THE APPLICATIONS AND ALTERNATIVE APPROACH OF ACCESSIBILITY MEASUREMENT BY THE PUBLIC TRANSPORT NETWORK INTEGRATION BASED ON URBAN RAIL TRANSIT

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ABSTRACT

The developing countries are suffering from the urban sprawling that the decline of accessible. The inaccessibility is challenging for the stakeholder to enhance the effective urban public transit implementations. Various modes of public transportation have been employed for urban travel such as Bus, TRAM, Bus rapid transit: BRT, Light rail transit: LRT, Monorail and Metropolitan rapid transit: MRT. The mobility with highly effective is the goal of public transport network. The critical issue focusing on the Accessibility based on the Costs/Revenues of transport mode, also an efficient and competitive will become crucial in the implementation stage. Research analysis presented by Public Transport Accessibility Index (PTAI). The analysis utilizes the time base consideration while using ArcGIS and the Building Informatics Technology: BIM. The accessibility index represented the definition of network performances based accessibility measure. KhonKaen prefecture, Thailand is the 1 of 6 prefectures to plan the investment of urban rail. The area covers 10,890 km^2 with 17 Sub-Districts. KhonKaen found the transport demand forecast had rapidly increased from a total of 656,500 trips per day to 1,146,400 trips per day during a period of 2018 to 2036 A.D. The 4 types of vehicles transport shared including: 1) Minibus; 2) Bus; 3) Taxi; and 4) Motorcycle. In analysis case, the transport-mode share is recently dominated by motorcycles (53.6%), private cars (32.1%) and public transport (14.3%) of trips. The conventional bus network consists of 19 routes that linked based on the 12 Sub-Districts. KhonKaen's public rail investment plan fully covered the 5 main routes (Called Red, Pink, Yellow, Green and Blue line, respectively). The routing construction plan is being expected to be completed in 2036 A.D. This public rail investment plan totally a length of 124 kilometers with 31 stop points. The research model development presents clearly understood of urban perception based public transport network in the future scenario plan. The research contribution demonstrated the comparison on current public transit and 3-time frame of urban rail future plan (2021 – 2036 A.D.). In this regard, the three timeframes were considered consisting of a short period (1-5 years), a medium period (5-10 years), and a long period (10-20 years) as mentioned in the Thailand's 12^{th} National Economic and Social Development Plan.

The research utilized an accessibility index while focusing between the travel times and different modes of public transport network. The residential buildings are represented the Origin (persons' unit) that perceived by Densely Inhabited Districts (DID). The network would connect a variety of activities existing in the Destination by building functional unit (square meter units). The building use in research scope that grouped into 3 building modes including 1. Commercial Use, 2. Mixed Use and 3. Public Facility. The Unimodal assessment presents the capability of access in those networks, compared to Bus and Urban rail network separately. The Multimodal transport model were presented to combine more than two modes of transportation in the start to end of destination designated. The research presented by 6 accessibility parameters by 1. Walk mode 2. Walk and Bus mode 3. Walk and Bus (Reform) mode 4. Train mode 5. Walk, Bus and Train mode and 6. Walk, Bus (Reform) and Train mode which the definition was the competency of accessible through different proposes and the cumulative opportunities of trip available on network up to time limit. The accessibility measured definition notions generally of graph theory

and spatial separation of travel time to all the zone's consideration. As the result, the cities proposing the urban rail system will be suffering the closely related service level between the rail network and conventional bus network layouts called redundancy. The notion of a secondary layer of urban rail by bus feeder was revealed. The characteristics of the bus feeder reformation by demand responsive connection (DRC) concept was studied. The feeder reform adopted by condition with the conventional bus routes attracted by track perpendicular within 300-meter rail of rail stations buffer. Moreover, the Transit-Oriented Development: TOD and optimization model (GRG model) was gathered to contribute to the grid promotion within the 800-meter station buffer plan. Additionally, the new knowledge of bus corridor territory between the demand-responsive area along with the rail line attractiveness and bus feeder improvement was pioneered

Unimodal transport assessment model by 60 – 95 minutes' times use explains the character of urban growth closely with the current bus route. The unimodal assessment aspect, the conventional bus route confirms the explicitly effective accessibility than the rail transit plan without the urban plan initiative. An ideal concept for those urban rail public transport plans was well explained by Multimodal transport assessment. The primary transport mode represented by the urban rail and bus network was secondary mode as a feeder. The changes of accessibility observed in 2 different urban phenomena (Promote the Low density and Medium density of DID in urbanized zone). The result reveals the strategy that was required to concentrate on the regional and corridor levels significantly. The research explored the comparison of the conventional bus route and route reform by demand responsive connection (DRC). The comparative result explained on the possible oversight from the new feeder demand by bus feeder position. The route reform impact result, the time usage for an enlarged route had been extended by around 11% of the average for the entire trip within 12 of 19 route reform. The accessibility had increased by approximately 67.75%, 47.9%, and 43.68% for the entire Multimodal transport network in analysis case. However, the effective feeder encourages the urban accessibility for the whole network. The understanding of the relationship between the city plan and public infrastructure networks was revealed. These notions found is alternative approach of innovative policies to complementarily support an effective feeder-bus network. Both of the fundamental concepts of 1. The compact city as the high-density zone and vertical urban development and 2. The feeder performance as the feeder transformation was a critical issue for the city. The development of a public transit network secondary layer such as DRC adoption is increasingly becoming crucial, especially within the sprawling residential areas. These analyses greatly contributed the understanding toward the future transformation and creative of urban innovation policies.

The research models represented the urban mobility assessment based on the urban rail transportation investment plan. The analysis disclosed the mechanics insight of public transportation network (Bus and Urban rail). The developed models elaborately describe the relationships between the land use in the city scale and the public transport networks. The models effectively provided support for the evaluation of the universal case of the urban plan guidelines.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Urban life quality is directly committed to public infrastructure as the public transport service should be accessible throughout the area. Also, the public transport network itself needs to be well connected. Therefore, the contribution of dissertation purposively illustrated the change of land use and the future public transit network investment. The cities where enhanced the public transport capability as a mass transit network are proved the urban rail network (TRAM), Light rail, and metro line. The accessibility transportation models converging walkability, bus network, TRAM network that supports a non – driven virtualization investigated while was following the Sustainable Development Goal (SDGs) to decline the private mobility consume, also present the model for assessment of public transit network performance. The economical scale aspects, the city scale sizeable and line capacity capability that to be performed of urban rail in term of public service support are presented by the rail length (km) and Population per kilometer track as seem in **Figure 1.1.** Especially in case of a low population density (approximately 1,500 persons per sq.km), a higher level of the road network per inhabitant leads to a lower congestion; namely, a city with high population density generally demonstrated a low level of congestion when a rail infrastructure/ resident ratio was high. Furthermore, the cities with an increasing of the railways per person become more effective in decreasing the level of congestions (Dingil et al., 2018).

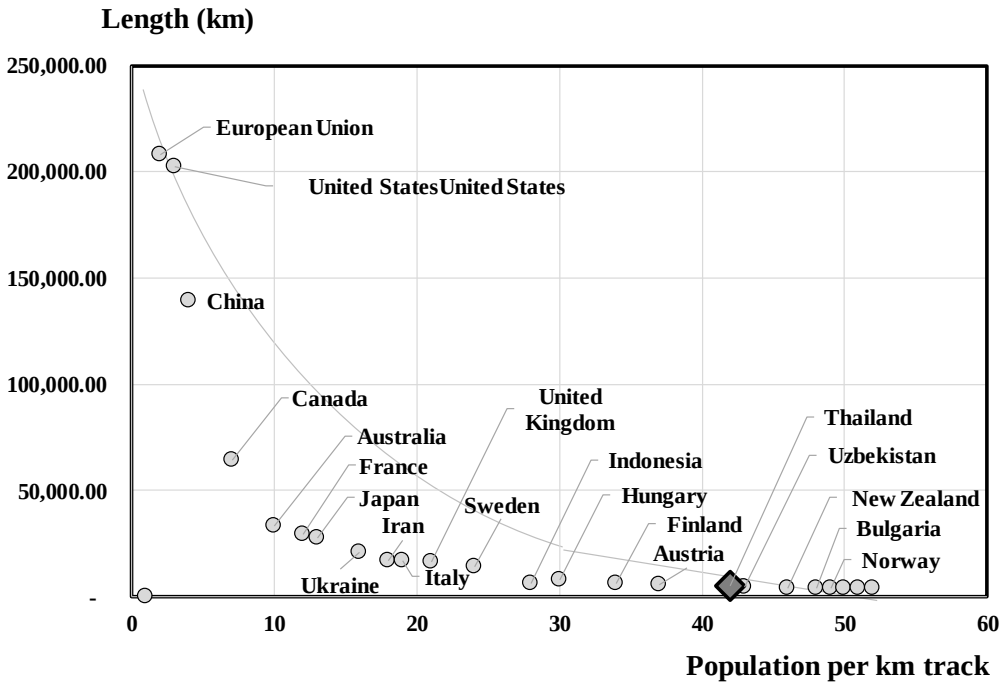


Figure 1.1. Rail transport network size (population per kilometer track and total rail length). (WHO) (WORLDBANK)

1.2 PROBLEM STATEMENT

Priority of transit corridor is the possibility of urban policies option was the next issue of the discussion for those cities where the planned investment of urban rail public transport was suffering from the unexpected of demand and supply-side customer use in advance. The key success of mass transit in city scale is the population in those public transit network reachability as a user demand, especially the walking access. However, structure of a notion strategies was applied on the prefecture character, gross domestic product: GDP, population density, public network and country vision and mission such as Capital, Regional center, City center, Community level city, Center community level city, respectively. All those famous functionality of urban policies is a Transit Oriented Development: TOD in which to promote the high density of population zone (Especially 800-meter buffer station) by the controlled base land use allotment and land acquisition by public sector, the compact city conceptual ideas in Japan appearances since 1950. The integrated knowledge of population and accessibility would provide a clearer insight on the public transport network performance and competency. The public transport become to the one of key development that linked between urban demographic while point to support the urban effectiveness mobility by the public service. The research focusing on the urban mobility based on the urban rail public transport network transferred called Accessibility index by various mode of investigates. The Financing Transit-Oriented Development principal presenting in **Figure 1.2.**

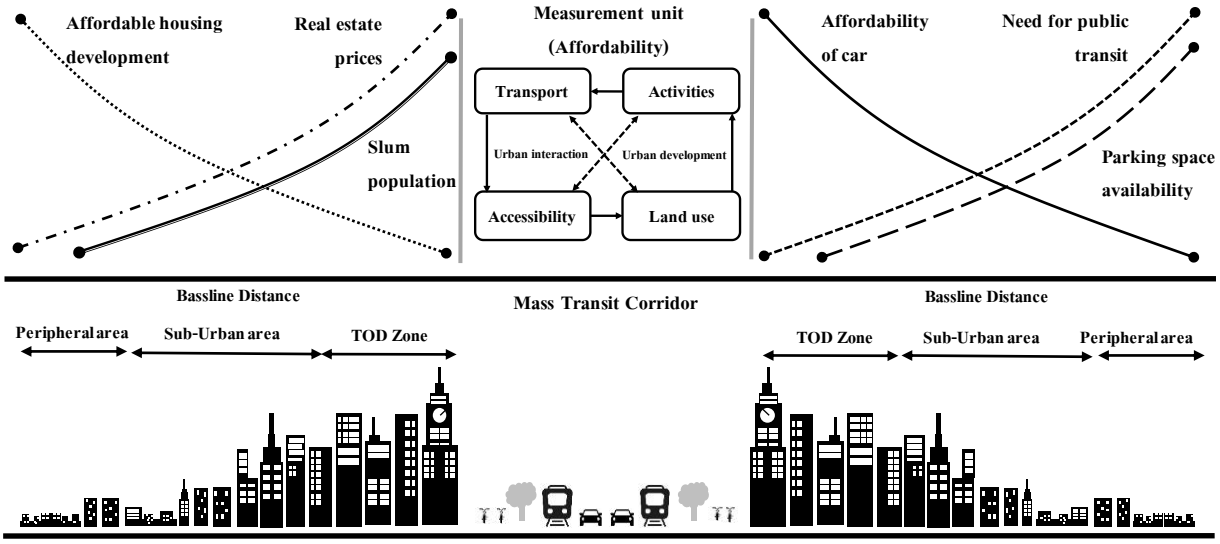


Figure 1.2. Financing Transit-Oriented Development (Sharma, 2016; Hiroaki Suzuki, 2015; Jinshuo Wang, 2019; Shishir Mathur, 2021; Dong, 2021)

Demand-side and supply-side factors of trip consumer's capability relatively proved urban public infrastructure as the high density immediately causes the effect on their behavior in the city scale (A.Bell and C.Greene, 1978) it is seen from **Figure 1.3.** Nowadays, most of the cities are lately aware of the environmental harm scenario focusing on reducing private car use and encouraging people to use more of public transportation. Meanwhile, the several modes of the

public transport (presenting by street bus, BRT, Tram and Metro line) had been proved to be the successful strategies (Tolley, 1997); meanwhile, the performance of the public transport related with urban morphology obviously defined the public transportation capability. In Japan, the urban concentration has been basically assisted by the fulfilled railroad network growing out rapidly from the center (Department of Urban Engineering, 1994). The more passengers reachable were proposed to relatively solve the poorly planned and unjustified routing expansion. Explicitly, passengers are affected by the phenomena in different manners according to the point perceived as locations of the stops (Akgol et al., 2020). In the places where the demand density was low or the roadways cannot support relatively large fixed-route buses, the flexible-route bus systems will be inevitably desired to serve people at their location (Kima et al., 2019). The critical implementation factor of public transport network affirmed by: 1) Timing; 2) Network; 3) Budget; 4) Political champion; and 5) Transport emission reduction (Attard, 2012). This research specifically on the public transit network which utilized the multimodal transportation investigation covering by Walk (Roy and Basu, 2020), Bus (conventional and reform phenomenon) (Birungi, 2017; Kim and Dickey, 2006) and Train network infrastructure project for all findings were finally presented the urban mobility.

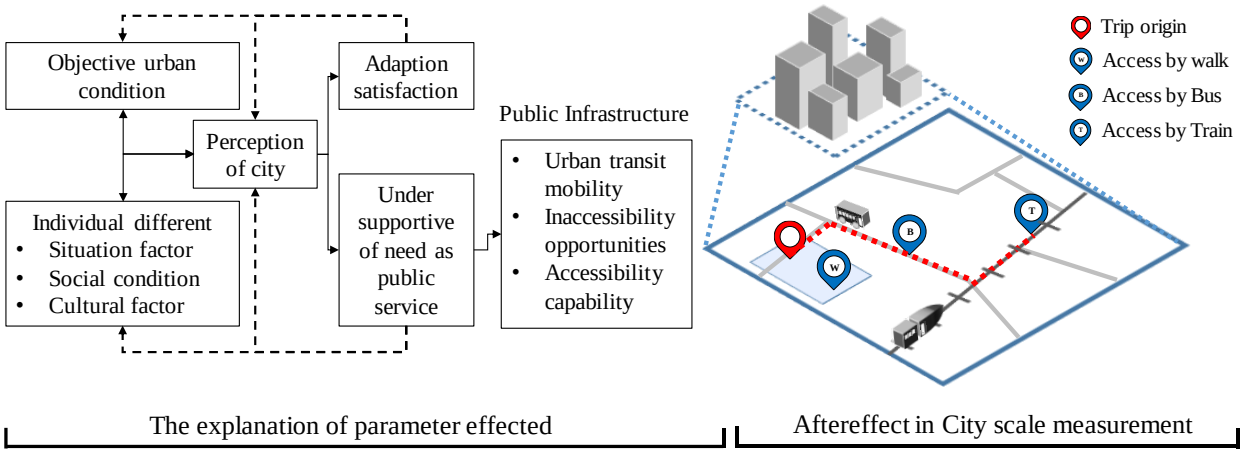


Figure 1.3. The Eclectic Model Applied into Urban Environment. (A.Bell and C.Greene, 1978) Catchment Area and Isochrones (Huang et al., 2020; Nigro et al., 2019)

The cities proposing the urban rail system that suffers the rail network and conventional bus network layouts are closely related to the level of service called redundancy (Sun et al., 2013); while, the transport assessment explicitly analyzed the public transport consisting of trip generation. The research exploring the innovative policies to support the effective feeder position. On the other hands, the inaccessibility is challenging for the stakeholder to enhance the effective feeder implementations in order to upgrade the feeder with more attractive design.

