 to 30 du/a or more. No Garages seen from street. Homes are 3-9 meter from street. Good surveillance to street.	15 to 35 du/a or more. Few Garages seen from street. Homes are 3-9 meter from street. Good surveillance to street.	> 35 du/a or more. No Garages seen from street. Homes are 3-9 meter from street. Good surveillance to street (windows/porches).
Mean (Max=3)				
1.87	2.04	1.98	2.01	1.96

Fig. 4 Tree and planter strips



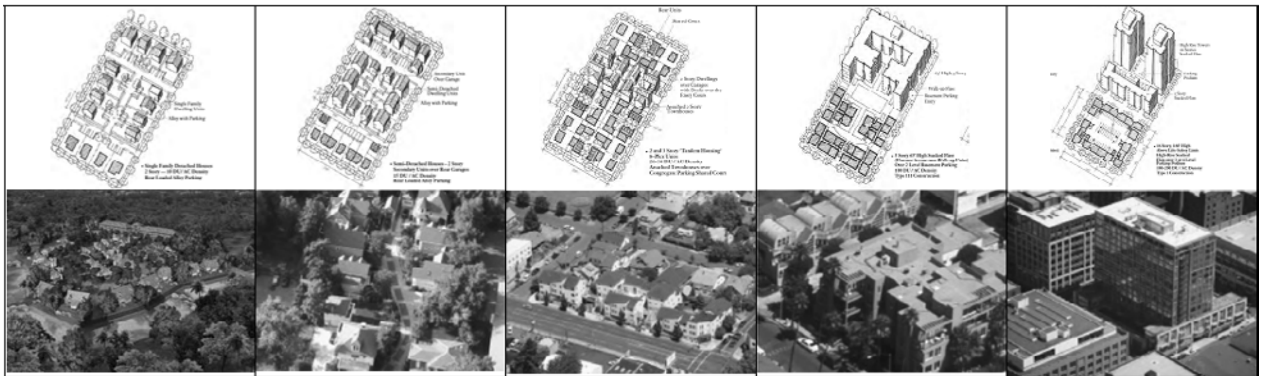
Block connections sparse, often 600 to 1,000 m apart. Speeds area a bit high due to long block length.	Most block connections are 600 m. If blocks are longer, trails or other links maintain connectivity. Speeds controlled.	Most block connections each 300x600 m. If blocks are longer, trails or other links maintain connectivity.	Most block connections each 250x500 m. If blocks are longer, trails or other links maintain connectivity.	Most block connections each 250x250 m. If blocks are longer, trails or other links maintain connectivity.
Mean (Max=3)				
1.37	1.51	1.81	2.24	2.50

Fig. 5 Connectivity

and planer strips (2.79) play more important role as the street facility to be included in the sidewalk facilities. Additionally, the result of respondents' survey demonstrated that most of them prefer to walk to the stations in the condition of trees and green landscape (2.60) as shown in Fig.4.

Blocks are driveway loaded Garages set back, no cars block sidewalks. Some or many driveways cross sidewalks with cross slopes	Some blocks are alley loaded. Few driveways or overhead wires in street corridor. No driveways cross sidewalks with cross slopes.	Many blocks are alley loaded. Few driveways and no driveways cross any portion of sidewalks with cross slopes.	Most blocks are alley loaded No driveways or overhead wires in most street. Alleys have Accessory Dwelling Units or other means for surveillance.	Most blocks are alley loaded No driveways or overhead wires in most street. Alleys have Accessory Dwelling Units or other means of surveillance.
Mean (Max=3)				
1.38	1.68	1.93	2.31	2.50

Fig. 6 Traffic management



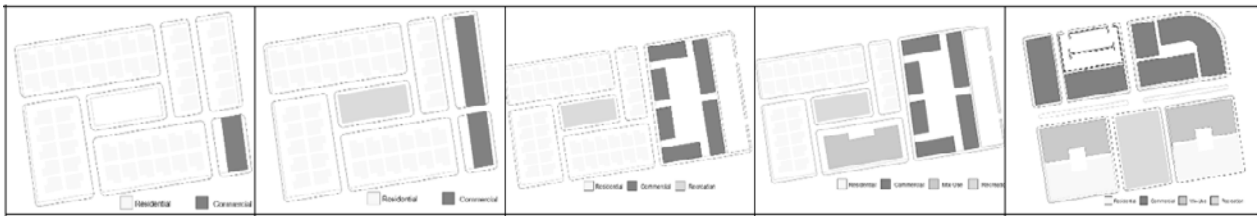
3 to 5 du/a or more. Garages seen from street but do not dominate. Homes 16 or more meter from street. Moderate surveillance.	5 to 10 du/a or more. No Garages seen from street Homes are 3-9 meter from street. Good surveillance to street.	10 to 30 du/a or more. No Garages seen from street. Homes are 3-9 meter from street. Good surveillance to street.	15 to 35 du/a or more. Few Garages seen from street. Homes are 3-9 meter from street. Good surveillance to street.	> 35 du/a or more. No Garages seen from street. Homes are 3-9 meter from street. Good surveillance to street (windows/porches).
Mean (Max=3)				
1.87	2.04	1.98	2.01	1.96

