

# Comparing the Efficiency of Urban Components in Proximity to Transit Service Area

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## Abstract

Mass transit plays a key role as a sustainable alternative to alleviate traffic congestion problems, especially in Bangkok, the capital of Thailand. To promote urban expansion around the concept of polycentric development, urban areas should maximize their utilization of transit oriented development. To incorporate several contributing factors into the design of efficient and effective transportation development, this study attempted to assess the multidimensional aspects of transit services in terms of attractiveness and accessibility in proximity to transit stations. By selecting three transit stations in Bangkok as case studies, the usefulness of the methodology was verified by using the results of both quantitative and qualitative approaches to demonstrate different typology of transit stations. The results reveal that finding the correct balance of land and non-land uses to achieve various mobility and environmental objectives remains a significant public policy challenge. Moreover, the study recommends planning improvements for promoting patronage of public transport systems whilst reducing the need for and use of private vehicles. It also supports policies for sustainable mass transit development.

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## 1. Introduction

Rapid urbanization has created both negative and positive impacts for urban residents, especially the problem of uncontrolled urban expansion together with inefficient transportation. The negative effects of automobiles on the physical environment and quality of life have become major concerns due to the accompanying trend of global “climate change”. The key factors driving both natural and anthropogenic climate change include the chain linking greenhouse gas (GHG) emissions to atmospheric concentrations. Additionally, it has already been recognized that carbon dioxide (CO<sub>2</sub>) plays an important role as an anthropogenic GHG, which accounted for the largest growth in GHG emissions between 1970 and 2004, as depicted in Figure 1. This huge volume of emissions has been generated by energy consumption, transport and industry, while residential and commercial buildings, forestry (including deforestation) and the agricultural sector have been growing at a lower rate.

It was also discovered that the most significant increase in energy consumption and greenhouse gas emissions in the future is expected to take place in mega-cities. These cities and their expanding populations enjoy higher living standards and material affluence than rural areas and smaller cities. In Asia, the number of people living in mega-cities has been increasing rapidly. While cities may play a major role in the promotion of global sustainability, they could also be an impediment to progressing towards this goal. This is due to the fact that to reach high living standards within cities requires the consumption of large amounts of material goods and plentiful transportation, which leads to the over-utilization of limited natural resources, including energy reserves, and emits large volumes of greenhouse gases. Figure 2 illustrates the effect of climate change across the whole region, demonstrating the gradual increase in temperature among Asian countries between 1950 and 1970. After 1970, the growing problem of rising temperatures across the region called for an urgent

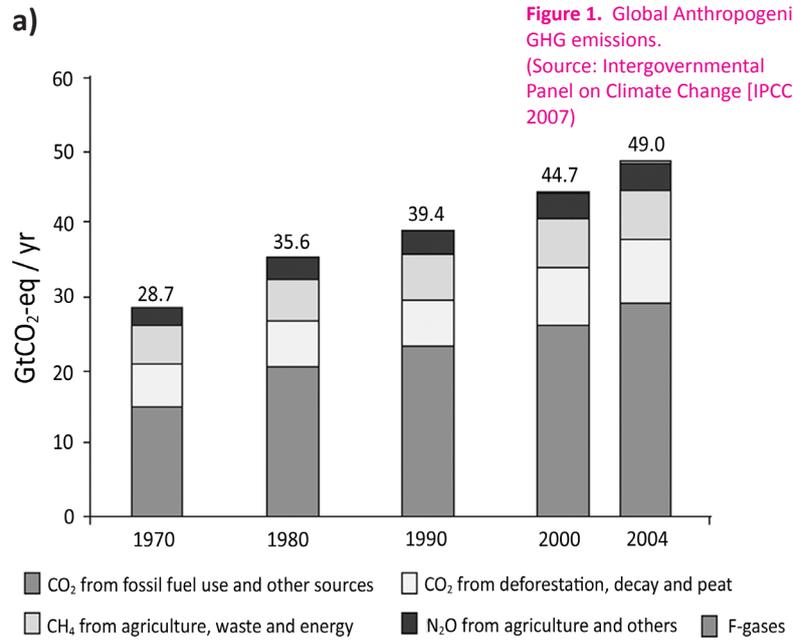


Figure 1. Global Anthropogenic GHG emissions. (Source: Intergovernmental Panel on Climate Change [IPCC], 2007)

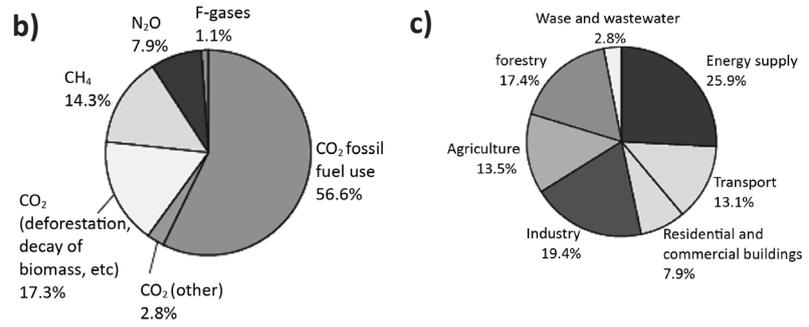
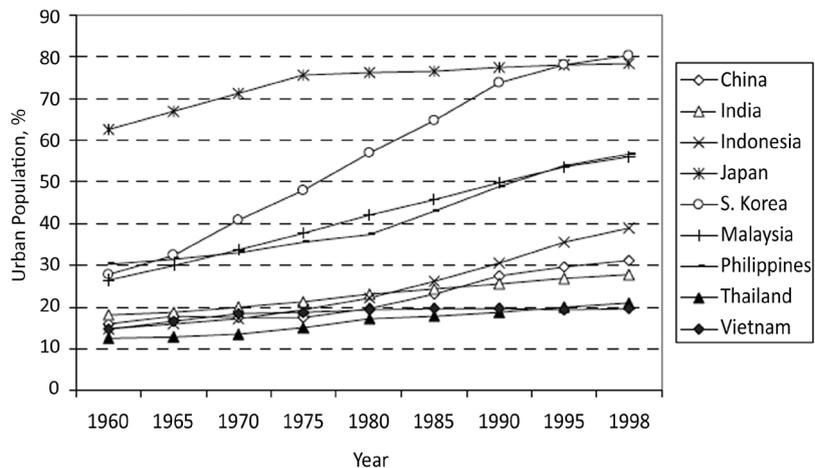


