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BANGKOK PUBLIC TRANSPORT ACCESSIBILITY LEVELS

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Bangkok Public Transport Accessibility Levels

SUMMARY
Bangkok transport problems are enormous and one of the major issues is the endless congestion which coincides with the low number of public transport users, especially that of the mass rapid transit. There are numerous issues that cause low patronage, this thesis analyzes to what extent patronage is affected by public transport accessibility levels. Different models, such as gravity and contour measures, can be utilized to measure accessibility. This thesis will use the Public Transport Accessibility Levels (PTAL) model, a model utilized by Transport for London. PTAL is an urban planning tool concerning parking standards and urban density in relation to the corresponding public transport density. From data collection of three university areas new parameters are created to make the PTAL model, such as walking catchment area and bus reliability. PTAL is applied to diverse areas across Bangkok and an in-depth analysis of the area follows.

DATE
2011 Bangkok

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PREFACE

With this thesis I am finalizing my Master International Economics and Business with a specialization in Urban, Port and Transport economics which I started September 2009. In front of you lies the end result of 6 months of intensive exploration together with a great deal of persistence from my part. The end result is a highly micro transport analysis of the public transport accessibility in Bangkok, the city that has become my second home.

Starting the thesis journey was mostly helped by having been offered to do a thesis internship at Thailand Development Research Institute, accepted by Ph. D. Narong Pomlaktong,and Sumet Ongkittikul, Ph.D.who have helped me a great deal with finalizing my thesis. I would also like to express gratitude to the rest of the Human Resources and Social Development team particularly Gritsana Patjakreng, Rattanakarun Rojjananukulpong, Rapee Pholpanich and Achareeya Anantathas. I would also like to express great appreciation to my supervisor Dr P.A. van Reeven for always providing with quick and insightful guidance towards my thesis progress and exceeding my expectations concerning the level of guidance and help he provided. Finally I would like to thank my family who support me in everything I do and without their support I would have never been able to conduct my thesis research here in Bangkok.

1. INTRODUCTION

"Everywhere is walking distance if you have the time"
Steven Wright: comedian, actor, writer

What effects total patronage levels of the public transit system? One answer to this question is accessibility to public transport. Accessibility to public transport can be seen from numerous points of view: infrastructural, activity and utility based. (Geurs et al, 2001) Public transport accessibility of the individual will depend on their income, age, location, job etcetera. Therefore, when dealing with public transport accessibility one must first determine from what perspective accessibility is researched and what factors are to be included in the analysis.

In this thesis the public transport accessibility levels in Bangkok are central, in trying to see if accessibility levels to public transport can indicate the current low amount of public transport users in Bangkok. Lacking high network of mass rapid transit, high unconstrained motorization levels; with a bus system active in mixed traffic has caused major chaos in Bangkok, this cluster of troubles has been referred to as the 'Bangkok syndrome'. (Barter, 2000). There has only been slight relieve of traffic by the implementation of mass rapid transit along the major roads such as Sukhumvit and Ratchadapisek. If the vast motorization continues it will result in a traffic disaster (if Bangkok is not already there) with low accessibility, economic stagnation, urban decay and pollution. (Barter, 2000).

Personal experience and the corresponding annoyances while commuting within Bangkok, has been the motivation for writing this report. To adopt any changes to improve the situation one must first know the current accessibility levels across different locations in Bangkok, and be able to create a visual map of these accessibility levels. Accordingly, the goal of this research is to try design a model which *could* be applied to the whole of Bangkok and represent the accessibility levels across different locations. To create such a model a deeper understanding of the highly general term accessibility is needed. From this the research question becomes: *how accessible is public transport in Bangkok?* The answer to this question will possibly help urban planning of Bangkok; mostly concerning an area's parking standards and residential/business assortment. When accessibility is low there are numerous actions which could be taken, depending on an area's existing urban density. For Bangkok the expectations are that many areas that *should* have high public transport accessibility, but will actually portray rather low accessibility levels. To answer this question first a fine tuned definition on accessibility is necessary. From literature one can look into previous accessibility models employed and from here the most applicable model for Bangkok and this research will emerge.

The first and second chapters deal with a general introduction and commence the term accessibility. Chapter 3-6 will discuss; the current traffic situation in Bangkok, patronage, user behavior and the interrelationship of node, mode and accessibility. The seventh chapter is a discussion of the different accessibility measures, where the most fitting model for this research will naturally emerge. Chapter 8 will discuss the model used in this research, which is a copy taken from Transport for London, known as Public Transport Accessibility Levels (PTAL). Chapter 9 reviews the survey data collected, while chapter 10 applies the data into the model and evaluates a few specific areas in Bangkok. The final chapter is the conclusion.

2. ACCESSIBILITY

"Measured in time of transport and communication, the whole round globe is now smaller than a small European country was a hundred years ago."
John Boyd Orr; Nobel Peace Prize winner 1949

In order for Thailand to maintain its unique economic model as a *sufficiency* economy[1] transformation in the transport sector are vital. The transport system in the capital Bangkok is not self-sustaining. Mainly, the public transport sector is in need of drastic alterations in order to become a competitive alternative to private car usage. One of the aspects that determine a public transport systems patronage is its accessibility. Accessibility in transport is the ease to enter a transport node, or how effortless it is to reach this node. (3G organization, 2011) Accessibility determines where you can go, the mode choice and the cost of the journey. *"Accessibility* refers to the ability to reach desired goods, services, activities and destinations (together called *opportunities*)." (VTPI: 2011). Accessibility is "the extent to which the land use transport system enables (groups of) individuals or goods to reach activities or destinations by means of a (combination of) transport modes." (Geurs *et al*, 2001). The measure of accessibility has been proposed by numerous scholars, all with different models, which posses diverse variables. Before a more detailed account is given on accessibility, one must note that accessibility and mobility are not the same. Mobility can be seen as an individual's *potential* for movement, so one's ability to get from one location to the next (Handy: 1994). Improve

Confusion between the two can exist, because they are interrelated. Policies that are created to increase mobility, will also improve accessibility levels, since it has become easier to reach an area. The 'Oregon Department of Transport' notes that large cities often have poor vehicle mobility. These cities might still have a high level of accessibility, because of large clusters containing a good transport and activities mix. This however, is not the case in Bangkok, where there is a vast amount of traffic congestion and no good public transport alternative. Bangkok should focus on improving public transport accessibility, because it will reduce travel distance, time and cost. Essentially, an improvement in accessibility could result in a substitution effect among users from their car to public transport. So this public transit progress simultaneously improves the road situation. Any policy aimed at tackling congestion could have small economical benefits. It might stimulate urban sprawl, reducing the accessibility for the society as a whole.

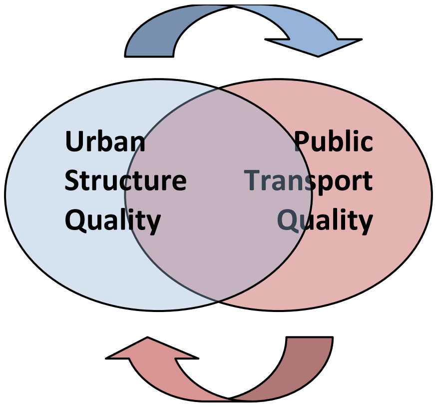
[1] Thailand has a unique philosophy of sufficiency economy which one can only comprehend by first understanding the relationship that exist among Thai people and their monarchy. For further information about 'sufficiency economy" see the following link: http://www.reflectedknowledge.com/clients/GSB/sufficiency/sufficiency.htm

3. BANGKOK TRANSPORT SYSTEM

> "....Bangkok traffic is far too severe and piece-meal efforts will never solve this chaotic problem .... a similar practice of using a ban-aid to patch a serious wound which definitely requires surgery.... but who could be a SURGEON for Bangkok's traffic problem?"
>
> *Yordphol Tanaboriboon; Professor of Transportation Engineering*

Bangkok's traffic problem is enormous: lack of reliable public transport, congestion, bad quality walkways and lack of rules and enforcement are just some of the major concerns. For example, Ratchadapisek Road, a large business area has seen traffic speed drop from 8 - 9 kilometers per hour (kph) to a meager 2-3 kph during rush hour. (Pianuan *et al,* 1994). According to the Office of Transport and Traffic Policy and Planning (OTP) the average speed during rush hour on Bangkok main roads in 2002 was around 22 kph (www.otp.go.th). Throughout history, changes in transport where not appropriately matched with transport policy and urban planning. This failure of correct planning was fatal, as urban structure and public transport are not mutually exclusive. They are highly interrelated, affecting each other quality levels. (Figure 1) (Veeneman, 2002) A paper published by Murdoch University discusses the changes in Asian cities compared to Western cities and how they changed as a" type" over time. The types of transport city design possibilities are represented in figure 2. When mass motorization started by the 1960s Bangkok had busses which were operating in mixed traffic and high density levels. This caused the "Bangkok syndrome", since the structure made the city vulnerable to the negative impacts of a rapid increase in motorization. The corresponding negative transport impacts of motorization where highly visible, such as congestion, high pollution and sprawling. (Barter, 2000) As motorization increased along the years, cities like Seoul and Singapore shifted from bus cities to transit cities by restricting motorization and promoting public transport. Bangkok, however now lies in a problematic area between auto and transit cities, because no country policies were undertaken to tackle the mobility trend of mass motorization. The position Bangkok is in now is highly volatile and actions have to be taken. Moving backwards is not an option. But neither is the direction of becoming a 'car city' as the diagram could suggest. This action is impractical as the current road network cannot support this action, nor is there space to expand this low road supply. (figure 3) Bangkok has favored the car as their main transport option for too long and should opt towards becoming a transit city.

Figure 1: Relation between Urban Structure and Public Transport



"You have to be cruel to be kind"[2]. So, disregarding the political probability of realizing them, one must look at those policies and strategies that will be able to alleviate the situation to benefit society as a whole. Bangkok seems to have a system of incrementalism, where urban

[2] http://idioms.thefreedictionary.com

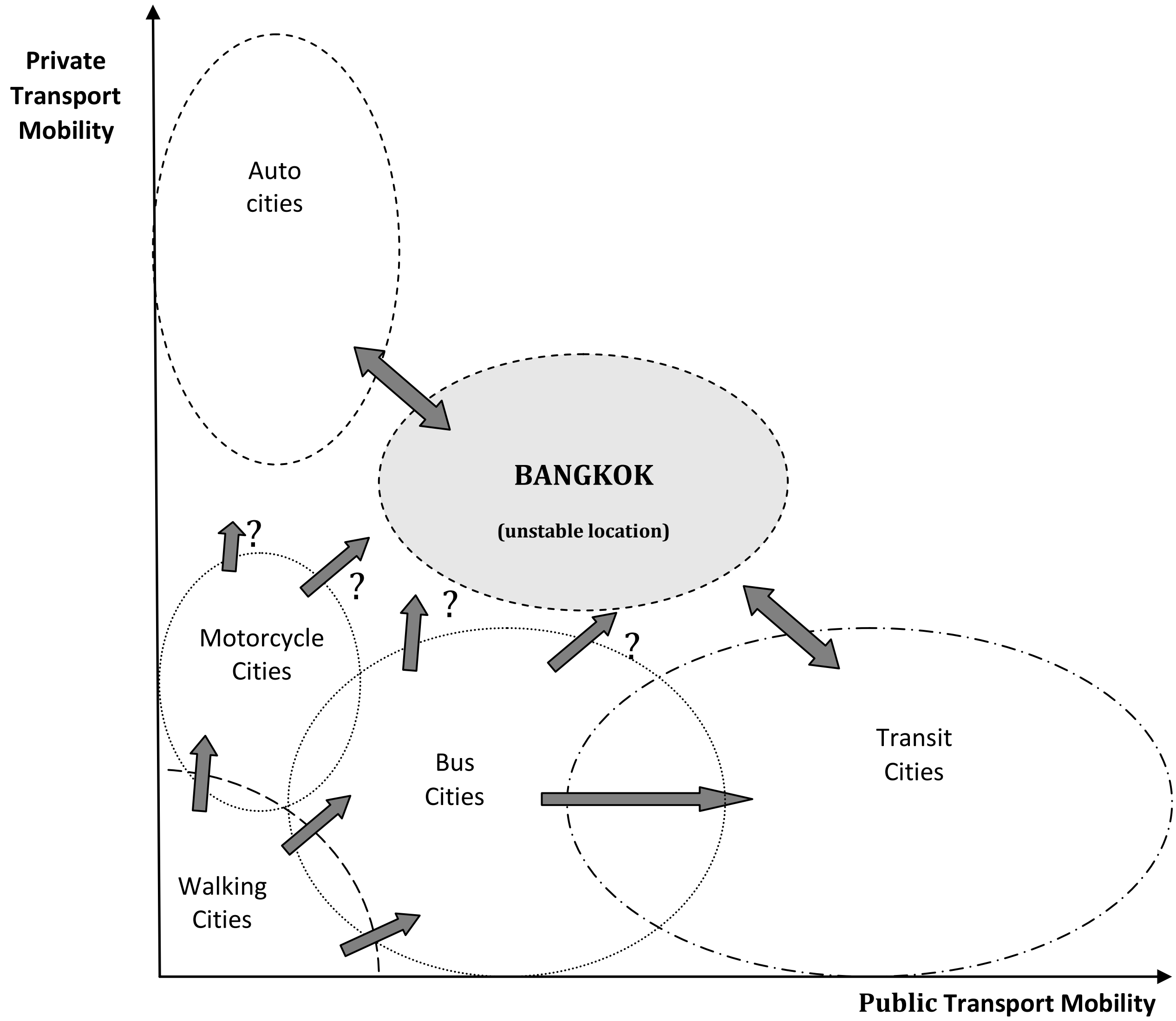
and transport planning is **not** necessarily executed keeping the interest of the people at heart and taking into account possible future city development. Rather Bangkok suffers from many stand alone projects across the city which can cause troubles with urban design efficiency. Ideally, Bangkok would deviate from a system of incrementalism and the government could initiate a big push across the economy with heavy investment and changes across the transport sector, as Mass Rapid Transit (MRT) development was late compared to other Asian cities (Seoul in 1974, Beijing in 1969)[3].

The current level of priority on the road is private vehicle, buses, freight transport, pedestrians. This priority pyramid needs to be reversed, with pedestrians at the top (World Bank Report, 2007). Authorities are still focused on moving vehicles and should switch standpoint and opt for moving people. The current transport structure is hard to change; especially the inner city road supply is highly fixed. (Tanaboriboon, 1992) However in the short run, improvement can be made through Transport Demand Management (TDM) but this is not highly welcomed by car users. (Bhattacharjee et al, 1997). TDM such as the introduction of bus lanes, increase of parking fees and raise in annual road tax are some of the least favored TDM measures according to car owners. However, on a short-term basis these TDM measures are most straightforward and effective in improving the situation instead of long-run MRT expansion. These steps have not yet occurred politically as can be seen from the World Bank Report displayed below.

> *The road network is characterized by the presence of very wide primary roads and small local side streets roads (known as "soi") that run off them. It is estimated that there are some 6,850 km of road in the BMR, comprising: (i) 520 km of expressway and special/national road and 1,450 km of rural road that are under the jurisdiction of the national government; (ii) 1,220 km of arterial road, 410 km of sub-arterial road and 2,450 km of local streets (sois) for which the BMA is responsible; and (iii) an indicative 800 km of road for which neighboring provinces are responsible. There are few medium-width distributor roads effectively connecting the primary roads. The first urban expressway, the First Stage Expressway, which is a toll road opened in 1981. Since that time an extensive series of major road and expressway projects have been completed.*
> *(Source: World Bank Report, 2007)*

[3] wikipedia

Figure 2: City types of private versus public transport mobility



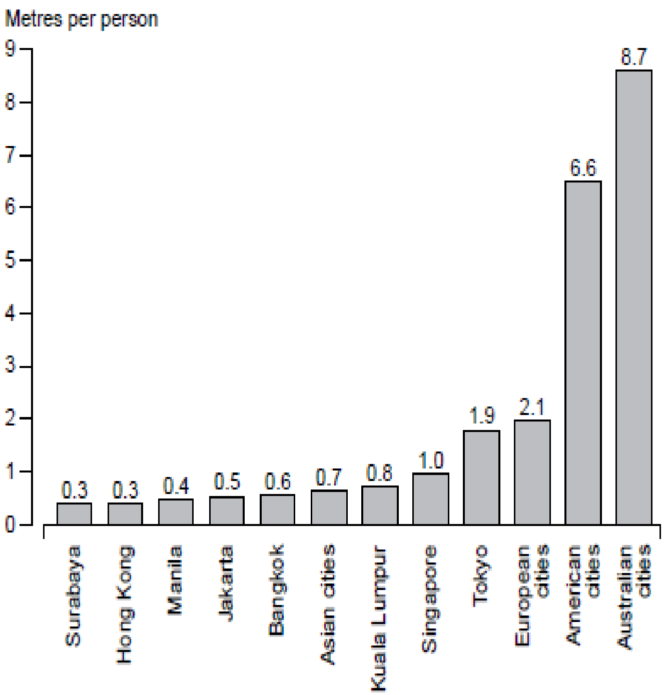
Source: Murdoch University

3.1 PRIVATE VEHICLE

"Infrastructure creates opportunities and constraints,
but commuter's behavior creates traffic"
Punpuing, Ross, 2000

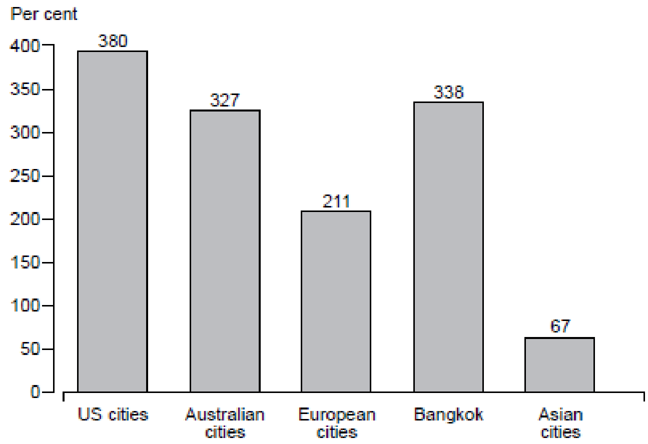
Claims are made that congestion is caused by the lack of road, especially when compared to other cities (see figure 3). Only 11% of urban area is road in Bangkok, opposed to 20% in other cities (Tanaboriboon, 1993). Despite the lack of road, the space allocated to car parking defiantly makes up for this loss. Parking is cheap and there are too many spaces when compared to other cities (figure 4). The total level of 338 per 1000 jobs exceeds that of Australian cities. This only enforces a person's reason for driving their car. The 'lack-of-road' argument and too many parking spaces do not solely explain congestion; other major contributors are inability to control traffic demand, institutional failure, lack and wrong knowledge about transport behavior with the road users, lack of corporation between transit modes, lack of qualitative and reliable public transport and low law enforcement. (Bhattacharjee et al, 1997) There are so many issues to deal with, that solving them is impossible, rather one must view imposing measures to *relieve* the problems. (Tanaboriboon, 1993).

Figure3: Length of road per person



Source: Sustainable Urban Transport Systems Project (ISTP)

Figure 4: Parking spaces (per 1000 jobs) in central business district (CBD) in Bangkok compared with other cities



Source: Sustainable Urban Transport Systems Project (ISTP)

To implement change, one must understand the current situation. Table 1 depicts the existing transport demand. In the Bangkok Metropolitan Region (BMR), private mode choice is defiantly the preferred mode, despite the known terrible traffic condition in Bangkok. The predicted travel forecast in 2015 was based on extensive public transport system, thus the extensions to the current Mass Rapid Transit. This number will surely not be realized, since the current lines suffer from huge delays due to political stress, land expropriate issues, transparency troubles, the 1997 economic crisis, financial problems and challenging civil engineering. (Wancharoen, 2010) Table 1 predicts that MRT patronage would increase by 12% due to a decrease in people using private mode, 46% to 40% and also due to bus users switching to use MRT, bus patronage decreases from 37% to 31%. Since the extension lines are not yet constructed or operational and therefore the actual coverage area of the MRT across the city is not very high yet, it can be assumed that this mode shift has yet to occur to a large extent.