1.3 OBJECTIVE OF STUDY

- The research develops the effective parameter that explained the public transport performance for the city scale where address the primary mode of public transit by urban rail system.

- The relative parameters were adopted consideration based 1. Land use scenarios 2. Public transport and 3. Development evaluation models to visualizes the possibility of urban innovative policies.

1.4 SCOPE OF STUDY

This contribution is conducted in the public transport network sites of KhonKaen, Thailand. The research identified city problem statement based on the literature review of the spatial development between public transit network investment, land use scenarios, and integrated theories of spatial accessibility measure. The data was proceeding and analysis mainly through the geographic information system (GIS) and computer aid programming. Those research framework was present in **Figure 1.4.**

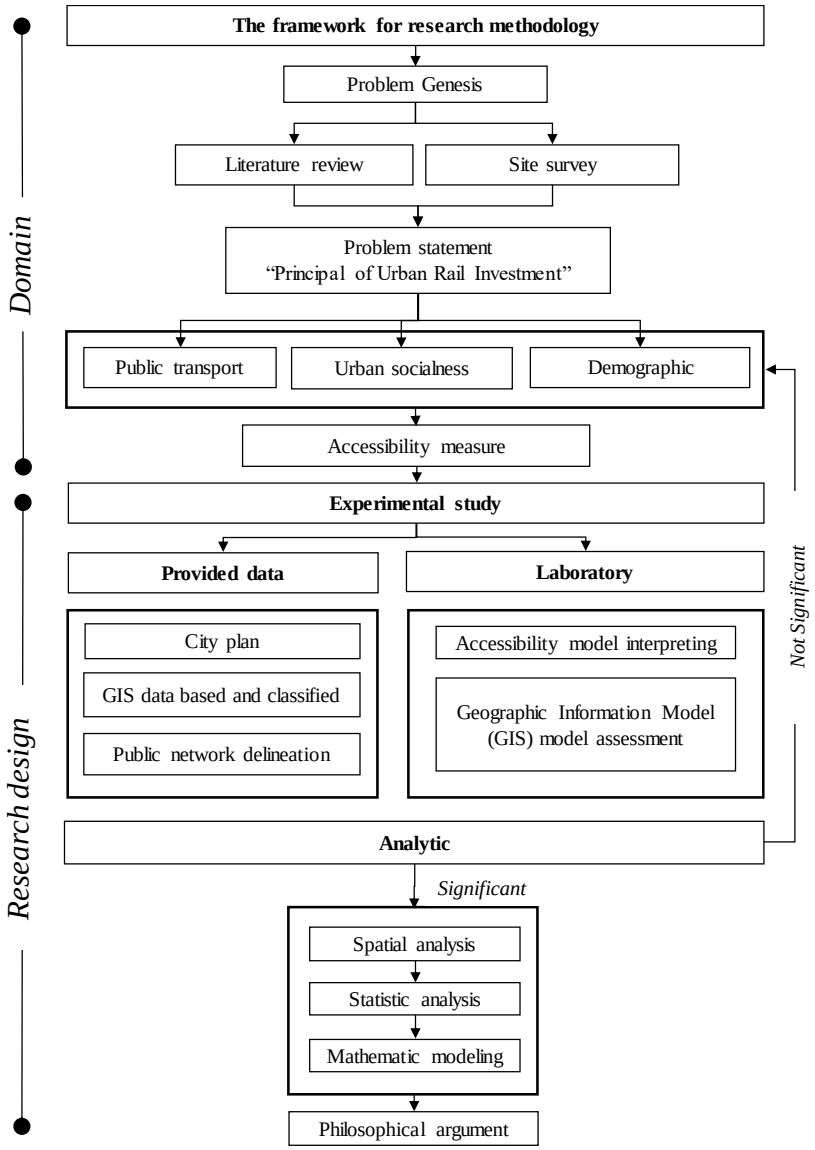


Figure 1.4. Research framework

1.5 CONTRRIBUTION

1). The accessibility measure development in different mode of public transport (Current bus network and Train network plan).

2). Accessibility index measurement within 2 transport modes call multimodal transport assessment which was gathering by train to be the primary and bus is the feeder position.

3). The character and possibility of bus feeder transform policies.

4). Transit Oriented Development policies options and effected.

5). The principle of the urban rail public transport development project

1.6 OUTLINES

The dissertation organized by 6 chapters in order to presents the original thought and process of accessibility assessment integration as follow structure presented in **Figure 1.5.**

Chapter 1 : An introduction of dissertation including the background of study, problem statement, proposes, scope, significant of study area. The context given overall framework of research contribution. The research depicted accessibility measure within city scale which integration between the conventional public transit called bus network and Urban rail project implementation plan in 3 timeframes.

Chapter 2 : Present the literature review by providing in 3 paths. Firstly, the meaning of population density while comparing based the area having the urban rail public transit network. Secondly, literature review that filled the gap of research aim is merit of integration between urban form, evaluation model and public transport options. Lastly, figuring the principal of Thailand regulation consist of regulation, urban plan, demographic with the detailing by sub distinct scale of the population ages structure.

Chapter 3 : Visualize the urban public transport structure in analysis case, comparative the public transit capability modes and an efficient. Detail the conventional bus network, also visual the building utility by rail station plan buffer catchment area. Both of network were detailing and gathering whole of project term from 2021 to 2036 A.D. The land use function was described in the last session that have been discuss in term of relative parameter as the urban policy options effect.

Chapter 4 : Explore the accessibility identification according to assessment term and implementation scope which consisting of graph theory-based measure, cumulative opportunity accesses and spaced-time based accessibility. Accessibility index interpreting to investigate based public transport network to destination attractive designate in different time frame considering. The evaluation of 4 sessions was cumulative presented in the conclusion.

Chapter 5 : The highlight of model assessment presenting the interaction of demand and destination trip within the period of urban rail public transit schedule plan. The dynamic of model

projection of network accessibility was presented. View of inaccessibility by mode of transport and network combined were revealed.

Chapter 6 : Discussion and conclusion, highlight the empirical model studies. The model sensibility parameter and effect definition development were discussed. The limitation is provided in this chapter. Summarize the result of each chapter.

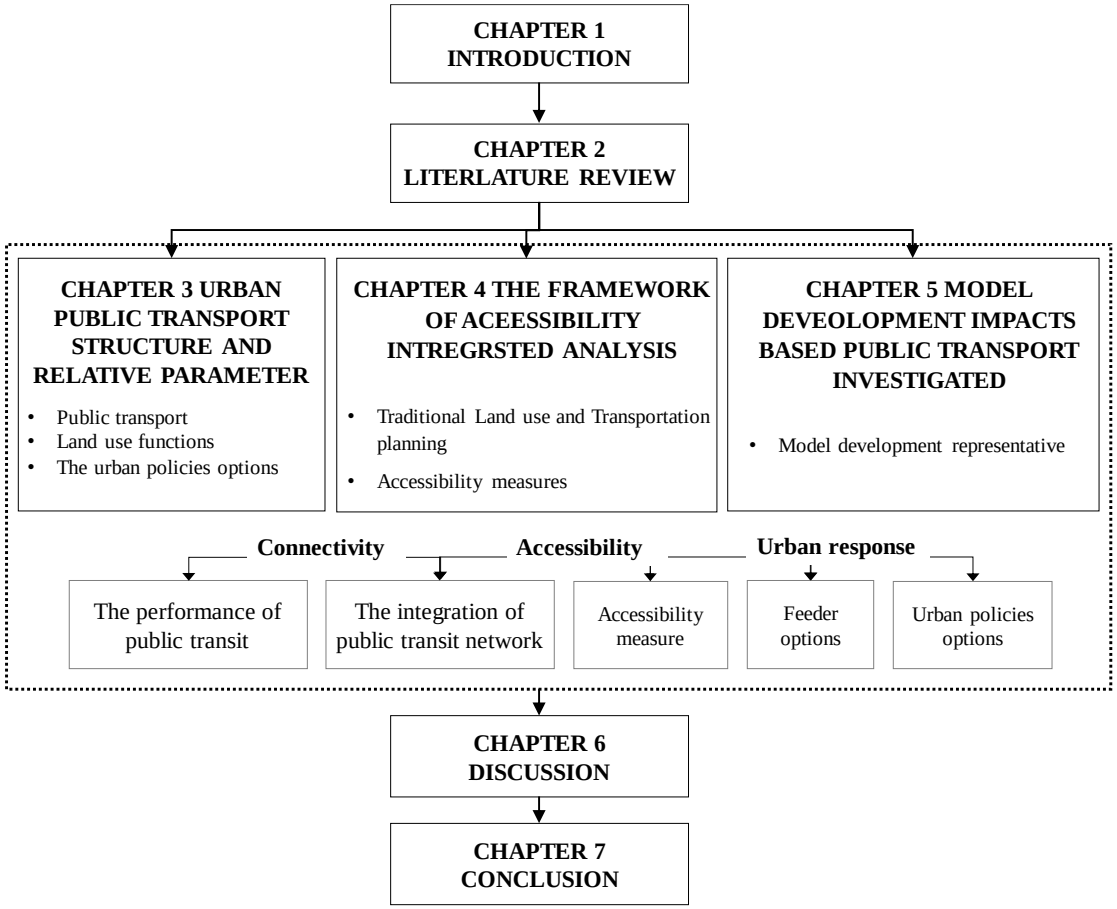


Figure 1.5. The chapter structure of dissertation

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter visualizes the 30 global city population estimates from the United Nations (UNDP, 2014). In the case of a developing country, Thailand presents the 6 main regional prefectures (Bangkok is the capital) by gentrification in square kilometer (NSO). The data available presenting in **Figure 2.1** Those evidence confirming the population density was significantly with the urban development. Thailand was separated by 6 regional called 1. North (Purple color), 2. North-east (Yellow color), 3. Western (Light blue color), 4. Central (Light orange color), 5. Eastern (Pink color), and 6. South (Hard orange color) while was linking with street network for private mobility and public transit provided by the city-train that present by railway length totally 4,034 km. Explicit, the grouping by double track rail route presenting in the 1. North line totally 781 km 2. North-east line totally 1,092 km 3. Western line totally 527 km 4. South line totally 1,569 km and 5. Mae krong line totally 65 km. Moreover, by track classification grouping presented in 3 types consisting of 1. Single track totally 3,675 km 2. Double track totally 252 km and 3. Triple track totally 107 km as seen by **Figure 2.2.** Ministry of transport, Thailand, established the Railway network investment plan covered 2018 – 2037 A.D. The double track rail plan and High speed rail plan and urban rail (Tram), also presenting flowing the 12th National Development Plan (2017 - 2021), Thailand., The rail infrastructure investment projection to 2037 A.D. with the primary contribution of double track rail plan expanding, New route plan and High speed rail plan. (Ministry of transport, Thailand) (Office of Transport and Traffic Policy and Planning, Thailand)

Thailand consisted of the working and childhood population as high as 52.8% and 42.1% respectively. The proportion of the childhood population was quite high at that time. As a result, Thailand has a continuous increase in the working-age population and reached its peak in 2010 (approximately 40 million people), but the proportion of the working-age population has gradually decreased. Compared to the elderly population in each country in 2016 A.D., Singapore had the highest number of elderly people in ASEAN (18.7%), followed by Thailand (16.5%) and Vietnam (10.7%). It is estimated that in the next 30 years, namely 2040, all three countries will enter the ultimate aging society. The aging situation of the Thai population that is about to step into an aging society like complete aged society by 2022 A.D., meaning the population aged 60 years and over will account for 20% of the total population that Thai society will become a super-aged society. (Wichanee, K., Man, W, Pornthip, K & Ratchata, M, 2018; Pramote, P & Napapat, S. 2021).

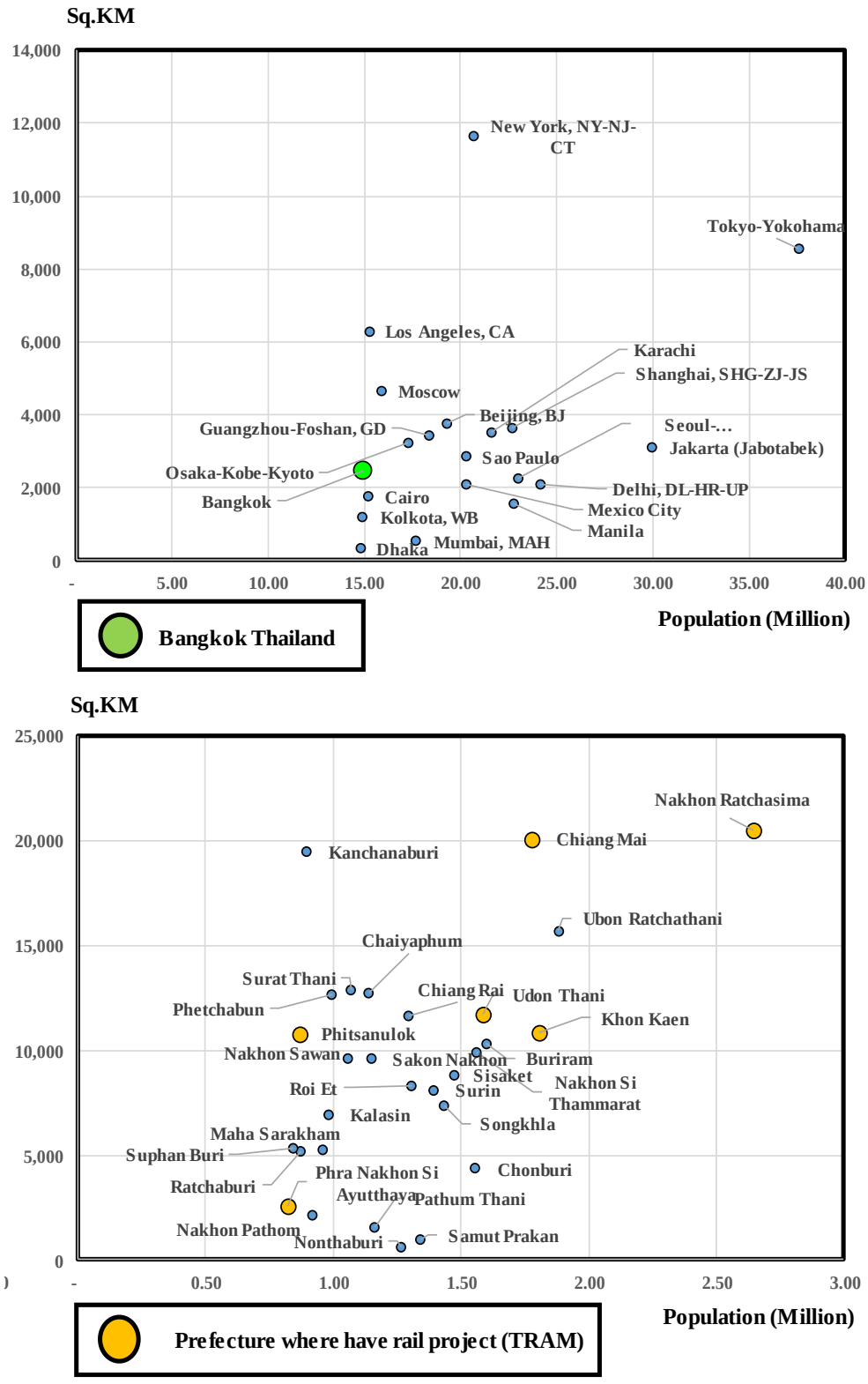
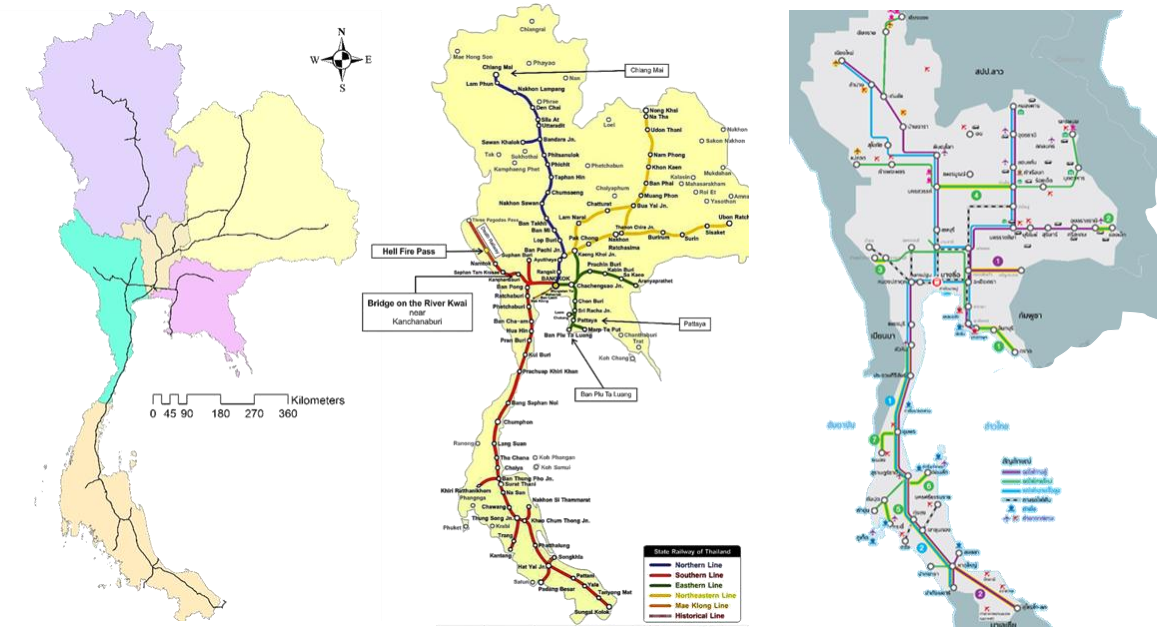