Figure 2. Urban population in selected Asian countries. (Source: World Bank Indicators CD-Rom, 2007)



mitigation plan to cope with the situation of climate change. Additionally, human-imposed threats to global sustainability from both population growth and the ever-increasing per capita demand for goods and services, particularly material needs and energy use, intensified. It was found that the weakest link was between transport and land use, resulting in an inefficient use of energy and resources (Global Environmental Research Fund [GERF], 2008). There is therefore an urgent need to develop sustainable solutions in order to reduce the environmental load and face the challenges of climate change.

This study examined Asian mega-cities, using Bangkok as a case study, with a focus on comprehensive action strategies to promote sustainable development in association with urban transportation planning. This is due to the reason that integrating land use and transportation planning profoundly influences the sustainability of 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 and also bring a variety of other benefits. Cities are increasingly applying transit-based strategies to solve the urban planning dilemma (Lin & Gau, 2006). To promote more public transit use, including mass transit, bicycle paths and public walkways, transit-oriented development (TOD) - a form of pedestrian-friendly, mixed-use, and location-efficient development with convenient transit services - is being employed in some urban areas. Many factors have begun to bring about a reconsideration of the urban components of our metropolitan landscapes. Commuters in many regions of the country are increasingly frustrated with congestion and arduous commutes. While concerns over sprawl and the loss of open space are growing, issues such as air pollution, greenhouse gas emissions, and pressure on foreign and domestic oil supplies are also in the public spotlight. Auto-dependent development and sprawl is also on the rise. This is due to the limited choices and opportunities for homeownership, in the context of rising housing prices in many metropolitan areas, for a large part of the population, including many who are solidly in the middle class (Belzer & Autler, 2002). The other aspect is economic performance: places with sprawling, auto-centric landscapes also represent poor economic performers (Kenworthy & Laube, 1999). Furthermore, it was also found the gross regional product per capita was generally higher in less auto-dependent cities. Auto usage does not therefore necessarily stimulate an increase in wealth, but tends to concentrate disproportionately among higher income groups.

Mass transit plays a key role as one of the alternative ways to alleviate the urban congestion problem, especially for many Asian cities. Bangkok, the capital of Thailand and one of the region's mega cities, will need to be planned effectively with a mass transit network and appropriate land use planning to drive its urban expansion in the direction of polycentric development. However, to maximize the utilization of urban space for transit oriented development, there are several factors that contribute to an efficient and effective transportation plan. This study attempted to assess the multidimensional aspects of transit services, in term of attractiveness and accessibility, in proximity to the transit station area. By selecting three separately located transit stations in Bangkok as case studies, the usefulness of the methodology could be verified with the results of both the quantitative and qualitative approaches. Different transit stations typologies (high intensity urban station, mixed use regional station and park & ride station) could be examined on the basis of their transit system function. Furthermore, their specific locational features and built environment characteristics could be determined and their influence on transportation infrastructure development demonstrated. Quantitative approaches were performed directly to provide valuable measurements of the available data, based on the application of GIS analysis. Conversely, qualitative methods were applied to gauge the degree of attractiveness and accessibility of transit-oriented development by using Likert scale analysis.

The integration of both quantitative and qualitative approaches as a tool of this study has the benefit of incorporating a number of factors other than the land-use environment that can also exert a profound impact on future commuting behavior. Finding the correct combination of land use and non-land use initiatives for achieving various mobility and environmental objectives remains a significant public policy challenge. Moreover, the implications of this study could serve as a guideline for transit system improvement and development. In particular, it would not only help promote ridership of the public transport system by enhancing its attractiveness and accessibility, while also reducing the need for and use of private vehicles, but also drive the policy for sustainable mass transit development.

## 2. Literature Review

During the 1950s, most transport engineers were educated in the planning perspectives of the United States, and designed their planning strategies around the North American vision of car-oriented transport. Highway capacity manuals were translated and applied without much

understanding of the effects these principles would cause to the urban structure. Traditionally, transport in cities was designed for the mobility of not only private vehicles, but also pedestrians, cycling and public transport (such as buses, trams and rail). The repeated mistakes of auto-oriented urban development, which are the major cause of urban sprawl, should be subjected to serious consideration before being implemented again as part of the city fabric. This is due to the reason that when multi-lane urban roads cut into the urban structure, they may create adverse effects for the local economy, damaging local trade and employment (Knoflacher, 2007). Future generations may be unable to bear the burden of wrongly conceived transport planning decisions. The availability of transit alternatives could offer a timely response to these impacts, together with the alleviation of urban congestion problems, especially in many Asian cities.