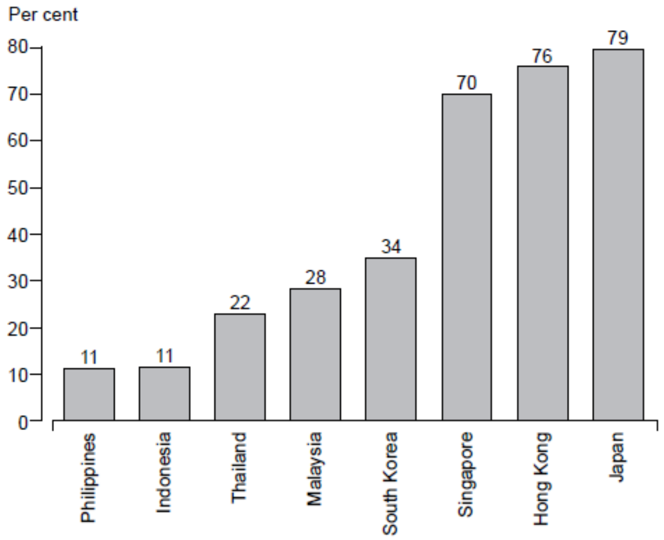
Table 1: Forecast travel demand in the Bangkok Metropolitan Region (BMR) Source: World Bank report 2007

	2005	2015
Population (M)	10.8	13.0
Travel Demand		
Person trips/day (M)	19.4	23.4
Modes of Travel (%)		
Private modes	46	40
MRT	3	15
Bus & other public transport	37	31
Walk	14	14
Total	100	100
Motor Vehicles		
Number of in-use vehicles (M)	3.1	Na
%household with no vehicle	25	na

In Bangkok, like many Asian cities, the percentage of motorcycles taking active part in everyday traffic is much larger than Western countries. Figure 6 shows that the total ownership of private vehicles is highest in Bangkok, 296 in total, with around 40% of the total fleet being motorcycles. When you split this figure into motorcycle and car, only Tokyo has a higher number of cars, 165 to 225. However, Bangkok still outshines every other Asian city in the total private vehicle ownership department. Bangkok has double the amount of vehicles compared to wealthier Singapore which has only 143 vehicles per 1000 people. (Kenworthy, 1995). This shows that income alone is not a reason for explaining high vehicle ownership, as Singapore on average has a much higher purchasing power (figure 5). Not only vehicle *ownership* in Bangkok is highest, also the *number of trips by private vehicle* in Bangkok over shines all other major Asian cities, as shown by figure 7. Figure 8 shows the vehicle ownership in Thailand for 2007 and clearly illustrates that the number of private vehicle ownership has increased rapidly. In 2007, per 1000 people 609 people own a private vehicle, of which 221 are motorcycles which is more than one-third of the total fleet. Comparing 1990 and 2007 one can see that motorcycle ownership has increased by 69%, whereas total car ownership has more than doubled by 135%.[4]

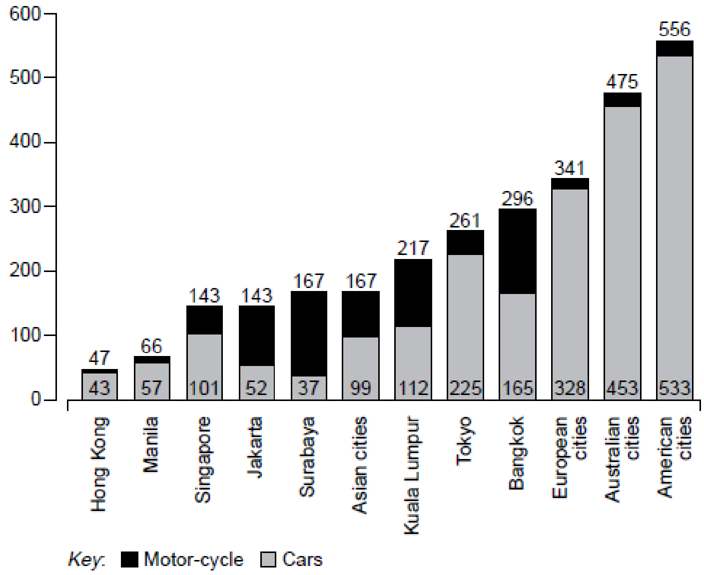
4 Percentage change calculation of (new value-old value)/old value e.g. motorcycle = 221-131/131= 0.6870

Figure 5: National purchasing power per capita in Asian countries compared with the USA (1990)



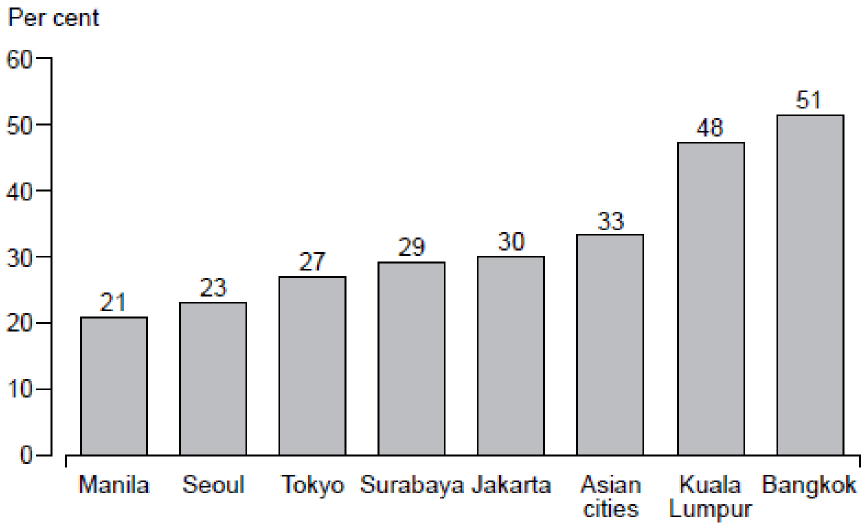
Source: Sustainable Urban Transport Systems Project (ISTP)

Figure 6: Car and motorcycle ownership per 1000 people



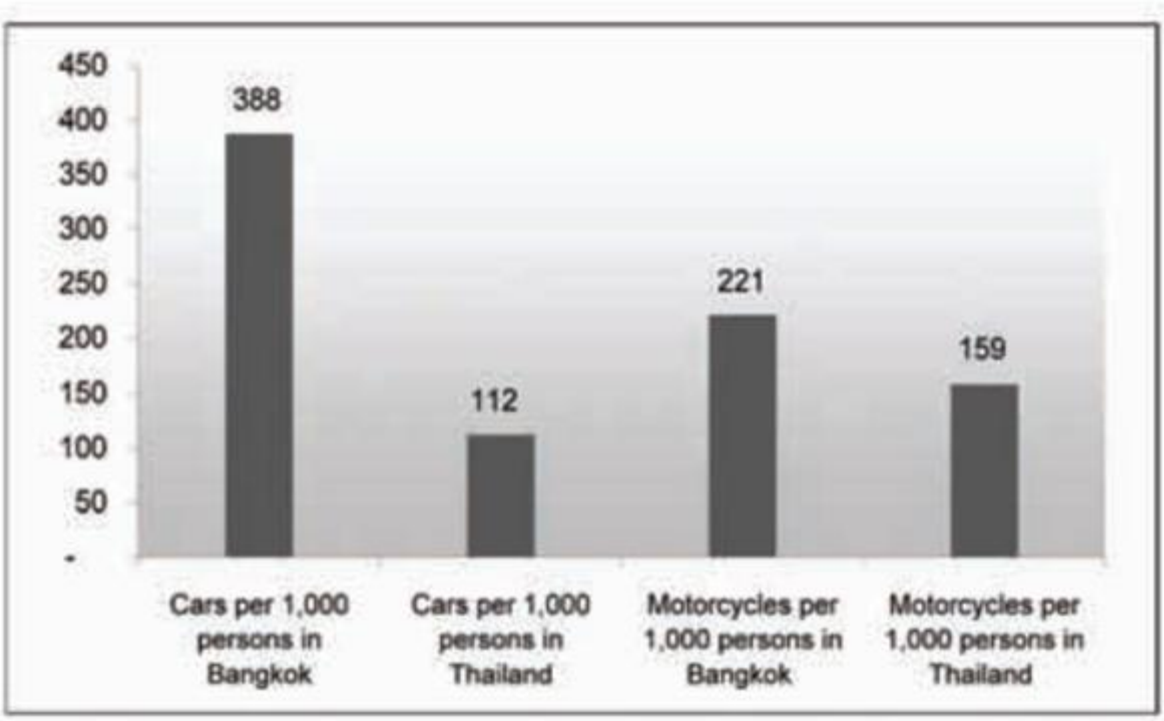
Note: Asian cities' figures are from 1990, the others are from 1980
Source: Sustainable Urban Transport Systems Project (ISTP)

Figure 7: The proportion of all daily trips by private transport in Asian cities



Source: Sustainable Urban Transport Systems Project (ISTP)

Figure 8: Vehicles ownership in Thailand and Bangkok in 2007 (In-use vehicles per 1,000 people)



Source: Based on data from the Department of Land Transport.
Note: Cars include sedans, personal vans and pickups. Population data for Bangkok and Thailand used for this calculation is from NESDB.[12]

3.2 BUS

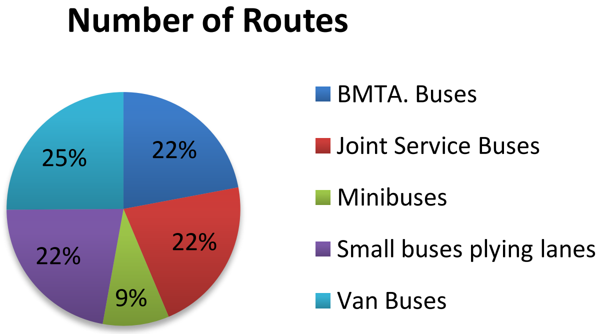
The bus system plays a vital role in human mobility, especially for the low income group and those people located outside of the central business district (CBD). (Bray and Sayeg, 2002) The Bangkok Mass Transit Authority (BMTA) is the sole operator of all bus lines in the BMR, however there are numerous private organizations who operate as a joint-service under BMTA concessions agreements. The BMTA is a state owned enterprise (SOE) with the government being 51% shareholder.[5] By 2006 there were a total of 16,639 busses on fixed-route services. These are subdivided into 3579 BMTA busses, 3504 joint service buses, 1078 minibuses, 2264 small bus lanes and 6214 Vans. Table 2 and pie chart 1 show the total number of busses and the fitting number of routes allocated to the different bus types. (BMTA website: http://www.bmta.co.th). The joint-service routes often operate similar routes as those of the BMTA. The minibuses can be classified into two types. The first one is main road buses on long routes, while the second one is *songtael* (a type of truck with side benches for seating) which act as feeder systems for the sois (streets in Thai).

[5] http://www.dlt.go.th/th

Table 2: Total number of busses

Type of Bus	Number of busses	% of total bus	Number of routes	% of routes
BMTA. Buses	3,579	22%	108	22%
Joint Service Buses	3,504	21%	106	22%
Minibuses	1,078	6%	45	9%
Small buses plying lanes	2,264	14%	108	22%
Van Buses	6,214	37%	123	25%
SUM	16,639	1	490	1

Pie Chart 1: Number of Routes according to bus type



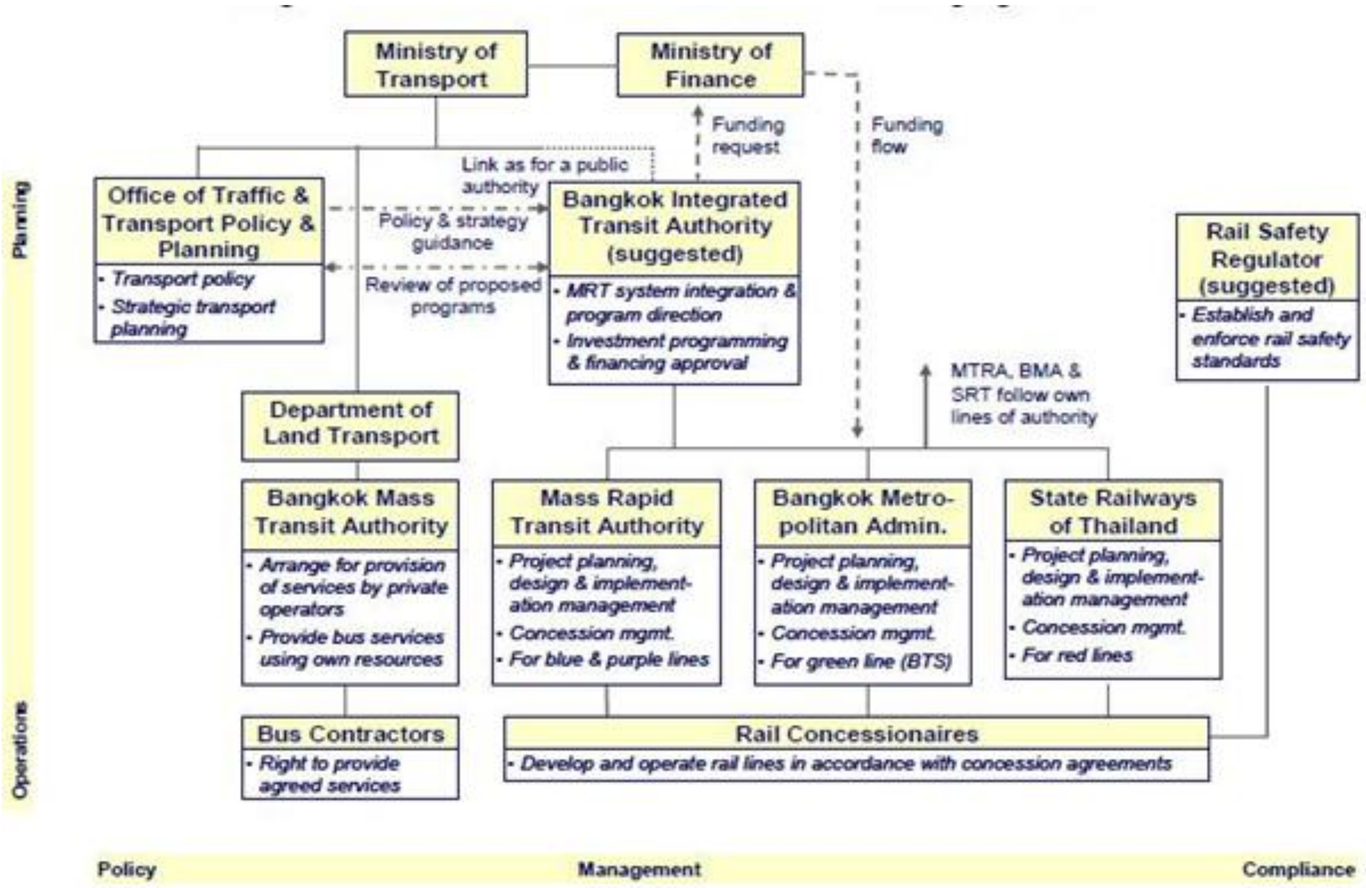
The BMTA has been incurring deficits since its first operation and is now close to approaching $1 billion (Maekin, 2005). There has been constant public pressure for higher levels of privatization. Also, there is high need for reevaluation of the current routes as there is a lack of a systematic bus route planning. The different public transport modes are not integrated with each other (or in response to each other) and this adds difficulty with journey planning, frustrations and possibly also elongates journey time. These failures of applying route alterations and adaptations are another possible issue that chases away potential patronage from choosing public transport as their preferred mode of transportation.

The root cause of all of Bangkok's transport problems are *institutional failures*,. Due to low transparency and no strong enforcement of rules any policy change or project will be met with high ineffectiveness. (Maekin, 2005) The BMTA enjoys a monopoly position and this lack of appropriate competition combined with low transparency continues to deteriorate the inefficient bus operating system. The lack or rules and regulations, blurred agency responsibilities and low transparency negatively affect policy planning and implementation. The high amount of bureaucracy really dampens progress and to a large extent gives rise to this corruption.

> *"Policies, regulations, protocols and tariffs which are subjective and non-transparent must be abolished to barricade opportunity for corruption and thus create a milieu for investment […] redundancy of responsibility creates confusion and disincentive to cooperate among parties concerned.*
> *(TDRI-Transportation Master Plan, 1997)*

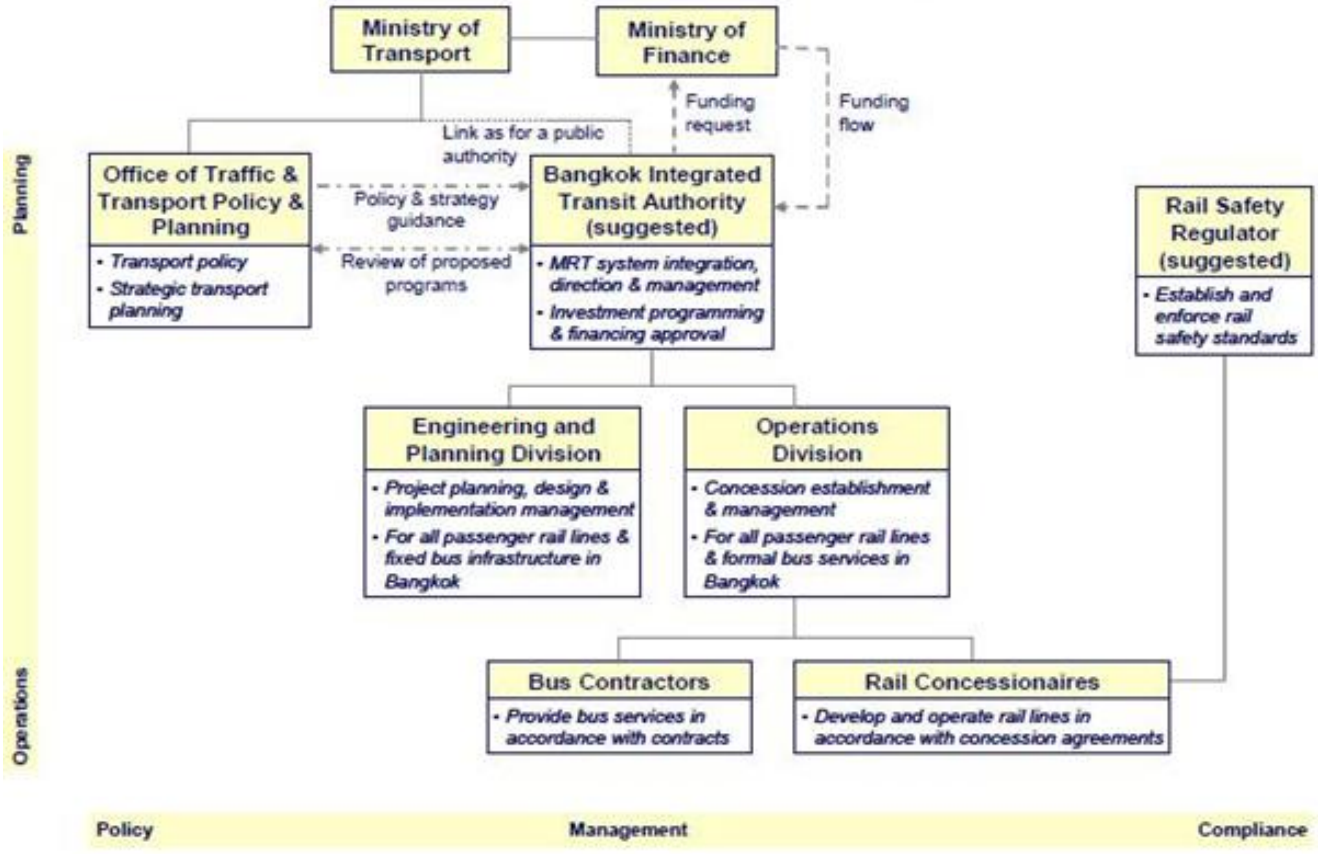
The flow chart below shows the current agencies involved and their roles, the second flow chart (figure 10) offers an idea about the proposed structure as given by the World Bank report 2007. The second flow chart will possibly lessen the extent of corruption occurring across different agencies. It also makes the whole process of transport planning more clair-voyant.

