Experiences of Using Opensource Transport and Traffic Simulation Software for Transport and Traffic Studies in Thailand

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Abstract—**This article summarizes the experiences of using open-source transport and traffic simulation software for transport policy and planning works in Thailand. The first software is the TRANUS, which is the Land Use Transport Integration (LUTI) software. The other software is SUMO (Simulation of Urban Mobility), which is the traffic simulation software. The reviews are general software features, input data requirements, and potential outputs. The paper also discusses the example of project implementations, which uses TRANUS and SUMO for evaluating the impacts of the metro line services around the activity center area. Experiences show that, even though there is a learning curve for both software, it's free of costs, diverge user communities, and prompt software features, are representing that open-source transportation software platforms could be an alternative for future transport policy and planning work in Thailand.**

Index Terms—**Land Use Transport Integration (LUTI), TRANUS, SUMO**

II. Introduction

The performance of Thailand's transportation infrastructure has been improved in the last 20 years. Perhaps, the tipping point was between 2005 and 2010, in which the performances had increased from 19.69 to 61.52 [1]. Additionally, after the first metro line opened its services in 1999, the metro system becomes the demanded public transportation services in Bangkok and its vicinity areas. Hence, from the first metro line in 1999, Thailand expects to have more than 400 kilometers of the metro transit serving a population who live in Bangkok and its vicinities by the year 2035.

According to Thailand's Infrastructure Development Master Plan (2015-2022), the new transportation development strategies (2015-2022) consist of 5 essential programs, including intercity rail network, highway network capacity enhancement, Bangkok's public transportation network development, and air transport capacity enhancement. The total investment budget is approximately 3.38 Trillion Baht, with more than 50 percent of the budget allocating to the action plan in 2016.

Based on the prior demands of the transportation developments, various project studies which including demand estimation, environmental impacts, project costs, and project benefits, are growth parallel to the needs and demands of the development. Transportation modeling software becomes a vital tool that is needed to use for assisting the project studies and the planning and development decisions.

There are many transportation software, either travel demand estimation software or traffic simulation software (both mesoscopic and microscopic simulation), and already applied in various projects in Thailand. For example, Cube Voyager and Cube Land from Citilabs, The Cube Voyager is the tool that provides advanced transport modeling techniques: forecasting and assignment of local, regional, and long-distance demand and Cube Land is an econometric model of land-use allocation that brings into the modeling process concrete land-transport interactions [2]. Additionally, VISSUM from PTV is also one of the leading transport and traffic planning tools that carry out traffic studies, predictions, and data management based on the GIS. The software can model all road users and their relationships, plan for the public transit system, and develop transport strategies and solutions [3].

However, this paper discusses the experiences of using two open-source software. One is the travel demand estimation software based on land use and transportation integration (LUTI), TRANUS. The other is the traffic simulation software, SUMO (Simulation of Urban Mobility). Discussions of their general features, input data requirements, the potential outputs, and the implementation examples are next.

II. Tranus

A. General Information

TRANUS is the travel demand modeling that considers the integration of land use and transport modeling. It can model the transportation demand for both the city and regional levels. The main feature of the program is the ability to evaluate the activity location and interaction, the real estate market, and the transportation systems and its demands. TRANUS has been used in various transport and urban studies projects. For example, it evaluates the different residential housing and transport development scenarios between 2020 and 2030 for the Urban Region of Grenoble, French [4]. A case study on Xiamen Island, China, also applies TRANUS to explore the relationship between urban transportation energy consumption and the transition of settlement morphology [5]. TRANUS also uses it to distinguish the land-use effects of road pricing based on the urban form [6].

TRANUS relied on several fundamental theories such as Von Thuneu (Spatial Microeconomics), Hensen Lowry (Gravity and Entropy), Input-Output (Leontief), Random Utility (McFadden), and Transport Models (Dijkstra). TRANUS has its structure divided into two parts, (1) Activities and (2) Transport. The activity structure evaluates the traveling demands consuming by economic sectors. This part also connects the activities analysis base on land uses of the study area. The transportation system transfers economic activities into transport activities before assigning traveling demand into individual mode and route in the studied transport network [7].