Figure 2.1. Top 30 Global City Population Estimates and Population in Thailand (UNDP) (NSO)



Intercity	km
North line	781
North east line	1,092
East line	527
South line	1,569
Mae krong line	65

Single track 3,675 km **(91.1 %)**

Double track 252 km **(6.2 %)**

Triple track 107 km **(2.7 %)**

	Phase 1 (2018 – 2022 A.D.)	Phase 2 (2023 – 2027 A.D.)	Phase 3 (2028 - 2037 A.D.)
Double track rail plan	14 (Project)	1 (Project)	2 (Project)
	2,476 km	70 km	390 km
New route plan	3 (Project)	4 (Project)	7 (Project)
	841 km	642 km	867 km
High speed rail plan	5 (Project)	2 (Project)	2 (Project)
	1,248 km	499 km	759 km

(A) (B) (C)

Figure 2.2. (A) Thailand gentrification present by regional, (B) The rail route by regional and (C) Double track rail plan expanding, New route plan and High speed rail plan

2.2 LITERATURE REVIEW

The problem statement had been focusing on the city where plan to invest the urban rail network which extracted the important word by literature searching consisting of 1. Model assessment and Urban policy (Transit oriented development: TOD) as seen from **Table 2.1.**, 2. Unimodal and Multi modal transportation model and Urban rail as seen from **Table 2.2.** The commonly use of transport planning is provided the service as accessibility. Those result was support to fill the gap of research notion that composes to present the principle of urban rail public transport development project.

Table 2.1. Model Assessment and Urban Policy (Transit oriented development: TOD)

No.	Authors	Research methodology and contribution	
		Model executed	Policies and strategies
1	(Olga Filippova, 2020)	Spatio-temporal weights matrix and STAR-DID	Residential property prices
2	(Di Huang, 2020)	A two-phase optimization model	Demand-responsive customized

3	(Raveau, 2021)	-	Demand-Responsive Transit
4	(FelipeMariz Coutinho, 2020)	-	Demand responsive transport system (DRTs)
5	(Jaafar Berradaa, 2021)	-	
6	(Bryan David Galarza Montenegro, 2021)	Optimize algorithm	
7	(Marie Harberinga, 2020)	-	Transport mode choice
8	(Christopher D. Higgins, 2016)	-	TOD
9	(Shiliang Su H. Z., 2021)	Five typical megacities	
10	(Jianyi Li, 2020)	Housing prices	
11	(John Blacka, 2016)	-	
12	(Dong, 2021)	Household expenditures	
13	(Quentin Lamour, 2019)	Walkability	
14	(Anna Ibraevaa, 2020)	-	
15	(Jamalunlaili Abdullah, 2016)	-	
16	(Bruce S. Appleyarda, 2019)	livability, health assessment	
17	(Christopher D. Higgins, 2016)	Latent class method	
18	(Qifan Shao, 2020)	Betweenness centrality	
19	(Pornraht, P. 2020)	Residential Location choice	
20	(Antonio Nigro, 2019)	-	Small city
21	(Wangtu, X., Linchuan, Y. 2019)	Accessibility	
22	(Daniel, P., Georges, D., Ramon, M.R., Joanna, M. 2018)		Urban rail
23	(Dimitrios, K.T., Olga, S.K., et al. 2016)		Urban mobility
24	Yigitcanlar, T., Sipe, N., et al. (2007)		A GIS-based land use
25	(Joseph, C.Y. L, Catherine C.H. Chiub, 2004)		Compact city
26	(Kwon, 2015)		
27	(Tatsuya Tanizaki, T. I., 2020)		
28	(Raza, A. and Zhong, M., 2019)		Public Transit Evaluating
29	(Geurs, K.T. and Wee, B.V., 2004)		Land use
30	(Robbin, D., Ahmed, E. (2018)		Public transport & job
31	(Tayebeh, S. Sara, M. Russell, G.T., 2016)		Incorporating pop-density
32	(Shiliang Su J. Z., 2021)		transit services
33	(Yue Lianga, 2020)		TOD
34	(Enrica Papa, 2015)		TOD (Node & place index)
35	(Jayasinghe, A. and Munshi, T. 2014.)	Transport Master Plan for Regional Cities	
36	(Breheny, M.J.,1978).	Spatial Opportunity measurement	
37	(Satish Chandraa, 2013)	Speed Distribution Curves for Pedestrians	
38	(Sahu, 2018)	Land use for TOD	
39	(Richard D. Knowlesa, 2020)	Role in shaping urban development	
40	(Robert Cervero, 2014)	Leveraging transit oriented development	
41	(Department of Urban Engineering, 1994)	Urban planning	
42	(Bhat, C., Handy, S., et al., 2000).	Development of an urban accessibility index	

Table 2.2. Unimodal and Multimodal Transportation Model and Urban rail

No.	Name	Mode and model assessment
1	(Ralf Elbert & Jan Philipp Muller, 2020)	Stochastic models & multimodal assessment
2	(Francesco Calabrese *et al*, 2013)	Mobile-phone-based mobility measures & unimodal assessment
3	(José Azucena *et al*, 2021	Hybrid simulation & multimodal assessment
4	(Qisheng, P., Haixiao, P., Ming, Z., Baohua, Z., 2014).	Rail Transit
5	(GAO., 2001).	Congressional requesters of Mass transit
6	(Dušan, T., 2017).	Transportation Engineering Theory, Practice and Modeling
7	(Rong Wu, Yingcheng Li, Shaojian Wang, 2022)	Heterogeneous impacts of HSR on urban land expansion
8	(Weihang Gong, Victor Jing Li, 2022)	The territorial impact of high-speed rail on urban land development
9	(XinjianLi, Peter E.D.Love. 2022)	Lesson learn of rail transit infrastructure Investment model by PPP
10	(Pengyu Zhu., 2021)	Impact of HSR on urban land growth and to explore how the impact varies between different types of cites.
11	(Miguel L. Navarro-Ligero, Luis Miguel Valenzuela-Montes. 2018)	Summary of contribution of plans to different planning hypothesis
12	(Yunxiang Guo. Wenhao Yu. Zhanlong Chen. Renwei Zou., 2020)	Mechanism analysis diagram of HSR's main impacts on cities.

2.3 URBAN STUCTURE AND RELATIVE PARAMATER

The urban relative core's component in this research contributed in 1. Urban morphology; that express in various character of urban expanding presented by **Table 2.3.**, 2. Demographic, while focus on 2 sample ages range as a workmanship and elderly people considering, and 3. Public transport in mention above that proposedly discuss on public transport network including currently situation and new the project schedules plan. The urban sprawling has been the classic case in previous literature. The commonly initiate innovative was adopted within 2 main concepts as 1. Enhance the public transport capability and 2. Urban promote as the compact city that linked by the whole public transport network (Robert E. Park and Ernest W. Burgess, 1925; Homer Hoyt, 1939; Harris and Ullman, 1945). All these principal presented in **Figure 2.3.**

Table 2.3. Urban morphology pattern

No.	Main	Parameter	Sub - parameter	
1	Urban morphology	1.1 The effect parameter to decision urbanization location	1.1.1 The supply consumption locations 1.1.2 The street link connectivity 1.1.3 Natural resource 1.1.4 The disaster conditions 1.1.5 The shelter and 1.1.6 Leader vision	
		1.2 City pattern expansion	1.2.1 Grid pattern	1.2.1.1 Conventional grid 1.2.1.2 Distended grid 1.2.1.3 Grid transected 1.2.1.4 Super block
			1.2.2 Concentric pattern	1.2.2.1 Concentric 1.2.2.2 Concentric highway 1.2.2.3 Concentric by pass
			1.2.3 Galaxy pattern	1.2.3.1 Galaxy 1.2.3.2 Linear & Galaxy combination

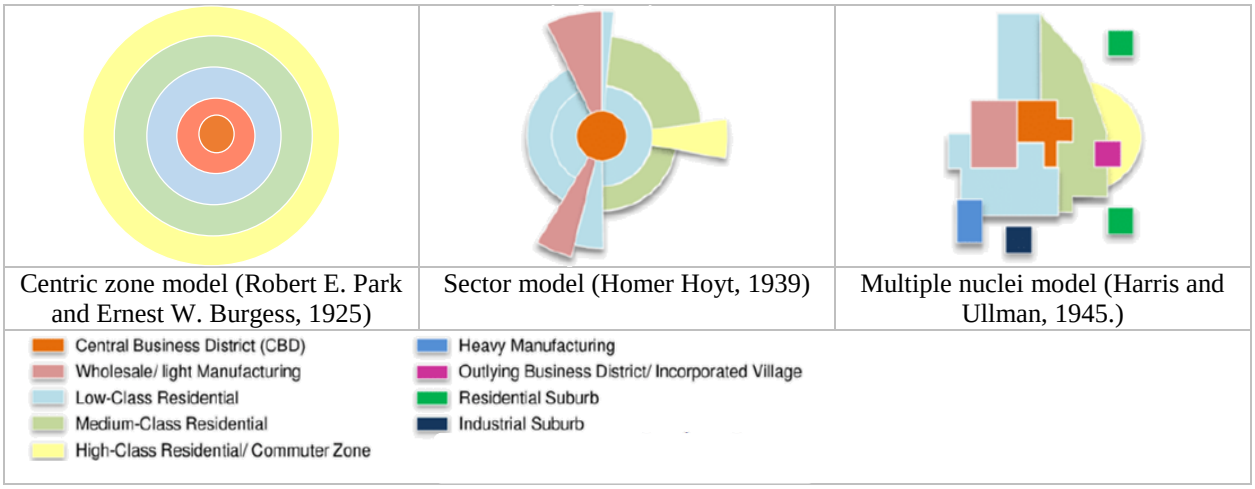


Figure 2.3. The urban land use models.

2.3.1 The Principal of Land Use Regulation, Bangkok, Thailand.

In Thailand, the town and city planning acts controlled the land use regulation since 1975 A.D. (Panpan Ronghanam., 2015). The land use condition controlled leveling by the city planning that presented by land use function as seen in **Figure 2.4.** Exploring the city with the urban boundaries, privileges and laws. For example, The Yellow: low-density residential land, The Orange : Medium-density residential land, The Brown : Very dense residential land, The Red : Commercial land, The Purple : Industrial land, The Purple cashew : Warehouse type land, The White framed and green diagonal lines : Conservation, Rural and Agricultural Land, The, Green : Rural and agricultural land, The Light Brown : Conservation-type land to promote Thai cultural identity, and The Blue : Land in the category of government institutions Public utilities and utilities. All those color shade definitions seen by **Figure 2.5.** for the case of Bangkok, Thailand. Anyway, the land use regulation relies on the law enforcement that to be the beginning of implementation stage for managing land use.

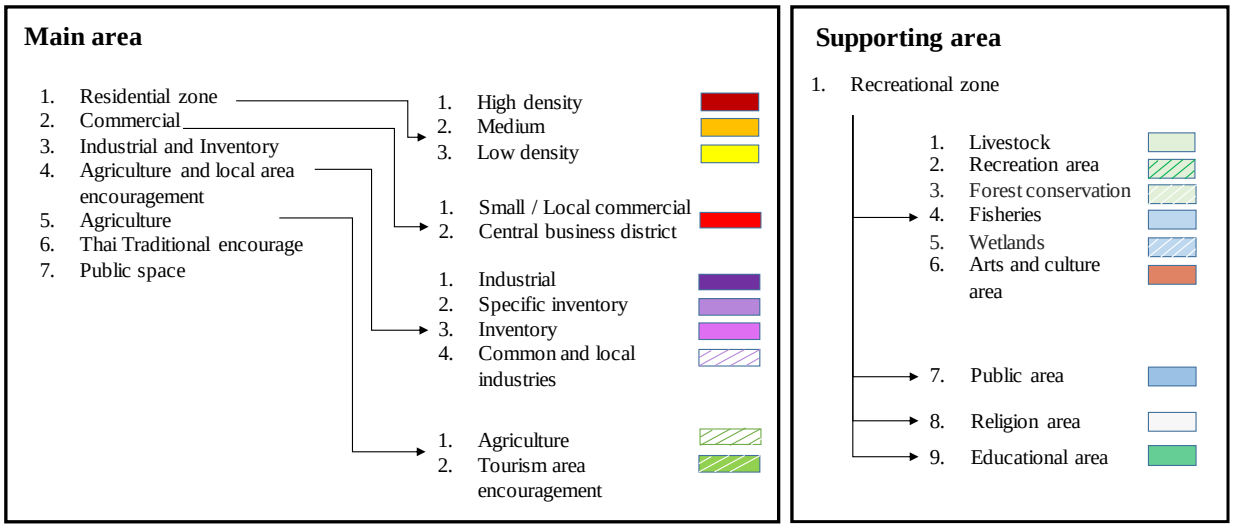
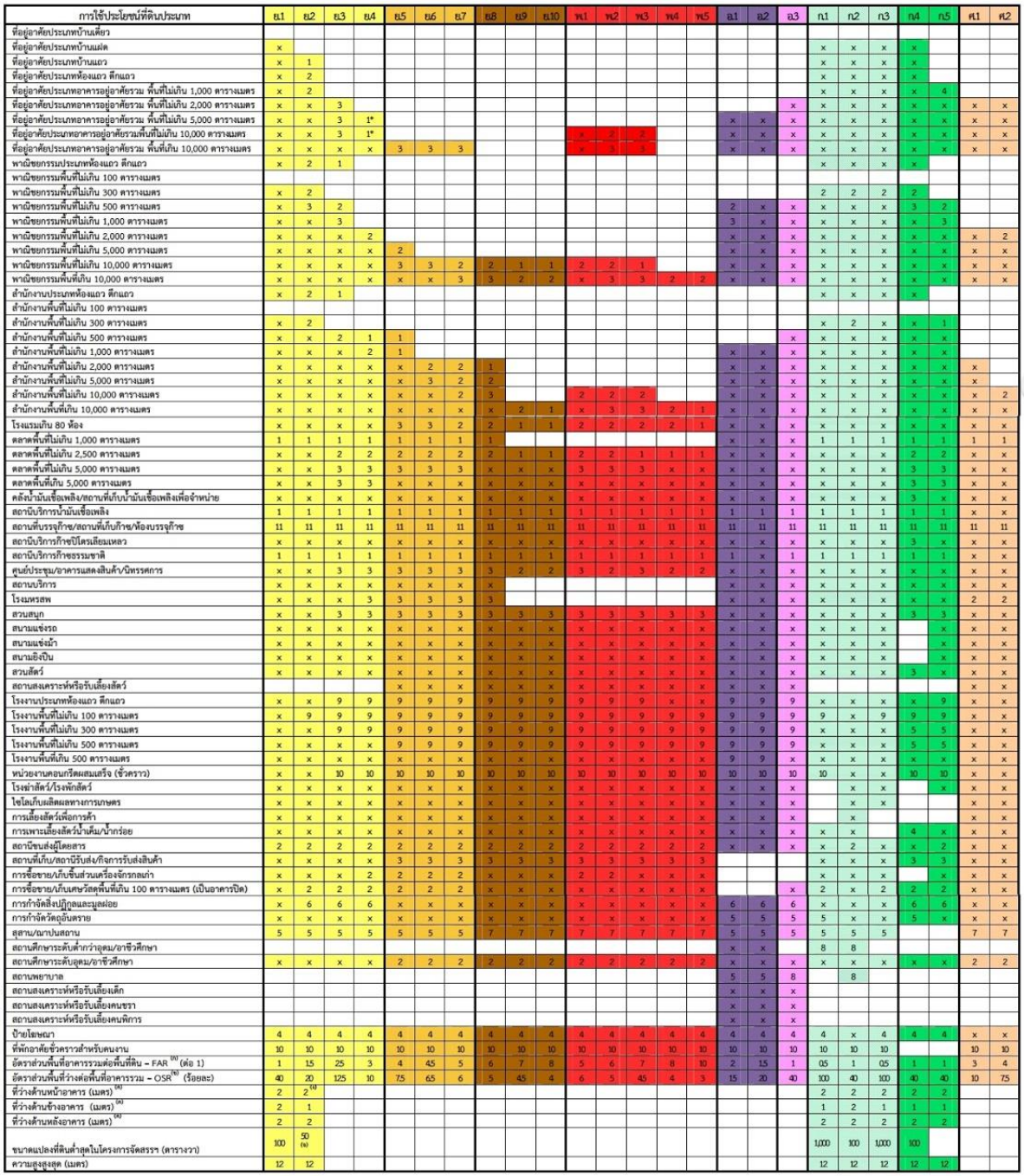


Figure 2.4. Land use color and definition, Thailand urban Regularly 2518 B.E.



