STUDY ON COMPARISON OF PUBLIC TRANSPORT ACCESSIBILITY FOLLOWING M-MAP MASTER PLAN IN BANGKOK METROPOLITAN REGION USING TIME-DISTANCE MAPPING

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1. Introduction

Recently there have been rapid developments in urban transit system to help ease the ever increasing traffic demand in Bangkok Metropolitan Region. The development of urban transit system in Bangkok largely based on studies in the aspect of cost-benefit. However, there are very few study conducted relating to the impact of urban transit systems on public transport accessibility and level of service in Bangkok Metropolitan Region. Therefore, it is important to find the proper method to evaluate the impact from the introduction of mass rapid transit systems on the improvement of public transportation accessibility in Bangkok Metropolitan Region.

2. Background & Literature reviews

To find the suitable approach to be apply in this study, commonly used transport accessibility evaluation methods have been reviewed based on three considerations. Suitability to be use in evaluating public transportation accessibility, the ability to measure accessibility as a whole rather than individuals travels behavior, and finally, the ability to display improvements in accessibility from different network scenarios.

Although not commonly used, **Time-distance mapping[1]** is an approach that effectively demonstrates the impact of transportation improvement during the course of time. This approach focuses on the characteristics of transport network in travel time and distance aspect, which is suitable to be use as transport accessibility evaluation tool.

3. Objectives

- To use transport simulation tool to develop the future BMR transport networks for evaluation.
- To find a method to best apply time-distance mapping to Bangkok transportation network as an accessibility evaluation tool.
- To use time-distance mapping to evaluate the improvement of public transport accessibility by comparing time-distance maps from different network scenarios.

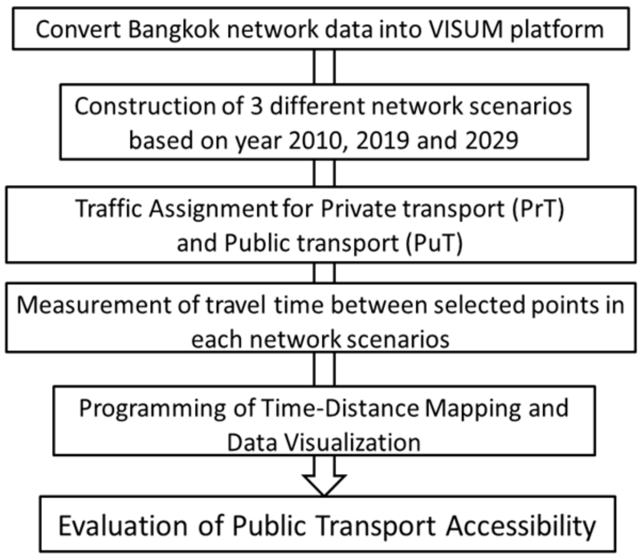

Fig.1 Structure of methodology

4. Methodology

(1) Convert Bangkok network data into VISUM platform

This research begins with the acquisition of Bangkok network data used in ATRANS research project **Integrating Congestion Charging Schemes and Mass Transit Systems in Bangkok[2]**. The goal is to operate network simulation in VISUM format which is more flexible and provide more functionality. The original network data is in EMME/3 format. The network was converted to the prior version of EMME transport model, EMME/2. Then it was imported and assigned into VISUM. This BMR network is based on year 2010.

(2) Construction of Network scenarios for Evaluation

The next step is to create three different network scenarios to be use as accessibility evaluation milestone by following the Mass Rapid Transit Master Plan in Bangkok Metropolitan Region (M-MAP). This study aims to evaluate the improvement in public transport accessibility during each phase of the development plan. The first scenario represents the current situation of BMR transport network in 2010 with BTS Silom & Sukumvit lines and MRT Blue line. The second scenario represents the first 10-year plan with 391km operating mass transit network once completed in year 2019. This scenario adds MRT Purple, Orange, Dark Red, Light Red and Dark Green lines plus the extensions to operating BTS lines, MRT Blue line and Airport Rail Link. In the last network scenario (second 10-year plan), the expected total mass transit network distance will be 509km. The improvements included MRT Yellow, Light Blue and Grey line, extensions to Dark Red, Light Red, Dark Green and Blue line.