B. Input Data Requirements

There are several inputs required for developing LUTI model. The most extensive inputs that, perhaps, are the barrier in developing LUTI model are land prices and land use data. However, other information is also crucial for modeling development. Notably, specific parameters represent traveling behavior, economic consumptions, and land consumptions in the study area. Table I summarizes the main TRANUS inputs that the authors use in the case studies, presenting in this paper.

TABLE I
Summary of Tranus Inputs in the Studies

Data	Description	Sources
Population (Zonal Data)	Number of population in the traffic analysis zone (TAZ), the data area usually evaluate base on population census while distributing in the smaller zone using land use data. However, this study uses the WorldPop Dataset	WorldPop Dataset, University of Southampton
Employment (Zonal Data)	Number of employment in each traffic analysis zone (TAZ), the employment may be classified into (1) primary, (2) secondary, and (3) tertiary or elaborate in more detail classes d	Business and Industrial Census (National Statistical Office)
Land Use (Zonal Data)	Land Use in the study area classified by land-use type that available in each TAZ in square meters	Manually create base on the project
Land Price (Zonal Data)	Land price is usually under the unit of Baht/Month/ Square Meter	Treasury Department
Road Network (Transport Infrastructure Data)	Roadway network including walk links	OSM file from the open street map network
Public Transport Service (Transport Infrastructure Data)	Link list for available public transport services can be both the same link as those provide for road network or separate links for individual public services (such as rail services)	Evaluate base on the specific survey results in the study area (Home Interview Survey)
Value of Travel Time (VOT) (Model Parameter)	Value of Travel Time or times spent while traveling from origin to destination including delay from traffic or signalize intersection in the study area	Home Interview Survey
Value of Waiting Time (VWT) (Model Parameter)	Value of Waiting Time or Time spent while waiting to travel usually occur for the public transport service	Home Interview Survey

TABLE I
SUMMARY OF TRANUS INPUTS IN THE STUDIES (CON.)

Data	Description	Sources
Percent of Vehicle Availability (Model Parameter)	Percent of vehicle ownership for each economic sector or group of traveler in the model (i.e., high incomes, medium incomes, and low incomes)	Home Interview Survey
Trip generation rate (Model Parameter)	Rate of trip generate for each economic sector or trip purpose, for example, home base work trip (HBW) for high-income persons, HBW for medium-income persons, and HBW for low-income persons	Home Interview Survey

C. Potential Outputs

Since TRANUS has two main programming structures that collaborate the land use and transport evaluation for the study area, the modeling outputs are various from transport performances to land use/ land price indicators. So far, various outputs that the authors have used are those related to the Transit Oriented Development (TOD) indicators. The authors classified the outputs from TRANUS into 4 groups, including Density, Diversity, Design, and Transport. Table II summarizes the TRANUS outputs using in this study.

TABLE II
SUMMARY OF TRANUS OUTPUTS

Indicator Group	Indicators	Unit
Density	• Population (residence) density • Basic Employment density • Service Employment density	persons / square kilometers
Diversity	The proportion of land uses or land consumptions by land-use types, i.e., residences, commercial, industrial	Percent base on land use type or in square meters' base on land use type
Design	Accessibility evaluated by average disutility on accessing the study traffic analysis zone	Baht
Transport	Number of trips for each transportation mode (elaborate between private and public transportation services)	Trips or percentage of trips by mode

III. SUMO

A. General Information

Simulation of urban mobility (SUMO) is an open-source computer-aided multimodal traffic simulator created by the German Aerospace Center (DLR) [8], which capable of analyzing various tasks of traffic simulation. The specialty of SUMO simulator is self-made user assignment and the usage of faster data structures. These features compose the simulator to be quick and portable, which is a significant advantage for traffic analyses.