การใช้ประโยชน์ที่ดินประเภท	ย1	ย2	ย3	ย4	ย5	ย6	ย7	ย8	ย9	ย10	พ1	พ2	พ3	พ4	พ5	อ1	อ2	อ3	ก1	ก2	ก3	ก4	ก5	ศ1	ศ2
ที่อยู่อาศัยประเภทบ้านเดี่ยว																									
ที่อยู่อาศัยประเภทบ้านแฝด	x																		x	x	x	x			
ที่อยู่อาศัยประเภทบ้านแถว	x	1																	x	x	x	x			
ที่อยู่อาศัยประเภทห้องแถว ตึกแถว	x	2																	x	x	x	x			
ที่อยู่อาศัยประเภทอาคารอยู่อาศัยรวม พื้นที่ไม่เกิน 1,000 ตารางเมตร	x	2																	x	x	x	x	4		
ที่อยู่อาศัยประเภทอาคารอยู่อาศัยรวม พื้นที่ไม่เกิน 2,000 ตารางเมตร	x	x	3															x	x	x	x	x	x	x	x
ที่อยู่อาศัยประเภทอาคารอยู่อาศัยรวม พื้นที่ไม่เกิน 5,000 ตารางเมตร	x	x	3	1*												x	x	x	x	x	x	x	x	x	x
ที่อยู่อาศัยประเภทอาคารอยู่อาศัยรวมพื้นที่ไม่เกิน 10,000 ตารางเมตร	x	x	3	1*							x	2	2			x	x	x	x	x	x	x	x	x	x
ที่อยู่อาศัยประเภทอาคารอยู่อาศัยรวม พื้นที่เกิน 10,000 ตารางเมตร	x	x	x	x	3	3	3				x	3	3			x	x	x	x	x	x	x	x	x	x
พาณิชยกรรมประเภทห้องแถว ตึกแถว	x	2	1																x	x	x	x			
พาณิชยกรรมพื้นที่ไม่เกิน 100 ตารางเมตร																									
พาณิชยกรรมพื้นที่ไม่เกิน 300 ตารางเมตร	x	2																	2	2	2	2			
พาณิชยกรรมพื้นที่ไม่เกิน 500 ตารางเมตร	x	3	2													2	x	x	x	x	x	3	2		
พาณิชยกรรมพื้นที่ไม่เกิน 1,000 ตารางเมตร	x	x	3													3	x	x	x	x	x	x	3		
พาณิชยกรรมพื้นที่ไม่เกิน 2,000 ตารางเมตร	x	x	x	2												x	x	x	x	x	x	x	x	x	2
พาณิชยกรรมพื้นที่ไม่เกิน 5,000 ตารางเมตร	x	x	x	x	2											x	x	x	x	x	x	x	x	x	x
พาณิชยกรรมพื้นที่ไม่เกิน 10,000 ตารางเมตร	x	x	x	x	3	3	2	2	1	1	2	2	1			x	x	x	x	x	x	x	x	x	x
พาณิชยกรรมพื้นที่เกิน 10,000 ตารางเมตร	x	x	x	x	x	x	3	3	2	2	x	3	3	2	2	x	x	x	x	x	x	x	x	x	x
สำนักงานประเภทห้องแถว ตึกแถว	x	2	1																x	x	x	x			
สำนักงานพื้นที่ไม่เกิน 100 ตารางเมตร																									
สำนักงานพื้นที่ไม่เกิน 300 ตารางเมตร	x	2																	x	2	x	x	1		
สำนักงานพื้นที่ไม่เกิน 500 ตารางเมตร	x	x	2	1	1													x	x	x	x	x	x		
สำนักงานพื้นที่ไม่เกิน 1,000 ตารางเมตร	x	x	x	2	1											x	x	x	x	x	x	x	x		
สำนักงานพื้นที่ไม่เกิน 2,000 ตารางเมตร	x	x	x	x	x	2	2	1								x	x	x	x	x	x	x	x	x	
สำนักงานพื้นที่ไม่เกิน 5,000 ตารางเมตร	x	x	x	x	x	3	2	2								x	x	x	x	x	x	x	x	x	
สำนักงานพื้นที่ไม่เกิน 10,000 ตารางเมตร	x	x	x	x	x	x	2	3			2	2	2			x	x	x	x	x	x	x	x	x	2
สำนักงานพื้นที่เกิน 10,000 ตารางเมตร	x	x	x	x	x	x	x	x	2	1	x	3	3	2	1	x	x	x	x	x	x	x	x	x	x
โรงแรมเกิน 80 ห้อง	x	x	x	x	3	3	2	2	1	1	2	2	2	2	1	x	x	x	x	x	x	x	x	x	x
ตลาดพื้นที่ไม่เกิน 1,000 ตารางเมตร	1	1	1	1	1	1	1	1								x	x	x	1	1	1	1	1	1	1
ตลาดพื้นที่ไม่เกิน 2,500 ตารางเมตร	x	x	2	2	2	2	2	2	1	1	2	2	1	1	1	x	x	x	x	x	x	2	2	x	x
ตลาดพื้นที่ไม่เกิน 5,000 ตารางเมตร	x	x	3	3	3	3	3	x	x	x	3	3	3	x	x	x	x	x	x	x	x	3	3	x	x
ตลาดพื้นที่เกิน 5,000 ตารางเมตร	x	x	3	3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	3	3	x	x
คลังน้ำมันเชื้อเพลิง/สถานที่เก็บน้ำมันเชื้อเพลิงเพื่อจำหน่าย	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	3	x	x	x
สถานีบริการน้ำมันเชื้อเพลิง	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	x	x
สถานที่บรรจุก๊าซ/สถานที่เก็บก๊าซ/ห้องบรรจุก๊าซ	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
สถานีบริการก๊าซปิโตรเลียมเหลว	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	3	x	x	x
สถานีบริการก๊าซธรรมชาติ	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	x	1	1	1	1	1	1	x	x
ศูนย์ประชุม/อาคารแสดงสินค้า/นิทรรศการ	x	x	3	3	3	3	3	3	2	2	3	2	3	2	2	x	x	x	x	x	x	x	x	x	x
สถานบริการ	x	x	x	x	x	x	x	x								x	x	x	x	x	x	x	x	x	x
โรงมหรสพ	x	x	x	3	3	3	3	3								x	x	x	x	x	x	x	x	2	2
สวนสนุก	x	x	3	3	3	3	3	3	3	3	3	3	3	3	3	x	x	x	x	x	x	3	3	x	x
สนามแข่งรถ	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x
สนามแข่งม้า	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x
สนามยิงปืน	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x
สวนสัตว์	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	3	x	x	x
สถานสงเคราะห์หรือรับเลี้ยงสัตว์					x	x	x	x	x	x	x	x	x	x	x	x	x	x						x	x
โรงงานประเภทห้องแถว ตึกแถว	x	x	9	9	9	9	9	9	9	9	9	9	9	x	x	9	9	9	x	x	x	x	9	x	x
โรงงานพื้นที่ไม่เกิน 100 ตารางเมตร	x	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	x	9	9	9	x	x
โรงงานพื้นที่ไม่เกิน 300 ตารางเมตร	x	x	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	x	x	x	5	5	x	x
โรงงานพื้นที่ไม่เกิน 500 ตารางเมตร	x	x	x	x	9	9	9	9	9	9	9	9	9	9	9	9	9	9	x	x	x	5	5	x	x
โรงงานพื้นที่เกิน 500 ตารางเมตร	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	9	9	x	x	x	x	x	x	x	x
หน่วยงานคอนกรีตผสมเสร็จ (ชั่วคราว)	x	x	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	x	x	10	10	x	x
โรงฆ่าสัตว์/โรงพักสัตว์	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x		x	x	x
ไซโลเก็บผลิตผลทางการเกษตร	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x			x	x
การเลี้ยงสัตว์เพื่อการค้า	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x				x	x
การเพาะเลี้ยงสัตว์น้ำเค็ม/น้ำกร่อย	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		4	x	x	x
สถานีขนส่งผู้โดยสาร	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	x	x	x	x	2	x	x	2	x	x
สถานที่เก็บ/สถานีรับส่ง/กิจการรับส่งสินค้า	x	x	x	x	3	3	3	3	3	3	3	3	3	3	3				x	x	x	3	3	x	x
การซื้อขาย/เก็บชิ้นส่วนเครื่องจักรกลเก่า	x	x	x	2	2	2	2	x	x	x	2	2	x	x	x				x	x	x		x	x	x
การซื้อขาย/เก็บเศษวัสดุพื้นที่เกิน 100 ตารางเมตร (เป็นอาคารปิด)	x	2	2	2	2	2	2	x	x	x	x	x	x	x	x			x	2	x	2	2	2	x	x
การกำจัดสิ่งปฏิกูลและมูลฝอย	x	6	6	6	x	x	x	x	x	x	x	x	x	x	x	6	6	6	x	x	x	6	6	x	x
การกำจัดวัตถุอันตราย	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	5	5	5	5	x	x	5	x	x	x
สุสาน/ฌาปนสถาน	5	5	5	5	5	5	5	7	7	7	7	7	7	7	7	5	5	5	5	5	5			7	7
สถานศึกษาระดับต่ำกว่าอุดม/อาชีวศึกษา																x	x		8	8					
สถานศึกษาระดับอุดม/อาชีวศึกษา	x	x	x	x	2	2	2	2	2	2	2	2	2	2	2	x	x	x	x	x	x	x	x	2	2
สถานพยาบาล																5	5	8		8					
สถานสงเคราะห์หรือรับเลี้ยงเด็ก																x	x	x							
สถานสงเคราะห์หรือรับเลี้ยงคนชรา																x	x	x							
สถานสงเคราะห์หรือรับเลี้ยงคนพิการ																x	x	x							
ป้ายโฆษณา	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	x	4	4	4	x	x
ที่พักอาศัยชั่วคราวสำหรับคนงาน	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10			10	10
อัตราส่วนพื้นที่อาคารรวมต่อพื้นที่ดิน – FAR [ข] (ต่อ 1)	1	1.5	2.5	3	4	4.5	5	6	7	8	5	6	7	8	10	2	1.5	1	0.5	1	0.5	1	1	3	4
อัตราส่วนพื้นที่ว่างต่อพื้นที่อาคารรวม – OSR [ข] (ร้อยละ)	40	20	12.5	10	7.5	6.5	6	5	4.5	4	6	5	4.5	4	3	15	20	40	100	40	100	40	40	10	7.5
ที่ว่างด้านหน้าอาคาร (เมตร) [ค]	2	2 [ฉ]																	2	2	2	2	2		
ที่ว่างด้านข้างอาคาร (เมตร) [ค]	2	1																	1	2	1	1	1		
ที่ว่างด้านหลังอาคาร (เมตร) [ค]	2	2																	2	2	2	2	2		
ขนาดแปลงที่ดินต่ำสุดในโครงการจัดสรร (ตารางวา)	100	50 [จ]																	1,000	100	1,000	100			
ความสูงสูงสุด (เมตร)	12	12																	12	12	12	12	12		

เงื่อนไข X = ไม่อนุญาต

1* = เงื่อนไขตั้งอยู่ริมถนนที่มีเขตทางไม่น้อยกว่า 10 ม./หรืออยู่ในระยะ 500 ม. จากสถานีรถไฟฟ้าขนส่งมวลชน

1 = เงื่อนไขตั้งอยู่ริมถนนที่มีเขตทางไม่น้อยกว่า 12 ม./หรืออยู่ในระยะ 500 ม. จากสถานีรถไฟฟ้าขนส่งมวลชน

2 = เงื่อนไขตั้งอยู่ริมถนนที่มีเขตทางไม่น้อยกว่า 16 ม./หรืออยู่ในระยะ 500 ม. จากสถานีรถไฟฟ้าขนส่งมวลชน

3 = เงื่อนไขตั้งอยู่ริมถนนที่มีเขตทางไม่น้อยกว่า 30 ม./หรืออยู่ในระยะ 500 ม. จากสถานีรถไฟฟ้าขนส่งมวลชน

4 = เงื่อนไขเรื่องที่ตั้ง

5 = เงื่อนไขความเกี่ยวเนื่องของกิจกรรม

6 = เงื่อนไขภายใต้การควบคุม/อนุญาต กทม.

7 = เงื่อนไขทดแทนของเดิม

8 = เงื่อนไขเรื่องขนาด/ระดับการบริการ

9 = เงื่อนไขตามบัญชีท้ายกฎกระทรวงฯ

10 = เงื่อนไขตั้งชั่วคราวในหน่วยสถานที่ก่อสร้างหรือบริเวณใกล้เคียงรับกิจการบางประเภทที่ระบุไว้ในกฎกระทรวงฯ

(ก) FAR (Floor Area Ratio) "อัตราส่วนพื้นที่อาคารรวมต่อพื้นที่ดิน" หมายความว่า อัตราส่วนพื้นที่อาคารรวมทุกชั้นของอาคารทุกหลังต่อพื้นที่ดินที่ใช้เป็นที่ตั้งอาคาร

(ข) OSR (Open Space Ratio) "อัตราส่วนของที่ว่างต่อพื้นที่อาคารรวม" หมายความว่า อัตราส่วนของที่ว่างอันปราศจากสิ่งปกคลุมต่อพื้นที่อาคารรวมทุกชั้นของอาคารทุกหลังที่ก่อสร้างในที่ดินแปลงเดียวกัน

(ค) ระยะร่นรอบอาคาร ไม่ใช้บังคับกับบ้านเดี่ยวที่มีขนาดแปลงที่ดินน้อยกว่าแปลงละ 40 ตร.ว.หรือมีด้านใดด้านหนึ่งน้อยกว่า 6 ม.ซึ่งมีการแบ่งแยกหรือแบ่งโอนก่อนกฎกระทรวงใช้บังคับ

(ง) บ้านแถว ห้องแถว และตึกแถว ให้มีระยะถอยร่นไม่น้อยกว่า 6 ม.