Figure 9 Institutional Structure with a "Managing Bangkok Integrated Transit Authority"



Source: World Bank Report 2007

Figure 10: Institutional Structure with a "Full Bangkok Integrated Transit Authority"



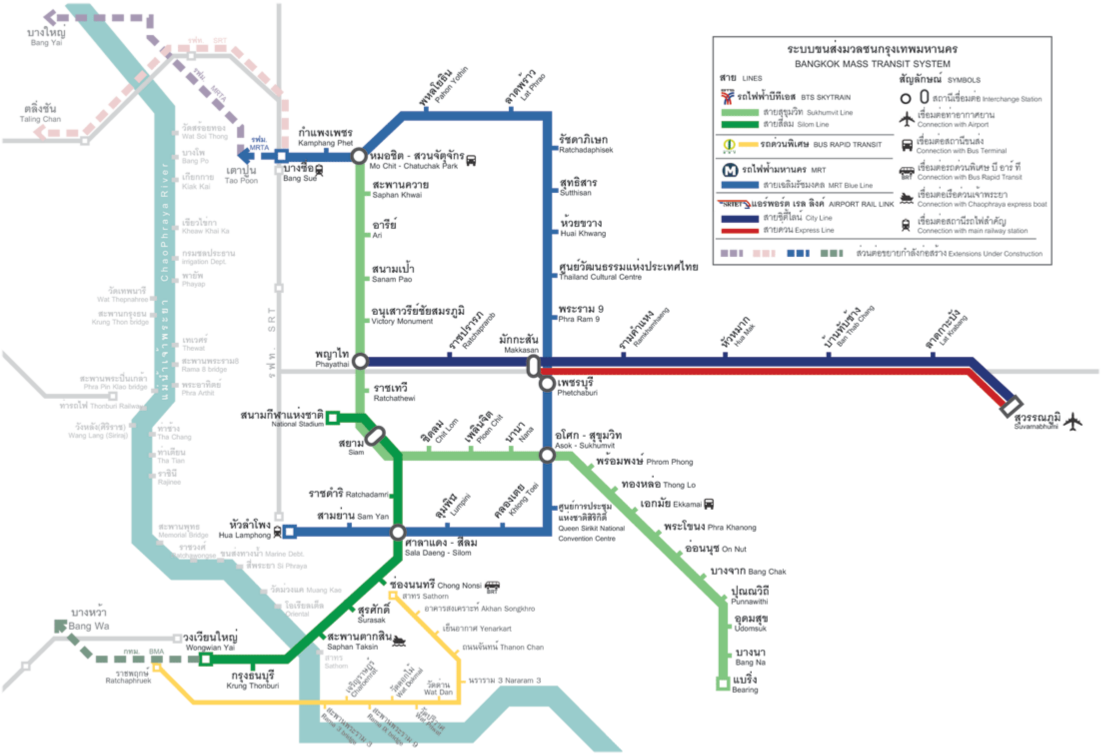
Source: World Bank Report 2007

3.3 MASS RAPID TRANSIT

A second public transport option is the Mass Rapid Transit and consists of the Bangkok Mass Transit System Company LTd (BTS) also known as the skytrain which has two lines, the sukumvit and silom line. The BTS operates under a 20-year concession granted by the Bangkok Metropolitan Administration (BMA). (http://www.btsgroup.co.th). The BTS now also operates the Bus Rapid Transit (BRT) since May 2010.

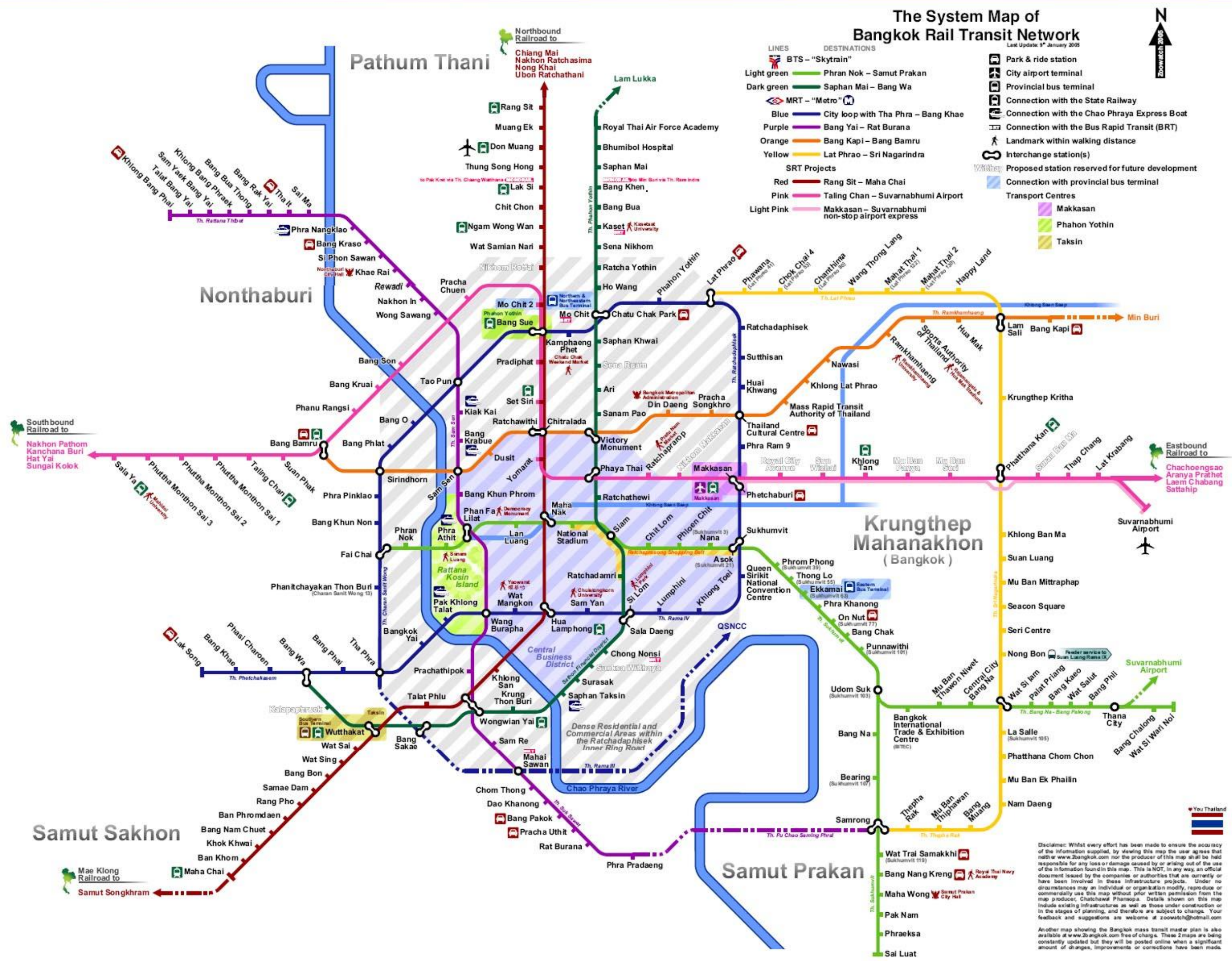
The second Mass Rapid Transit option is the subway with only one line. The Mass Rapid Transit Authority of Thailand (MRTA), a government agency, build most of the infrastructure of the subway and it handed over a 25-year concession agreement. The Bangkok Metro Company Limited (BMCL) is the only private operator who won the bid. (The Daily Star, 2010)

Suvarnabhumi Airport Rail Link (SARL) is open since August 2010 which links the Airport to BTS Phaya Thai Station and subway station Phetchaburi. It was build and operated by the State Railways of Thailand (SRT). A full diagram of the 3 mass transit options is displayed below.



Source: ReviewThailand (http://reviewthailand.wordpress.com)

Table 1 displayed the forecasted travel demand for 2015. It shows that MRT ridership is expected to increase from 3% to 15%. This forecast was made according to the expected MRT extension lines. However, it will still take a long time before these lines will be in operation. Due to numerous circumstances, construction has not even started yet for the new lines. (BMCL 2009 Annual Report) The delay in construction and the low return are not surprising according to Flyvbjerg *et al,* (2003) they refer to this as "the Megaprojects Paradox", where despite the poor performance of major projects, they are still being planned and built. The figure below represents the future (planned) transport system of Bangkok with all mass transit lines in place.

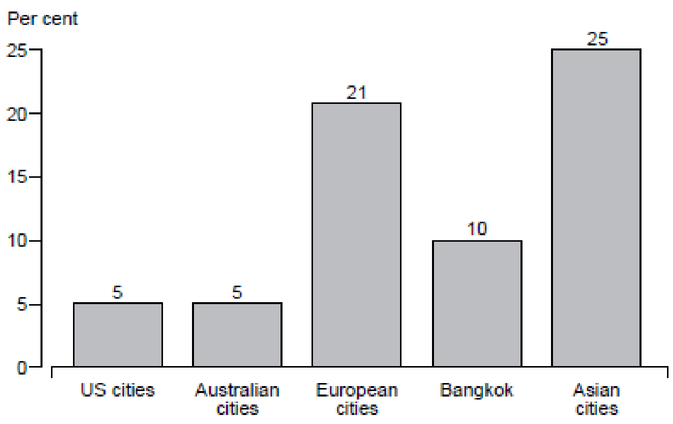


Source: The Subway Page (http://people.reed.edu/~reyn/transport.html)

3.4 OTHER MODES

Other modes refers to walking, klong (a taxi-boat), tuk-tuks, taxis and motorcycle taxis. Taxis are relatively cheap compared to Western countries and opt for a good substitute for long distances, especially when travelling with 3 or more people. Motorcycle taxi's are popular among Thai for commuting short distances, or when wishing to avoid traffic.[6] Walking ranks last according to prioritization of most important modes. Prioritization according to level of importance goes car, bus, freight transport, walking. (World Bank Report, 2007). Walkability in accordance with the World Bank definition is: "The extent to which the built environment is friendly to the presence of people living, shopping, visiting, enjoying or spending time in an area". Compared with other Asian cities Bangkok is falling behind with the total amount of people using walking as a mode of transport. This is clearly displayed in figure 11, accordingly the BMA should focus on promoting and improving walkability for Bangkok's residents. (Kenworthy, 1995) Walkability in Bangkok is a complete nightmare for several reasons. First, responsibility of pathway quality maintenance is unclearly defined in Bangkok. Broadly speaking the responsibility falls with that agency accountable of the linked road. (Bangkok Post, 2009) Secondly, the main concern with historical planning of space distribution was *not* walkability. At last, utility agencies are not held responsible when they damage or move sidewalks and can leave them in ruins. Improving walkability would greatly enhance accessibility. People behavior concerning walkability is observed by Townsend and Zacharias (2009) who found that people choose with greater frequency those exits with a platform level or smooth walkways. This path choice might however be irrelevant to the walkability as there is high path dependence. Those areas which are most visited tend to have smooth walkways (observe the high quality pathways at BTS Siam and National Stadium to the shopping malls). Another major hindrance of walkability is obstacles along the way. Often, especially near MRT area, there is enough space allocating towards footpath, however part of this space has been allocated to other facilities, such as food stalls. (Pamanikabud and Pichittanapanya, 2003). A walkability index was created by the World Bank (2009) and the report on Bangkok is shown in figure 12. It is shown that the quality of footpath is highly differentiated among differentiated areas in Bangkok. However, the quality of reference to this index is doubtful, since the results were based on only 29 valid surveys.

Figure 11: The proportion of workers using walking and cycling for the journey to work



Source: Sustainable Urban Transport Systems Project (ISTP)

[6] http://www.thailandguru.com/motorcycle-taxis.html

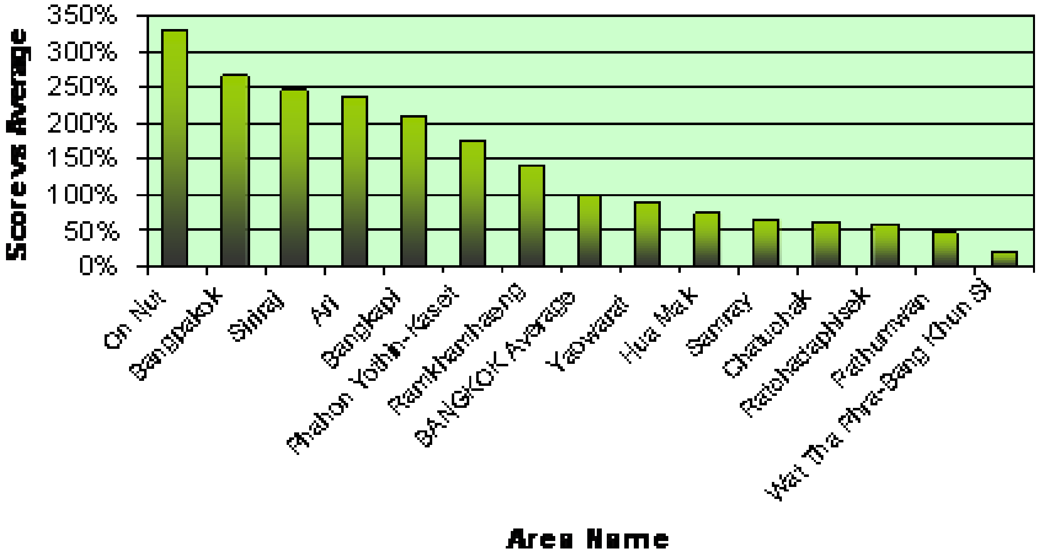


Figure 12: Walkability Scope per Area

Source: World Bank Report 2009- Walkability

4. PATRONAGE

This thesis aims to investigate the accessibility levels across Bangkok, as it might explain to some extent the depressing number of public transports users. Figure 7 shows that more then 50% of all daily trips are done by private mode, the highest in Asia, indicating that patronage of public transport is rather low. Also, the rapidly increasing number of private vehicles per 1000 people is among the highest in Asia with car ownership having increased 135% between 1990 and 2007 (figure 6 and 8) The rise of the economic power of the middle income group is also present in Bangkok, and these people are quickly switching from public transport to private cars. The inefficient bus system in Bangkok has seen patronage drop 5% annually (World Bank, 2007). As shown in table 1 by 2015 the total population in BMR is 13 million with about 23.4 million trips per day. The current patronage for the skytrain mounts to 451,300 trips per working day, 346,281 trips for the weekend and official holidays have an average of 245,708 trips per day. (BTS 2009-2010 annual report). Initially the forecasted demand was much higher then later was realized; the megaprojects paradox (Flyvbjerg *et al,* 2003). For the BTS the current patronage is around 70% of the forecasted demand.[7] The subway ridership sticks around 220,000 riders per day which is far less than the expected 400,000 riders per day (BMCL website, 2011) The low number of users might be due to the relatively short coverage area of the MRT.

> *"For example, in Buenos Aires between 1993 and 1999, the metro and suburban rail systems increased with 75 percent of its previous length, and the number of trains on time by 20 percent, the patronage increased by 125 percent even though the fare rose by 30 percent over the period in real terms under a Build-operate transfer agreement. (BOT)" (Bengtsson,2006)*

This example might clearly show that forecasted demand will only be realized once the extension lines are intact. The relatively limited accessibility the MRT offers and accordingly the low number of opportunities that can be reached, offers an explanation for the low patronage. Comparing patronage levels to other cities, especially Western cities might not offer great insights. Every city is unique and has its own historical development, geographical location, urban development, density and problems. Accordingly, every city should be seen as a case study with its own set of transport problems which needs to be dealt with fittingly. Many Western cities managed urban density and transport planning much more efficiently, because from an early stage they managed to control the situation. Besides, Western cities are not comparable to the population size of Bangkok. For example, the biggest city in the Netherlands concerning population size is Amsterdam with 747,290 inhabitants[8]. The modal split is dissimilar compared to Bangkok because a large number of the population performs daily trips by cycling. Public transport ridership is higher in larger cities such as Amsterdam and Utrecht with 16% and 12% respectively, opposed to smaller cities in the Netherlands where total ridership is around 5% (2007). [9] Wikipedia provides a list which shows the most used metro systems in terms of passenger rides per year with at top Tokyo with 3.160 billion people (2009) while the Bangkok skytrain takes the 60th place with 136 million and the subway is at place 91 in the list with 63.7 million passengers. London, with a population of more then 8 million people, is the second European city after Paris with 1.107 billion users per

[7] http://infofile.pcd.go.th/air/DIESEL2_Sayeg_Section_1.pdf?CFID=4877908&CFTOKEN=85911780
[8] http://www.iamsterdam.com/en/visiting/touristinformation/aboutamsterdam/factsandfigures
[9] http://www.vejdirektoratet.dk/imageblob/image.asp?objno=7178.pdf

year. There are cities with a far lower population size then Bangkok but a relative similar amount of MRT patronage as Bangkok. For example, Rotterdam has 87.1 million passengers per year and a city population of 611,000, less then 1/10 the size of Bangkok's population. Another example of high ridership is the European city Vienna with 1.7 million people and a total patronage of the U-Bahn at 534.4 million. Many Asian cities have surpassed Bangkok in public transport patronage numbers, such as Shanghai, Singapore and Taipei; with 2 billion 744.8 million and 505.4 million rides each year.

Obviously, patronage is not solely determined by accessibility. Another reason causing the lack of qualitative transport structure is the failure of institutions. There is a lack of accountability across those parties involved in the transport sector. Rules are not highly enforced and there is corruption across all levels in society, often by means of regulatory capture. Many transport agents are both complementary to each other but also direct competitors, such as the bus and subway system. Regulations to ensure healthy competition between these agents without harming society are not commonly in place or enforced. There is no standardization among these transport agents, with for example the ticketing system. Due to all these regulatory problems, transport agents in Bangkok are stuck in "game theory situation". A good example of a game theory situation is represented in table 3, where the accessibility problem is the lack of a skywalk to ease the interchange between the airport link station Makkasan and subway station Phetchaburi. The table below shows the situation as a dilemma. There is lack of accountability and neither of the two organizations has built the skywalk so far. The walking distance between the two stations is far with a bad quality road, lack of walk way and a busy traffic crossing for pedestrians. Thus, many pedestrians might avoid this 300 meters irritating walk and opt for a taxi instead.[10] As a consequence, both parties loose in the current situation, because potential customers switch to other modes of transport. The only way to solve this problem is by collective action and sharing the cost of the skywalk construction.

Table 3: Game Theory Approach about whether or not to construct a sky-walk between Makkasan and Phetchaburi station

		State Railways of Thailand (SRT)	
		Cooperate	**Do nothing**
Bangkok Metro Company Limited (BMCL)	**Cooperate**	Both gain customer satisfaction and possible increase in ridership	BMCL financially loose SRT financially gain
	Do nothing	BMCL financially gain SRT financially loose	**Both loose (current situation)**

[10] http://reservethaihotels.net/2385/whats-wrong-makkasan-airport-railway-link-baggage-check-in-service/

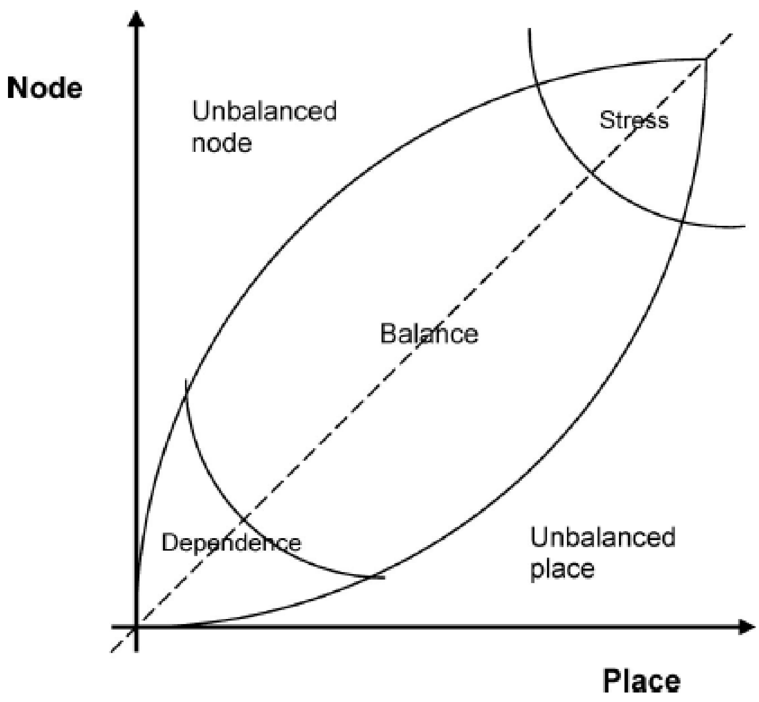
5. NODE, MODE AND ACCESSIBILITY VISUAL MODELS

Node is that area in a transport sector where people are able to enter public transport or switch between different modes. *Mode* refers to the different types of transport options available. One can measure accessibility applying only some elements of the transport system, more significantly, only to the nodes along the route of a certain mode. (Rodrigue, 2011). “Accessibility is a good indicator of the underlying spatial structure as it takes into consideration location as well as the inequality conferred by distance to other locations.”(Rodrigue, 2011). A high number of route options at a node increase accessibility, but decreases it at the same time. This is due to interchange and the prolonged mode travel time due to more stops, which might be relatable to the total number of public transport users. A high number of unpleasant transfers adds uncertainty and incentivizes the commuter to use private vehicle transportation instead. “Transfers are endemic in the public transport system, especially in large multimodal networks” (Vuchic, 2006). Operators are aware of the inconvenience transfers can cause; however there has been a lack of research on this matter. (Smart *et al*, 2009). Guo, *et al* (2010) explain how there are numerous transfer experience assessment difficulties. Firstly, the analysis is based on stated preference (SP) and reliance on mode choice. As SP gives low predictability for the different transfers and the difficulty in distinguishing between mode choice and (non) preference for transfer can cause biased in the data. Secondly, there are definitional issues such as how to measure “transfer”. (Wardman, 2001). Thirdly, transfer experience is not solely determined by the waiting time, there are other factors such as the transfer environment that can play a vital role on the overall experience. (Clever, 1997) “There are a number of interchanges attributed desirable to commuters: personal security, travel info, ticket arrangements reliability, short waiting time, reduce institutional and organizational barriers.” (Hine, Scott, 2000)

5.1 NODE-PLACE MODEL

The Node-Place Model proposed by Bertolini (1999) states that station quality improvement, will improve accessibility, creating *circumstances* for even further progress and there will be diversification of the area, accordingly responsive infrastructural development will take place. This whole progress shows a possible multiplier effect and show the importance of accessibility in a transport network. In view of this, process will ultimately depend on the circumstances; the model shows existing and *potential* development. The model he proposed as shown in figure 13 relates node and place. In the diagram five average options surface. The points along the middle line are in balance concerning their mixture of land use and patronage is at sufficient levels. At the bottom of the middle line one can observe a dependent location. Here the competition for space is low, and the demand for diverse transport options is minimal. For example, a rich suburb where everybody owns a car and explores his/her activities outside of the suburb. The highest point ‘stress’ shows that the diversity and intensity of both transport options and activities is at a maximum, so it’s a strong node (high land use) and strong place (realized it is a strong node). This area can become under stress, as too many options and land use can cause chaos, such as train central stations. Lastly, two unbalanced locations are identified. In one location transportation options are too high relative to the number of activities, which would mean a depressing number of public transport users. While in the other locations high number of activities are in place, but no qualitative node network to support this. This could indicate overcrowded public transport modes (or too few users) or too many cars on the road from people trying to reach the attractions. The direction adopted by the unbalanced locations is of interest. Since, an unbalanced place can either decrease its place value, (increase property tax) or it can increase node value (increase supply of modes which could increase patronage). A reverse interpretation can be used for an unbalanced node value, thus patronage could increase if place value increased. This shift from an unbalanced node, by increasing place value holds true for certain areas in Bangkok. A good example is the new Central Plaza shopping mall that is being built close to subway stop Phra Ram 9. This is likely to result in a high rise of patronage specific to this station, turning the node more towards becoming a balanced node along the middle line. Buck Consultants International (2003) applied this model to suggest the effect of accessibility on real estate value. Where, if the location is not at a "stress' point yet, one can draw the line for market potential and distinguish what possible node or place value adjustments should occur to realize this potential. "There is a strong mutual relationship between the two as node and real estate add each others market potential and they reinforce each others competitiveness" (Peek *et al.*, 2006). Most of the locations in Bangkok will fall under *unbalanced locations*. Urban density is high in most areas, while the available number of public transport options is rather depressing. The transit system is not competitive as most busses are always stuck in gridlock traffic. (Kenworthy, 1995). Accordingly, node quality in most area across Bangkok is weak. In view of that, there are two options available with respect to the Node-Place Mode to either reduce land use or to improve node value. The first one to tackle land use does not seem a viable choice. Public transport simply *has* to improve in order to augment the node values and shift most of Bangkok's current unbalanced places up towards a more balanced location. This equilibrium is where place value aptly meets node value.