The features provided in this software included the applications for preparing road networks and relevant traffic data, modeling the traffic performance, and supporting different dynamic user assignment algorithms. Preparation of street network addressed in three methods as manually generation, employ the street network generation application through "Netgen" command, and import compatible street network file from external sources. Refocus on the external compatible file; there are several standard formats such as VISUM, Vissim, Shapefiles, Open Street Map (OSM), RoboCup, MATsim, OpenDRIVE, and XML-Descriptions. Simulation features support a traffic modeling based on space-continuous and time-discrete vehicle movement, various vehicle types, multi-lane streets with lane changing, assignable right-of-way, and traffic signaling rules to operate urban mobility simulation such as traffic evaluation, route-choice analysis, traffic forecast. An excellent example of using SUMO for real-world studies are: tracking the traffic emission reduction based on traffic management strategies [9], forecasting the traffic impacts for the City of Cologne during the world youth day in 2005 and the soccer world cup in 2006 [10], and testing and designing the Vehicle Actuated Intelligent Traffic Signal Control (VITAL) [11].

B. Input Data Requirements

Most input data requirements for SUMO using in this study are the road network and the Origin Destination (OD) matrix. The road network is gathered by importing the OSM files from the open street network. The road connectors and their turning scheme are then checked for their completeness. On the other hand, the OD matrix using in this study is transferred from the TRANUS model. Only OD for the peak hour traffic is used in this study, both morning peak hour and afternoon peak hour traffic.

Fig. 1 presents the idea of data transformation from TRANUS to SUMO.

Fig. 1. Data transformation from TRANUS to SUMO

C. *Potential Outputs*

The main outputs that the authors take from SUMO traffic simulation model are 1) the total network performance and 2) the individual (specific) link performances. The general indicators for the total network performances gathered from SUMO software are 1) Number of traffic enter and leave the study network, 2) average speed entering the network, 3) average speed leaving the network, 4) average speed while traveling in the network, 5) total waiting time, and 6) average delay. Additionally, the link performance indicators are used to collect the link data at the specific location in the model where the authors plan to test the small roadway improvement in such a location. Hence, only the two most common indicators are selected for representing the link performances. These indicators are average speeds and link delay. Table III summarizes the SUMO's potential outputs used in this study.

TABLE III
Summary of Sumo Outputs

Indicator Group	Indicators	Unit
Network Performances	• number of traffic enter and leave the study network	vehicles/hour
	• average speed entering the network	kilometer/hour
	• average speed leaving the network	kilometer/hour
	• average speed while traveling in the network	kilometer/hour
	• total waiting time	second
	• average delay	second
Link Performances	• average speed	kilometer/hour
	• average delay	second

IV. Case Study: Tranus and Sumo Integration for the Evaluation of Metro Line Service Impacts Around the Activity Center Area

To evaluate the use of both modeling software (TRANUS and SUMO), the authors select the study area which is currently under the construction of the metro line services and expected to open for its operations within 2 years. This case study uses TRANUS to evaluate both the changes in land uses and travel characteristics in the study area. On the other hand, the authors use SUMO to simulate the traffic conditions along the main street of the study area and comparing the traffic performances before and after the construction period.

A. *Study Area*

The study area located in the North part of Bangkok. The area connects two districts, Pak Kred (Nonthaburi province) and Lak Si (Bangkok). The 8 lanes highway (Chaengwattana) is crossing the study area from East to West and Srirat expressway crossing from North to South. There is a 300,000 population (night time population) living in the study area [12]. Additionally, there is approximately 65,000 employment, which mostly (62.38%) is the employment from the commercial sector. Further, the employment for the industry sector, the office service sector, and the retail service sector is 4.83 percent, 24.97 percent, and 7.83 percent of the total employment in the study area, respectively. Fig. 2 presents the study area, and Table III presents the study boundary, both physical and temporal boundaries.