(จ) บ้านแถว ห้องแถว และตึกแถว ให้มีขนาดต่ำสุดของแปลงที่ดินไม่น้อยกว่า 20 ตร.ว.

หมายเหตุ ตารางสรุปข้อกำหนดนี้ได้จัดทำขึ้นด้วยวิธีการสรุปสาระสำคัญมาจากกฎกระทรวงให้ใช้บังคับผังเมืองรวมกรุงเทพมหานคร พ.ศ. 2556 โดยมีวัตถุประสงค์เพื่ออำนวยความสะดวกสำหรับใช้เป็นคู่มือปฏิบัติการให้เป็นไปตามกฎกระทรวงดังกล่าว หากปรากฏข้อความ ข้อกฎหมาย หรือข้อเท็จจริงประการใดที่ขัดหรือแย้งกับกฎกระทรวงดังกล่าวแล้ว ให้ยึดถือข้อความในกฎกระทรวงและบัญชีท้ายกฎกระทรวงให้ใช้บังคับผังเมืองรวมกรุงเทพมหานคร พ.ศ. 2556 เป็นหลัก

กฎกระทรวงดังกล่าวประกาศในราชกิจจานุเบกษา ฉบับกฤษฎีกา เล่ม ๑๓๐ ตอนที่ ๔๑ ก ลงวันที่ ๑๖ พฤษภาคม ๒๕๕๖

Figure 2.5. Land use controlled functions by color shade and definition, Thailand urban Regularly.

2.3.2 Urban Plan of KhonKaen, Thailand.

The principal of urban plan development as presenting in **Figure 2.6.**; Tokyo, New York and Paris cases in 1980 (Department of city planning, Tokyo). The Thailand urban planning regulations (Panpan Ronghanam., 2015) and strategies was carry on 3 levels hierarchy structure including 1. Regional sector plan; the propose tandemly with the National Economic and Social Development Plan. and has practical effect by coordinating policies, projects plan and budget allocation to various government agencies. 2. City plan: the development based Infrastructure and Development Phasing for Growth Management and 3. Specific town plan: The Urban Renewal in areas where there is a need to correct the deterioration of the city, respectively. (Town Planning Act, B.E. 2562.). In KhonKaen Thailand, there had been published the 3rd development planned as seen by **Figure 2.7.** City Planning, KhonKaen Province. The urban plan also considering with the mass transit as the city-train link based on walkable access by 1. The highly effective land use present by walk access in 5 minutes (500-meter station buffer) 2. The effective land use present by walk access in 3 minutes (250-meter station buffer) and 3. The motivational distance for walk access in 10 minutes (800-meter station buffer) as seen by **Figure 2.8**. Based on the TOD strategies plan tandemly with urban morphology functional aspects were enforcement by 1. Gentrification boundary 2. Physical condition 3. Travel demand 3. Urban mentality 4. Infrastructure 5. The development strategy and plan 6. Land regulation.

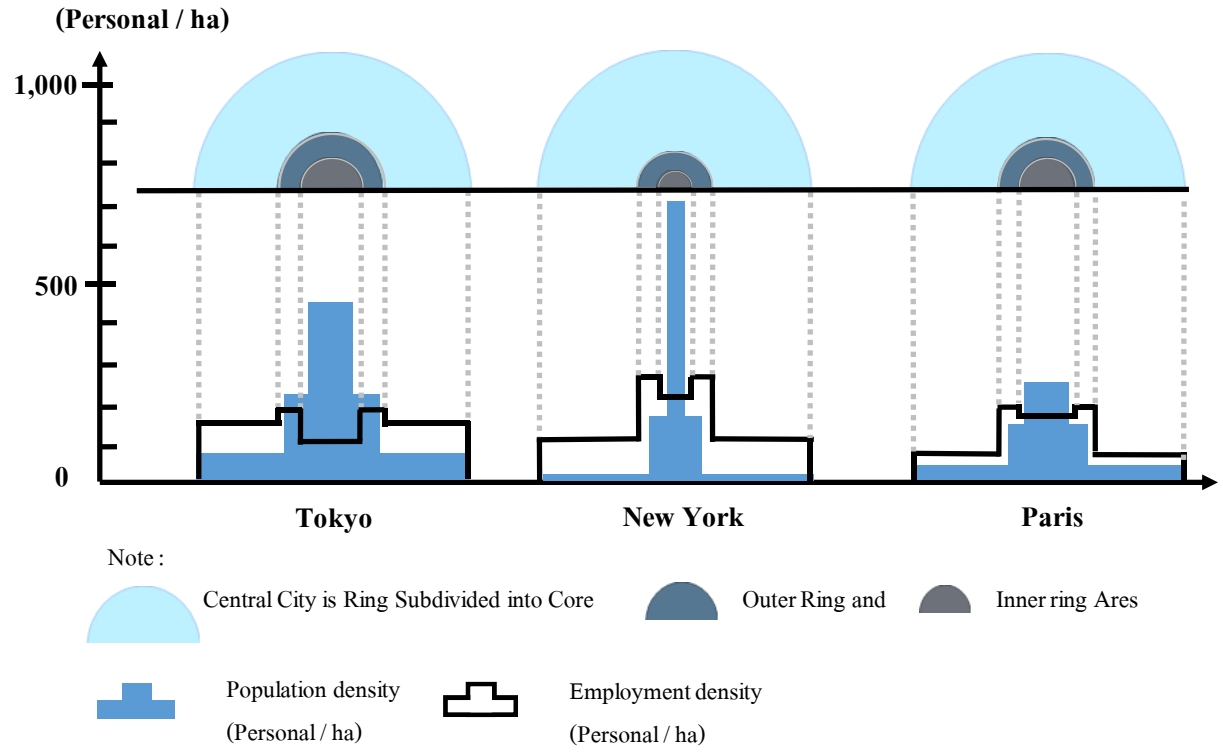
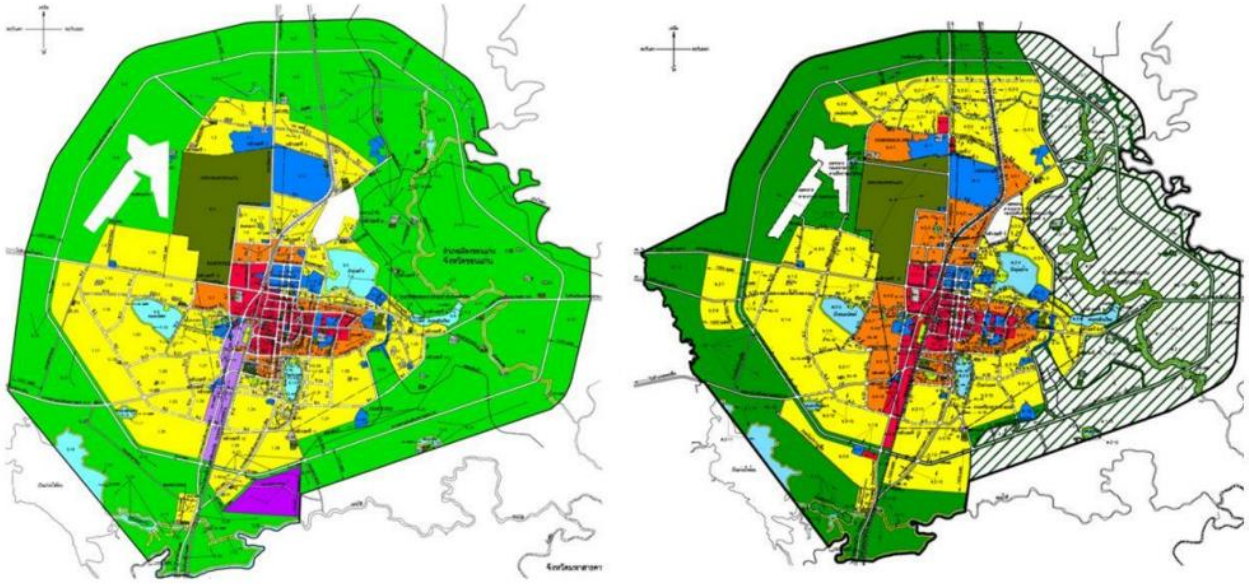


Figure 2.6. The spatial Structure of central area of Tokyo, New York and Paris represented by population and employment densities in 1980-



Ministerial Regulation No. 432 B.E. 2542 (1999 A.D)	KhonKaen city plan (3rd revised edition)

Figure 2.7. City Planning, KhonKaen Province

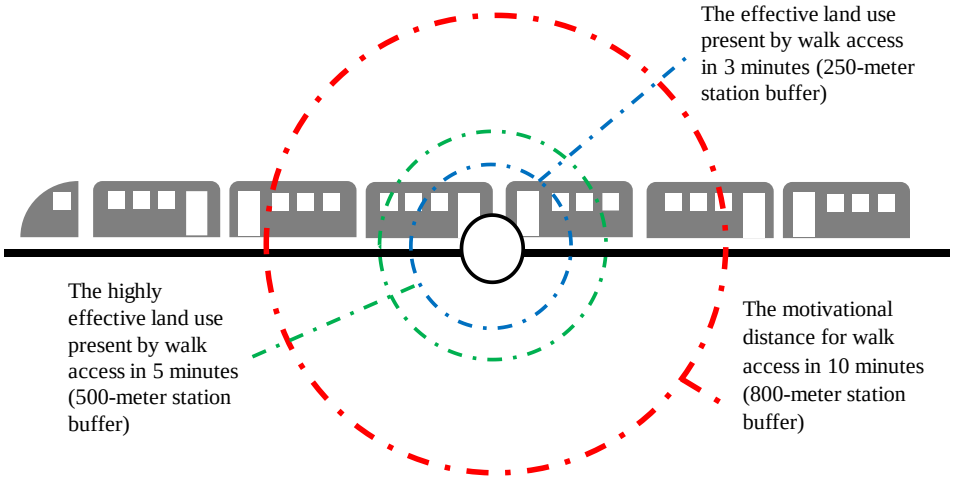


Figure 2.8. The Urban Plan with the Mass Transit Walkable Access Distance, KhonKaen, Thailand.

2.3.3 Demographic of KhonKaen, Thailand.

In case of city scale, the urban rail was promoted for urban effective mobility by urban rail project that many successful case was confirmed in Japan is Nagasaki, Kumamoto, Hiroshima and Kagoshima (「長崎駅周辺再整備事業」の記事一覧, 2021) (「多核連携都市」と市電延伸の位置づけ, 2021) (鉄道計画データベース, 2021) (公共交通体系づくりの基本計画, 2021) city where the TOD strategy was also applied. In Thailand, the 7 cities including 1. Chaing Mai 2. Pitsanulok 3. Udonthai 4. KhonKaen 5. Nakorn ratchasrima 6. Phuket and 7 Songkha have been presenting by **Figure 2.9 and Table 2.4.** which have been promoting the urban public transport

investment. Urban rail as TRAM is a public transport vehicles running on a tramway track by public urban streets. This chapter addressing the city case that compose the development of urban public transport mobility for visualizes the urban mobility accessibility projection in advances. The thesis contribution in KhonKaen, Thailand. Firstly, the demographic and morphology has been extensively implemented on approximately 120,000 households living within the study area, KhonKaen covering 10,890 sq.km of the land with approximately 1.806 million residents as found in 2018 (KhonKaen Provincial Statistical Office,2020). Research exposed a Densely Inhabited Districts (DID) criteria in 100 x 100 basic unit blocks that Japan were designated (Statistics bureau of Japan, 2021) as seen in **Figure 2.10.** As previously mentioned, this research also presented the comparative results on the effect of public transport between 2 sample groups: 1) 10 to 64 years and 2) over 65 years (Office of Transport and Traffic Policy and Planning, Thailand. (2020)).

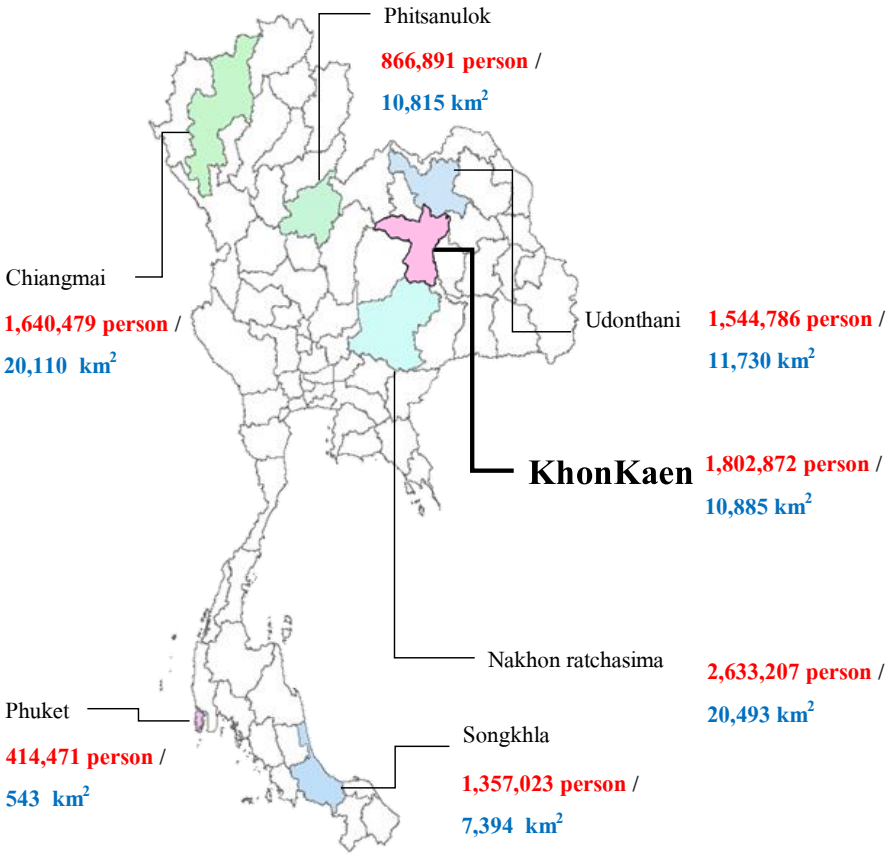
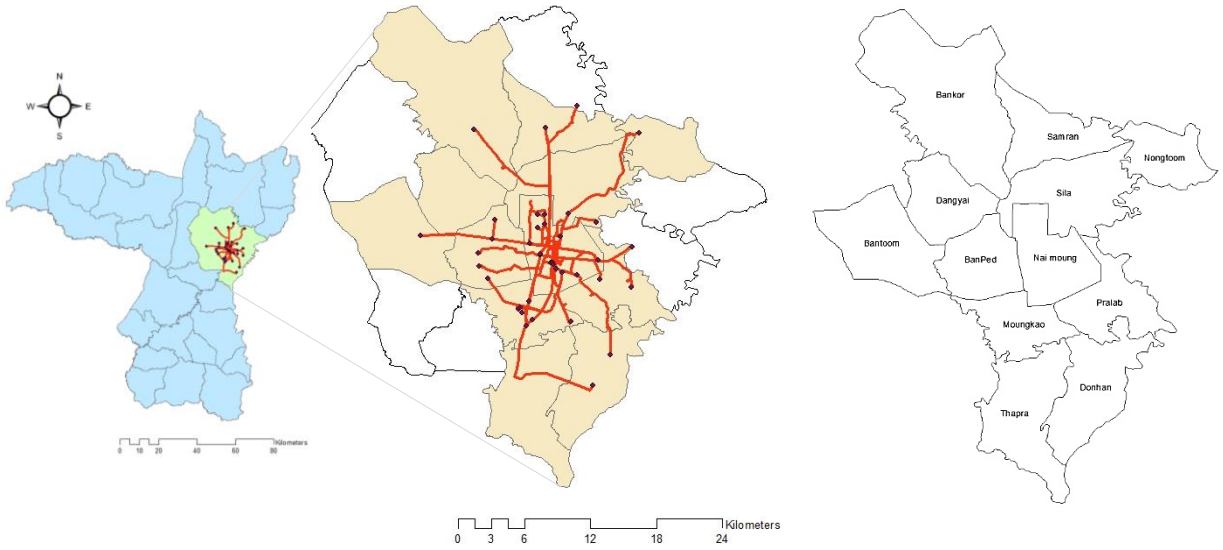


Figure 2.9. The 7 cities have been presenting to promote the urban public transport investment

Table 2.4. Population, Area (Km^2) and Pop dense of the 7 cities

No.	Name	Aumphor	Tumbon	Population	Area (Km^2)	Pop dense
1	Chiang Mai	25	204	1,640,479	20,110	82
2	Phitsanulok	9	93	866,891	10,815	80
3	Udonthani	20	155	1,544,786	11,730	132
4	KhonKaen	26	199	1,802,872	10,885	166
5	Nakhon ratchasima	32	289	2,633,207	20,493	128
6	Phuket	3	17	414,471	543	763
7	Songkhla	16	127	1,357,023	7,394	184

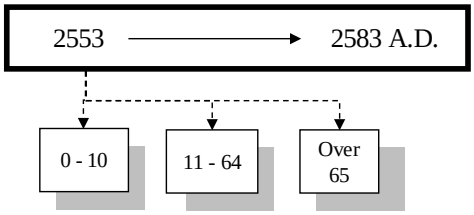


A Case of KhonKaen City, Thailand, covering 25 cities (called "Amphor")

Tambon's Name (12 out of 19 sub-prefectures were based on the public transport (bus) network)

Figure 2.10. Gentrification of Sample Case of KhonKaen City, Thailand

This research adopted the population structure following the Town and planning regulation that were collected by the survey data in every 5 years (public data). The structure of prefecture commonly deployed in sub prefecture called "Aumpur", breakdown to the sub of Aumpur is called "Tumbon". The researcher utilized the forecasting data covered 2553 to 2583 A.D. (Nation statistic of Thailand) dispersing of the population data perceived by building area (square. meter) calculating by population in each Tumbon that contributed by 3 groups of ages consist of 1. 0-10 years 2. 11 – 64 years and 3. Over 65 years. As seen in **Table 2.5.** and **Figure 2.11 -2.13.**



- Prefecture
  - Aumpur XX
    - **Tumbon XX** xxx xxx xxx
  - Aumpur XX
    - **Tumbon XX** xxx xxx xxx
  - Aumpur XX
    - **Tumbon XX** xxx xxx xxx
  - Aumpur XX
    - **Tumbon XX** xxx xxx xxx

Figure 2.11. Structure of Population Demographic in Analysis Case.