Figure 13: Node-Place Model



6. USERS BEHAVIOR

"I am not against cars. But your city does not have to be oriented toward them. A car is like your mother-in-law. You want to have a good relationship with her, but you can not let her conduct your life. When a city has good public transportation, it becomes for people and for cars."
Jamie Lerne; former Mayor of Curitaba, Brazil

Accessibility levels can be essential in shaping a person's travel behavior. Commuting is part of everyday life and in Thailand one might adopt the Thai cultural '*mai pen rai'* attitude to all the transport problems. *Mai pen rai*, can mean numerous things, such as it does not matter, it is ok, do not worry or let it be. It is applied to many daily life situations and for many commuters they might complain about the traffic conditions, but most Thai have also adopted the *mai pen* rai attitude about commuting. The opportunity cost between work and home location for most Thai is very elastic, as one should not worry about what one cannot change or explain. (Punpuing, Ross, 2001)[11] Car ownership can explain to a large extent users behavior in Bangkok. Steg et al (2001) classified the determinant of car ownership in 3 categories: symbolic, affective and instrumental factors. There is a fourth option, which applies to Bangkok: 'social orderliness'. (Choocharukul *et al*, 2007) Social orderliness refers to 'Thii tam thii soong' literally meaning 'high place and low place' as everything in "Thai perception is according to a hierarchical system. People can be "high" or "low" according to their age, family background, occupation or professional rank and whether they are Buddhist monks or clergymen in other religions." (Vongvipanond, 1994) Thus, any individual of a high social rank will surely own a car and use it in their daily commute. This social orderliness attitude in Thailand will only add complexity in attempting to shift people from private car to public transport with the rise of the middle income group. This social orderliness partly indicates a possible explanation for low patronage of public transport.

To gain insight into accessibility, it is of use to know current people travel behavior; stated preferences (SP) and their revealed preference (RP). Townsend and Zacharias (2009) did an observational study on those passengers leaving MRT stations. Firstly, they found that the most important destination was a motorcycle taxi. Motorcycle taxis are a highly popular way for commuting short distance between different short haul locations, and long haul locations during rush hour. Secondly, between stations there is a large variety in intermodal proportionately trips. This shows the pre-existing urban situation and bus arrangement which has been in place before construction of the MRT. These results show a few important inclinations. Firstly, since motorcycles are relatively the most expensive mode per kilometer and the MRT fares are relatively high too. The group using MRT can **afford** a door-to-door service. 'The average household income of BTS users is about 50% higher than the average households in Bangkok, […] 75% of BTS users interviewed came from households that had at least one car"(Bray and Sayeg, 2002). Secondly, interchange ease between MRT and bus is low which really decreases accessibility for the users and thus there is a high need for bus reorganization and route changes. (Chotichinda Mouchel Consultants Ltd). Bray and Sayeg (2002) also looked at BTS users and non-BTS users. The top three reasons for using BTS according to importance was travel speed, comfort and the reliability. The reasons why

[11] Some general links about Thai culture: http://www.businessbackpacker.com/mai-pen-rai-a-lesson-on-letting-go/

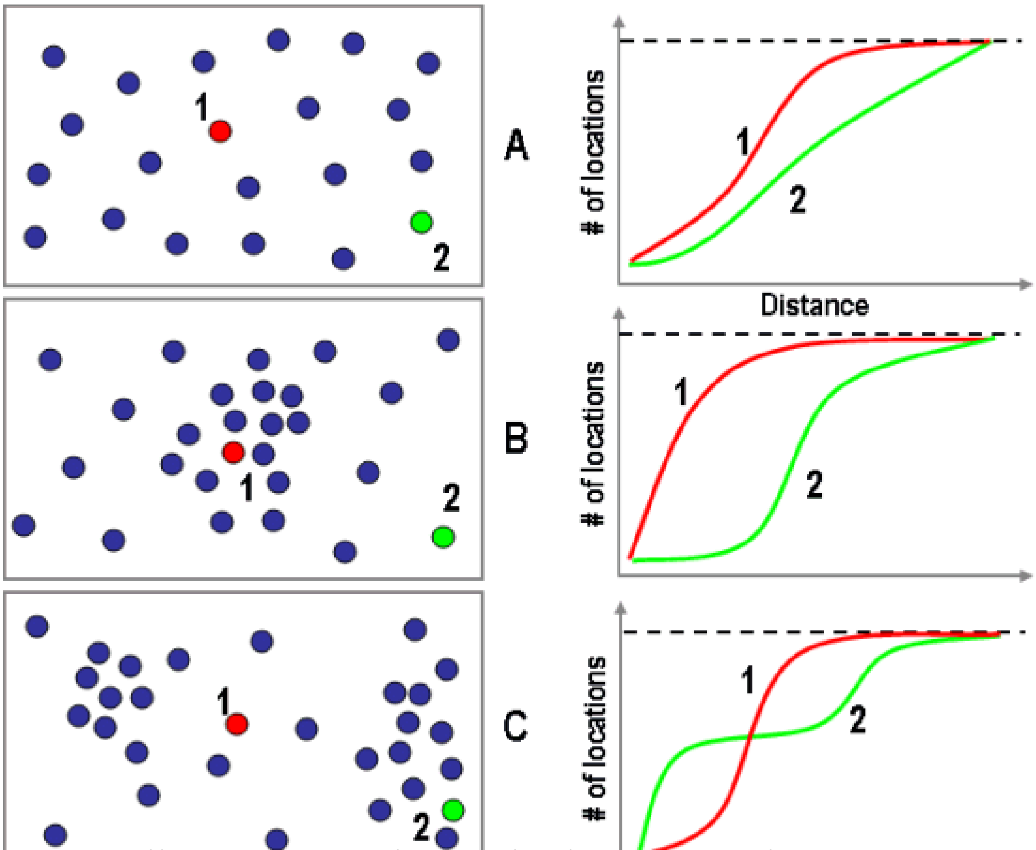
bus users did not pick BTS in order of importance was the inconvenient network, high cost and difficult pedestrian access. This clearly shows that if BTS wishes to increase patronage they need to improve accessibility, both in terms of network length and in terms of infra-structural accessibility (walkability).

7. ACCESSIBILITY MODELS

Townsend and Zacharias (2009) did an observational study with walking distance between station and destination being the dependent variable. They found a significant effect to only be present between walking distance and destination types (destination indicating land use and activity). It was shown that there is already a high density sidewalk network, so greatest payoff would come from improving facility design. For example, reducing walking distance when transferring between modes, remembering to simultaneously improve walking condition for those who are *not* interchanging. "Interchange, […] is perceived negatively by users […] findings indicate that interchange and the public transport journey could become more attractive to all users if: the emotional burdens of interchange are reduced" (Hine and Scott, 2000).

Figure 14 offers a visual representation on the effect distance and opportunities have on accessibility. (Rodrigue, 2011) The figures below show different instances concerning accessibility. Figure A shows that both locations 1 and 2 have a similar density dispersion of opportunities, indicating a similar trend line. With B, most opportunities are located around 1, thus the distance travelled to all opportunities is much lower when compared to 2. With example C, initially location 2 is much closer to a number of opportunities, as the distance catchment area increases location 1 has access to many opportunities situated to its west. Location 1 and 2 now reach equilibrium and show equal amounts of accessibility levels.

Figure 14: Opportunities and Accessibility



Source: http://people.hofstra.edu/geotrans/eng/ch2en/meth2en/spatialstructureaccess.html

When measuring accessibility, one must first decide from which perspective. There are 3 distinct perspectives concerning accessibility measurement: infrastructure-, activity-, and utility based accessibility models.

First one is, ***infrastructure based***, where one looks at the performance of transport, such as the speed and congestion level. Infrastructure based accessibility is an important economic driver and is adopted by many European transport policies. Ypma (2000) looked at different European Union countries and what accessibility measures they adopt in their transport policies. An example is that of Lopez (2005) where it was found that accessibility by road for the whole of Spain has improved between the years 1992-2004, while the rail network has been falling behind. Another example is SUMA (2009) who produced a report on bus-bike integration and the important role of infrastructure-based measurement in determining the eventual extent of integration success.

Secondly, one can design an ***activity based* accessibility** model. This type of measurement looks at the activities in the area, such as shopping or entertainment, and takes that into account for accessibility calculation. Behavior pattern is the unit of analysis and thus this model aims to predict which activities are performed when, where, what time, with whom and what transport mode is involved. The activity based accessibility models will appear in two types. They are either *of a geographical* nature; so how accessible a location is to all other destinations. Thus accessibility is measured between two points. Or they are a *space-time design*, where one observes within a given time period the number of potential activities an individual can access. Thus, space-time refers more to area zoning and classifying their accessibility. The two figures 15 +16 represent the different visual interpretation of activity based model, a geographical versus a space-time measurement.

Figure 15

GEOGRAPHICAL MEASURE

With node 'a' being most accessible, because has lowest distance to all other nodes

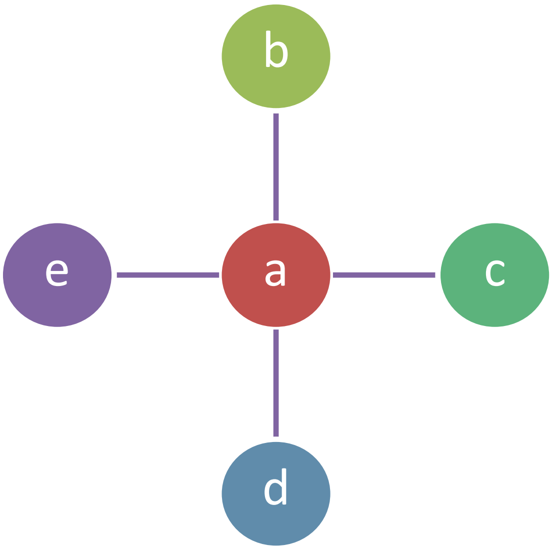
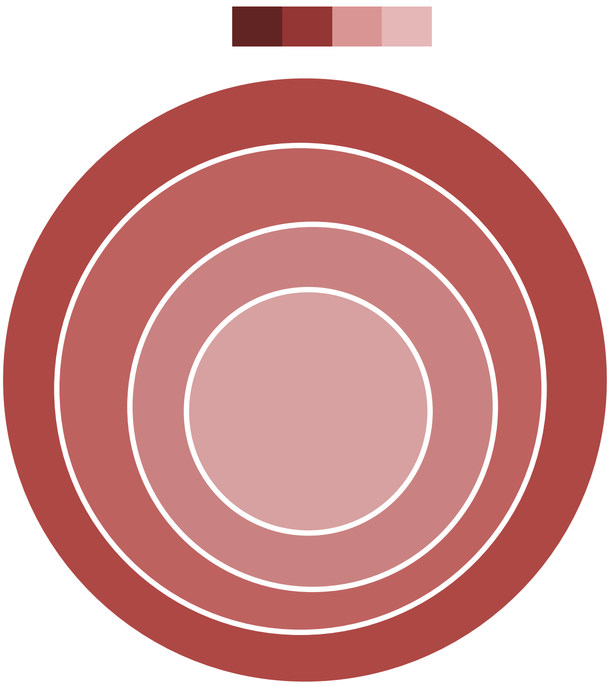


Figure 16

SPACE TIME MEASURE

Low accessibility --- high accessibility



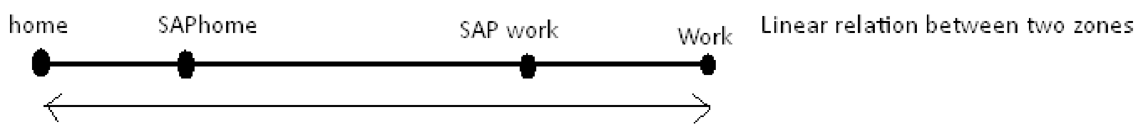
Activity-based accessibility model can be subdivided into *distance, contour and gravity measures*, each measure is an extension of the previous measure. Distance is the most simply model where one measures the linear distance between location and destination. Contour measures take into account the *number* of destinations one can reach from a specific location. Gravity models take contour measurement even further by applying weights to different destinations. So there is a discount distance factor, destinations that are further away are accordingly less accessible.

Ingram (1971) developed a simple distance measure, concerning "*relative distance*; the degree to which two points or places on the same surface are connected" (Geurs *et al*, 2001:p49). This kind of measurement appears in urban planning pertaining to specific rules, such as the explicit distance between hospitals in a city. This model appliance has high constraints, since it usually incorporates only two points, origin and destination This means that the accessibility results do not offer great insight into many situations. The model is displayed below including diagram 1 showing a visual representation of a distance measure. (Varameth, 2008; Rodrigue, 2011; Xiaojing *et al*, 2006)

$$A_i = \frac{\sum_j d_{ij}}{b}$$

A_i = the accessibility at zone i
D_{ij} = distance between zone i and zone j
b = general parameter

Diagram 1: Distance Measure

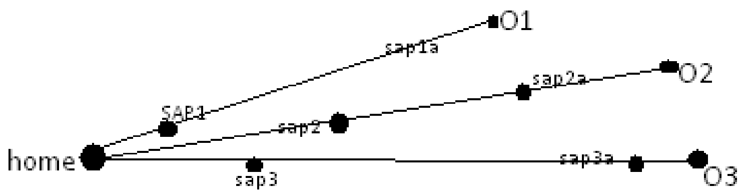


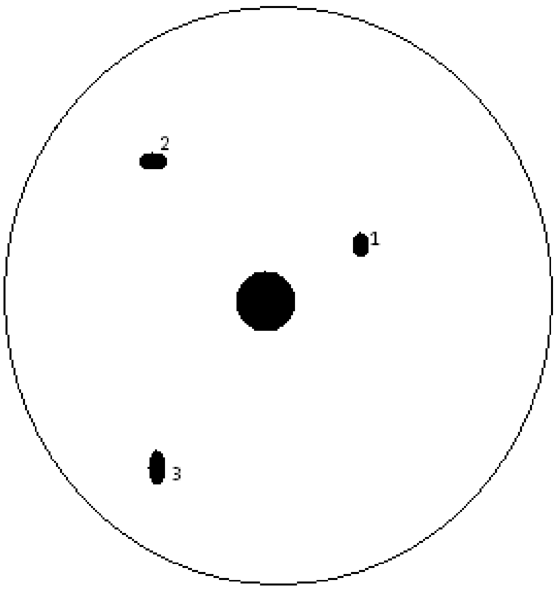
When there are several destinations it is more appropriate to use *contour measures*. According to this measure, the more destinations that can be reached from a location the higher that locations accessibility. Research has shown there is a high correlation between low accessibility and problematic demographic developments. Accordingly, job accessibility is highest in dense urban areas. (Vickerman *et al,* 1999; Spiekermann and Neubauer, 2002) An example of contour measure is given below together with a visual representation. Note that one of the major shortcomings of this model is that there are no weights applied. (Varameth, 2008; Geurs and van Wee, 2004). Opportunities need to be clearly defined such as the number of jobs or the number of hospitals. So, for the model calculation one needs the location of all the specified destinations within a pre determined catchment area.

$$A_i = \sum_t O_t$$

A_i = the accessibility at zone i
t = time (also can be seen as threshold)
O_t = the opportunity that can be accomplished in given t

Diagram 2: Contour Measure





Simply count the numer of opportunities which is 3 in this case, distance does not affect the value of the opportunity, there is only a maximum distance set within which the opportunity must be present

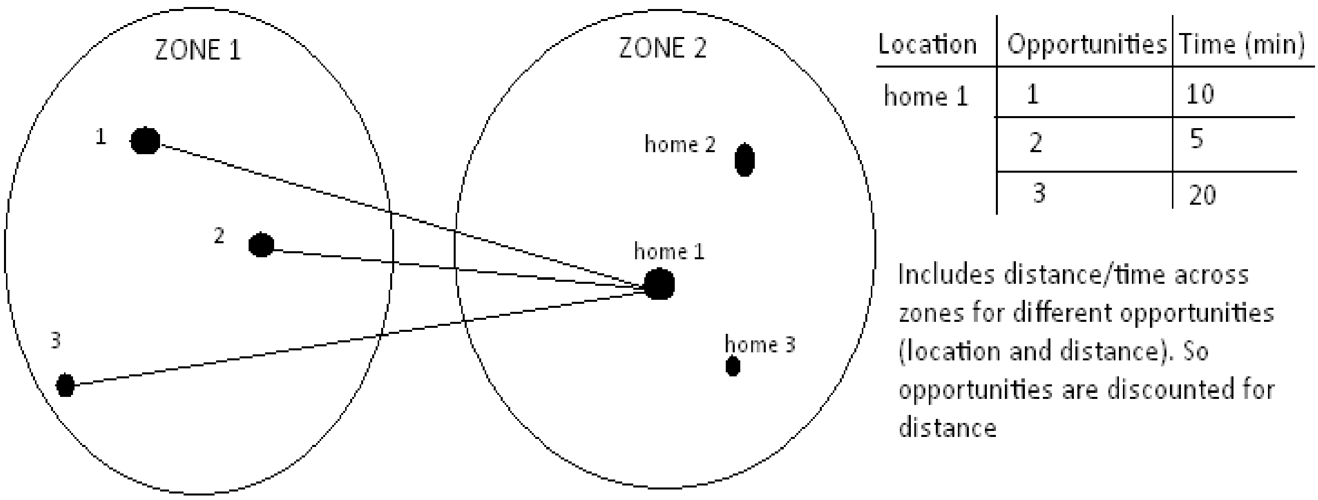
Location (home)	Opportunities
home	1
	2
	3

Varameth (2008) also introduces a *gravity* measure. This model is an extension of contour measures, where an attraction factor and a 'separation factor' are included. There is a continuum measurement and the model discounts opportunities that are further away from the origin. What lacks with this function is that accessibility is assumed to be the same for each individual. (Rietveld, Bruinsma, 1998; Xiaojing *et al*, 2006) To collect this type of data one needs the size and location of the actions of interest and the travel time/distance between the zones. The amount of activities in a zone is reflected by the attractions component of the gravity measure, which the contour measurement does not have. Below is a generalized equation of a gravity model as well as a visual illustration.

$$A_i = \sum_j \frac{O_j}{t_{ij}^{\alpha}}$$

A_i = the accessibility at zone i
tij = travel time component
O_j = the opportunity at zone j

Diagram 3: Gravity Measure



Following the analysis above it is important to determine the different components. Infra-structure, activity and utility based accessibility models all have four components, *transport, land use, temporal and individual.* (Geurs *et al*, 2001; Varamath, 2008; Curtis and Scheurer, 2007) The table 4 below shows the type of accessibility measures and their appropriate components. While table 5 looks at the three most obvious *elements* within the transport component; time, cost and effort and how they differentiate between modes. These tables offer a fine overview of the variables that have to be collected to obtain the right data set with which one can create an accessibility index.