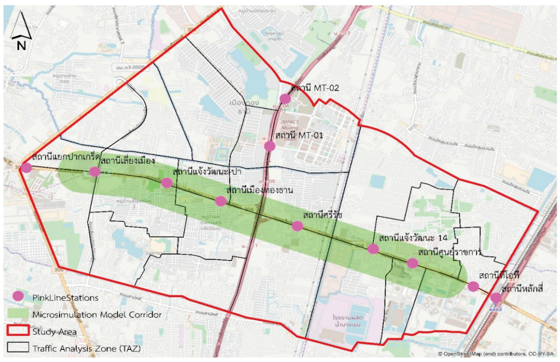

Fig. 2. Study area

TABLE IV
CONCENTRATED STUDY AREA BOUNDARY

Model	Physical Boundary	Temporary Boundary
TRANUS (Land-use Transport Integration Models)	the area located between Laksi District (Bangkok) and Pak Kred (Nonthaburi province) (Fig. 2 red color boundary)	daily traffic volume, morning and evening peak hour
SUMO (Traffic Microsimulation Model)	the 8 lanes highway (Chaengwattana) (Fig. 2 green corridor)	morning and evening peak hour

B. Modeling Structure

There are two components for the TRANUS modeling structure. The first component is the land-use model, and the second component is the transport model. For the land-use model, there are two types of economic sector, transport, and non-transport sectors. The transport sector is usually divided into three subgroups: basic employment (exogenous), service employment (endogenous), and residences. In this study, there are two sub-economic sectors for basic employment, which are the service sector (office employment) and the industry sector. Two sub-economic sectors for service employment, including retails (malls/markets) employment and retail (commercial service) employment. Also, for residences, this study divides residences into three income groups (high, medium, and low incomes). Further, there are four groups of the non-transport sector (industry building area, office building area, commercial building area, and residential building area). Fig. 3 presents a land-use modeling structure. Table IV summarizes the modeling structure for the transport sectors. Table V summarizes the modeling structure for the non-transport sectors.

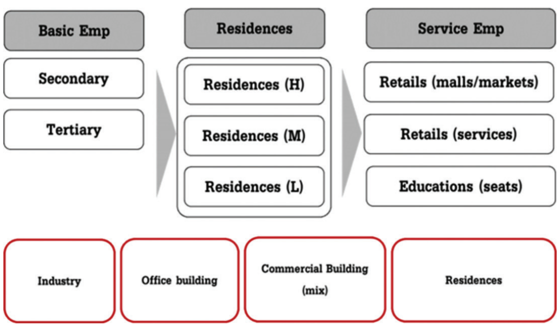

Fig.3. Land-use modeling structure in TRANUS

TABLE V
MODELING STRUCTURE FOR THE TRANSPORT SECTORS

Activity Sectors	Main Sector	Type
1. Basic: Industry 2. Basic: Services	Basic Employment	Exogenous Exogenous
1. Service: education 2. Service: commercial 3. Service: retails 4. High inc. res. 5. Medium inc. res. 6. Low inc. res.	Service Employment	Induced by res. Induced by res. Induced by res. Induced by emp. Induced by emp. Induced by emp.

TABLE VI
MODELING STRUCTURE FOR THE NON-TRANSPORT SECTORS

Land Types	Consumed by
1. Industrial	Industry emp.
2. Office building	Services emp and Retails emp.
3. Commercial Building (mix)	Retails (services)
4. Residences	Residence (high, medium, and low inc.) Industry emp, service emp, and retail emp

For the transport model, the model creates two groups of traveling based on the land-use model's economic sectors. The first group is the traveling demand from the household activities, which are Home Base Work (HBW) trips and Home Base Education (HBE) trips. The second group is the traveling demand from other activities or Non-Home Base (NHB), which are the trip to service (work trips) and the trip to shop/retails. Table VI summarizes the transport category

TABLE VII
TRANSPORT CATEGORY

Activity Sectors	Main Sector
1. Household	1.1 HBW High Incomes 1.2 HBW Median Incomes 1.3 HBW Low Incomes 1.4 HBE
2. Service / Retail / Education	2.1 Trips to Service 2.2 Trips to Shop/Retail

C. TRANUS Modeling Parameters and Assumptions

Several parameters and assumptions are used in the case study's model. Most of them are decided base on the survey results, while some parameters are assumed based on the secondary data or previous study results. The essential parameters are as follows.