Starting with the 2010 BMR transport network as a base, the urban mass transit network for 2019 and 2029 scenarios were created by importing ArcGIS shape files into VISUM network. The ArcGIS shape file was edited with Quantum GIS program according to each phase of the master plan (M-MAP).The merging of data and attributes are done within VISUM program.

The acquired 2010 BMR OD data was separated into Private transport (PrT) OD and Public transport (PuT) OD. The estimation of future OD started by merging PrT and PuT OD into total OD. Total OD for future scenarios were estimated from the **population growth rate**[3]. With year 2010 total OD as a base, 19.6% and 49.6% growth rate were used for year 2019 and year 2029 respectively. Nest Logit model modal split utility function was applied to both 2020 and 2030 total OD to separate traveler's modal choice in to PrT and PuT.

(3) Traffic Assignment for PrT and PuT

In this study, equilibrium assignment (static) procedure for private transport (PrT) and headway-based assignment method for public transport (PuT) are selected based on required input data, accuracy of results and computing time.

In this study, links impedance value for private transport is determined from the current travel time tCur. The current travel time tCur is in turn determined by the saturation of links which result from the traffic volume and the capacity of that link. Additionally, the influence of road tolls on link impedance is also taken into consideration. Therefore, travel times are converted into monetary unit using a "value of time" factor to express impedance in terms of monetary unit. Referring Sittha et. al. (2010), the impedance of link *a* is defined by the following function (1).

$$t_{Cur} = t_a^0 \left[1 + 0.73 \left(\frac{V_a}{C_a} \right)^3 \right] + \frac{\tau_a}{\gamma_{travel}} \tag{1}$$

Where : t_a^0 = Free flow travel time of link a
V_a = Hourly volume of link a
C_a = Capacity of link a (veh/hour)
τ_a = Toll fee
γ_{travel} = Value of travel time (1.27 baht/min)

The travel time function for the bus passengers (in minutes) is defined in equation (2).

$$t_{Cur}^{Bus} = 1.1 t_a^0 \left[1 + 0.73 \left(\frac{V_a}{C_a} \right)^3 \right] \tag{2}$$

Since bus is generally moving slower than private transport, it is assumed that the bus travel time on any link is equal to 1.1 times of the corresponding time for private transport (Sittha et. al. 2010).

For PuT assignment, the choice model for route search apply in this study is based on the assumption that the passengers do not have any information on departure times and the headways are constant. In order to model the stop choice behavior of passengers prior to boarding or transfer events and to model the behavior of passengers when deciding whether to stay on board or to alight, a discrete choice model is used in this study. Logit parameter beta β is taken as 0.5.

For the impedance function for route choice in PuT assignment, perceived journey time (PJT) is used to evaluate individual connections during the connection choice. PJT results from weighted components of the journey time and further components as stated below.
PJT = (1.0 x in-vehicle time) + (3.0 x walk time) + (1.0 x transfer wait time) + (1s x number of transfers)

(4) Measurement of travel Time from selected points in each network scenario

The definition of Time-distance in this study is based on travel time between zones within the network. Since Time-distance mapping method cannot covers all of 244 zones in the network, the goal is to select those zones that represent the overall Public transport network of Bangkok Metropolitan Region. The selection of zones was done based on the principle that each selected zone is most likely to be effected by the development of Mass rapid transit network. 29 zones in total were selected to represent the overall accessibility of travelling within BMR with 28 links represent travel time between them.

Travel time data to be use as an input for the Time-distance mapping program are collected from each network scenario. After traffic assignment process, travel times between selected zones in the case of private transport were observed from the PrT paths data. For the case of public transport, the travel times were observed from OD pairs PuT section of the assignment result data. The travel time between zone *i* and zone *j* is the averaged value of travel time from zone *i* to zone *j* and from zone *j* to zone *i* for both PrT and PuT.

(5) Programming of Time-Distance Mapping and Data Visualization

Time-distance mapping is the method that generates a map that represents relation of time and space. The elements between them are organized in such a way that the distances between them are not proportional to their physical distance (as in kilometers) but proportional to the travel times between them. In this study, Time-distance mapping will be used as an indicator of improvement in travel time, therefore improvement of accessibility by the introduction of mass rapid transit development.