In particular, the development of mass transit mainly aims to reduce the reliance on vehicular traffic and hence relieve road congestion and associated environmental problems. However, as megacities in developing countries have been growing and expanding, traffic speeds have tended to remain stable with moderate to high congestion in central areas, especially Bangkok, Thailand. The congestion in Bangkok has spread outward, geographically and temporally, to off-peak periods, including weekends. Despite the fact that its road network has been rapidly expanding, the travel time and number of trips per person have both grown at similar rates. The increase of suburbanization and a possible slight decline in central area population density should be planned with an effective mass transit network and land use plan to drive its urban expansion around the concept of polycentric development (as depicted in Figure 3). However, an effective urban plan should not only encourage compact settlement, but also promote higher population density in cities. This phenomenon could also help lead to the reduction of per capita infrastructure and distribution costs, and open up opportunities for economies of

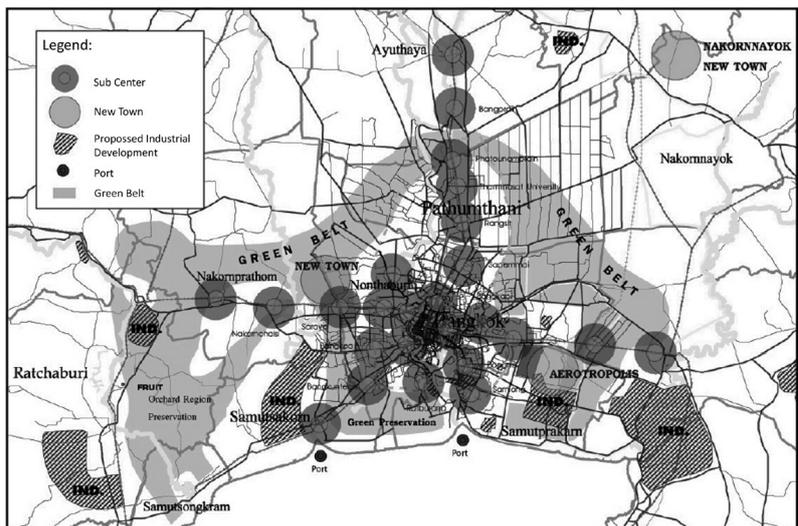
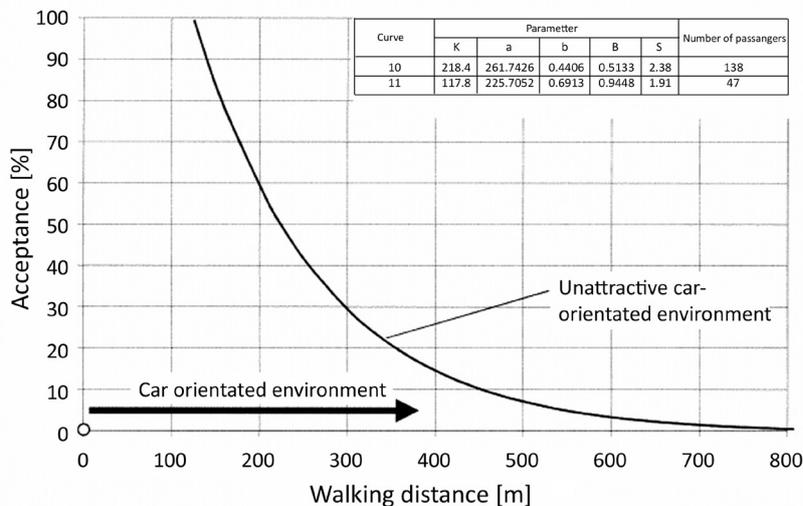


Figure 3. Polycentric development plan of Bangkok and its vicinity. (Source: IMAC, 2005)

scale. Bangkok, as a representative example of an Asian megacity, could greatly benefit in terms of reducing its environmental stress by implementing these sustainability measures.

Therefore, urban sustainability can be linked to three dimensions of strategic development policy: enhancing development density to increase transit ridership; diversifying land use (through 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 & Kockelman, 1997; Givoni & Rietveld, 2007). Figure 4 provides supportive informa-

Figure 4. The relationship between auto-dependent and acceptances of cars. (Source: Knoflacher, 2007)



tion about the acceptance levels of people to commute on foot, depending on the walking distance and the quality of the built environment. Thus, it is important to identify how different elements of site attractiveness combine to attract nonmotorized commuters to the transit station area, in accordance with these goals.