1) *Value of Time (VOT)*
   This study evaluates the VOT value based on monthly residence incomes, which classified into three groups (high income, medium income, and low income). The calculation assumes that there are 187.5 working hours per month (45 hours x 50 weeks x adjustment factor/12 months). The adjustment factors are assumed to be 0.6 for work trips and 0.5 for others.
2) *Value of Waiting Time (VWT)*
   The VWT in this study is assumed to be two times the VOT.
3) *Vehicle Availability*
   Gathering data from the personal interview survey, most population in the study area own or able to access personal vehicles (either motorcycle or car). Seventy-five percent of the population in the low-income population have access to private vehicles. There are also 88 percent and 98 percent of the population in the medium and high-income groups, respectively, owning private vehicles.
4) *Trip Generation Rate*
   Trip generation rate for each trip category (Table VI) were estimated base on the personal interview survey conducted for the project. The results found that the low-income population travel at 2.69 trips per day (on average), while the medium and high-income population travels at 2.77 and 2.73 trips per day (on average), respectively. Results also found that the average trip for education is, approximately, 2.79 trips per day and the average trips to service is at, approximately, 2.99 trips per day.
5) *Land Prices*
   This study estimates the average land price (rental price/month) base on the evaluation price of the property in the Nonthaburi province published by the Treasury Department. The rental price was then assumed to be 1 percent of those property prices. Additionally, the one percent assumption is considered base on the general depreciation rate.

D. *TRANUS Results*

The modeling outputs were evaluated by comparing the study area characteristics before and after implementing metro line stations in the study area. The model evaluates 3 scenarios including (1) BAU20: Business As Usual in 2020 or the base case study at the existing condition, (2) BAU30: Business As Usual in 2030 or the future year in 2030 with no implementation of the metro services, and (3) SCA: SCenario A or the future year in 2030 with the metro line service implementation.

From the density perspective, results present a slight decrease in population and employment in the overall study area after connecting the metro line services. The results present in the opposite of common sense that the metro line should bring up more population and employment to the study area. However, considering the study area in Fig. 2, we could see that metro line service increasing the accessibility between the study area and the external zones. This connection provides more opportunities for people to decide to live or working out of the study area. Fig. 3 presents of results of density indicators on the model.

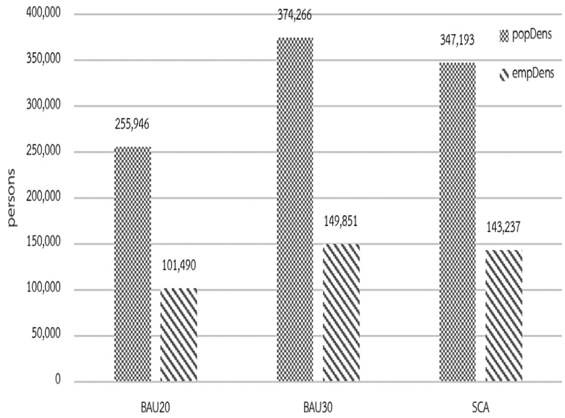

Fig. 4. Comparing population and employment density

Additionally, by introducing metro line services, the model presents that the proportion of the low-income and the high-income population living in the area is increasing, while the medium income population in the area is decreasing. However, these changes in diversity only show in small numbers. Fig. 4 presents income diversity results from the model. Further, the land-use diversity also changes after the implementation of the metro line, regarding the modeling results. More, activities in the study area tend to consume the office building and commercial building more than before introducing the metro services. Fig. 5 presents land-use diversity results from the model. From the figure, by introducing transit services in the study area, it helps to recover the proportion of commercial and office building back to the study area.