Table 2.5. The Different Ranges of the Population's Age, KhonKaen, Thailand

	Sub - district											
	Nai moung	Samran	Thapra	Bantoom	Moungkao	Pralab	Bankor	Dangyai	Donhan	Sila	BanPed	Nongtoom
Total	115,998	9,570	10,473	17,992	29,660	22,440	16,601	8,777	10,009	51,644	43,074	7,698
0-4	4,217	397	455	915	1,450	837	899	412	382	2,028	2,427	385
5-9	5,177	509	611	1,050	1,593	1,229	936	476	567	2,748	2,591	438
10-14	6,093	465	534	1,097	1,725	1,221	929	450	594	2,796	2,368	430
15-19	8,465	475	571	1,049	1,799	1,312	1,071	486	537	2,860	2,556	404
20-24	19,291	677	738	1,332	2,213	1,613	1,252	532	671	4,990	3,365	516
25-29	7,760	745	777	1,216	2,197	1,789	1,209	752	796	4,098	3,225	576
30-34	6,911	702	708	1,232	2,151	1,651	1,141	753	720	4,033	3,541	572
35-39	7,355	724	802	1,447	2,639	1,770	1,377	771	722	4,107	4,007	581
40-44	7,612	726	847	1,505	2,560	1,876	1,367	668	764	3,890	3,776	563
45-49	8,137	858	862	1,563	2,603	2,011	1,460	690	880	4,095	3,633	672
50-54	8,326	861	914	1,484	2,426	1,983	1,364	709	902	4,100	3,706	692
55-59	7,598	691	798	1,137	2,059	1,549	1,010	621	715	3,867	2,854	504
60-64	5,874	558	625	943	1,579	1,254	879	488	556	3,076	1,896	428
65-69	4,514	404	484	782	1,104	898	705	352	454	2,022	1,333	361
70-74	3,450	334	362	558	705	657	442	269	318	1,357	856	271
75-79	2,415	220	182	350	443	422	267	175	211	814	469	168
80-84	1,542	142	111	200	250	231	160	115	126	497	285	79
85-89	780	53	59	86	127	91	93	39	70	189	130	41
90-94	291	18	29	33	31	33	31	15	17	57	37	15
95-99	130	8	4	9	4	8	7	4	6	17	15	1
100 more	60	3	0	4	2	5	2	0	1	3	4	1

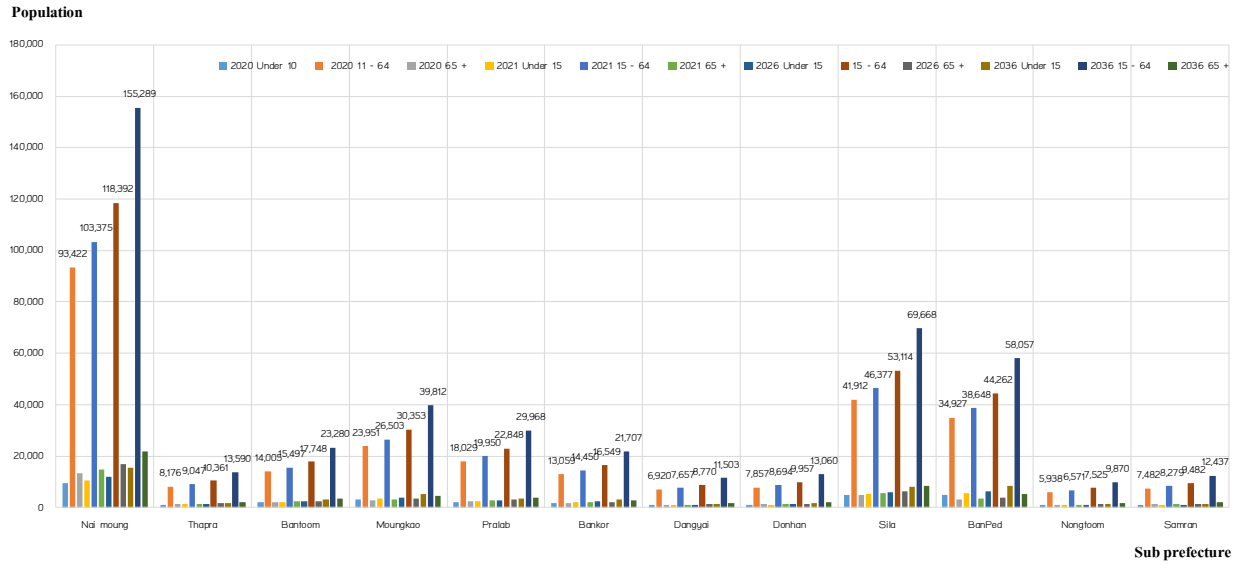


Figure 2.12. Ranges of Population's Age Forecast during 2020 to 2036 in Each of the Sub-Prefecture Tendency (2 age ranges for consideration were 10 – 64 (Working Age) and over 65 years old (Elderly People).

Figure 2.13. Population covering 2020 – 2036 A.D. by sub distinct (Tumbon) (National Statistical Office, Thailand, 2020.; KhonKaen Provincial Statistical Office, Thailand, 2020.; Office of Transport and Traffic Policy and Planning, Thailand, 2020)

2.4 Conclusion

The world population growing character was slightly down. In next decade, Thai society will become a super-aged society of world scenarios in 2040 A.D. The demographic survey presenting the confront between aging societies and urban sprawling are became. The challenge of urban enhance livability is a key success that support the peaceful coexistence society. Urban mobility is the one of the key support which considered within the public transit network, that was an affirmation of the urban policies maker to disclose and encourage effective mobility proposes. The thesis declaration is developing the evaluation of urban mobility methods and modes of integration in various a scenario where imposes the urban rail is promoted to be the city mass transit.

CHAPTER 3

URBAN PUBLIC TRANSPORT STRUCTURE AND RELATIVE PARAMETER

3.1 INTRODUCTION

The public transport options relative with an urban regulation and financial option. The financial projection was relative term of return of investment. The urban regulation has been more complexity while urban public transport imposes to effective urban mobility. The land use, public transit network integration, modal assessment and accessibility performance are addressed the ability of urban transport network. In addition, the transport infrastructure was a support for those population as decrease transport cost and increase accessible. As mention above, the city where plan to invest Urban rail transit network was necessary to understand the relationship between 1. Urban form 2. Urban mobility based public network investigated and 3. Policy option, maturity, and sensibility. This chapter was an introduces of public transit through the Urban rail network plan, also present the policy options vitalizes the phenomenon of urban effective accessibility.

3.2 PUBLIC TRANSIT

3.2.1 Conventional of Public Transit

The principle of bus attraction provided a connectivity in those catchment area. The bus stop point as a point of demand perceived for consumer mobility. The economic growth has been profound that significantly relate with bus public transit while supported by the governance duty. However, the developing city suffered the social inequality represented by the lost opportunity for education, living, and public transport. The performance of urban was related and relying on the connectivity's urban structure leveling by road structure though bus network as mention in term of "Conventional of public transit". Exactly, the average cost per vehicle kilometer, the degrees of service, transport fares, and the number of passengers were proved to be the key factors in transport reforming ability in Israel. (Ida and Talit, 2017). In Canada, the interface between bus and light rail (Guillot, 1984) presents the charity position in a different mode.

There are many types of public facility function as rely on country regulation, budget, goals and prefecture tendency. Anyway, the goal of sustainable urban transportation policy will provide a high and effective performance of service. In the cases of developing cities, there are many models and functionalities represented for the options of public transportation in different levels that was consisting of Bus Rapid Transit (BRT), Light Rail Transit (LRT), Regular Bus (RB), Metropolitan Rapid Transit (MRT), and Street Car (SCR) in which the distinct function was considered as presented in **Table 3.1.** and **Figure 3.1.** and The Railway Cost/Revenue and track density presented in **Figure 3.2.** that comparative between 1. maximum capacity 2. Line capacity

3. Average investment cost and 4. Property impact. In Charlotte, North Carolina - the public planning and funding on light rail-transit (LRT); LRT provides a neighborhood impact of 11.3% for the property sale within 1 mile around the LRT stations so that the LRT investment could be a productive tool for economic development in a particular district rather than a transportation facility in cities contained with sparser development patterns (Billings , 2011). This successful introduction of LRT systems was inevitably related to the realistic estimation of their ridership as it would attract a minimum capacity for about 23,000 passengers daily and shift a small percentage of 3.5% of traffic within the system. It was also found that approximately 33%of these trips was corresponding to the urban area of the network and about 62% of the estimated ridership (Konstantinos Kepaptsoglou, 2017). The land-use model aimed to properly investigate the land-use change around the stations. On this matter, the successful cases in Japan presented the rail urban system by Nagasaki Electric established on 16 November 1915 A.D .with 5 official lines and totally 11.5 km (Nehashi A., 1998).

Table 3.1. Comparative of Public Transit Capability (Haixiao Pan *et al*, 2009; GAO, 2001; Qisheng Pan *et al*, 2014).

No.	Parameters	Bus system		Urban rail transit	
		Bus	BRT	Light rail	Metrorail
1	Maximum capacity (passenger's/vehicle unit).		160-270	170-280	240-320
2	Line capacity: Typical peak hour passengers.	1,000 3,000	2,000 10,000	3,000-18,000	13,000-41,00
	Line capacity (passengers/direct/hour).		5,000 45,000	12,000 27,000	40,000-72,00
3	Average capital costs (2,000 USD/km).		8.4	21.5	104.5
	Capital costs (USD 1990 per route mile, millions)		10.24	26.4	128.2
4	Construction cost (Dollars in millions).	0.68-8.97	13.49	34.79	
5	Property impact: apartment (USD 1990 per square meter while away from transit).			0-38	46-62

Bus (Kyoto, Japan)

Bus Rapid Transit (Austria)

Light rail (Nagasaki Electric Tramway)

Metro rail (BTS, Thailand)

Figure 3.1. Public Transit options (Google, 2021)

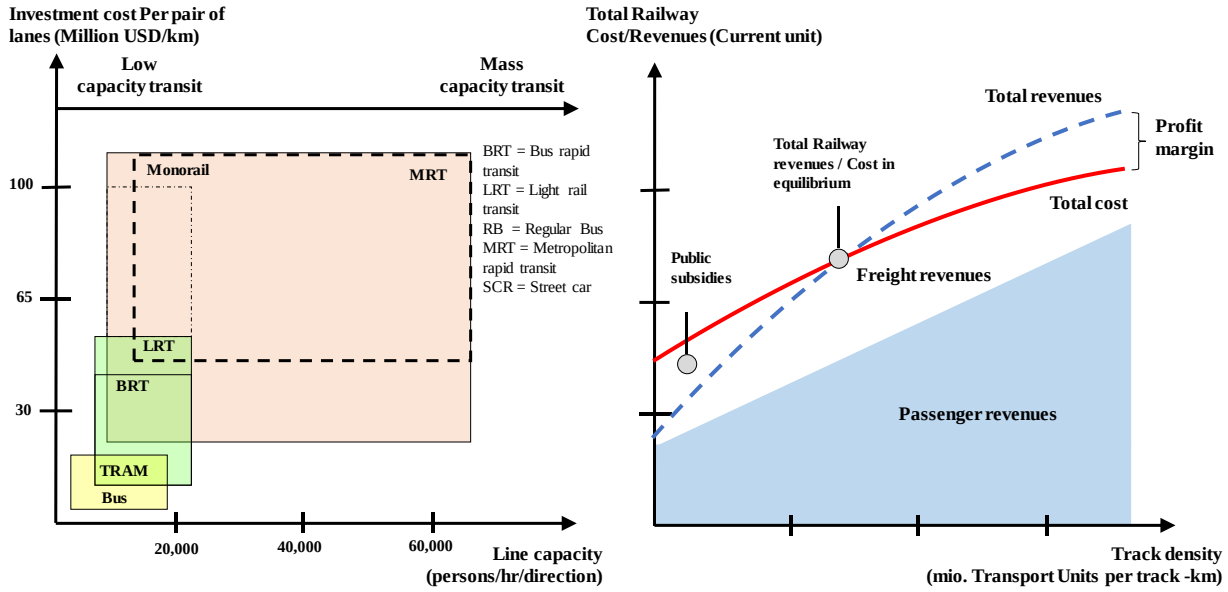


Figure 3.2. Simplified Representation of Costs/Revenues of A Railway System and Bus Rapid Transit (BRT): An Efficient and Competitive, Mode of Transport (Cervero, 2013; Association, 2008; Kittelson & Associates, 2003; Vuchic, 2007; PCBK International Co., 2011; Daniel Pulido *et al*, 2019).

Khonkaen's main public transport shared with 4 types including 1. Mini bus 2. Bus 3. Taxi and 4. Motorcycle as seen in **Figure 3.3.** It can be classified by operation pattern to regular route and non-regular route service. Minibus and bus are the regular route service of which KhonKaen, there were 20 route (only 19 route available in 2021.) of mini bus with the fare is about 20 – 40 baht (Thai currency units - around 1 dollar) per person for whole the trip. The bus route and bus stops were shown the detail (Name) and total length of route in **Table 3.2.** Minibus and bus route, Khonkaen, Thailand. while were explain by map and morphology as seen in Appendix 1. Notably, the transport demand forecast had rapidly increased from a total of 656,500 trips per day to 1,146,400 trips per day during a period of 2018 to 2036 A.D. In analysis case, the transport-mode share in KhonKaen city is recently dominated by motorcycles (53.6%), private cars (32.1%) and public transport (14.3%) of trips (PCBK, 2011; OTP, 2018). In this chapter visualizes the commonly use of current bus public network that covering in 12 sub-district within 19 bus route by 367.5 km length and 314 bus stop points**.** Also presented in the appendix sections.

Figure 3.3. Khonkaen's main public transport (1. Mini bus 2. Bus 3. Taxi and 4. Motorcycle)

Table 3.2. Minibus and bus route, KhonKaen, Thailand.