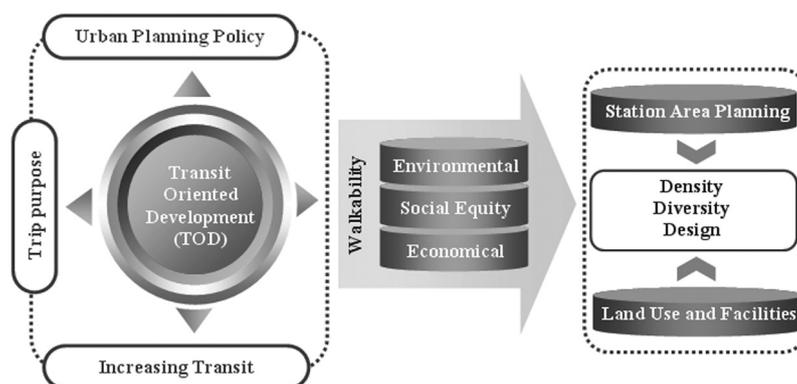
However, it was found that there are also two negative influences associated with the promotion of transit ridership, resulting from an increased development density in transit station areas (Lin & Gau, 2006). First, the quality of the living-environment in station areas could be adversely impacted by the congestion and chaos caused by an increase in human activity. Second, there are potential social problems in terms of a perceived unfairness in the differences in development density regulations between station areas and other areas. To minimize the negative consequences with regards to the progress of Transit Oriented Development (TOD) planning, integrating land use and transit operations has become a powerful tool. The TOD concept has been researched extensively and discussed as a strategy for station area planning (Cervero, 1994; Lin, 2006; Casello, 2007). However, to implement the TOD concept and enhance transit operations in the most efficient way with the limited resources available, TOD planning must be comprehensive and balance the tradeoffs between three objectives: efficiency, environment and equity (Transportation and Growth Management [TGM], 2003). Based on these criteria, the accumulated evidence suggests that certain characteristics of the built environment, such as site attractiveness, may influence people’s travel behaviors. An effective approach should consider how best to link different types of trip purpose within station areas in order to encourage nonmotorized connectivity through multimodal usage. These behaviors may reflect their accessibility, in terms of trip-making frequency, distance and time traveled, and as studies have shown may be influenced by a number of elements in the built environment: for example, a variety of land use patterns,

street networks, and streetscape design features (Cervero, 1996; Estupiñán & Rodríguez, 2008; Hensher & Rose, 2007). As a consequence, this study aims to establish a methodological framework to assist planners in developing guidelines for TOD planning with the aim of enhancing transit usage in a more comprehensive manner, based on a consideration of site attractiveness and accessibility. Three case studies of TOD in Bangkok are evaluated and compared, with the objective of achieving a sustainable transit system while enhancing the living environment quality and maintaining social equity in land development.

### 3. Method of Analysis

With a focus on sustainability and the tradeoffs within TOD planning, this study aims to identify the particular dimensions of the built environment that enhance the attractiveness and accessibility of transit utilization. This approach to promoting TOD can be conceptualized as the extent to which characteristics of the built environment in proximity of transit stations may or may not be conducive to bringing together a variety of residents or commuters within the transit service area for a range of purposes, whether for leisure, exercise or recreation, to access services, or to travel to work (as seen in Figure 5). To achieve this, the three objectives are:

Figure 5. Enhancing ridership for TOD planning and urban sustainability.



1. To increase the efficiency of transit station area development through land use planning policy;
2. To enhance the quality of the living environment around station areas through design and the allocation of public facilities (such as parks, squares, green fields, institutions, etc.);
3. To maintain social equity in terms of accessibility by creating a walkable network to the station areas.

Despite their limited numbers, alternative urban forms like transit-oriented developments, new neighborhoods and walkable communities continue to grow in popularity. Such communities are intended to support more active lifestyles (Cho, Rodríguez, & Khattak, 2009). To maximize the utilization of urban areas for transit oriented development (TOD), incorporating the concepts of sustainable development to mitigate global climate change, there are several factors that contribute to an efficient and effective transportation plan to enhance the ridership of mass transit. This study attempts to explore the efficiency of station area planning in terms of their urban components, and the varying levels of attractiveness and accessibility relating to their functions. Firstly, site attractiveness was determined by analysis of the three stations' characteristics in term of land use, floor area ratio, environment and street facilities. A geographic information system (GIS) was then employed to graphically demonstrate the detail of spatial site distinctiveness and illustrate in a comprehensible manner the compatibility of the existing land use and living environment (Malczewski, 1999). Secondly, the accessibility of the transit station area was defined by the convenience of its right of entry to the transit service area. This analysis was performed to evaluate the existing road network design for both motorized and non-motorized transport. This provides a more objective way to reduce automobile demand: most people are now highly dependent on car travel and this presents new challenges to planners, operators, the public, and other stakeholders (Beirão & Cabral, 2007; Tang & Lo, 2008). Thus, using space syntax techniques, the suitability of the road network within the station area could be determined in terms of the integration index and connectivity index. Space Syntax represents a set of analytical and computational tools for the analysis of urban systems which can be considered as a form of geometrical accessibility where a functional relationship is made, or attempted, between the structure of the city and its social, economical and environmental dimensions (Bera & Claramunt, 2004). With the application of space syntax analysis, the accessibility of the spatial layouts can be identified based on the idea that some places or streets are more accessible than others, though the terms used for accessibility such as proximity, integration, connectivity, cost, effort or centrality differ (Porta, Crucitti & Latora, 2005).

Afterward, this study is carefully designed to bring together both qualitative and quantitative data. The quantitative approaches have the advantage of measuring the reactions of many subjects to a limited set of questions, thus allowing the comparison and statistical aggregation of the data. On the other hand, the qualitative methods are a powerful tool to explore the complexities of these responses, since they allow a grasp of the individual's own explanations for their behavior and attitudes. This is due to transit development opportunities such as in-fill projects within the existing zoning that will include increased residential densities to compliment the current commercial development that already exists. This also includes a dense mix of uses, access to transit by direct connections from buildings, ease of transfer among modes, and a continued focus on enhanced pedestrian environment, walkability, bicycling, and access to transit. In order to ensure that transit-oriented development opportunities explicitly account for site attractiveness, this study integrates the aforementioned results of the quantitative analysis approaches with the findings of the qualitative approach, based on the application of Likert scale analysis. This is due to its ability to examine respondents' opinions and convert them to an interval scale by calculating the numerical averages. The Likert scale is commonly used in survey research to measure respondent attitudes by asking the extent to which they agree or disagree with a particular question or statement. The scale of this study is designed at four levels and varies from 1 to 4, representing the preference or degree of agreement with a set of statements - 'strongly agree', 'agree', 'disagree' and 'strongly disagree', respectively.