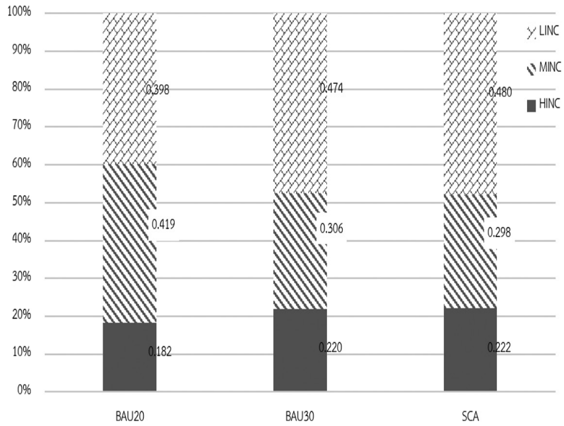

Fig. 5. Population income diversity in the study area

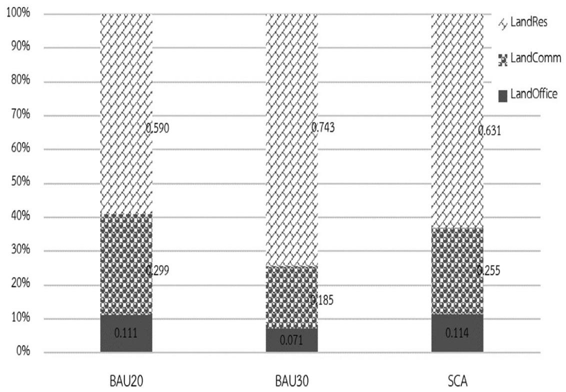

Fig. 6. Land-use diversity in the study area

In terms of design, the disutilities for each traveling purpose are measured from the model. The results present a notable trend (decreasing) of the disutilities for all traveling purposes after implementing the metro line services in the study area.

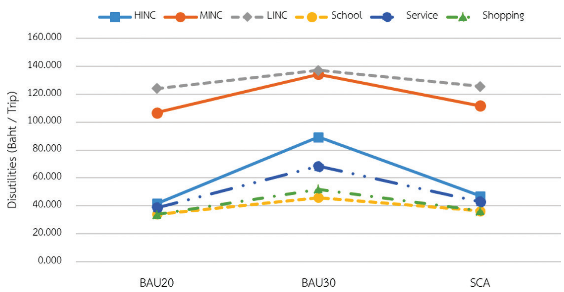

Fig. 7. Disutility measurements for each traveling purposes

Lastly, as expected, by introducing the metro line service to the study area, the number of trips traveling in by the private vehicles is decreasing, while walking trips and trips using public transport are increasing. Fig. 7 compares the number of trips in each traveling mode.

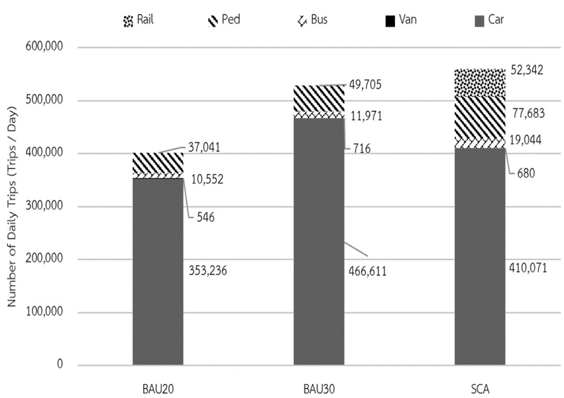

Fig. 8. Number of trips in each traveling mode

E. *SUMO Results*

Origin and Destination (OD) matrix outputs from TRANUS model are used as inputs in SUMO to evaluate the traffic characteristics on a micro-scale. Fig. 8. Presents the SUMO road network, which constructs a base on the open street map layer (https://www.openstreetmap.org). General traffic characteristics such as the total number of vehicles getting in-out of the study area, average speed, total waiting time, and average delay are measured from the SUMO model.