Table 4: Type of accessibility measures and components

measure \ component		transport component	land-use component	temporal component	individual component
infrastructure-based measures		average travel time; travelling speed; vehicle hours lost in congestion		peak hour period 24-hr period	trip-based stratification (e.g. home-work, business trips)
activity-based measures	geographical measures	travel time and/or travel costs between locations of activities, typically using a distance decay function	distribution of opportunities in space (e.g. number of jobs per zone or grid)	travel time and costs may differ between hours of the day, between days of the week, or seasons	stratification of the population (e.g. by income, educational level)
	time-space measures	travel time	distribution of opportunities in space	temporal constraints for activities and time available for activity participation are accounted for	accessibility is analysed at individual or household level
utility-based measures		travel costs between locations of activities, using a distance decay function	distribution of opportunities in space	travel time and costs may differ between hours of the day, between days of the week, or seasons	utility is estimated for population groups or at individual level

Table 5: Elements within the transport component of accessibility

elements \ mode	Car	public transport	bicycle/walking
time	walking to parking place in vehicle travel time congestion time finding a parking place walking to destination	hidden waiting time travel time of access/egress mode waiting time at station in vehicle travel time transfer time	travel time bicycle parking
costs	fixed costs fuel costs maintenance costs parking costs road-pricing costs	costs of tickets/fares	fixed costs maintenance costs
effort	level of (dis)comfort physical effort reliability stress accident risk information status	level of (dis)comfort physical effort reliability stress accident risk social safety information status	level of (dis)comfort physical effort social safety

Source: based on Hilbers & Verroen, 1993; MuConsult, 1994

Lastly, one can do ***utility based measurement***, where the focus lays on the benefit people gain from different **destinations** accessibility. (Geurs *et al*, 2001; Miller, 1993; Yao, 2007; Litman, 2011). This is a model towards strong behavioral economics and will not be discussed in detail further. The importance of separate accessibility viewpoints can be explained with the following example. If one used the infrastructure-based accessibility model and the level of congestion, applying this to Bangkok, one would conclude there is very low accessibility compared to other areas in Thailand. However, when using activity -based accessibility models (e.g. the total number of employment opportunities within a 30 minute car commute) it would be easy to conclude Bangkok is highly accessible, in spite of the high congestion levels.

The models discussed above are not used in this research for several reasons. The main issue is that the data that needed to be collected to implement any of these models is extremely hard to collect. Surely, activity-based accessibility models seem most interesting to implement and would offer a great insight into accessibility. But the data collecting based on activity, cost and time, location and complementary destination is close to an impossible one-man task. Secondly, the above models can only be applied to a relatively small area in Bangkok, as they are highly focused on extreme localized micro-accessibility. Thirdly, for the majority of application of these models advanced mathematical and programming is crucial, a type of skill that is not available for this research. For these reasons the less complex PTAL model is used for measuring accessibility within Bangkok. Only slight adjustments to the current London model had to be made, which are the mode reliabilities and the walking catchment area. The following chapter will further discuss the PTAL model, methodology and its policy recommendations.

8. PUBLIC TRANSPORT ACCESSIBILITY LEVELS (PTAL)

PTAL calculations were originally produced by the London Borough of Hammersmith and Fulham, 'Transport for London' later adopted this model as its standard for calculating public transport accessibility in London. Essentially what PTAL calculates is the accessibility from a point of interest (POI) to a service access point (SAP), while taking into account walk access time and the service availability. In other words, it measures the *public transport density* at location (POI). As displayed in figure 17, density will depend on the distance to the service access points. So, a high density area will have plentiful SAP within close proximity of the POI. PTAL calculation has been adopted by several researches such as Wu and Hine (2003); Gent and Symonds (2005).

Figure 17: Relationship between Distance and Service Access Point

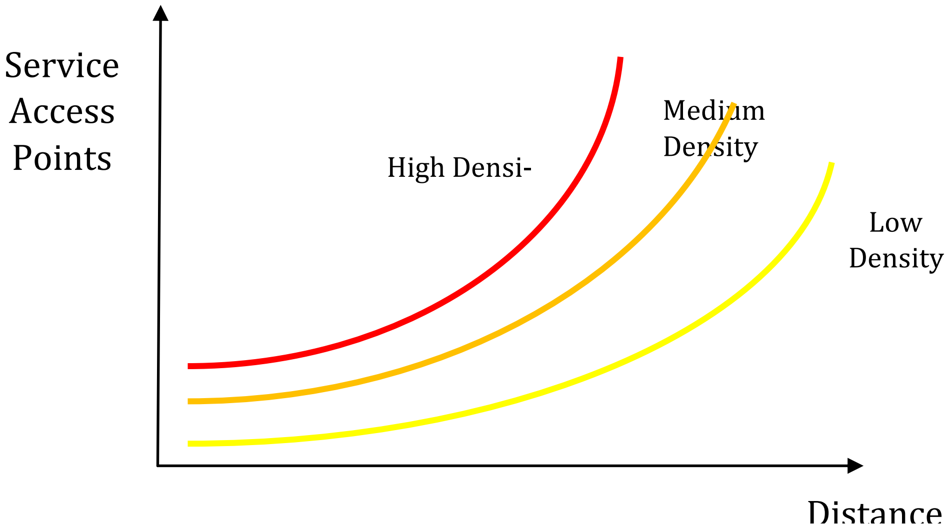


Table 6: Parameters and the according models

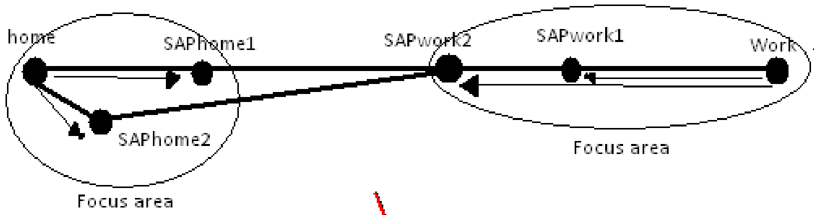
Parameter	Model
Point of Interest (POI-current location)	• PTAL • Rodrigue, 2011 • Ingram (1971) – relative distance • contour measures • gravity measure
Service access point (SAP-node location)	• PTAL • Townsend and Zacharias (2009) • Rodrigue, 2011 • Ingram (1971) – relative distance • contour measures • gravity measure
Service level at SAP	• PTAL (waiting time, reliability)
Walking catchment area per node	• PTAL • Townsend and Zacharias (2009) • Rodrigue, 2011

	• contour measures • gravity measure
Frequency of mode	• PTAL
Generalized cost	• utility based
Demographics	• Contour measure- Spiekermann and Neubauer, 2002
Ease of interchange	• Townsend and Zacharias (2009) • Hine and Scott, 2000
Number of users	• utility based
Weights	• PTAL (low in strength) • Varameth (2008) gravity measure
Peak hour	• PTAL
Trip purpose	• utility based
Distribution of opportunities	• Townsend and Zacharias (2009) • Rodrigue, 2011 • Gravity measures • contour measure- Vickerman et al, 1999
Effort	• Hine and Scott, 2000

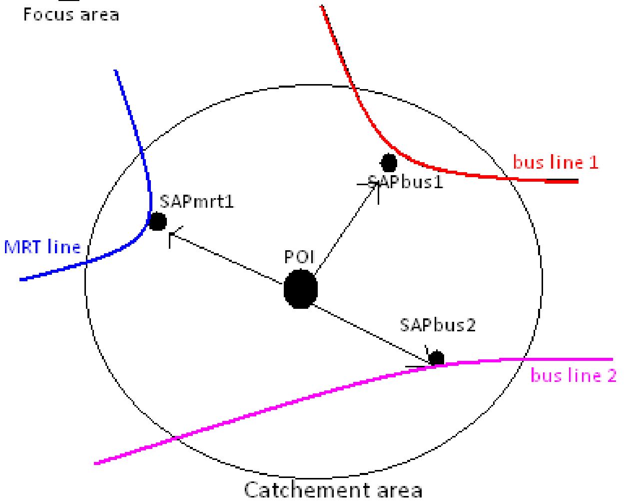
PTAL deemed most fitting for this research, because the other accessibility models had too many limitations regarding data collection and/or creation. There is a lack of statistical data in Thailand and PTAL can be derived from certain city areas with the current available data. Table 6 above gives a short representation of the models previously discussed and what type of parameters they include. Parameters such as distribution of opportunities are extremely difficult to collect. Therefore, PTAL is further used to shed light on how accessible public transport is in Bangkok.

Following from the previous discussion about the different types of accessibility measures, PTAL does not clearly fall into one specific category. It is most certainly a space-time measure. Since accessibility will depend on the service hours of the public transport, in this research peak hour frequency will be used for the modes. One must therefore be cautious when drawing conclusions, since public transport accessibility across the whole day might be overestimated. PTAL can mostly be interpreted as an inner zone gravity measure. It is an **inner** zone gravity measurement, because gravity is measured across zones. Normal gravity models measure the distance between zones. PTAL measures only part of the journey that lies within a particular zone (the walking catchment area).. PTAL is most relevant to Bangkok due to the lack of easily available quality data on the footpath network (as walking time is measures across the road network). Other variables, for example the number of jobs in an area, are extremely difficult to collect. A visual diagram is shown of the model area calculation in diagram 4.

Diagram 4: PTAL Model



Location	Opportunity (SAP)	Time (min)	Weight
POI	SAPbus1	1	depends on frequency
	SAPbus2	1.5	
	SAPmrt1	1	



The model focuses on one part of the whole trip. In this case the opportunities are the number of public transport service access points possibilities within a specific catchment area. Distance is not the same concept as with the gravity model, however PTAL does take into account the mode type and its frequency. Highest weight is given to highest frequency and there is a discount factor for those within the catchment area.

PTAL is a planning tool which can suggest area development, concerning urban and office density and also help to determine suitable parking standards. (Miller, 2011) The model says that those areas offering elevated PTAL should have a high density of urban and office mixture. Whereas, areas with meager PTAL are better suited for large parking lots and industrial area. (Kesten and Tezcan, 2006).Thus, the model offers insight about the existing public transport infrastructure in place in Bangkok. Also, a detailed report of the current POI catchment area content can suggest if the POI vicinity urban mixture is in line with what the PTAL model suggests. This model could be applied to the continuum sprawling, as to better plan area development. Future residential and commercial units ought to be developed in the most accessible areas. A mode shift can be encouraged if parking availability is lowered in highly accessible areas. One can also adopt parking demand management by introducing high paid parking at locations most accessible by public transport. It might also be of interest to apply the model to areas in close proximity to the future rapid transit extension lines and suggest urban development of the catchment areas.

5.1 PTAL INDEX CALCULATION

The PTAL index is defined as follows:

Total access time = Walking time + average waiting time

To derive values for these features one must first define the POI. Since the PTAL score is considerably affected by the POI location. The model determines accessibility levels from that particular POI. When the POI spreads over an extensive area, such as a large supermarket, one must realize that PTAL should be determined at different POI across the area. SAP is defined as the location entrance of a station. Bus stops are classified by pairs, so a bus stop on either end of the road will be classified as one SAP; however, the model will take into account multiple bus lines. Walking time will be found by translating the walking path distance between POI and SAP into a time value using the average walking speed. The total distance between POI and SAP is not a straight line, rather one takes into account the road network and uses the shortest path following the road network to determine total walking distance. The maximum distance someone is willing to walk between a POI and SAP has to be found, so as to determine the catchment area of the SAP near POI.

To find the average waiting time one needs the mode reliability and the scheduled waiting time. Scheduled waiting time is assumed to be half the headway.

Average waiting time = reliability + scheduled waiting time

Table 7: PTAL values

PTAL value	PTAL index	Accessibility level
0-2.5	1a	Very poor
2.5 – 5	1b	Very poor
5-10	2	Poor
10-15	3	Moderate
15-20	4	Good
20-25	5	Very good
25-40	6a	Excellent
40+	6b	Excellent

Having found average waiting time and walking time the final steps have to be taken, where total access time has to be transformed into an equivalent doorstep frequency (EDF). This transformation will treat access time, as if the route were available as a door-to-door service for the selected POI. To find EDF a minute value is set for maximum travel time by car and divide it by access time of public transport. The average travel time by car, giving the highest utility in this research is assumed to be half an hour, taken from the Transport for London Model (2003). This is a mere psychological effect where a person's feeling about driving decreases when it surpasses 30 minutes (Transport for London Model, 2003). To find the final Accessibility Index (AI) value weights are applied to the EDF values, one is given to the highest frequency transport option, while all other receive a value of 0.5 so numerous AI_{mode1} are found. Finding the matching weights to use for this research is a tough process; in view of this the weights that were chosen were directly copied from the Transport for London model. Next, the sum of all individual transport option (TO) accessibility indexes AI_{TO_n} will create a final PTAL value for that particular POI. The PTAL results will display a range from 0 until infinity (table 7). The equation form that goes with the last two steps is displayed below.

$$AI_{TO\_n} = EDF_{TO\_n}*weight$$

$$AI_{poi} = \sum(AI_{TO\_1} + AI_{TO\_2} + \ldots + AI_{TO\_n})$$

One can also use EDF to find the accessibility of a specific mode. So, given the POI, what is the accessibility to a particular mode? This kind of mode accessibility calculations can offer insights into what the strongest mode of transport is.

$$\text{Accessibility Index(AI)}_{mode\_n} = EDF_{max\_mode\_n} + (0.5*\text{All other EDFs}_{mode\_n})$$

Table 8: Overview of the step by step calculations that are needed to obtain the PTAL values. This step by step calculation is done in Excel.

Step 1	Step 2			Step 3	Step 4
POI	Stop	Route	distance	Frequency (peak period MRT)	Weights (highest frequency = highest weight = 1, 0.5 others)

Step 5	Step 6	Step 7	Step 8	Step 9	Step 10
Walking time (distance / walking speed)	Scheduled waiting time = half the headway (0.5) x {60/frequency-(step 3)}	Reliability (minutes)	Total access time = step 5 + step 6 + step 7	Equivalent doorstep frequency (EDF) = 30/step 8	Accessibility index = step 4 x step 9

There are several refinements which ought to be added to the model, to make it more valuable. First, accessibility levels will be dissimilar across different time intervals. Since the current accessibility index is only based on peak period frequency. Secondly, the model can be expanded to include more parameters. The walking distance catchment area could be related to the number of lines present at a SAP and the frequency of the lines at the SAP. Thirdly, the walking distance could also be related to trip purpose. Fourthly, walking speed is determined by many variables which could be included, such as the person age, trip purpose, service walkability of the area and weather conditions. Fifthly, in PTAL each mode is expected to have the same weight, except for the mode with the highest frequency. It would be ideal to include accurate weights, but this is extremely difficult since the weight is ultimately area specific and depends highly on area characteristics. (Transport of London, 2003)

5.2 METHODOLOGY

The parameters in PTAL are

- Walking speed
- Reliability of bus, subway, skytrain
- Maximum walking time (catchment area)
- Maximum walking distance (catchment area)
- Peak hour service frequency bus, subway, BTS per hour

Using the parameters above one can include the independent variables in the model, which are:

- Number of lines
- Weight of the different modes (mode frequency)
- Actual walking time; directly related between walking distance, walking speed and half the headway
- Average waiting time; related to scheduled waiting time and reliability

Numerous secondary resources were inspected to find most of the parameters and variables. Using BMCL/BTS final reports it is possible to establish the appropriate frequency and reliability of MRT. With the use of Google maps, one can calculate the distance between POI and SAP, the number of SAP within the catchment area and also the number of lines at each SAP. The distance between the POI and SAP is not measured in a straight line; rather the road structure is used as the base for distance calculations. The frequency of specific bus lines is also found on Google maps, Google maps source is the BMTA website. Walking speed is a difficult variable to collect. To establish a good indication of a person's average walking speed, one needs a large population sample of people walking at a constant speed on a smooth surface. The walk ability levels of Bangkok are highly dependent on your location; accordingly walking speed is also affected by trip purpose, age, gender, crowding etcetera. Finding the average walking speed is a limitation and it is therefore assumed that on average a person walks 1 meter per second, and thus 60 meters per minute and 3.6 km per hour.[12]

A survey style data collection process is needed to obtain value for the missing parameters. Due to time constraints, it is not possible to collect data from all over Bangkok, nor will the final accessibility analysis for the whole of Bangkok. The survey collection took place at three universities, which are spread across the city. The reason for this is that university areas should be in close proximity of several public transport options, because most students are on a tight financial budget. It is easy to locate the different entry/exits across a university complex assigning them as the POI across the complex and calculate their appropriate accessibility levels. This study of university areas using PTAL offers insight on what the accessibility levels and urban density ought to be and what it is. Data collected from these 3 areas will be averaged to find the crucial missing parameters which are: *bus reliability* and *catchment area per mode*.

[12] http://www.thinkmetric.org.uk/speed.html

There are 300 surveys collected to find the maximum walking distance a person is willing to walk for each mode (mode catchment area). The survey response will mostly be from students as the data collection will be near a university. This data collection will also cause strong biased, as only students are surveyed. Any generalized observations are therefore limited, since many people from different age groups were disregarded in this data. By including questions about students current travel behavior one can determine what kind of commuter the person is. This can be of interest regarding the catchment area. It is expected that current car users are willing to walk less far for a SAP opposed to people currently already using public transport. Also, to find bus reliability, bus users are asked how long on average they wait for their bus. The difference between scheduled waiting time and stated average waiting time will give a sense of bus reliability. The study area, concerning the point of interest, will be three universities campuses: Bangkok University, Chulalongkorn University and Mahidol University. The results from these areas, such as average bus reliability and catchment area, can the implemented as the models parameters. With the model parameters completed, one can now apply the model to different areas across Bangkok to find PTAL.

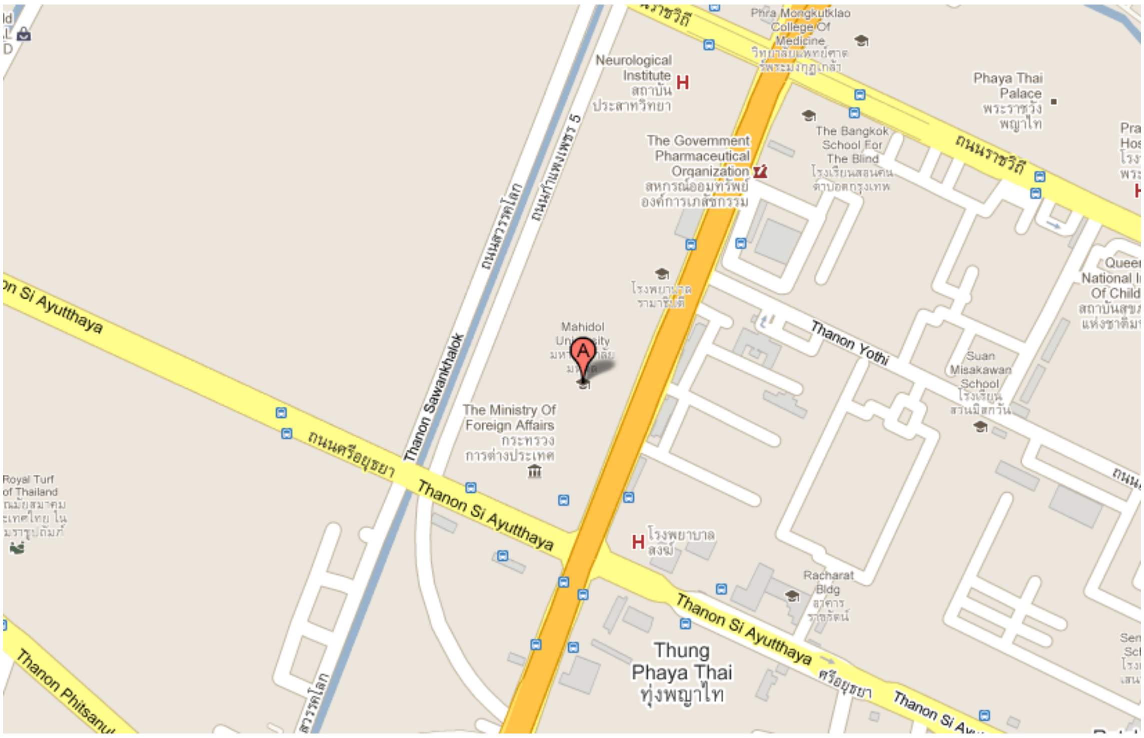
One of the functions of PTAL is to provide information about the parking standards that ought to prevail in an area. In view of that, it is worthwhile to take a closer look at the current parking standards near the POI, such as the number of car parks. A type of parking measure which is calculated in a similar way as PTAL will be helpful for comparison. The OTP provides a virtual map with the location of current car parks spread across Bangkok. This map also bestow upon information concerning the cost per hour and the number of available parking spaces.[13] With this information one can make more sound evaluations about specific area's and their success and/or failure in providing the appropriate public transport accessibility levels. The PTAL model can be adjusted to become a "parking accessibility level" (PAL) to some extent. This PAL model will disregard any frequency value and waiting time. So when PTAL is high, it should coincide with a low PAL.