Fig. 7 Urban density

Streets are 12- 15m wide with parking. Rollover curbs are used. Evidence that some people park by mounting curb.	Streets are 9 to 12 m wide with parking on both sides. Curbing is used, or no indication cars park to side.	Streets are 8-10 m wide with parking on both sides. Curbing is used, or no indication cars park to side.	Streets are 6-8 m wide with parking on both sides. Curbing is used, or no indication cars park to side. Non–mountable curbs.	Streets are 6-8 m wide with parking on both sides. Curbing is used, or no indication cars park to side. Non–mountable curbs.
Mean (Max=3)				
1.75	1.70	1.67	2.45	2.85

Fig. 8 Street qualities

Furthermore, the small block with 250m.x250m. (2.50) is the most preferable walking size for pedestrian to reach the transit station as shown in Fig.5. The result of survey confirms that the small street with walkable environment (2.50) and street calming (2.85) is also better choice for pedestrian (Fig.6). Figures 7 and 8



Minimum Hours of 'Significant' Activity is less 10 hr. Average 1 Jobs per 2 Housing Units. Mix of uses are 90 % Residential and 10 % Non-Residential.	Minimum Hours of 'Significant' Activity is 14 hr. Average 1 Jobs per 1 Housing Units. Mix of uses are 70 % Residential and 30 % Non-Residential.	Minimum Hours of 'Significant' Activity is 16 hr. Average 5 Jobs per 1 Housing Units. Mix of uses are 50 % Residential and 50 % Non-Residential.	Minimum Hours of 'Significant' Activity is 18 hr. Average 10 Jobs per 1 Housing Units. Mix of uses are 30 % Residential and 70 % Non-Residential.	Minimum Hours of 'Significant' Activity is 20 hr. Average 15 Jobs per 1 Housing Units. Mix of uses are 20 % Residential and 80 % Non-Residential.
Mean (Max=3)				
1.89	2.03	2.04	1.97	2.04

Fig. 9 Mixed use and diversity

reveal that people are fond of walking in the moderate urban density and relative good access to street. The moderate and high level of mixed use and urban diversity would attract people to enjoy more walking as illustrated in Fig.9.

AHP Survey from Different Stakeholders of TOD Planning

This study also includes the experts' view which was also assessed by using the AHP survey. The survey was conducted by 2 means of survey;

- Distribute to the government offices and private company as part of concerned authorities in TOD planning;
- Distribute via mailing list of experts in domestic and international level, mostly are belong to academic area.

Final set of questionnaires were obtained about 30 sets (among 100 sets of distribution). The group of expertise consists of; transportation economics and policy, travel demand analysis and forecast, logistics and freight transportation, regional planning and environment, public and non-motorized transportation, highway design and maintenance, road traffic engineering, traffic accident and safety and air and water transportation. The AHP survey for experts was designed in 3 parts (Fig.10);

- Part A: Background of respondents in term of knowledge and experiences;
- Part B: Perception of different respondents to rate score (5 levels) of different criteria which related to walkability level (5=high level and 1=low level);
- Part C: Make the comparison of different criteria which could enhance the level of walkability for sustaining transit demand on the consideration of TOD concept.

The consistency index (CI) was derived to be less than 010 to verify the satisfaction of experts' judgement.