Furthermore, TOD contains a variety of service benefits perceived by different types of transit users, such as residents and employees, and links them through the transit system. However, satisfaction levels among different stakeholders who use the service may be determined by the attractiveness of the site's built environment. Those traveling by bicycle or on foot to the station would in addition consider the degree of site accessibility as a significant factor in their selection of modal choice. This is also an important aspect which must be considered for TOD planning. However, the effect of these factors in relation to transit service demand remains somewhat uncertain. Although there is some ambiguity in the findings from prior researches, this study assumes a considerable relationship exists between perceived needs and transit utilization, which is also directly associated with the characteristics of the built environment and perhaps also indirectly with demand for transit utilization. This is consistent with the focus on applying the concept of 'placemaking' to the station area, which can help support both the ridership goals

of the transit agency and the liveability goals of the surrounding residential area as well. A measurable index should be developed, drawing on the opinions of the experts interviewed in this study, to assess empirically the mediating effect and comparative efficiency of urban components in proximity to transit service areas, and the relationship between the several factors influencing the degree of attractiveness and accessibility.

#### 4. Study Area

Bangkok is the capital of Thailand and has grown rapidly in recent years, with a population approaching 11 million. Currently, private vehicles, bus, railway and several types of paratransit are the main land transport options. In particular, its mass transit system of electric railway is a dominant travel mode in the city, although it only accounts for a small portion of overall journeys due to the limited length of service. This study selected three stations as examples of the present network of mass transit stations, comprising two different types of metro system. The first, the 'Skytrain', has 23 stations and consists of two lines: the Sukhumvit (16.8 km) and Silom (8.5 km) lines. The second system is the MRT subway, a 21 km underground metro with 18 stations. However, all three selected stations (Victory Monument, Chidlom and Morchit stations) belong to the Skytrain service. The details of their locations and site characteristics are illustrated in Table 1.

The case studies here involve three stations, chosen according to their distinctive typologies as represented by various aspects of their function and built environment. The different typologies of the station areas encompass a relatively wide range of densities, urban forms, and land uses. The variety of locational characteristics and land uses, including a central business district (CBD) and subcenter, also determined their selection. This is due to the fact that different potential development opportunities will incorporate a balance of residential and employment densities with retail or other uses that serve residents and visitors and

**Table 1.** Three Selected Stations of mass transit service in Bangkok

Station	Location and site characteristics	
Victory Monument		
		
Chidlom		
		
Morchit		
		

promote activity near the station area. Among these different land use intensities, the development incentives and traffic conditions were included for consideration in the selection process, e.g. floor area ratio (FAR), open space ratio (OSR). This screening process served to single out distinctive stations from a group of overall services. The descriptions of these stations are outlined below:

*Victory Monument station:* This station has its own unique character as a Bangkok landmark and a major mass transit hub connecting with other transport modes, such as bus, van and taxi. The development intensity allows for a 7 or 8 FAR and a 4.0 to 4.5 OSR due to the potential of this area as an important node of economic and social activity. Thus, the station area should be planned and developed according to the particular attributes and characteristics of its surroundings.

*Chidlom station:* This station is located in the CBD area with a FAR equal to 10 and an OSR restricted to 3 percent. These characteristics bring together a high concentration of people, jobs and services and so require well-designed transit-oriented development in the area to make it efficient, safe and convenient to travel on foot or by bicycle, public transit or car to access its service area.

*Morchit station:* The key element of this station is its role as a terminal and interchange station connecting with the subway service. Its location is also situated in a sub-center of Bangkok with 10 FAR and 3 OSR. Furthermore, this station has been selected for the future extension of the railway service to support suburban area development as part of the satellite town expansion plan. To assist this process, the station area needs to be carefully designed to create attractive investment opportunities for the private sector and facilitate local economic development goals.

The serious imbalance between growing travel demand and limited transport supply in Bangkok creates much heavier traffic congestion in the city center. Furthermore, the increase in private car ownership is also a key aggravating factor of the congestion problem. Thus, the current crisis could be alleviated through a more sustainable approach involving TOD. This study was innovative in performing a comparative analysis of the urban components in the proximity area of the mass transit station to obtain in-depth information on the site attributes. Consequently, GIS-based measurements of the built environment along with survey-based data were adopted as the methods for obtaining input data for further analysis of the land use characteristics (floor area ratio and density). Environmental features were measured at many geographical scales,

including the street network and its facilities. The role of a new transit system is to relax traffic congestion, provide better public transit services, and fill the current gap in transportation supply. To do so, the innovative concept of TOD planning should determine the final site design to maximize the ridership of the public service.