Results from the traffic simulation found that overall network performances are getting better after opening the metro line services. The average speed of the road network is getting slightly better both in the morning and evening peak hour traffic. Total waiting is quite different. After opening the metro line services, traffic for the overall network have a better total waiting time and average delay, especially during the evening peak hour traffic. However, the results from the simulation model present a very slight improvement for the average speed on the network. Table IV and Table V show the results of traffic characteristics for morning and evening peak hour traffic, respectively.

For the overall perspective on the model results by comparing network performances between before and after opening metro line services, results represent that there is minimal improvement in the traffic performances in the study area. Hence, only implementing the metro line services on the site may not be an overall solution to solve the traffic-congested problems in the area. Other policies must be considered: improving the feeder systems, encouraging non-motorized trips, or improving the traffic follow problems or bottleneck problems in a specific location in the area.

Fig. 9. SUMO network in the study area

TABLE VIII
Traffic Characteristics for Morning Peak Hour Traffic

Indicators	Unit	BAU20	BAU30	SCA
Vehicles in-out of the network	veh/hr	37,782	44,224	44,395
Average Speed	km/hr	11	11.62	11.65
Total Waiting Time	min	43,676	38,709	35,277
Average Delay	min	10	11	11

TABLE IX
Traffic Characteristics for Evening Peak Hour Traffic

Indicators	Unit	min	BAU30	SCA
Vehicles in-out of the network	veh/hr	min	36,342	36,371
Average Speed	km/hr	min	12.10	12.82
Total Waiting Time	min	min	28,238	3,084
Average Delay	min	8	9	2

V. Conclusion

This article summarizes the experiences of using open-source transport and traffic simulation software for transport policy and planning works in Thailand. The first software is the TRANUS, which is the Land Use Transport Integration (LUTI) software. The other software is SUMO (Simulation of Urban Mobility), which is the traffic simulation software. The reviews are general software features, input data requirements, and potential outputs. The paper also discusses the example of project implementations, which uses TRANUS and SUMO for evaluating the impacts of the metro line services around the activity center area.

From the case study, the TRANUS model helps evaluate the changing of land and transport activities in the study area. Results also represent the impacts of introducing the metro line services to the site and confirms that encourage excellent public transportation services could help to develop the site both in terms of traffic and economical in the area. However, this study also using the microscopic traffic simulation to evaluate the overall traffic performance in the study area, and results from the model only represent a slight improvement of the traffic performances on the study area road network. These results also present that, besides introducing the metro line services in the area, other improvement policies must be considered.

Finally, experiences show that, even though there is a learning curve for both software, it's free of costs, diverge user communities, and prompt software features. They represent that open-source transportation software platforms could be an alternative for future transport policy and planning work in Thailand. However, barriers and limitations that should be aware of while applying these models and software in the future are as follows. First, TRANUS will require detailed data on land use and land prices in the study area. These data are usually not available in the area and, both time-consuming and costly to collect. Lacking land use and land price data will significantly affect the results of the model. Second, calibrating TRANUS model for its elastic demand (land consumptions) are not yet have standard tools. Hence, this step will take time for parameter calibrations and perhaps one of the critical parts that will make the model quite hard to use and apply in the case study. Third, for SUMO, this study only applies the OD matrix output from TRANUS directly to the SUMO traffic simulation program. At the same time, assume that all traffic demands are already good base on the TRAUS model development processes. Hence, there are needs for calibrating traffic microsimulation parameters for future improvements of the model to the local traffic, especially those in Bangkok, Thailand.

Acknowledgments

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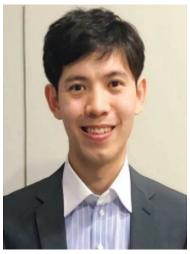

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