Time-distance map is created by transforming physical coordinates of a physical map into time-distance coordinates. This can be expressed in global terms in equation (3).

$$u = f(x, y), v = g(x, y) \tag{3}$$

where : x, y = coordinates of point on physical map

u, v = coordinates of point on Time-distance map

The technique of Multidimensional scaling (MDS) is commonly used for the generation of Time-distance map. It generates a spatial configuration in multidimensional coordinate space of additional attribute such that the distance between items are as close as possible to the know distances.

If available set of the links ij between the points i and j is expressed as L, t_{ij} is the travel time and d_{ij} is the distance between points i and j, all points are configured in two-dimensional space as shown in equation (4).

$$\min \sum_{ij \in L} \left(t_{ij} - d_{ij}\right)^2 \tag{4}$$

By applying Pythagorean Theorem to d_{ij}

$$d_{ij} = \sqrt{\left(x_j - x_i\right)^2 + \left(y_j - y_i\right)^2} \tag{5}$$

Time-Distance mapping can be express as a non-linear least squares problem as in equation (6), where x_i, y_i are coordinates of point i and x_j, y_j are the coordinates of point j.

$$\min \sum_{ij \in L} \left(t_{ij} - \sqrt{\left(x_j - x_i\right)^2 + \left(y_j - y_i\right)^2} \right)^2 \tag{6}$$

This method however, plots Time-distance nodes only on the basis of travel times and does not take the geographical features of original map into account. Therefore, the result could be too distorted and cannot be compared with original map for evaluation.

Introduced by Shimuzu et.al., the generalized solution defined "directional angles of links on the geographical configuration" as an initial input into the equation in order to keeps the original geographical shape. The approximate value of direction angle of link ij is defined as θ'_{ij} in equation (7).

$$\min \sum_{ij \in L} \left[\left(t_{ij} \sin\theta'_{ij} - \left(x_j - x_i\right)\right)^2 + \left(t_{ij} \cos\theta'_{ij} - \left(y_j - y_i\right)\right)^2 \right] \tag{7}$$

The Python interface was used to develop the program that generates the Time-distance map. The algorithm of this program is following the algorithm explained in Fig.2. The initial inputs are time-distance data of links and real world coordinates of each node. Geographical angles of each links are realized from nodes coordinates.

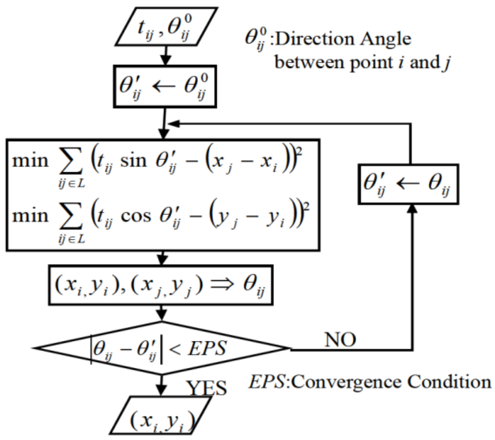

Fig.2 Time-distance mapping algorithm

In this study, the convergence condition was set at EPS = 10e-2. The program algorithm and programming steps are explained in detail in the full dissertation, as well as the program source code.

Although the initial visualization of Time-distance maps was included within the program via Matplotlib module from Python library, the purpose of this visualization was only for the output examination. The visualization of Time-distance maps for accessibility evaluation was done with Quantum GIS. Time-distance coordinates were plotted by importing output.cvs file as Delimited Text Layer.

5. Results and Evaluation

The improvement of public transport accessibility from Mass Rapid Transit Development in BMR are realized from the comparison of three Time-distance maps, one for each scenario as can be seen in Fig.3, Fig.4 and Fig.5. Comparing with year 2010, the overall travel time of public transport decreased dramatically in year 2019, especially in outer skirts areas of BMR. This resulted from many planned mass rapid transit lines that started to operate in year 2019. As these commuter trains connect Bangkok city with surrounding provinces and shorten the travel time between them. The most noticeable improvement from the year 2010 to year 2019 is the northern section of the MRT Dark Red line that connects Don Mueng district and northern Bangkok to Bang Sue hub station.