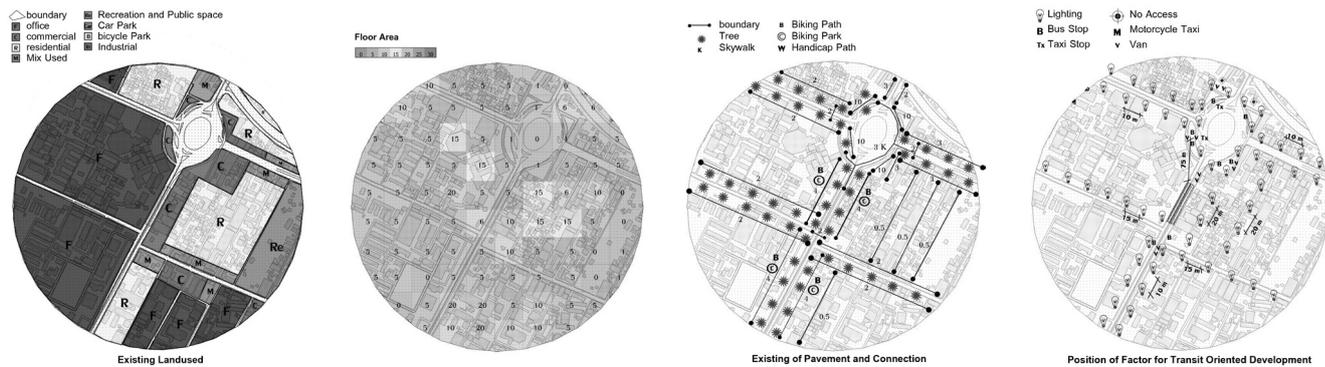
## 5. Results of Analysis

Several studies have pointed out that the attractiveness of a site or the location of other services may change commuter choices. The opportunity and flexibility to access certain activities such as shopping, banking and personal errands will also affect their decision. This study employed a GIS tool to analyze the characteristics of the site and to ensure its structures were placed in a manner to induce more ridership to the system. Figure 6 outlines the characteristics of the three sites in terms of land use, floor area ratio, environment and street facilities. The attractiveness of these sites in the study areas is described in terms of their building use and land use. Its findings demonstrate that Chidlom station was located in the most commercial area, with a high intensity of mixed activities such as retail, institutional, residential and office complexes. It represented the strongest potential for transit-oriented development around the station. Greater density and a higher degree of mixed-use development in the commercial district would encourage a strong concentration of office and residential uses with ready access to the station and sufficient street furniture and green streetscaping.

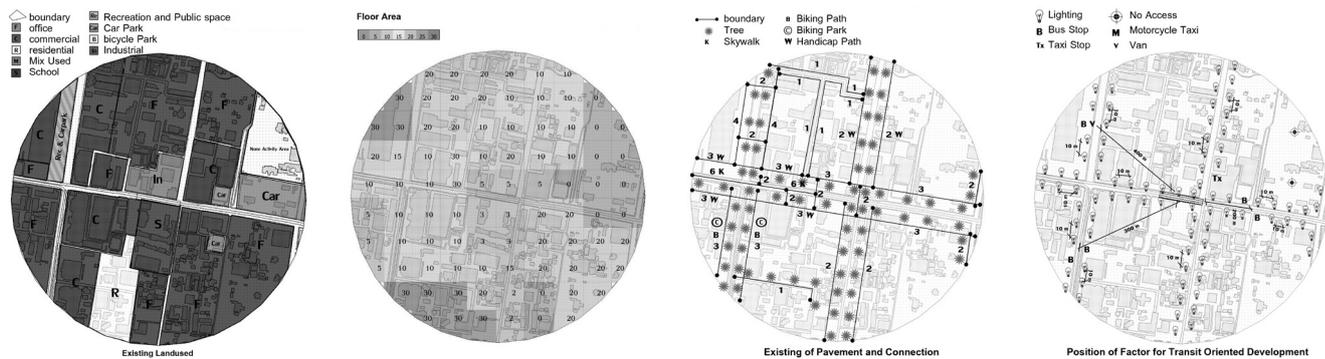
## 6. Attractiveness of Transit Station Areas

Based on the application of GIS, Figure 6 shows the existing site characteristics of the case study areas and illustrates their land use, floor area, living environment and street facilities. The analysis of the attractiveness of the three selected transit stations revealed that Victory Monument represents a moderate level of building and land use intensity. However, the high degree of available transport options at this station enhances its multimodal accessibility. As for Morchit station, the large amount of parking area and public green space nearby could attract people from suburban areas to 'park and ride' at the station for different trip purposes.

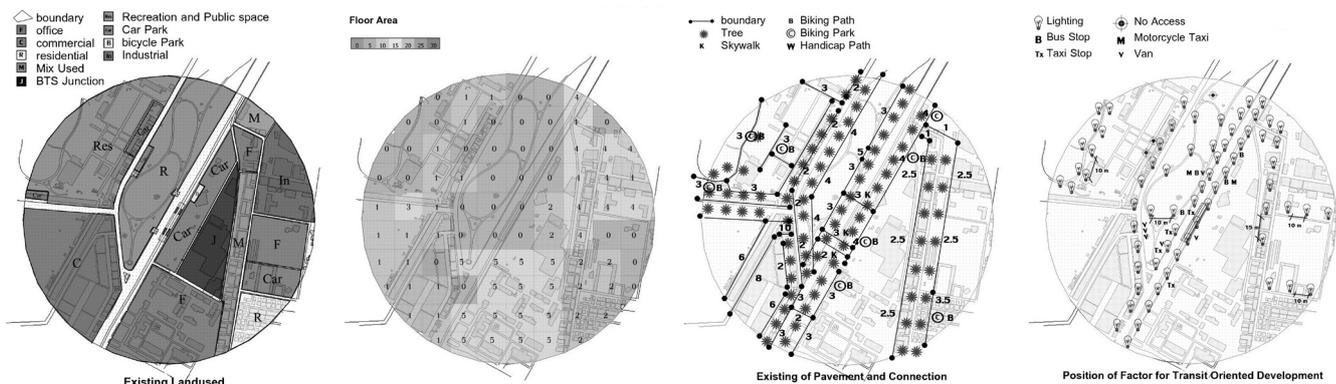
However, it is clear that this area is the lowest of the three stations in terms of the intensity of its building use. Additionally, it is difficult to create the opportunities for the sort of spontaneous development around the station that would encourage many firms to locate in the transit station area and integrate with other uses like restaurants, shops



a. Victory Monument station



b. Chidlom station



c. Morchit station



Figure 6. Attractiveness of study area.