Like everywhere in the world, many trips are not done my one mode and Bangkok is no different. Multi-modal travel by using a motorcycle taxi is a popular way, but motorcycle taxi commuting is not included in this model. It would be interestingly to create a motorcycle catchment area. So, to find the number of SAP if one arrives by means of a motorcycle taxi. This thesis will not go into further detail concerning PTAL using motorcycle taxis instead of walking. The emphasis of this thesis is to find the accessibility to public transport by means of *walking* there.

5.3 MAHIDOL UNIVERSITY

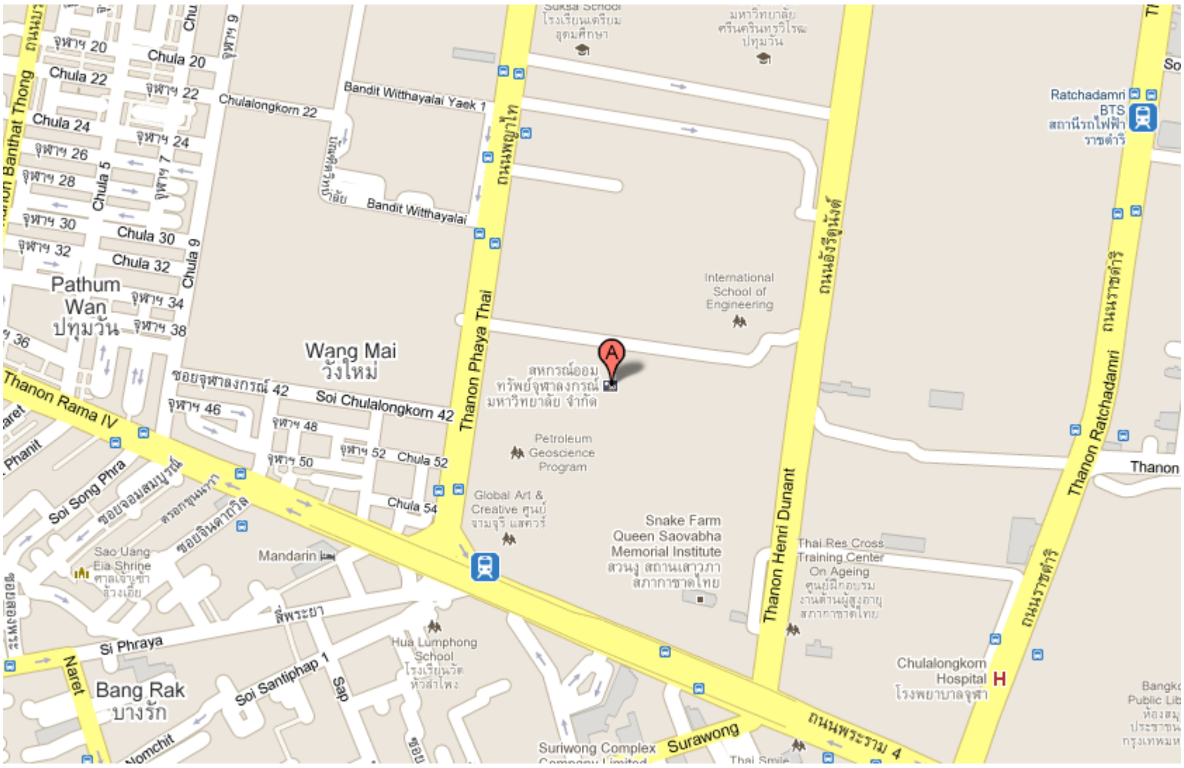
Intuitively, one expects high PTAL due to the presence of the BTS. However, the BTS as a SAP is likely to fall outside of the catchment area. It is expected there will be a feeder line. This feeder line, specific to Mahidol University student will most likely not be visible on Google maps. As the BTS falls outside the catchment area, PTAL will be low.

[13] http://www.itsotp.net/



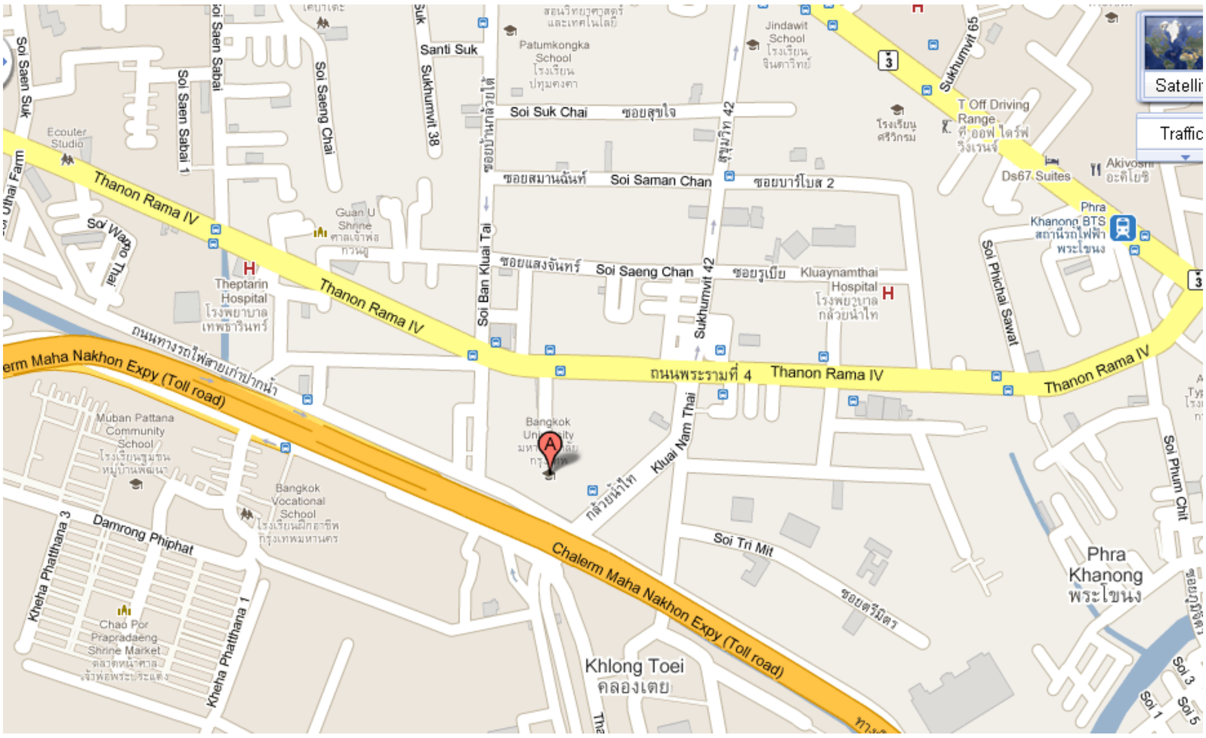
5.4 CHULALONGKORN UNIVERSITY

Expectations for Chula are that PTAL will be high, due to the presence of numerous bus lines, subway Sam Yan and proximity to Siam large shopping area.



5.5 BANGKOK UNIVERSITY

Intuitively, one expects high PTAL due to the presence of the BTS. However, the BTS as a SAP is likely to fall outside the catchment area. It is expected there will be a feeder line. This feeder line, with their main customer being Bangkok University students, will most likely not be visible on Google maps. As the BTS falls outside the catchment area, PTAL will be low.



9. SURVEY DATA ANALYSIS

Survey data collection was necessary in order to find mean bus reliability and the maximum catchment walking area for each mode. Using Excel a mean calculation for each of variables was found as displayed in table 8. The bus average waiting time value however is not used to find the reliability needed to calculate PTAL. To find overall bus reliability one calculates the difference between each observation of scheduled and stated waiting time. All these observations combined will provide an average reliability factor of 6.78 minutes for the bus. The reliability of the skytrain and subway were calculated using the annual reports.[14] The reliability for the subway is 0.10 minutes and for the skytrain it is 0.21 on average for both lines combined.

Table 8: Statistics

	mean	median	mode	mini-mum	maxi-mum
bus average waiting time	11.78	10	8.33	2.67	36.67
bus times	6.16	5.67	6.67	1	18.33
BTS times	4.68	4.17	3.67	1	13.33
MRT times	3.59	3	2.33	0.67	11.33
motorcycle taxi times	2.82	2.5	2	1	8.33
private vehicle (motorcycle + car)	1.14	0	0	0	18
walking	4.79	5	5	1.33	10
minimum walking willingness MRT	6.93	5.33	5	1.33	18.33
minimum walking willingness BTS	7.37	6.67	8.33	1	18.33
minimum walking willingness bus	5.89	5	5	0.83	21.67
minimum walking willingness parkspace	4.74	5	5	1	15
gender	0.55	0.67	0.67	0	1
age	19.79	19.67	18	15	29

[14] For detailed calculation of each reliability factor see Appendix

For the catchment area the following averages were found. (Table 9)

Table 9: Catchment Area

		Minutes	Meters
Catchment area	SUBWAY	6.93	415.91
	BTS	7.37	442.05
	bus	5.89	353.34
	parking lot	4.74	284.36

As expected, willingness to walk for a parking spot is the lowest, since car driving is associated with high mobility and people want to be able to park to a specific location as close as possible. As reliability for MRT is rather high it was expected that people will be willing to walk much further for MRT. But this data shows that the difference between bus and MRT is no more than an average 80 meters. This low difference might be due to the low network coverage of the MRT system. Only a limited amount of destinations can be reached using MRT and the bus offers a higher network density at a lower price.

A detailed investigation can be run on the survey collected data; regression analysis, correlations and scatter plots but that is not of major concern to this research. The problem is that the given data set is limited when trying to draw conclusion about the presence of a correlation or not. This is mostly due to the demographics, since any relation of age would require all ages to be included. However, in this data set the oldest person in the data set is 29 while the youngest is 15. So it is impossible to determine any correlation or not between age and any other variable, because to make such distinctions one needs observations of all ages.

Below is a short discussion of two observations that were found. But regarding the previous paragraph, any statistical evidence that is found is low in strength and therefore any findings are disregarded as relevant. *Firstly, If the data set is filtered according to private vehicle usage of once or more times per week, a significant relation among private vehicle users and the following variables is found: minimum willingness to walk for parking space and subway and the amount of times people use the subway*. This relation of private vehicle and subway shows a possible high amount of modal split for daily commuting. The BMCL puts high focus on providing car parking in close proximity to its subway stations in order to attract more users. These results do support such a possible modal split of the daily commute however, the number of observations is probably too low (around 40 observation) to make any real sound conclusions.

Secondly, a regression analysis with the dependent variable represented by bus times could show some potential interesting results. When one includes the following independent variables: subway times, BTS times, private vehicle usage, walking, minimum walking willingness bus and minimum walking willingness parking space; the correlation coefficient proves to be very strong at 0.988 as is the coefficient of determination at 0.977 (table 10). This could suggest a high model fit, but the significance level all proof unfit to make such conclusions about having found a model fit. None of the variables are significant and some of the coefficients values are doubtful. (Table 11 and 12)

Summing up, there are *no relations in the **given** data set*. So the scatter plots did not show any trend, no (multiple) regression that could be accepted and very weak correlations. Also, some of the observations for the different variables were highly low in quality and using them for correlations or regression will accordingly not be appropriate. In view of that, expectations, such as the willingness to walk for public transport is lower for private vehicle users then bus users, could not be proven given this data set.

Table 10: Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.988[a]	.977	.907	1.676

a. Predictors: (Constant), min_walking_willigness_parkspace, BTS times, privatevehicle_car_plus_moto, min_walking_willigness_bus, walking , MRT times

Table 11: ANOVA

ANOVA[b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	236.506	6	39.418	14.028	.068[a]
	Residual	5.620	2	2.810		
	Total	242.126	8			

a. Predictors: (Constant), min_walking_willigness_parkspace, BTS times, privatevehicle_car_plus_moto, min_walking_willigness_bus, walking , MRT times

b. Dependent Variable: bus times

Table 12: Coefficients

Coefficients[a]					
Model		Unstandardized Coefficients		t	Sig.
		B	Std. Error		
1	(Constant)	-1.570	2.182	-.719	.547
	BTS times	-2.088	1.186	-1.761	.220
	Subway times	3.022	1.408	2.146	.165
	Private vehicle car plus motorcycle	-.040	1.105	-.036	.975
	walking	2.088	.686	3.042	.093
	Min walking willingness bus	-.106	.469	-.226	.842
	Min walking willingness parkspace	-.750	.460	-1.630	.245

a. Dependent Variable: bus times

10. VARIOUS BANGKOK PTAL AREA RESULTS

This section is a thorough analysis of different areas across Bangkok, the PTAL results and policy recommendations. Table 13 offers an explanation about the value interpretation of different PTAL results while table 14 shows actual PTAL results for each area.[15] The following discoveries will made; *firstly*, the PTALs that were found will *not* match to the current urban blend because either parking is high and PTAL is high. Or parking is high and PTAL is low but the area is high in urban density, which is not in line with the PTAL model suggestions. *Secondly,* accessibility measured according to singular mode will show that the bus offers the highest amount of PTAL across Bangkok's.

Table 13 : PTAL Values

PTAL value	PTAL index	Accessibility level
0-2.5	1a	Very poor
2.5 – 5	1b	Very poor
5-10	2	Poor
10-15	3	Moderate
15-20	4	Good
20-25	5	Very good
25-40	6a	Excellent
40+	6b	Excellent

[15] The appendix shows the same table's but has color coordinated the different values and shows the exact results opposed to the transformed values with a range from 1a to 6b, see under name: PTAL Value Results

Table 14: PTAL Results

AREA	LOCATION	PTAL - AI	PAL	AI bus	AI MRT	AI BTS
Chulalong-korn University	1	3	1a	3	1a	1a
	2	1a	1a	1a	1a	1a
	3	4	4	3	2	1a
	4	1a	1a	1a	1a	1a
	5	4	4	3	2	1a
Mahidol University	1	2	1a	2	1a	1a
	2	2	1a	2	1a	1a
Bangkok University	1	2	1a	2	1a	1a
	2	2	1a	2	1a	1a
	3	2	1a	2	1a	1a
Meechai Mansion	1	1b	1a	1b	1a	1a
TDRI	2	1b	1a	1b	1a	1a
Thailand Cultural Center	Esplanade	3	6b	2	1b	1a
	Carrefour	3	6b	2	1b	1a
	Thai life As-surance (business)	3	6b	2	1b	1a
	Thailand Cul-tural Center	1b	2	1b	1a	1a
Chatuchak	1	2	6a	1b	1b	1a
	2	5	2	6a	1b	1b
	3	4	4	6a	1b	1b

7.1 CHULALONGKORN UNIVERSITY, MAHIDOL UNIVERSITY, BANGKOK UNIVERSITY

At Chulalongkorn University, Mahidol University and Bangkok university data concerning reliability and catchment area were collected. Universities should have high accessibility for students to attend the university easily and affordably, however the data result show that this accessibility requirement is absent at the universities. At Chulalongkorn University if the POI is on the eastern side of Chulalongkorn campus *any* type of public transit is absent.[16] If the university feels the need for a having a car park on campus, the eastern side is most suitable, because here the car park would not interfere with public transport accessibility.

[16] See Appendix for a visual map of the different campus areas

Nonetheless, there is a car park present, but it is located on the western side with moderate PTAL. This is the area has a subway SAP within its perimeter and the chosen POI 3 and 5 both show PTAL and PAL values of 4. These equal values result in a lacking mode shift incentive from car to MRT in terms of accessibility. As this is a university, the area should focus mostly on public transport- ridership and -accessibility. Accordingly, the policy recommendation for Chulalongkorn is to either increase the number of bus lines; implement a possible feeder line in the eastern side of campus or to tackle the parking situation[17]. Changing the parking situation could mean high parking fees, change car park location or limit parking hour's availability.

Continuing area analysis one can adopt Bertolini's (1999) Node-Place model. This model states that location 3 and 5 near the subway are classified as an 'unbalanced place'. To make it a balanced place the model suggest to either decrease place value, e.g. increasing hourly parking fees and thereby enforcing a mode shift. Or improve the node value by e.g. implementing more lines or improving bus reliability to encourage people to the use public transit. Bus reliability is a difficult feature that the BMA should tackle and solve. The daily congestion and irregular bus departures cause low reliability of the bus; the average waiting time is more than 5 minutes.[18] Actions such as implementing bus lanes, would probably improve bus reliability; the problem is that these measures are strongly opposed by car users and the BMA still seems to favor public transport over public transport improvement. (Bhattacharjee, *et al.* 1997). Currently Bangkok has one dedicated bus lane, the BRT, it is a new project and strong remarks about whether it is a success story or not can not be made yet. Bus lanes were introduced in Bangkok before, but over time car drivers started using these bus lanes again and the problem of low bus reliability returned.[19] The recommendation for improving bus operations is further supported when one considers the individual mode accessibility levels. The Accessibility index (AI) for the bus (AI_{bus}) already exceeds the AI of the subway, (AI_{subway}). AI_{subway} cannot be improved much further at many locations due to infrastructural limitations and the lines almost running at maximum frequency, but AI_{bus} can be enhanced, mostly by tackling bus reliability, augmenting the accessibility strength of this singular mode even further.

Mahidol and Bangkok University show similar results to one another, with both having zero PAL and poor PTAL. Despite these two areas having low PTAL, it does *not* indicate these areas should mostly provide industrial complexes or large car parks as the PTAL model suggests. This clearly shows part of the limitation of the PTAL model, as one still has to take a close look at the standing infrastructure and not blindly apply recommendations in accordance with PTAL after obtaining area results. Relating to the Node-Place Model these university areas are "unbalanced places" because place-value is high, but node value is not matched. Node value is low because many students travel daily to university, but the supporting public transport is not intact. Thus node value has to improve, e.g. by offering more lines, feeder systems or large improvements in bus reliability. [20] These policy recommendations are enforced when looking at independent mode AI. The PTAL value is solely made up of the AI_{bus} and policies should be adopted to improve upon this mode to boost AI_{bus} and thus PTAL as a whole.

17 There is an actual small feeder line already present on campus. This feeder line however is limited to on campus locations
18 Taken from the collected data set on bus reliability
19 http://2bangkok.com/2bangkok-news-7318.html
20 See Appendix for a Google map view of the area

7.2 MEECHAI MANSION (RESIDENTIAL), TDRI (BUSINESS)

Both these areas show low PTAL and PAL levels. These are residential and business areas and therefore ought to score higher concerning PTAL. On the OTP map it shows there are no parking lots, but knowledge of the area indicates that both these locations have quite a high number of parking spaces. As these are privately owned land, it possibly explains why they are not displayed on the parking map of OTP. This shows the accuracy the OTP parking map is limited, as it only mentions a few car parks spread across Bangkok. These area analyses also indicate a limitation with using a fixed walking catchment area in the model. If the catchment walking area for Meechai Mansion would be only slightly increased the PTAL value would raise enormously, because many more bus lines would be included and also a subway stop.

In the case of TDRI there is defiantly a need for PTAL improvement. There is one bus line and one *songtael*, acting as a feeder system, while there are numerous businesses and residential houses in this area and it would serve the area well to improve overall PTAL. On the other hand, one might conclude that PTAL is what it ought to be as most people commute to this area by private car and a higher PAL is justified.[21] TDRI and the surrounding area are not within the CBD and if most private vehicles come from suburbs and avoid CBD, thereby avoiding creating traffic problems, a high number of parking spaces may be suitable for this area.