No.	Code	Abbreviation	Type	Route		Distance
				Origin	Destination	(km)
1	2	Bus No.2	Minibus	Ban kok fan pong	Ban khok noi	25
2	3	Bus No.3	Minibus	Khonkaen terminal 3	Ban pron nimit	25
3	4	Bus No.4	Minibus	Khonkaen terminal 3	Ban nong nam kliang	23
4	5	Bus No.5	Minibus	Nong phai lom market	Ban tum	15
5	6	Bus No.6	Minibus	Municipal 1 Food market	Ban lao nok chum	27
6	8	Bus No.8	Minibus	Khonkaen University	Ban donbom	12
7	9	Bus No.9	Minibus	Ban Sam Lieam	Ban sa at	13
8	10	Bus No.10	Minibus	Khonkaen University	Khonkaen club race cource	15
9	11	Bus No.11	Minibus	Ban Non sawan	Ban kam Charoen – Maliwan Rd	18
10	12	Bus No.12	Minibus	Khonkaen national museum	Thepra wittayaon school	17
11	13	Bus No.13	Minibus	Noi Nivet village	Sawang Mukana Co.Ltd	22
12	14	Bus No.14	Minibus	Ban none tun	Police station 4	15
13	16	Bus No.16	Minibus	Ban none tun	Adulyaram Temple	12
14	17	Bus No.17	Minibus	Ban none tun	Ban khoktha	24
15	18	Bus No.18	Minibus	Khonkaen Railway station	Ban dong pong	15
16	19	Bus No.19	Minibus	Nong phai lom market	Ban noneruang	18
17	20	Bus No.20	Minibus	Nong phai lom market	Klanghoong	18
18	21	Bus No.21	Minibus	Ban none khawao	Ban donyang	20
19	22	Bus No.22	Minibus	Ban nong hai	Ban nong yang	12
20	23	Bus No.23	Minibus	Municipality 1 Food market	Ban huatoey	22

3.2.2 Period of Urban Rail Project Plan

The authority of urban public investment decisions is consisting of 1. The State Railway of Thailand (MOT, 2020) whose was imposed the responsibility of rail operation in Thailand 2. Office of Transport and Traffic Policy and Planning, Ministry of transport (MOT, 2020) whose was imposed the responsibility of recommend policies and prepared the transportation, traffic and safety plans for land, water, air, traffic and safety transportation and 3. Department of Public Works and Town & Country Planning, Ministry of Interior (DPT, 2020) whose was imposed support, determine, supervise and develop for the city planning and public works improvement within the academic standards that is able to address societal needs, economic effects, and environmental considerations for sustainable development. The build engagement between the government and population in the implementation of urban planning, local and community development, and develop, improve, promote good governance and law enforcement efficiency of land use. As a result, the master plan for mass public transportation investment will be authorized based on these authority structure agreements.

In Khonkaen, Thailand has been approved the Environmental Impact Assessment: EIA study of urban rail project since 2015 A.D. (Office of Transport and Traffic Policy and Planning). Also, the KhonKaen municipal supporting and operating based on Department of Public Works and Town & Country Planning Act that present the update of city plan discussed above in chapter 2, the 3rd city plan revision. The urban rail project plan composes within three timeframes while were considered consisting of a short period (1-5 years), a medium period (5-10 years), and a long

period (10-20 years) as mentioned in the Thailand's 12th National Economic and Social Development Plan. (NESDC, 2019). Particularly, the regulation route service in the city comprised the 19 routes of minibus and bus; meanwhile, the KhonKaen's public rail investment plan fully covered the 5 main routes in which the routing construction plan is being expected to be completed in 2036 A.D., this public rail investment plan totally a length of 124 kilometers with 93 stop points (31 stations) in 12 sub-districts as seen by **Table 3.3.** and **Figure 3.4.** The thesis analysis by the designated destination that was reached at different velocities inside various networks was clearly effective as a comparative criterion. The bus speed deployment is 15 km/hr and the Rail speed plan 60 km/hr.

Table 3.3. Public Transport Mode and Information.

No.	Mode	Number of routes	Total length (km)	Rail transit plan	Speed (km/hr)	Number of stations	Year
1	Bus	19	294.39		The bus speed 15 km/hr	314 bus stops	2020
2.1	Train	1	22.68	Red line	Rail speed plan 60 km/hr	16 stations in the first line up to 93 train stations	2021
2.2		3	46.38	Red line, Yellow line and Pink line			2026
2.3		5	73.13	Red line, Yellow line, Pink line, Blue line and Green line			2036

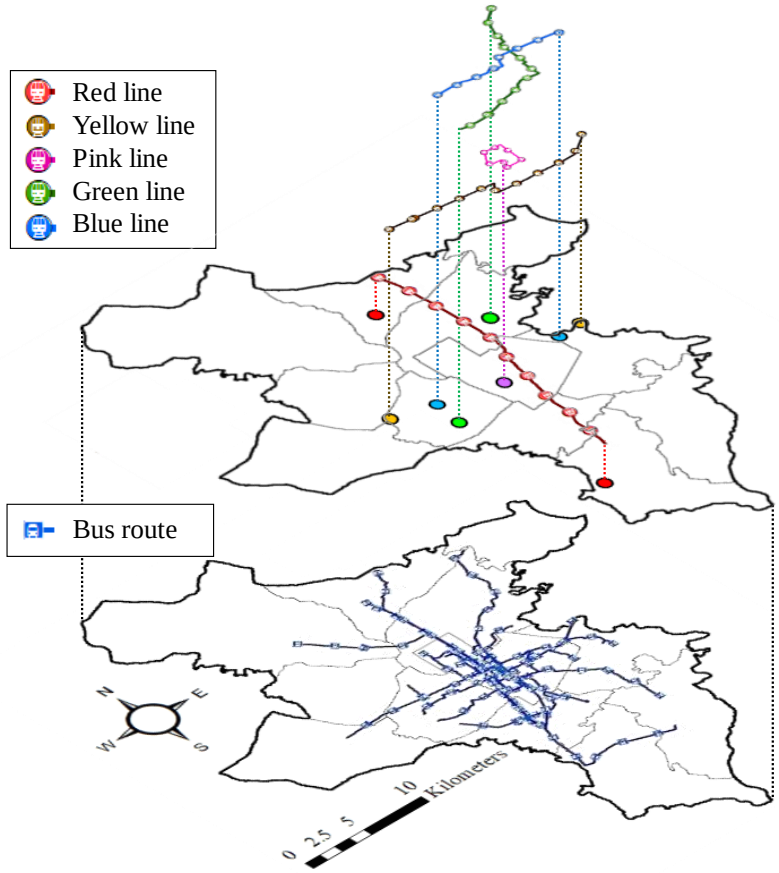


Figure 3.4. Comparative Data of Urban Rail Public Infrastructure Investment Plan and Bus Network.

3.2.3 Urban Rail Line

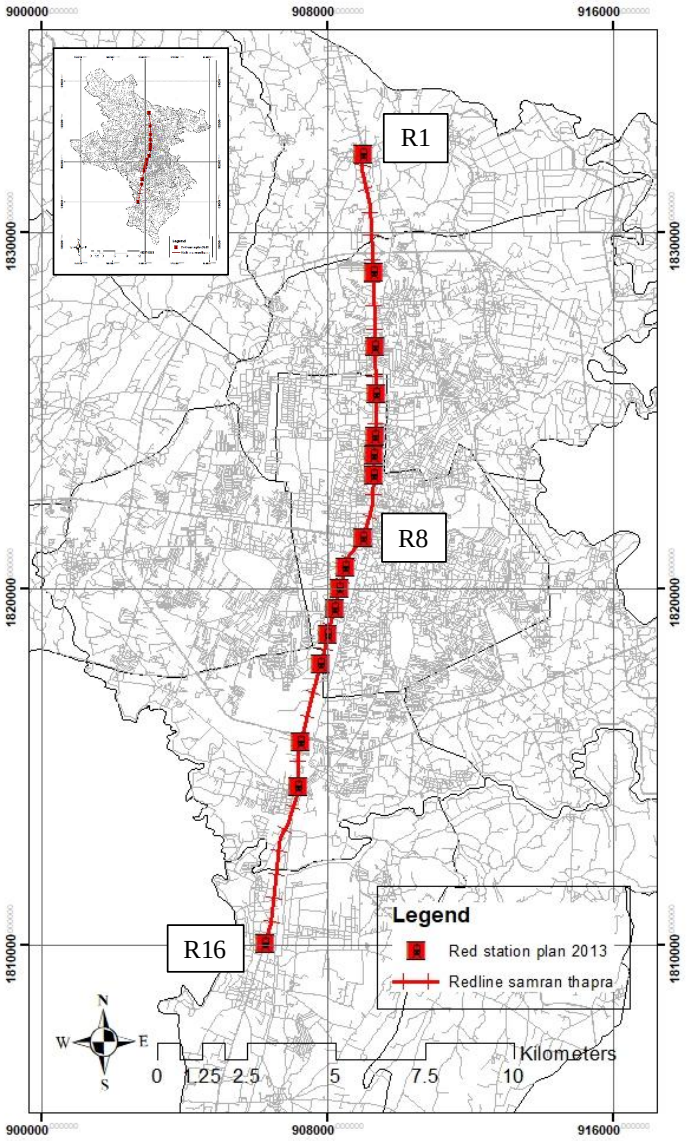
Firstly, this session would to introduces the station separately by route in 1. Red line (16 stations) 2. Pink line (10 stations) 3. Blue line (19 stations) 4. Green line (25 stations) and Yellow line (23 stations) along the way through by 800-meter buffer (detailing in the appendix sections). The station type and transition station shown in **Table 3.4.** and **Figure 3.5 – 3.9**. In addition, the building presenting in 7 types as seen in the appendix sections. The building color was presented by 1. Residential building – White color 2. Commercial building – Red color 3. Industries building – Orange color 4. Infrastructure – Blue color 5. Education building – Yellow color 6. Religious building – Dark-yellow color 7. Public service building – Light blue color 8. Infirmary building – Green color and 9. Recreational building – Pink color.

Table 3.4. Station Detail (Name: Abbreviation and count number)

Red line (Abbreviation)				**Transition stations.**			
No	**Name (Abbreviation)**		**Sta. types**	**Pink line**	**Blue line**	**Green line**	**Yellow line**
1	Samran	(R1)		-	-	-	-
2	Nongkung	(R2)	A	-	-	-	-
3	Lotus sila	(R3)	A	-	-	-	-
4	Triangle KKU	(R4)	A	-	-	-	-
5	Heart hospital	(R5)	A	-	-	-	-
6	Toyota	(R6)	A	-	-	-	-
7	Rachpruk 2 Hospital	(R7)	A	-	-	-	-
8	Samlearm station	(R8)	F	(P9)	(B10)	-	(Y14)
9	Central mall	(R9)	C	(P10)	(B11)	-	(Y15)
10	Makro	(R10)	A	-	-	-	-
11	Big C	(R11)	A	-	-	-	-
12	Chroensri intersection	(R12)	A	-	-	-	-
13	Pratunam	(R13)	A	-	-	-	-
14	Terminal 3	(R14)	A	-	-	-	-
15	Kudkuang	(R15)	A	-	-	-	-
16	Trapra	(R16)	A	-	-	-	-
Pink line (Abbreviation)				**Transition**			
	Name (Abbreviation)		**Sta. types**	**Red line**	**Blue line**	**Green line**	**Yellow line**
17	Terminal 1	(P1)	A	-	-	-	-
18	KK Kindergarten	(P2)	A	-	-	-	-
19	Terminal 2	(P3)	A	-	-	(G9)	-
20	Police station	(P4)	A	-	-	-	-
21	Kalaya school	(P5)	A	-	-	(G11)	-
22	Ruenrom Hotel	(P6)	A	-	-	-	-
23	Railway station	(P7)	A	-	-	-	-
24	City hall	(P8)	A	-	-	-	-
25	Central mall	(P9)	A	-	-	-	-
26	Samlearm station	(P10)	A	-	-	-	-
Blue line (Abbreviation)				**Transition**			
	Name (Abbreviation)			**Red line**	**Pink line**	**Green line**	**Yellow line**
27	Mitre Sampan	(B1)	A	-	-	-	-
28	RMUTI KKC	(B2)	A	-	-	-	-
29	Bandit asia Uni.	(B3)	A	-	-	-	-
30	Chata phadung	(B4)	A	-	-	-	-
31	Centrara	(B5)	A	-	-	-	-
32	Intersection	(B6)	A	-	-	-	-

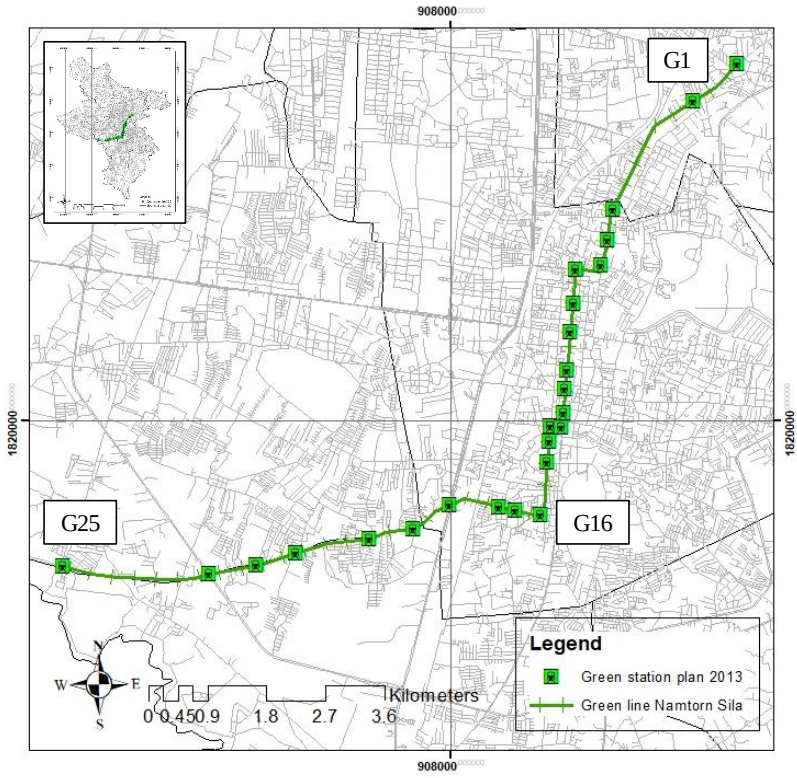
33	KK City hall 2	(B7)	A	-	-	-	-
34	KK Kidergarden	(B8)	A	-	(P2)	(G8)	-
35	Terminal 1	(B9)	A	-	(P1)	-	-
36	Samlearm station	(B10)	F	(R8)	(P10)	-	(Y15)
37	Central mall	(B11)	C	(R9)	(P9)	-	(Y14)
38	KK Ram Hospital	(B12)	A	-	-	-	-
39	Sri-Than	(B13)	A	-	-	-	-
40	Boodsarin	(B14)	A	-	-	-	-
41	Boung Nongkod	(B15)	A	-	-	-	-
42	Kamhai	(B16)	A	-	-	-	-
43	Chonlapruk	(B17)	A	-	-	-	-
44	Siwalee	(B18)	A	-	-	-	-
45	VIP Home	(B19)	A	-	-	-	-
Green line (Abbreviation)				**Transition**			
	Name (Abbreviation)			**Red line**	**Pink line**	**Blue line**	**Yellow line**
46	Sila	(G1)	A	-	-	-	-
47	Khamkaen School	(G2)	A	-	-	-	-
48	Sripatcharin military	(G3)	A	-	-	-	-
49	Ratchkanoung	(G4)	A	-	-	-	-
50	Jomphol	(G5)	A	-	-	-	-
51	City hall 3	(G6)	A	-	-	-	-
52	City hall Monument	(G7)	A	-	-	-	-
53	KK Kindergarten	(G8)	A	-	(P2)	(B8)	-
54	Terminal 2	(G9)	A	-	(P3)	-	-
55	Police station	(G10)	A	-	(P4)	-	(Y10)
56	Kalaya school	(G11)	A	-	(P5)	-	-
57	Market 1	(G12)	A	-	-	-	-
58	Ruenrom intersection	(G13)	A	(R12)	-	-	-
59	Fairy Mall	(G14)	A	-	-	-	-
60	BBL Bank	(G15)	A	-	-	-	-
61	Watkraung municipal	(G16)	A	-	-	-	-
62	KK Stadium	(G17)	A	-	-	-	-
63	Kaennakorn school	(G18)	A	-	-	-	-
64	Chroensri intersection	(G19)	A	-	-	-	-
65	PEA station	(G20)	A	-	-	-	-
66	Haeoun	(G21)	A	-	-	-	-
67	Kham chareon	(G22)	A	-	-	-	-
68	Nongkham	(G23)	A	-	-	-	-
69	Yak leangmoung	(G24)	A	-	-	-	-
70	Namton	(G25)	A	-	-	-	-
Yellow line (Abbreviation)				**Transition**			
	Name (Abbreviation)			**Red line**	**Pink line**	**Blue line**	**Green line**
71	Boungnieum	(Y1)	A	-	-	-	-
72	Dondu	(Y2)	A	-	-	-	-
73	Seang-aroun temple	(Y3)	A	-	-	-	-
74	Nongyai market	(Y4)	A	-	-	-	-
75	RMUTI KKC	(Y5)	A	-	-	-	-
76	Chata phadung	(Y6)	A	-	-	-	-
77	KK hospital	(Y7)	A	-	-	-	-
78	Kaen kam	(Y8)	A	-	-	-	-
79	Yak lung moung	(Y9)	A	-	-	-	-
80	Police station	(Y10)	A	-	(P4)	-	(G10)
81	Yak Na moung	(Y11)	A	-	-	-	-