and homes, which would provide employees with choices and amenities. The phenomenon of a mixed-use setting is rarely found in this area and this has been an obstacle for the development of office and commercial spaces. The area has a low level of accessibility for non-motorized travelers, reflected in the lower rate of interaction between employees and related businesses in this area. The large block size also makes access difficult on foot since pedestrian facilities are provided only along the main road, where access is further obstructed by telephone booths, street vendors, motorcycle taxi stands and other street furniture.

## 7. Accessibility of Transit Station Areas

From the analysis of the stations' attractiveness, it can be seen that most of the station area plans and land use reflect the degree of intensive, high quality development within the transit station area. When considering the physical conditions around the station properties, it was found that all three stations have a mixture of higher intensity land uses and are noticeably denser than the conditions in locations without transit station development. Furthermore, a mix of employment in retail, service, and other sectors could serve a relatively wide ranging, high density, mostly multifamily buildings of three or more stories, including high-rise buildings around the station areas. However, there are still some barriers to intensifying land use to enhance its value and the performance of the mass transit system. Supportive policy or planning actions should be focused on promoting everyday needs within the project. This study also attempted to develop performance-based station access strategies to examine transit access within the context of both developments around transit and access strategies on a corridor or line segment basis. This is to encourage direct connections to stations from surrounding developments in order to promote pedestrian and non-motorized access.

The accessibility of the station areas' facilities are evaluated in this study because walking behavior is a complex phenomenon and so a deep understanding of people's perceptions and attitudes is required. This study evaluated the site accessibility of the three stations based on the application of Geographical Information System (GIS), using the space syntax analysis technique. With this powerful tool, it was possible to spatially demonstrate a variety of data layers. The visualization of the results presents them in a more comprehensible and understandable format for different types of user.

The results of the analysis of the accessibility and connectivity of the selected stations are shown in [Figure 7](#). The

results revealed that the highest integration value for non-motorized accessibility was Chidlom station (1.711-1.845), as expected. This calculation could be used to support the functional integration of land use and transit via the creation of a compact and mixed-use environment which would induce more pedestrian ridership. However, when connectivity was taken into consideration, it could be seen that Morchit station (17-18) represents the highest value as a terminal and interchange station with huge areas of parking space. But as it facilitates motorized connections to the station area, a design to reduce the sense of auto domination should be considered for the planned expansion to other transit lines and future land use development.

Based on these results, it seems obvious that to sustain the transit area development, nonmotorized transport has to be able to compete 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. Commuters tend to prefer walking a direct route between households, shops and places of employment, based on the design of the street network. The availability of destinations, together with an interconnected street network, makes walking a more competitive and attractive mode of travel compared to other options. The most direct route should be facilitated with barriers or obstructions (freeways, walls, physical obstacles). Furthermore, the cost, availability, location, and design of parking facilities at destinations is also a critical predictor of travel choice, and impacts on the relative traveling time. Therefore, intermodal transfer facilities appear to be very important in attracting people to use the service, especially nonmotorized amenities. Moreover, it is also important to take accessibility into consideration, as if the station is located far from the trip origin, the number of passengers would be expected to be lower in accordance with the longer distance. There are considerable risks that the anticipated demand and benefits will not be achieved without accessibility improvements to attract more ridership within the service area. However, the provision of sustainable development is also encouraged to promote suitable development consistent with the type of station. This is due to the reason that there are two negative influences associated with the promotion of transit ridership. Lin and Gau (2006) stated that the living-environment quality in station areas will decline with rising congestion, and overdevelopment of living environments in station areas can also create problems for other areas.