7.3 THAILAND CULTURAL CENTER (TCC) AREA

TCC has been a focus point in Bangkok for encouraging a model split for people's daily commute, transferring from car to MRT by providing abundant parking in close proximity of MRT. In TCC area there is a high urban density, which means PTAL should be high and PAL low, but this is not the case. PAL shows extreme high values of 6b, with PTAL meagerly around a value of 3. So the benefits, of the moderate PTAL and the corresponding urban mixture, are offset by the presence of excessive parking opportunities. In view of this, the area is a mismatch between "what is" and "what ought to be". Since the BMA and BMCL seem determined to develop TCC into a mode transfer area, more thought should have been put into where to construct the car park. In accordance with policy recommendations from PTAL model, it might have been more appropriate to build the large parking lots further away from the TCC area. Particularly the car parks in close proximity to the subway should have been located further away. To still attract customers to the subway, a high frequency feeder line could have been developed between car park and subway. The area, which is now used for car parking, would reap greater benefits if used for commercial exploration. The AI for both AI_{bus} and AI_{subway} show poor PTAL with AI_{bus} just somewhat higher. Improving the AI_{subway} is limited, however vast improvements can be made for the AI_{bus} as has been discussed in previous examples. The car parks in the TCC function towards those car drivers who will switch to the subway and *not* to the bus. This is *intuitive,* as it is improbable that car drivers change mode and continue by bus, as the bus system in Bangkok is

[21] Further research is needed to truly determine if the majority of people commute by private vehicle or not

dreadful. (Dissanayake and Morikawa, 2010) Perhaps if policies, as previously mentioned in the other are examples, were implemented people would be encouraged to use the bus fully or partially.

If the aim is to attract car users to switch mode and travel further by bus, changes beyond bus lane implementation is necessary. Car drivers are likely unwilling to change mode to a non-airco, dirty, old, high rise bus. Thus, new, air-conditioned, low rise busses will incentivize people further to opt for bus commuting, if not fully, perhaps partially. Also, mode shift between MRT and bus deserves more consideration. Good inter-linkages between the two modes and a network design that supports one and another, opposed to competing on the same track will see an augmentation of the patronage levels. In places, such as Ratchadapisek (=TCC) and Sukhumvit the bus and MRT system are still largely competing with each other. The bus largely attracts the lower income group, as the bus is still a cheaper option. But the bus also attracts people who diverge away from using the MRT not only because of the cost, but also due to the low network coverage of the MRT. The high costs together with the low coverage area of the MRT, causes the loss of many potential customers. AI_{subway} clearly shows this low network coverage, as AI_{subway} is relatively low. Extension of the MRT lines will improve network design and attract more users.

7.4 CHATUCHAK

Table 14 shows mixed results concerning PTAL and PAL in the Chatuchak area. This is an important node because many bus lines, skytrain and subway line run through this area. In view of that, PTAL shows moderate to good levels, while PAL shows a relative high amount of parking as well. These car parks were implemented mostly to support the large shopping area. These car parks also increase model split commutes, with people parking their car at Chatuchak and continuing their journey by MRT. Seen from a PTAL perspective, the car park locations are not proper. As mentioned before, car users will almost certainly not transfer to the bus for the rest of their journey. In view of that, an benfits brought about by the positive PTAL situation is offset by the high number of parking opportunities. This reduction in public transport accessibility *benefits,* such as corresponding surrounding urban density, ought to be tackled to improve the overall situation. As with TCC, it would have been more beneficial to locate the car park elsewhere and develop a feeder line.

Also, AI_{bus} is highest, so bus users should be rewarded for opting to use the bus. Instead the BMA has chosen to reward car users by providing excessive amount of parking opportunities. As with TCC, further improvement of AI_{bus}, should be undertaken. This is the easiest mode to improve and perhaps then the bus will attract more people.

7.5 LIMITATIONS

The results and policies discussed above are subject to several limitations. These limitations mostly derive from problems with measurement, applying the model suggestions and the data set. The first limitation would be *the number of SAP found within the catchment area*. This depends on average willingness to walk, which in turn depends on variables such as trip purpose, time of day, age etcetera. This shows that using only one value for catchment area creates limited predictive interpretation. Continuing on this point, the average catchment area of *all modes* was found to be around 400 meters. However, people might judge an *area* opposed to the *distance*. One might walk all the way from one end of Chulalongkorn campus to the other, even though this is 800+meters in distance. Concluding on the previous statements, the following factors are not included in the PTAL model: walkability (the pavement quality), demographics (income constraints, age, and etcetera) and weather conditions.

The second limitation is the *quality of the OTP map* which shows only *known* car parks. Parking in Bangkok is possible almost everywhere. This quantitative lack of knowledge about parking space locations, limits a qualitative analysis of the parking level present.

The third limitation is the high uncertainty about the accuracy of the stated bus frequency on Google maps. Google maps claims that every bus line in Bangkok has a frequency of 6 per hour, so one bus every 10 minutes. From personal experience it can be said that this is most certainly not the case and many lines appear more frequent then other lines. This is certainly not due to the endless congestion. Congestion or not, many lines appear every 5 minutes while others show up once every hour. Also, Google maps states its reference source to be the BMTA website, however any type of timetable or frequency cannot be found on the BMTA website.

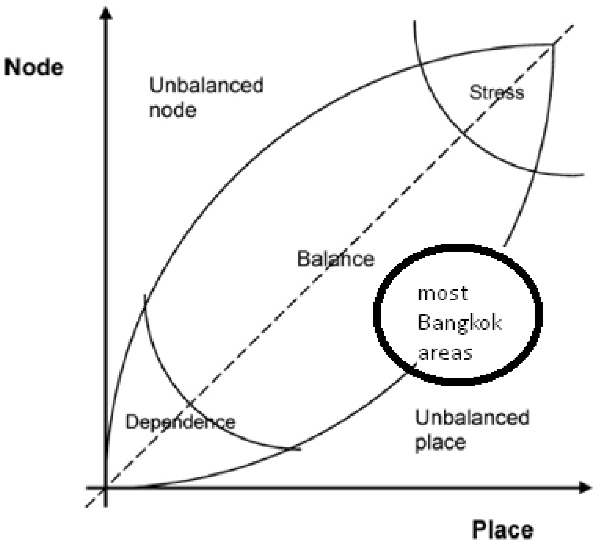
The fourth limitation the policy recommendations derived from the PTAL model are constrained. For Bangkok it would be more applicable to utilize the PTAL model to the growing suburbs and outside the CBD. The high urban densities in the CBD make large infrastructural changes vastly limited. Changes to the traffic mix, like dedicated bus lines, would be extremely beneficial in enhancing reliability for the bus. Furthermore, when there are low PTAL within the CBD the model suggest that this area ought to be dedicated towards parking or large industrial sites, such as warehousing. This is a shortcoming of the PTAL model, as this area is merely underrepresented in qualitative and/or quantitative public transport options. The only necessary amendment to most low PTAL areas, is the provision of quality public transport in order to boost accessibility. In view of that, using PTAL as a sole model for urban planning is highly inefficient and closer views of specific areas have to be taken simultaneously with PTAL application.

11. CONCLUSIONS

"I think transportation and corrections are not the first two areas that I would go looking for massive change."
William Weld; former Governor of Massachusetts

The area examples previously discussed represent a minuscule analysis for Bangkok and one has to be cautious when drawing any large generalized conclusions for Bangkok concerning public transport accessibility and to what extent it might affect patronage. From these few areas the following two general observations for Bangkok are found. Firstly, *public transport accessibility does not appropriately meet urban density in two ways. Either PAL equals or exceeds high PTAL areas OR there is low PTAL with moderate PAL in areas with high urban density.* The areas with relative moderate or good levels of public transport accessibility correspondingly offer good parking accessibility. Many of the large parking garages are situated near MRT and are BTS or BMCL property and constructed with the intention of hiking up patronage. To some extent, this does boost patronage as the accessibility between the parking garage and MRT is soaring. This incentivizes a model split commute for car drivers by ensuring MRT ease, reliability and affordability. However, PTAL policy recommendations state that greater benefits would be achieved if the surrounding MRT area is reserved for residency and commercial units and *not* parking. The large parking lots ought to be situated outside the moderate and good PTAL perimeters with a high frequency feeder line to the high PTAL area. The second mismatch is that despite the towering urban density across most of Bangkok and the presence of rather high availability and inexpensive parking across the city, plus low accessibility of good public transport, can explain the possible low patronage of the public transport system. The mode accessibility for MRT was low; this could result in people diverging away from this mode. Thus, due to the vast parking availability and unwillingness of car users to take the bus, there are *no* large incentives for car owners to opt away from driving. This surely dampens patronage levels for all public transport modes.

Figure 18: Node Place Model Bangkok Area Locations



The second observation was the strong $AI_{bus.}$ Actions should be taken to further enhance its value. The first recommendation for public transport accessibility improvement is to tackle the bus reliability, by implementation of bus lanes. Secondly, the number of lines has to be extended, particularly that of the MRT, to improve network coverage. Thirdly, with future urban planning it has to be discouraged to construct large car parks in areas with moderate or good PTAL. Fourthly, further car driving ought to be discouraged by applying TDM measures, such as high parking fees. These policies could shift many of Bangkok's unbalanced places upwards towards becoming balanced. At this point, access to opportunities is assembled with the fitting amount of (pubic) transport options.

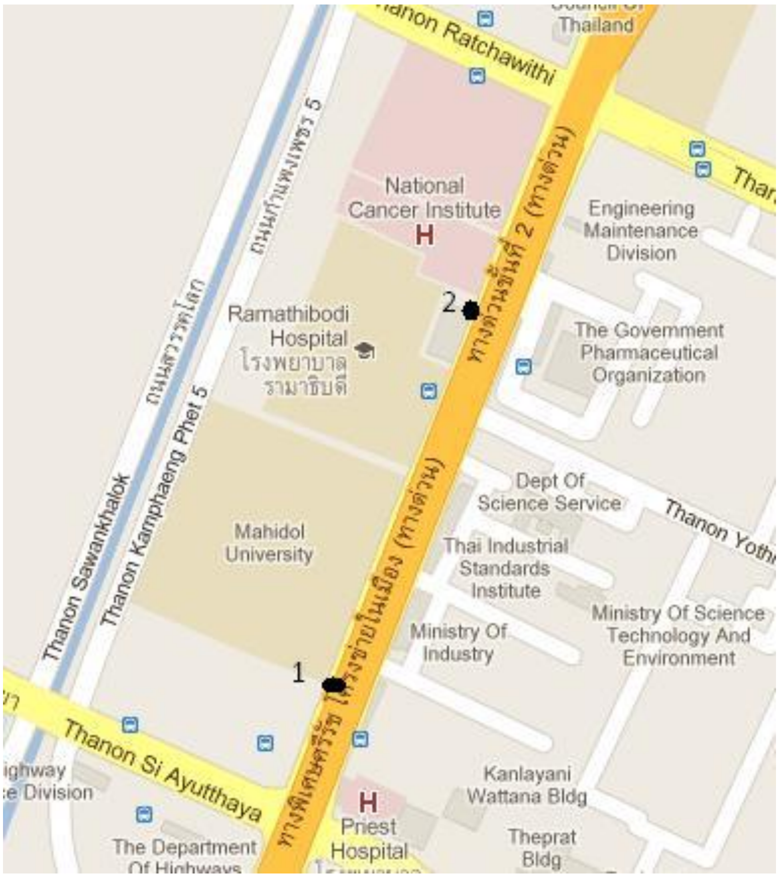
Further study is necessary to establish a more accurate bus reliability. A graphical representation of the PTAL values for the whole of Bangkok will add to a clearer understanding of the diverse PTAL across the city.[22]

[22] http://www.londonprofiler.org/ (Transport, PTAL)

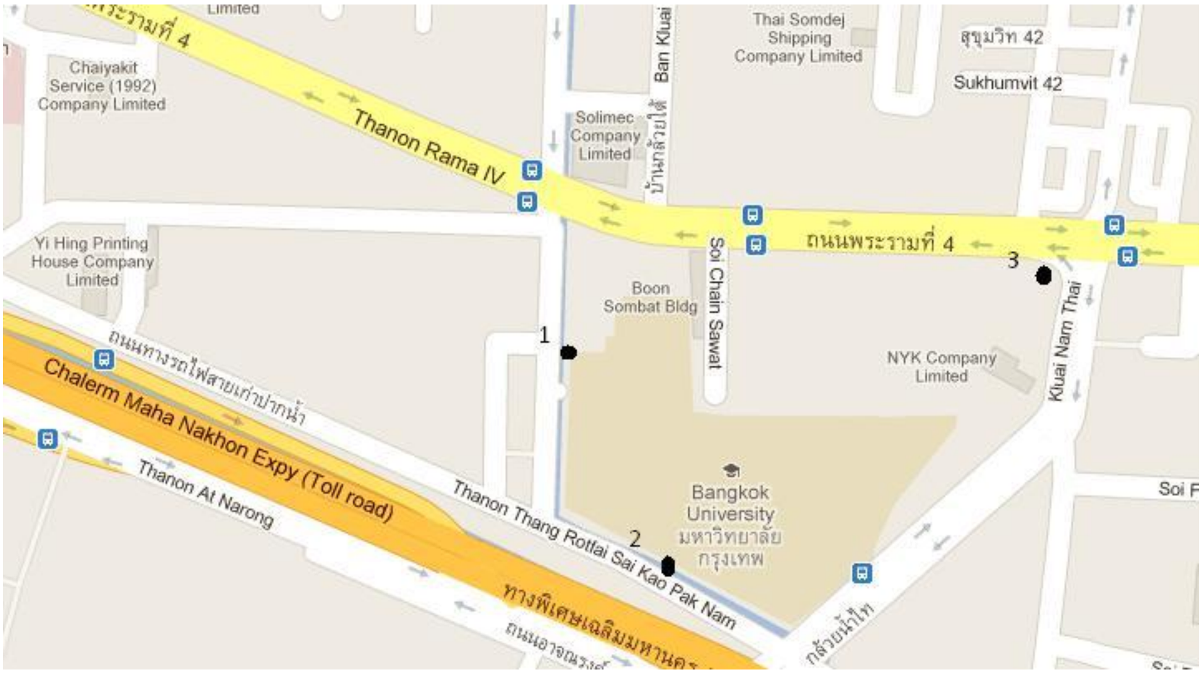
12. APPENDIX

CHULALONGKORN UNIVERSITY

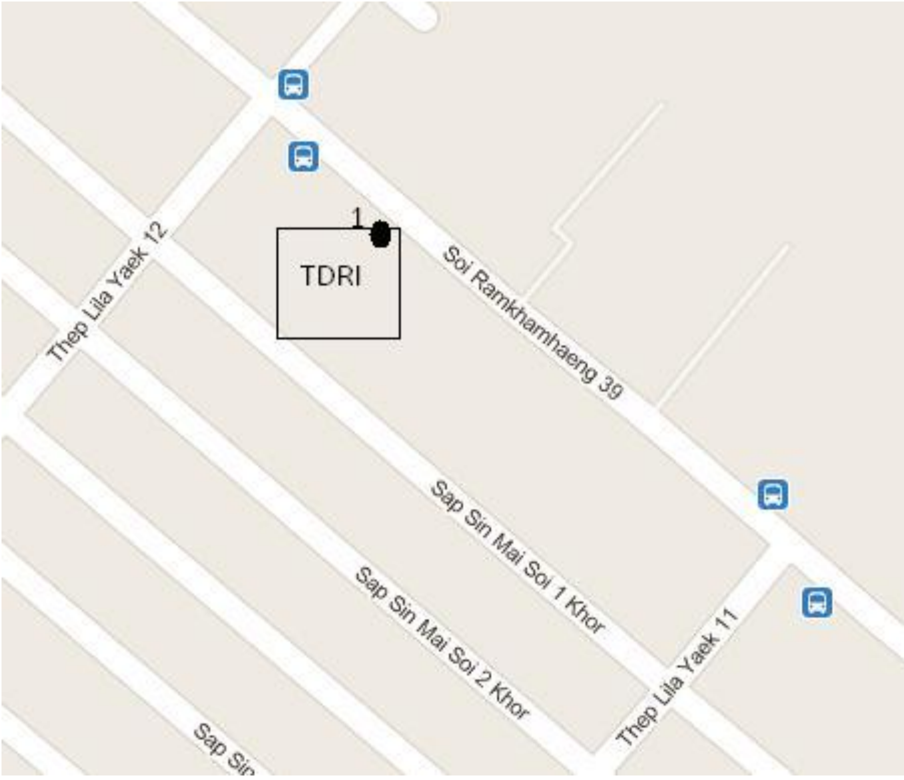
MAHIDOL UNIVERSITY



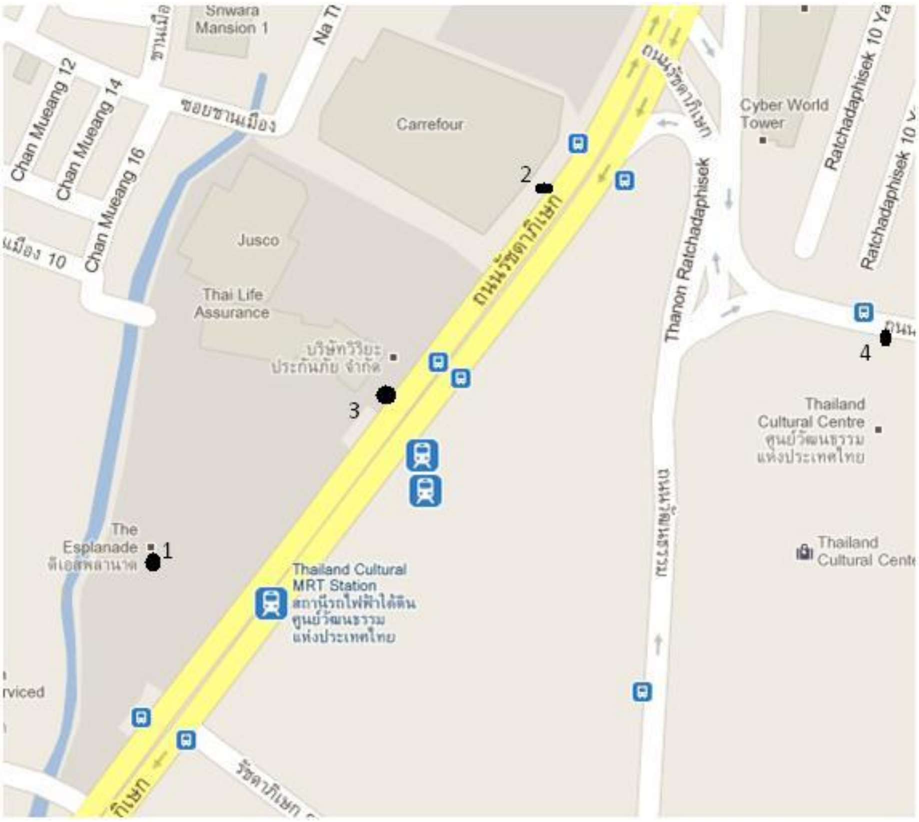
BANGKOK UNIVERSITY



TDRI



THAILAND CULTURAL CENTER



CHATUCHAK

RELIABILITY CALCULATIONS

scheduled waiting time	bus average waiting time-chula	Reliability chula	bus average waiting time-mahidol	Reliability mahidol	bus average waiting time-BKKuni	Reliability BKKuni
5	15	10	5	0	10	5
5	5	0	5	0	10	5
…	…	…	…	…	…	…
…	…	…	…	…	…	…
…	…	…	…	…	…	…
5	10	5	10	5	2	-3
		Averagec		Averagem		Averageb
		9.6521739		4.964706		5.7297297
Total average	=	Averagec	+	Averagem	+	Averageb
	=	**6.7822032**				

SUBWAY RELIABILITY

service reliability	year	target (%)	realized (%)	decimal
	2009_Q1	99.65	99.79	0.9979
	2009_Q2	99.65	99.69	0.9969
	2009_Q3	99.65	99.79	0.9979
	2009_Q4	99.65	99.83	0.9983
	2009	99.65	99.77	0.9977
	2010 Q1	99.65	99.9	0.999
	2010 Q2	99.65	99.77	0.9977
	2010 Q3	99.65	99.81	0.9981
	2010 Q4	99.65	99.84	0.9984
	2010	**99.65**	**99.83**	**0.9983**
average	2011	99.65	99.802	0.99802
expected	2011	99.65		

Seconds*hour	**3600**
Second*min	60
Minutes*hour	60
hour	1
Average realized train on time last year realized	99.83
	0.9983

If something happens 0.5 part of the time, it is 50% of the time, .5 times 100 equals 50%.By the same token, if something happens 99.83% of the time, DIVIDE by 100 to get the portion of the time it happens, 99.83%/100 means it happens 0.9983 part of the time

1 hours x 60min/hour x 60sec/min =	**3600**	
0.9983 x 3600 sec=	3593.88	
3592.872sec x min/60sec	59.898	
penalty = 60-59.8812	**0.102**	**minutes**

period	line	frequency (seconds)	frequency per hour	frequency one day 06.00-24.00	number of trains per year	last year total number of late trains (2010)	percentage late of total trains
peak	silom	185	19.4594595	350.2702703	127848.6486		0
peak	sukumvit	160	22.5	405	147825		0
average		172.5	20.9797297	377.6351351	275673.6486	966	0.003504