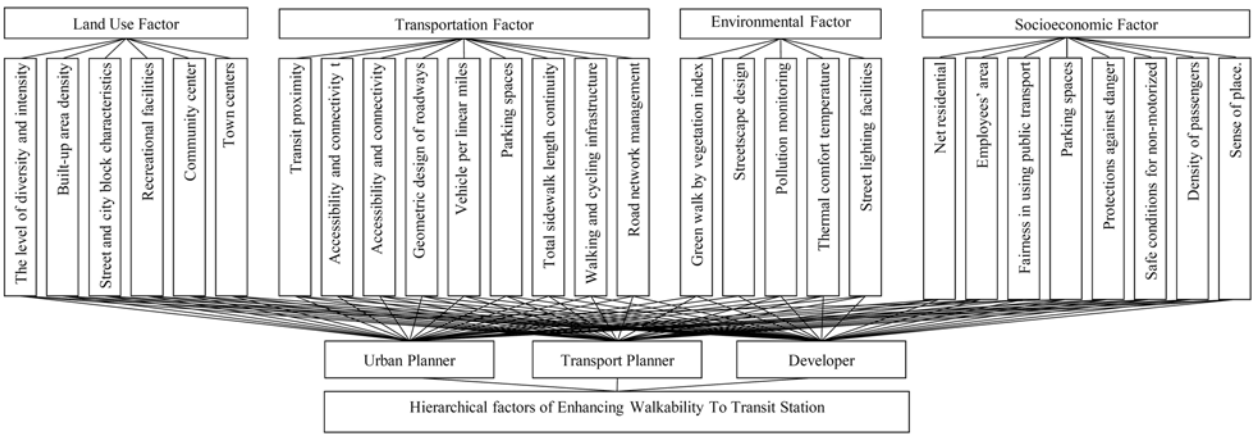


Fig. 10 AHP structure

The structure was designed to assess 2 different levels of factors (major and minor). The result of weighting calculation is described as follows;

- Landuse (0.283): Diversity, density, form, public center, node of activity;
- Transportation (0.292): Public transit proximity, accessibility and connectivity, road network characteristics, street network density, vehicle per linear miles, parking, sidewalk and walkways, street management;
- Environment (0.236): Green ratio index, urban landscape, air and noise pollution, temperature, street lighting facilities;
- Socioeconomic (0.096): population density, employment proximity, equity, road safety, crowed, site attraction.

When the consideration was made to differentiate the view of different stakeholders, the planner agreed that the transportation factors (0.307) play an important role to sustain the transit demand, while the transportation engineer have an opposite view. They had an idea that the land use factors (0.307) are the major influence to induce on the commuters' demand to shift to mass transit service. However, the developers also have different opinions about the major factors which were focused on the socioeconomics characteristics (0.320) of trip makers who can make any choice which is consistent with their level of affordability as depicted in Fig.11.

When making the comparison of the minor factors, it was found that among the land use factors, the node of activity is the most important (0.208) factors influence on the attractiveness of mass transit demand as shown in Fig.12. For transportation factors (Fig.13), it can be seen that the walkability is the most important factor in term of the total sidewalk length continuity along major street and walking quality (0.190) to encourage traveler make their choice to the transit station, follow by the other aspects of accessibility and connectivity. This is an assessment for the directness of travel route based on space syntax approach with the discrete model of an urban space and street design.

For environmental factors, urban landscape (0.243) which was measured by streetscape design, trees and planter strips, street furniture plays a key role to enhance the walkability to transit station. Follow by the temperature factor (0.222) which was determined by thermal comfort temperature calculated in surface temperature based on Satellite image analysis with Lansat as shown in Fig.14.

For socioeconomic factor, road safety (0.209) which reflects safety conditions for non-motorized and public transportation is the most important to promote the walkability of transit station. Follow by, the security (0.194) which was demonstrated in term of degree of protection against danger, damage, and crime inside public transit conditions (Fig.15).

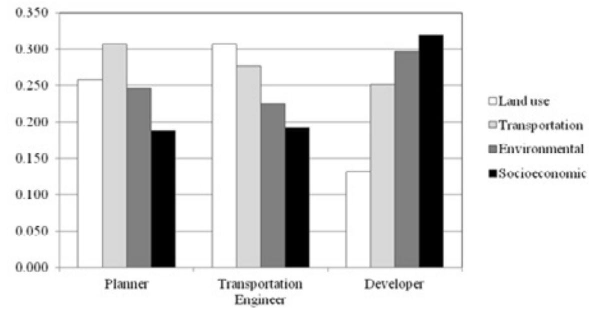


Fig. 11 AHP results of different stakeholders

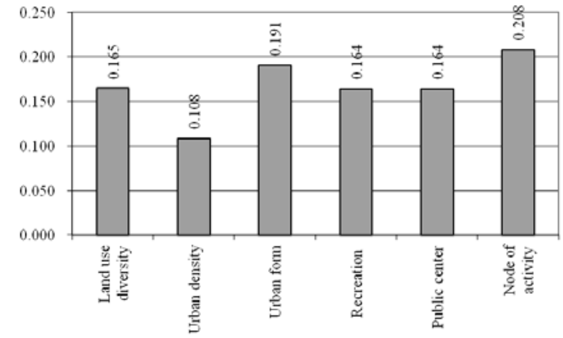


Fig. 12 Land use factors

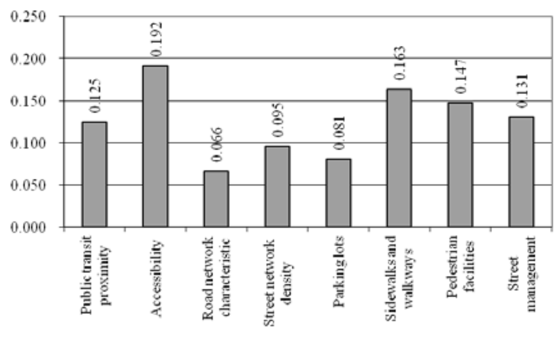


Fig. 13 Transportation factors

CONCLUSIONS AND RECOMMENDATIONS

This study proposed a TOD planning model to assist urban planners in reviewing land use density in transit station areas by focusing on an enhancing walkability of transit users. To extend the considerations of TOD planning, this model incorporates cause and effect analysis, which includes not only the economic efficiency aspect of transit ridership, but also the living environment aspect of service facilities, and the social equity aspect of inequalities in land development, between planned areas and other areas. However, the