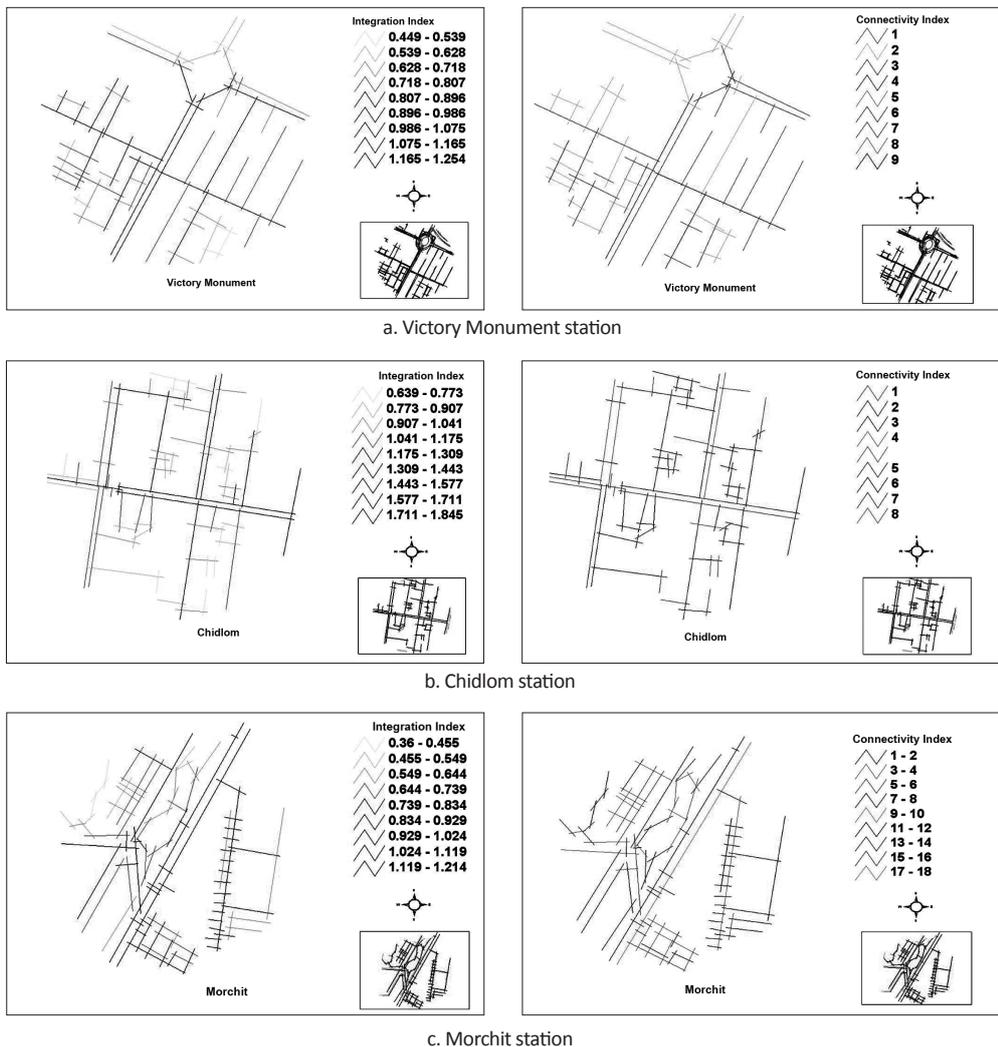


Figure 7. Attractiveness of study area.

### 8. Experts' opinions: Transit Oriented Development Policy

Based on the methodology of the study, more qualitative data collection was conducted by adapting the questionnaire survey as a tool for gathering useful information to incorporate with the obtained data from the checklist and site survey. In the previous section, the survey results of the study area covering a 500 meter service radius of the transit station were explained. Furthermore, this study also employed GIS to integrate spatial data from different sources to calculate the existing characteristics of the site. To confirm the influence

of land use and non-land use factors, this study employed the Likert scale to examine expert opinions and converted them to a numerical value. This was to assess the impacts of all these associated factors of transit oriented development policy which may in some way impact on non-TOD land development. Additionally, to extend the considerations of TOD planning, this study incorporates the quantification of land use development impacts to provide an idea for improving development opportunities where existing development around the station is less appropriate. Based on this concern, the recommendations should be applied to enhance future mobility by locating

residential and employment close to transit station while enhancing nonmotorized access (pedestrian and bicycle). This is due to the fact that higher densities, greater diversity of land uses, and better design are associated with increased transit use and walking, which also results in fewer automobile trips per resident and per worker. To verify the results of the qualitative and quantitative analysis, expert opinion was gathered from 20 specialists, including urban and transportation planning professionals, practitioners, local planners and government officials, regarding transit oriented development policy. These interviews were used to understand how to attract new riders to public transit based on the three different contexts of the sites (Table 2).

The results of the interviews provide valuable evidence to confirm the different degrees of transit oriented development in the three selected stations. Chidlom station has the highest value (2.89) as the station area development has the most potential to attract people, jobs and services, especially in term of its density and connectivity. This is followed by Victory Monument station (2.48), which is able to attract several activities due to its connective role as a major transportation node. The lowest value corresponding to TOD policy is Morchit station (1.43), which requires an efficient transportation and development strategy to create a successful TOD.

## 9. Conclusion

This study developed a TOD planning model to assist urban planners in reviewing land use density in transit station areas by focusing on enhancing transit utilization. To extend the considerations of TOD planning,

Transit Oriented Development Policy	Victory Monument Station	Chidlom Station	Morchit Station
High density	2.10	3.05	1.50
Promoting pedestrian	2.30	3.00	1.40
Create more activity	3.25	2.60	1.50
Connectivity level	2.20	3.30	1.35
Small area for development	2.35	3.00	1.40
Parking	2.70	2.40	1.45
Total	2.48	2.89	1.43

this model incorporates multidimensional analysis, which includes not only the economic efficiency aspect of transit ridership, but also the living environment in terms of its service facilities, and the social equity aspect of inequalities in land development between planned zones and other areas. A number of factors other than the land-use environment can also have a profound impact on future commuting behavior. Finding the right balance between these influencing factors for transit usage to achieve various mobility and environmental objectives remains a significant public policy challenge. Moreover, the implications of this study could help serve as a guideline for the development of a new transit system that not only promotes ridership of public transport while reducing the need for and use of private vehicles, but also drives sustainable policies for mass transit development. It can therefore be suggested that a suitable plan for the proximity area of a station should be primarily determined by land use variables. The more compact and intermixed an urban environment is, the more preferable it is to pedestrians due to the shorter distances between destinations.

**Table 2.** Transit oriented development policy

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