1 hours x 60min/hour x 60sec/min =	3600	
0.003504 x 3600 sec=	12.61491629	
12.61491629sec x min/60sec	0.210248605	
penalty	**0.210248605**	**minutes**

CORRELATIONS PRIVATE CAR USERS

Correlations - observations private car users

		private vehicle car n motor	Min walking willingness parkspace	Min walking willingness MRT	Min walking willingness BTS	bus times	Min walking willingness bus	BTS times	MRT times	motorcycle taxi	walking	gender	age
private vehicle car n motor	Pearson Correlation	1	.331*	.239*	.177	-.289**	.070	.125	.591**	.063	-.421*	.112	-.089
	Sig. (2-tailed)		.028	.029	.103	.007	.551	.303	.000	.650	.026	.242	.357
	N	110	44	83	86	87	75	70	41	55	28	110	110
Min walking willingness parkspace	Pearson Correlation	.331*	1	.361**	.256**	.001	.102	-.167	.094	.429**	-.160	-.003	.016
	Sig. (2-tailed)	.028		.000	.003	.994	.294	.121	.487	.004	.300	.965	.844
	N	44	162	140	135	131	107	88	57	43	44	162	162
Min walking	Pearson Correlation	.239*	.361**	1	.547**	-.096	.321**	.194*	.121	.178	.046	-.039	-.119

wil-lingness MRT	Sig. (2-tailed)	.029	.000		.000	.181	.000	.029	.281	.127	.705	.541	.064
	N	83	140	244	195	197	161	126	81	75	70	243	244
Min walking wil-lingness BTS	Pear-son Corre-lation	.177	.256**	.547**	1	-.217**	.279**	.066	.066	.034	.093	-.055	-.137*
	Sig. (2-tailed)	.103	.003	.000		.003	.001	.456	.575	.762	.456	.415	.041
	N	86	135	195	224	184	152	131	75	80	67	224	224
bus times	Pear-son Corre-lation	-.289**	.001	-.096	-.217**	1	.126	.022	.127	-.234*	.148	.044	-.070
	Sig. (2-tailed)	.007	.994	.181	.003		.099	.810	.309	.036	.207	.506	.287
	N	87	131	197	184	236	171	121	66	81	74	235	235
Min walking wil-lingness bus	Pear-son Corre-lation	.070	.102	.321**	.279**	.126	1	-.114	-.037	.007	.296*	-.087	-.064
	Sig. (2-tailed)	.551	.294	.000	.001	.099		.259	.775	.952	.016	.232	.376
	N	75	107	161	152	171	192	100	63	69	66	192	192
BTS times	Pear-son Corre-lation	.125	-.167	.194*	.066	.022	-.114	1	.016	.179	.163	.121	.015
	Sig. (2-tailed)	.303	.121	.029	.456	.810	.259		.910	.164	.252	.126	.849
	N	70	88	126	131	121	100	162	54	62	51	162	162
MRT tim	Pear-son Corre-	.591**	.094	.121	.066	.127	-.037	.016	1	-.279	.069	.223*	.044

es	lation												
	Sig. (2-tailed)	.000	.487	.281	.575	.309	.775	.910		.135	.728	.027	.669
	N	41	57	81	75	66	63	54	98	30	28	98	98
mo-tor-cycle taxi	Pear-son Corre-lation	.063	.429**	.178	.034	-.234*	.007	.179	-.279	1	-.172	.009	.013
	Sig. (2-tailed)	.650	.004	.127	.762	.036	.952	.164	.135		.315	.931	.900
	N	55	43	75	80	81	69	62	30	99	36	99	99
walking	Pear-son Corre-lation	-.421*	-.160	.046	.093	.148	.296*	.163	.069	-.172	1	.178	.142
	Sig. (2-tailed)	.026	.300	.705	.456	.207	.016	.252	.728	.315		.084	.171
	N	28	44	70	67	74	66	51	28	36	95	95	95
gender	Pear-son Corre-lation	.112	-.003	-.039	-.055	.044	-.087	.121	.223*	.009	.178	1	.113*
	Sig. (2-tailed)	.242	.965	.541	.415	.506	.232	.126	.027	.931	.084		.047
	N	110	162	243	224	235	192	162	98	99	95	310	310
age	Pear-son Corre-lation	-.089	.016	-.119	-.137*	-.070	-.064	.015	.044	.013	.142	.113*	1
	Sig. (2-tailed)	.357	.844	.064	.041	.287	.376	.849	.669	.900	.171	.047	
	N	110	162	244	224	235	192	162	98	99	95	310	311

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

CORRELATIONS FULL DATA SET

	bus times	BTS times	MRT times	motorcycle	pri-vate_ve-hicl	walking	minute_wa	minute_wa	minute_wa	minute_walkin	gender	age

					taxi	e		lking_willingness_MRT	lking_willingness_BTS	lking_willingness_bus	g_wil-lingness_parkingspace		
bus times	Pearson Correlation	1	.220*	.347**	.028	-.145*	.323**	.041	-.027	.234**	.181*	.077	.078
	Sig. (2-tailed)		.012	.002	.790	.025	.003	.556	.711	.002	.032	.234	.227
	N	245	130	75	91	240	83	206	193	180	140	242	244
BTS times	Pearson Correlation	.220*	1	.235	.280*	.065	.344**	.329**	.211*	.074	.116	.148	.149
	Sig. (2-tailed)	.012		.063	.017	.410	.007	.000	.012	.444	.260	.054	.052
	N	130	171	63	72	163	60	135	140	109	97	169	171
MRT times	Pearson Correlation	.347**	.235	1	.127	.166	.340*	.252*	.265*	.155	.269*	.262**	.175
	Sig. (2-tailed)	.002	.063		.437	.099	.040	.016	.015	.193	.029	.007	.071
	N	75	63	107	40	100	37	90	84	72	66	105	107
motor-cycle taxi	Pearson Correlation	.028	.280*	.127	1	.021	.126	.306**	.227*	.168	.480**	.060	.231*
	Sig. (2-tailed)	.790	.017	.437		.832	.403	.004	.031	.138	.000	.540	.016
	N	91	72	40	109	101	46	85	90	79	53	107	109
private-vehicle	Pearson Correlation	-.145*	.065	.166	.021	1	-.138	.029	.021	.105	.107	.053	.022
	Sig. (2-tailed)	.025	.410	.099	.832		.177	.652	.759	.142	.170	.351	.703
	N	240	163	100	101	312	97	242	224	195	165	309	310
walking	Pearson Correlation	.323**	.344**	.340*	.126	-.138	1	.235*	.285*	.405**	.148	.243*	.273**
	Sig. (2-tailed)	.003	.007	.040	.403	.177		.037	.013	.000	.291	.014	.005
	N	83	60	37	46	97	104	79	76	75	53	102	104
min_walking_willigness_MRT	Pearson Correlation	.041	.329	.252*	.306	.029	.235*	1	.590	.391	.441**	-.007	-
	Sig. (2-tailed)	.556	.000	.016	.004	.652	.037		.000	.000	.000	.914	.967
	N	206	135	90	85	242	79	253	204	170	149	251	253
min_walking_willigness_BTS	Pearson Correlation	-.027	.211*	.265*	.227*	.021	.285*	.590**	1	.363**	.365**	-.012	.021
	Sig. (2-tailed)	.711	.012	.015	.031	.759	.013	.000		.000	.000	.858	.753
	N	193	140	84	90	224	76	204	233	161	144	231	233

min_walking_willigness_bus	Pearson Correlation	.234**	.074	.155	.168	.105	.405**	.391**	.363**	1	.274**	-.050	.056
	Sig. (2-tailed)	.002	.444	.193	.138	.142	.000	.000	.000		.003	.487	.428
	N	180	109	72	79	195	75	170	161	201	116	199	201
min_walking_willigness_parkspace	Pearson Correlation	.181*	.116	.269*	.480**	.107	.148	.441**	.365**	.274**	1	.045	.155*
	Sig. (2-tailed)	.032	.260	.029	.000	.170	.291	.000	.000	.003		.565	.043
	N	140	97	66	53	165	53	149	144	116	171	169	171
genderd	Pearson Correlation	.077	.148	.262**	.060	.053	.243*	-.007	-.012	-.050	.045	1	.135*
	Sig. (2-tailed)	.234	.054	.007	.540	.351	.014	.914	.858	.487	.565		.016
	N	242	169	105	107	309	102	251	231	199	169	319	319
age	Pearson Correlation	.078	.149	.175	.231*	.022	.273**	-.003	.021	.056	.155*	.135*	1
	Sig. (2-tailed)	.227	.052	.071	.016	.703	.005	.967	.753	.428	.043	.016	
	N	244	171	107	109	310	104	253	233	201	171	319	321

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

PTAL VALUES

PTAL value	PTAL index	Accessibility level
0-2.5	1a	Very poor
2.5 – 5	1b	Very poor
5-10	2	Poor
10-15	3	Moderate
15-20	4	Good
20-25	5	Very good
25-40	6a	Excellent
40+	6b	Excellent

PTAL VALUE RESULTS

AREA	LOCATION	AI	PAL	AI bus	AI MRT	AI BTS
Chulalong-korn University	1	11.23545336	0	11.235453	0	0
	2	0	0	0	0	0
	3	19.77929912	20	11.25106	9.7783572	0
	4	0	0	0	0	0
	5	19.07006435	16.5	11.908277	8.1541435	0
Mahidol University	1	6.461945649	0	6.4619456	0	0
	2	5.960647293	0	5.9606473	0	0
Bangkok University	1	6.583450696	0	6.5967732	0	0
	2	8.988140762	0	8.9881408	0	0
	3	7.822456261	0	8.0563348	0	0
Meechai Mansion	1	3.406084167	0	3.4060842	0	0
TDRI	2	3.714239148	0	3.7142391	0	0
Thailand Cultural Center	Esplanade	13.34648408	100.5230769	9.9046377	4.6799261	0
	Carrefour	12.20312898	111	9.3880529	3.9885827	0
	Thai life As-surance (business)	13.01448727	120.8142857	9.6783015	4.5459735	0
	Thailand Cul-tural Center	4.756040297	7.5	4.7560403	0	0
Chatuchak	1	5.001798419	36	3.1516229	2.9128344	0
	2	22.02378161	9	34.050831	3.5670302	2.620346
	3	16.90824038	15.6	25.545631	2.9770693	2.1507119

13. ABBREVIATIONS

AI	Accessibility Index
BMA	Bangkok Metropolitan Administration
BMR	Bangkok Metropolitan Region
BMCL	Bangkok Metro Company Limited
BMTA	Bangkok Mass Transit Authority
BOT	Build Operate Transfer
BRT	Bus Rapid Transit
BTS	Bangkok Mass Transit System Company Limited
CBD	central business district
DLT	Department of Land Transport
EDF	Equivalent Doorstep Frequency
Kph	kilometers per hour
MRTA	Mass Rapid Transit Authority of Thailand
MRT	Mass rapid transit
OTP	Office of Transport and Traffic Policy and Planning
PAL	Parking Accessibility Levels
POI	accessibility from a point of interest
PTAL	Public Transport Accessibility Levels
RP	Revealed Preference
SAP	service access point
SARL	Suvarnabhumi Airport Rail Link
SOE	state owned enterprise
SP	stated preference
SRT	state railways of Thailand
SUMA	Sustainable Urban Mobility in Asia
TCC	Thailand Cultural Center
TDM	Transport Demand Management
TDRI	Thailand Development Research Institute
THB	Thai Baht (Thai currency)

14. REFERENCES

3G-the Next Generation of Transport. (2011). *Mobility versus accessibility: Toward a theory of good transportation, including the experience of the ride itself*

Acharya, S. R., & Morichi, S. (2007). Motorization and role of mass rapid transit in easy Asian megacities.*31*(2)

Bangkok Mass Transit Authority. *Bangkok mass transit authority.*http://www.bmta.co.th

Bangkok Mass Transit System Public Company Limited. *BTS-MRT map (skytrain and subway in Bangkok).*, 2003, from http://www.bts.co.th/en/map.asp

Bangkok Mass Transit System Public Company Limited. (2011). *Bangkok mass transit system public company limited.*http://www.btsgroup.co.th/en/about_us_at_a_glance.php

Bangkok Metro Public Company Limited. (2009). *Annual report 2009*

Barter, P. (2000). Urban transport in asia: Problems and prospects for high-density cities.*2*(1), 33-66.

Bentsson, M. (2006). The Bangkok skytrain, the transportation solution for Bangkok people?

Bhattacharjee, D., Haider, S. W., Tanaboriboon, Y., & Sinha, K. C. (1997). Commuters' attitudes towards travel demand management in bangkok .*4*(3), 161-170.

Bray, D., & Sayeg, P. (2002). *Valuing externalities of Bangkok's mass transit (skytrain) system* Economic & Policy Services Pty Lts; Policy Services Pty Ltd.

Chen, Y., & Liy, N. (2007). STATISTICAL PROPERTIES OF URBAN GROUND BUS-TRANSPORT NETWORKS FROM SELF-AVOIDING RANDOM WALKS.*21*(16)

Choocharukul, K., & Tan Van, Hong Fujii, Satoshi. (2007). Psychological effects of travel behavior on preference of residential location choice., 116-124. doi:10.1016/j.tra.2007.06.008

Chotichinda Mouchel Consultants Limited. (-). *Study of travelling behavior of passengers and evaluation of the social and economic benefits for the M.R.T. chaloem ratchamongkhon line*

Clever, R. (1997). Intermodal: Integrated timed transfer: A European perspective., 107-115.

Curtis, C., & Scheurer, J. (2007). Multiple accessibility: Developing a tool for evaluating land use-transport integration.

Denant-Boèmont$, L., & Hammiche, S. (2009). Public transit capacity and User's choice: An experiment on downs-thomson paradox.(1)

Dissanayake, D., & Morikawa, T. (2009). Investigating household vehicle ownership, mode choice and trip sharing decisions using a combined revealed preference/stated preference nested logit model: Case study in Bangkok metropolitan region.

Dong, X., Ben-Akiva, M. E., Bowman, J. L., & Walker, J. L. (2006). Moving from trip-based to activity-based measures of accessibility., 163-180.

Flyvbjerg, B., Bruzelius, N., & Rothengatter, W. (2003). *Megaprojects and risk: An anatomy of ambition*. United Kingdom: University Press, Cambridge.

Gent, C., & Symonds, G. (2005). Advances in public transport assessments for development control-A proposed methodology.

Guo, Z., & Wilson, N. H. M. (2010). Assessing the cost of transfer inconvenience in public transport systems: A case study of the London underground.

Hammersmith and Fulham. *Public transport accessibility levels.*http://www.lbhf.gov.uk/

Handy, S. (1994.). Highway blues: Nothing a little accessibility can't cure.(No. 5), pp. 3-7.

Handy, S. (2002). ACCESSIBILITY- VS. MOBILITY-ENHANCING STRATEGIES FOR ADDRESSING AUTOMOBILE DEPENDENCE IN THE U.S.

Hine, J., & Scott, J. (2000). Seamless, accessible travel: Users' views of the public transport journey and interchange.*7*(3), 217-226.

Ingram, D. R. (1971). The concept of accessibility: A search for an operational form.*5*, 101-107.

Kenworthy, J. (1995). Automobile dependence in Bangkok: An international comparison with implications for planning policies.*1*(3), 31-41.

Kesten, A. S., & Tezcan, H. O. (2006). Bus and subway stations' ubiquity: A case study for stations along Istanbul metro line.

Kongrut, A. (2009, **BANGKOK FOOTPATHS**: **Time to take a step in the right direction.** . *Bangkok Post: The World's Window to Thailand,*

Litman, T. A. (2011). *Evaluating accessibility for transportation planning: Measuring peoples ability to reach desired goods and activities* Victoria Transport Policy Institute; efficiency, equity, clarity.

Loader, C. (2011). ***A simple look at passenger transport trends in Australian cities***. http://chartingtransport.wordpress.com/about/

Lopez, E. (2005). Measuring regional cohesion effects of large-scale transport infrastructure investments: An accessibility approach.*5*, 480. Retrieved from http://www.ersa.org

Miller, H. J. (1999). Measuring space-time accessibility benefits within transportation networks: Basic theory and
computational procedures.*31*

Miller, M. (2011). *Transport* Able Magazine.

Ministry of Transport. *Office of transport and traffic policy and planning.* http://www.otp.go.th/th/

Murdoch University. Institute for sustainability and technology policy.

Oregon Department of Transportation. *Accessibility and mobility differences.* http://www.oregon.gov/ODOT/SUS/accessibility_mobility.shtml

Pamanikabud, P., & Pichittanapanya, S. (2003). SERVICEABILITY ANALYSIS OF PEDESTRIAN WALKWAY AT BANGKOK MASS TRANSIT STATION.*5*

Peek, G., Bertolini, L., & De Jonge, H. (2006). Gaining insight in the development potential of station areas: A decade of node-place modeling in the netherlands.*21*(4), 443-462.

Pianuan, K., Santikarn Kaosa-ard, M., & Pienchob, P. (1994). **Bangkok traffic congestion: Is there a solution?**.*9*(2), 20-23.

Pitot, M., Yigitcanlar, T., Sipe, N., & Evans, R. (2006). Land use and public transport accessibility index (LUPTAI) tool: The development and pilot application of UPTAI for the gold coast.

Punpuing, S., & Ross, H. (2001). Commuting: The human side of Bangkok's transport problems.*18*(1), 43-50.

Reynolds, R. *The subway page: Links to world subway and other transportation information resources.*, 1997, from http://people.reed.edu/~reyn/transport.htm

Rietveld, P., & Bruinsma, F. (1998). *Is transport infrastructure effective: Transport infrastructure and accessibility: Impacts on the space economy*. Germany: Springer-Verlag.

Rietveld, P., & Bruinsma, F. (1998). ***Is transport infrastructure effective?*** *Transport infrastructure and accessibility: Impacts on the space Economy***.** Germany: Springer-Verlag Berlin Heidelberg New York.

Rodrigue, J. ***The notion of accessibility***. http://people.hofstra.edu/geotrans/eng/ch2en/meth2en/ch2m1en.html
Shafahi, Y., & Khani, A. (2010). A practical model for transfer optimization in a transit network: Model formulations and solutions.
Smart, M., Miller, M. A., & Taylor, B. D. (2009). Transit stops and stations: Transit managers' perspectives on evaluating performance.*12*(1), 59-77.
Spiekermann, K., & Neubauer, J. (2002). European accessibility and peripherality: Concepts, models and indicators.
Steg, L., Vlek, C., & Slotegraaf, G. (2001). Instrumental-reasoned and symbolic-affective motives for using a motor car.
TANABORIBOON, Y. (1993). BANGKOK TRAFFIC.*15*
Think Metric. *Speed.*http://www.thinkmetric.org.uk/speed.html
Townsend, C., & Zacharias, J. (2009). Built environment and pedestrian behavior at rail rapid transit stations in Bangkok.
Unknown. (2010, Going underground: The Bangkok experience. *The Daily Star,*
Veeneman, W. W. (2002). Mind the gap; bridging theories and practice for the organization of metropolitan public transport. DUP Science).
Vichiensan, V. (2008). Transportation research challenges in Thailand. sub-project on: Mobility and accessibility
Vickerman, R. W., Spiekermann, K., & Wegener, M. (1999). Accessibility and economic development in europe.*33*, 1-15.
Victoria Transport Policy Institute. (2011). http://www.vtpi.org/tdm/tdm84.htm
Vongvipanond, P. (1994). **Linguistics perspective of Thai culture**
Vuchic, V. R. (2006). Urban transit systems and technology. (). New Jersey: John Wiley & Sons, Hoboken.
Wancharoen, S. (2010, Skytrain delay poses puzzle: Resident cannot fathom why line is idle. *Bangkok Post: The World's Window to Thailand,*
Wardman, M. (2001). The value of travel time: A review of British evidence.*32*(3), 285-316.
Willigers, J. (2003). HIGH-SPEED RAILWAY DEVELOPMENTS AND CORPORATE LOCATION DECISIONS: THE ROLE OF ACCESSIBILITY
World Bank. (2007). *Strategic urban transport policy directions for Bangkok*
World Bank. (2009). *WALKABILITY-improving pedestrian infrastructure and services in Bangkok*
World Bank, & Office of the National and Social Development Board. (2009). *THAILAND : MAKING TRANSPORT MORE ENERGY EFFICIENT. Thailand-World Bank country development*
partnership for infrastructure
Wu, B. M., & Hine, J. P. (2003). A PTAL approach to measuring changes in bus service accessibility.*10*, 307-320.
Zhu, X., & Liu, S. (2004). Analysis of the impact of the MRT system on accessibility in Singapore using an integrated GIS tool.*12*, 89-101.
Zuidgeest, M., Bruseel, M., Arora, A., Bhamidipati, S., Amer, S., de Souza, F., et al. (2009). *On bus-bike integration* Asian Development Bank.