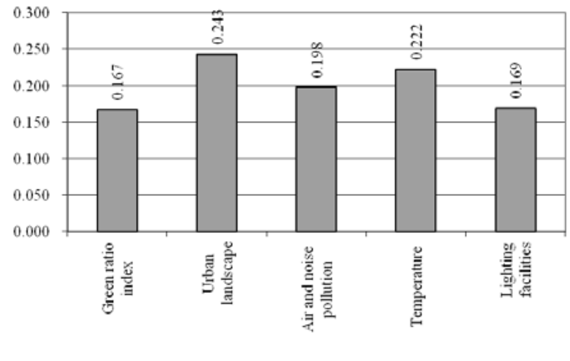


Fig. 14 Environmental factors

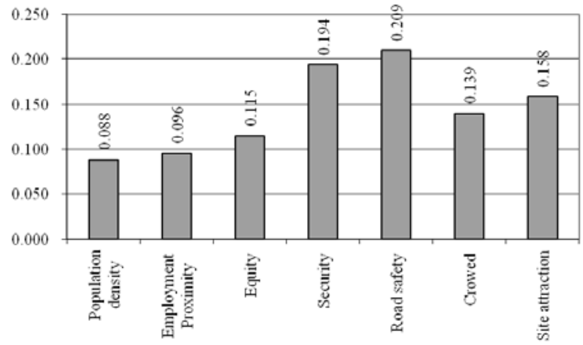


Fig. 15 Socioeconomic factors

provision of sustainable development is also raised to encourage the suitable urban growth pattern in order to support transit investment. The study could address users' experience and expectation of stations' area development in terms of sidewalk and walkways, tree and planter strips, connectivity, traffic management, street quality, urban density and mix use and diversity as they relate to transit-oriented development. Since the location of transit station could be varied in different place types ranging from urban to rural, the designing of station area should focus on serving for people rather than vehicles with ultimately support healthy transit ridership.

Finding the right combination of cause and effect on walkability to transit is an initiative for achieving various mobility and environmental objectives which remains a significant public policy challenges. Moreover, an implication of this study could help as a guideline for a new transit system development in not only promoting ridership of public transport system while reducing the need for and use of private vehicles, but it also drives the policy for sustainable mass transit development. Since, it can be suggested the suitable plan for proximity area of the station that is primarily determined by land use variables. It may be obviously seen that walking has to be competed with other modes of travel and may be a particularly disadvantaged choice with respect to travel distance. Moreover, where there are many interconnecting streets laid out in a regular grid pattern, walking for transport is facilitated, the commuter tends to have a preference to walk directness of the pathway between households, shops and places of employment which is based on the design of the street networks. The availability of destinations together with an interconnected street network makes walking a more competitive and attractive mode of travel to other options. The direct travel should be facilitated with lack of barriers (freeways, walls and physical obstacles).

Furthermore, in order to limit auto demand, the cost, availability, location, and design of parking facilities at destinations is also a critical predictor of travel choice, and impacts the relative walking time. Regarding to the built environment that impact walking for practical purposes, the result of study could also be explained the choice to walk for leisure, exercise or recreation. Therefore, the intermodal transfer facilities give the impression to be very important in order to attract people to use the service, especially nonmotorization for transit demand. Moreover, accessibility is also important to be taken into consideration since the number of passengers would be expected in lower number in accordance with the longer distance. Moreover, the stakeholders in the planning and development of stations area include not only the government sectors but the local authorities, developers, private sectors and residents are as key players to assist in the planning and development process and to reduce delay, frustration and conflict among all.

The implication of this study is to guide for promote vibrant and livable station areas to benefit both commuters who are target group of the service and the surrounding community and to promote the use of station as a primary means of transportation. The benefit from development focused around its stations when it generates ridership and revenues from local businesses would help the station service more efficient. Finally, to reach an ultimate aim in shaping urban structure for create successful TOD at dissimilar stations, the uniqueness of different community should be taken into account to demonstrate its own character and transportation needs. Thus, certain transportation project could be developed to incorporate land use planning in a way that respect and strengthens the positive aspects of community's identity with proper development priorities.

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