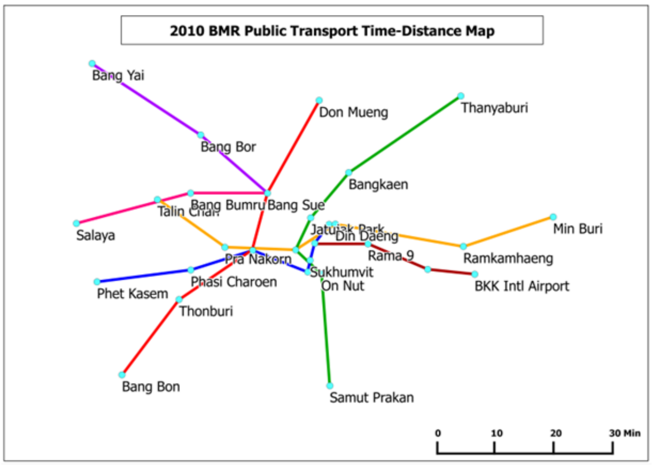

Fig.3 2010 BMR Public Transport Time-Distance Map

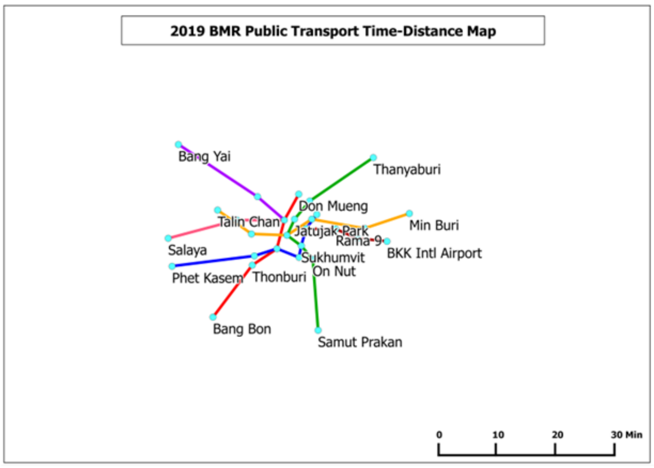

Fig.4 2019 BMR Public transport Time-Distance Map

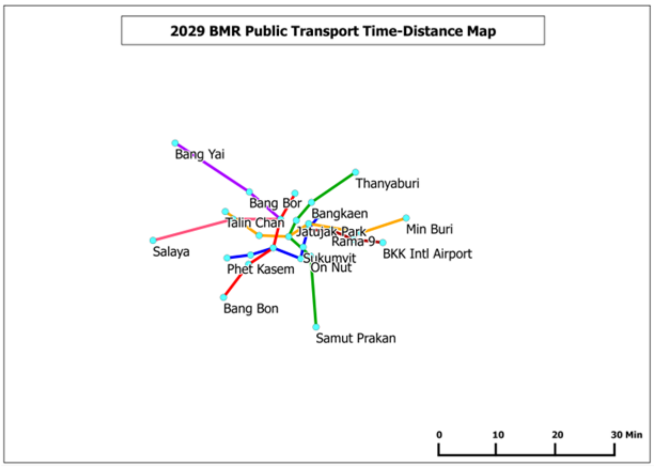

Fig.5 2029 BMR Public transport Time-Distance Map

As can be seen by comparing 2019 BMR public transport Time-distance map with 2029 BMR public transport Time-distance map, most improvements of accessibility concentrated in those lines connecting to outer Bangkok and surrounding provinces. The most impressive of all is Phet Kasem area located west of the MRT Blue line. The extension of MRT Blue line during the year 2019 and year 2019 (second 10-year plan) reduced the travel time between Phasi Charoen and Phet Kasem dramatically, thus providing commuters who live along Buddha Monthol 4 highway and those farther away in Nakorn Prathom province with greater accessibility. The accessibility along the southern MRT Dark Red line between Bang Bon district and Thonburi district significantly improved as well due to the extension of Dark Red line during the second 10-year plan.

6. Conclusion

This study concluded that the Mass Rapid Transit Master Plan in Bangkok Metropolitan Region or M-MAP will significantly improve accessibility in BMR especially in areas along the routes that connect to outer Bangkok. Time-distance mapping proved to be a useful tool for the evaluation of accessibility and transport level of service. In this study, the utilization of transport demand forecast model with Time-distance mapping leads to the new possibility to evaluate the feasibility of the mass rapid transit development project, at least in the transport accessibility aspect. The utilization of Time-distance mapping also provided a valid visual data that can be understand easily. This could be use as a promotional tool to help citizens understand the importance of mass rapid transit system.

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