82	Hug mall	(Y12)	A	-	-	-	-
83	San-lug moung	(Y13)	A	-	-	-	-
84	Central mall	(Y14)	C	(R9)	(P9)	(B11)	-
85	Samlearm station	(Y15)	F	(R8)	(P10)	(B10)	-
86	Sentosa samliam	(Y16)	A	-	-	-	-
87	Kanjanapisek convention center	(Y17)	A	-	-	-	-
88	KKU east	(Y18)	A	-	-	-	-
89	PPT maliwan	(Y19)	A	-	-	-	-
90	Row-8 intersection	(Y20)	A	-	-	-	-
91	Airport	(Y21)	A	-	-	-	-
92	Secha village	(Y22)	A	-	-	-	-
93	Ban toom	(Y23)	A	-	-	-	-



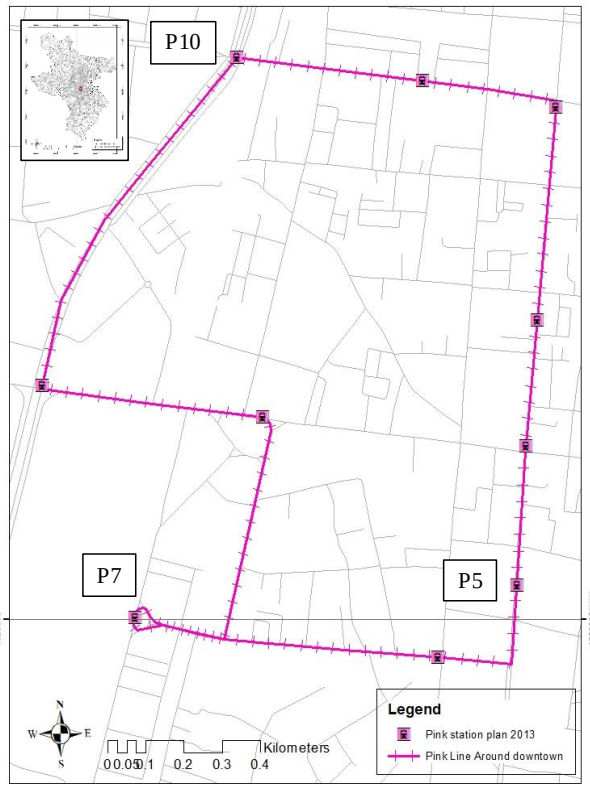
No	Red line	
	Name	Abbreviation
1	Samran	(R1)
2	Nongkung	(R2)
3	Lotus sila	(R3)
4	Triangle KKU	(R4)
5	Heart hospital	(R5)
6	Toyota	(R6)
7	Rachpruk 2 Hospital	(R7)
8	Samlearm station	(R8)
9	Central mall	(R9)
10	Makro	(R10)
11	Big C	(R11)
12	Chroensri intersection	(R12)
13	Pratunam	(R13)
14	Terminal 3	(R14)
15	Kudkuang	(R15)
16	Trapra	(R16)

Figure 3.5. Red Line (Sam ran – Tha phra)



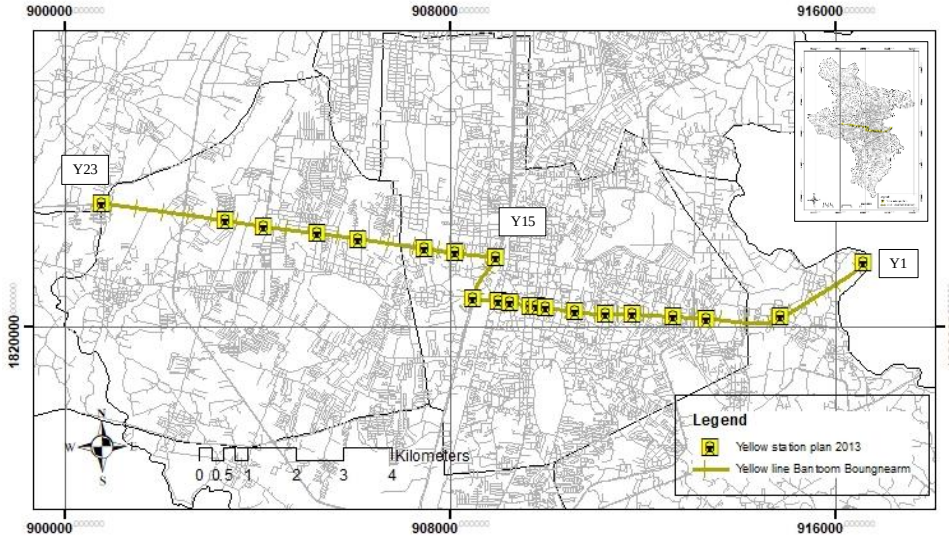
	Green line	
	Name	Abbreviation
1	Sila	(G1)
2	Khamkaen School	(G2)
3	Sripatcharin military	(G3)
4	Ratchkanoung	(G4)
5	Jomphol	(G5)
6	City hall 3	(G6)
7	City hall Monument	(G7)
8	KK Kindergarten	(G8)
9	Terminal 2	(G9)
10	Police station	(G10)
11	Kalaya school	(G11)
12	Market 1	(G12)
13	Ruenrom intersection	(G13)
14	Fairy Mall	(G14)
15	BBL Bank	(G15)
16	Watkraung municipal	(G16)
17	KK Stadium	(G17)
18	Kaennakorn school	(G18)
19	Chroensri intersection	(G19)
20	PEA station	(G20)
21	Haeoun	(G21)
22	Kham chareon	(G22)
23	Nongkham	(G23)
24	Yak leangmoung	(G24)
25	Namton	(G25)

Figure 3.6. Green Line (Namtorn - Sila)



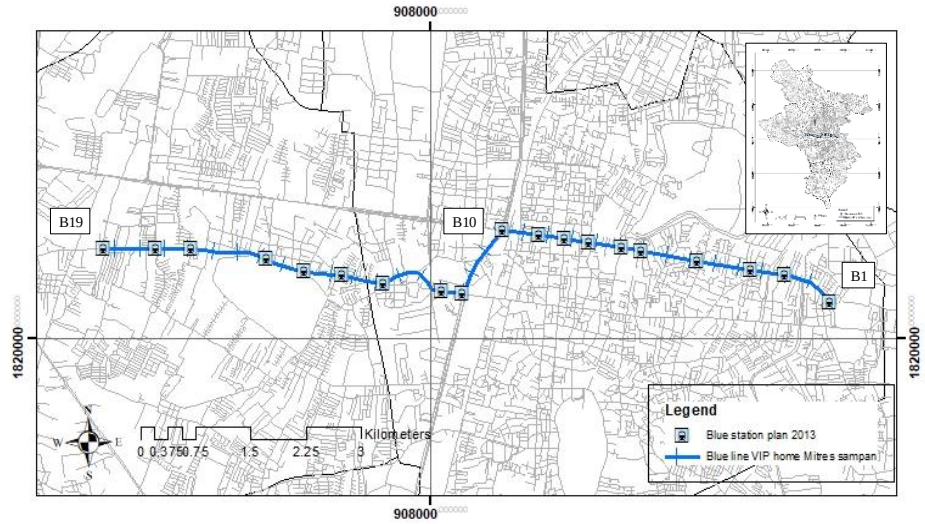
No	Pink line	
	Name	Abbreviation
1	Terminal 1	(P1)
2	KK Kindergarten	(P2)
3	Terminal 2	(P3)
4	Police station	(P4)
5	Kalaya school	(P5)
6	Ruenrom Hotel	(P6)
7	Railway station	(P7)
8	City hall	(P8)
9	Central mall	(P9)
10	Samlearm station	(P10)

Figure 3.7. Pink Line (Nai moung)



No	Yellow line	
	Name	Abbreviation
1	Boungnieum	(Y1)
2	Dondu	(Y2)
3	Seang-aroun temple	(Y3)
4	Nongyai market	(Y4)
5	RMUTI KKC	(Y5)
6	Chata phadung	(Y6)
7	KK hospital	(Y7)
8	Kaen kam	(Y8)
9	Yak lung moung	(Y9)
10	Police station	(Y10)
11	Yak Na moung	(Y11)
12	Hug mall	(Y12)
13	San-lug moung	(Y13)
14	Central mall	(Y14)
15	Samlearm station	(Y15)
16	Sentosa samliam	(Y16)
17	Kanjanapisek convention center	(Y17)
18	KKU east	(Y18)
19	PPT maliwan	(Y19)
20	Row-8 intersection	(Y20)
21	Airport	(Y21)
22	Secha village	(Y22)
23	Ban toom	(Y23)

Figure 3.8. Yellow line (Bantoom – Boungnearm)



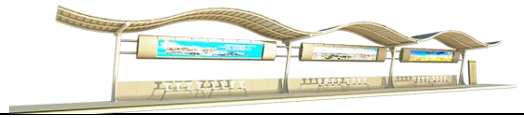
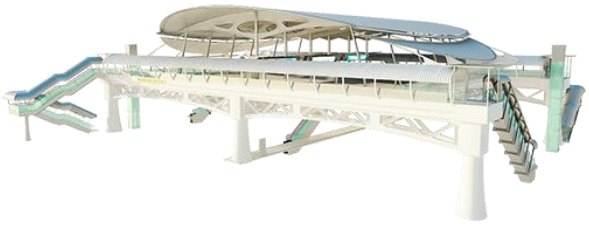
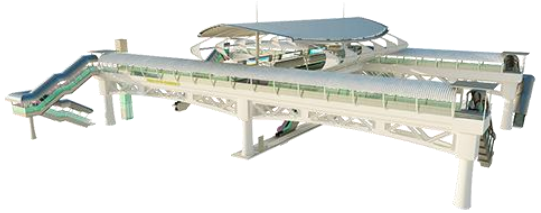
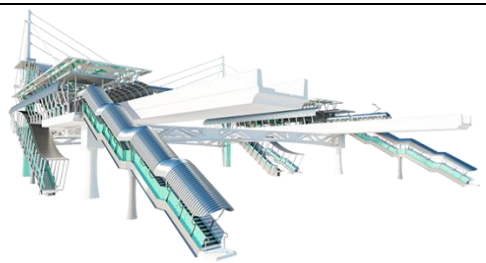
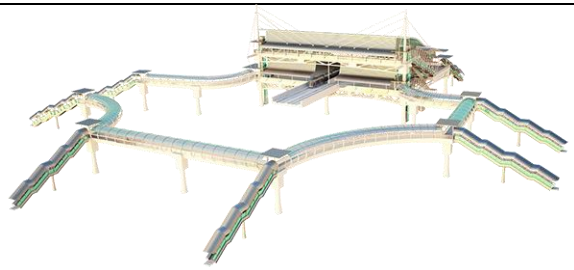
No	Blue line	
	Name	Abbreviation
1	Mitre Sampan	(B1)
2	RMUTI KKC	(B2)
3	Bandit asia Uni.	(B3)
4	Chata phadung	(B4)
5	Centrara	(B5)
6	Intersection	(B6)
7	KK City hall 2	(B7)
8	KK Kidergarden	(B8)
9	Terminal 1	(B9)
10	Samlearm station	(B10)
11	Central mall	(B11)
12	KK Ram Hospital	(B12)
13	Sri-Than	(B13)
14	Boodsarin	(B14)
15	Boung Nongkod	(B15)
16	Kamhai	(B16)
17	Chonlapruk	(B17)
18	Siwalee	(B18)
19	VIP Home	(B19)

Figure 3.9. Blue line (VIP home - Mitres sampan)

3.2.4 Rail Station Design

Report from Office of Transport and Traffic Policy and Planning and KhonKaen University and KKTT introduces the 5 type of Rail station design as shown in **Table 3.5.**

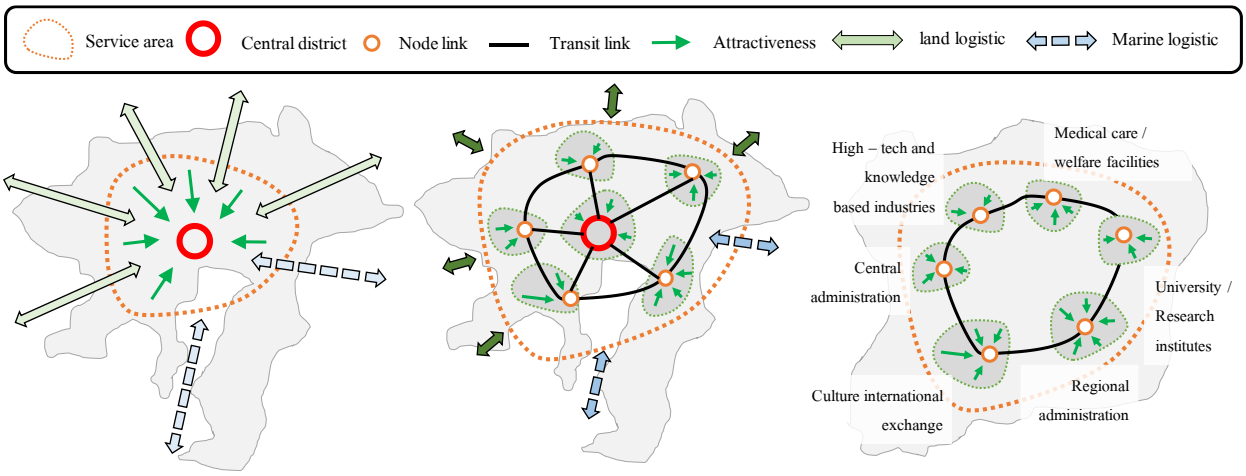
Table 3.5. The 5 type of Rail Station Design, KhonKaen, Thailand.

No.	Type	Description	Rail Station concept design, KhonKaen, Thailand.	World's experiences (Google, 2021)
1	Type - A	The station's character has similarity with the bus stop, dispersion all zones that don't have the main station.		 Tokyo, Japan.
2	Type - B	The station's personality was shaped by the core station's location, which was proposed to be substantial and capable of supporting demand mobility and node transfer.		
3	Type - C			 Berlin, Germany.
4	Type - E	The station's character was significant stop point such a Big mall, Stadium, Hospital, Museum and Prefecture exhibition area.		 Luxembourg.
5	Type - F	The station's character was directly support the cross of street intersection.		 Hague, Netherlands.

3.3 LAND USE FUNCTIONS

3.1.1 Population represent by Density Inhabitant District: DID

The urban capability relative directly with public transport sharing, gradient with distance by CBD (Central business district) (Di Huang, 2020.; Antonio Nigro, 2019). Tokyo, Japan and Sejong, South Korea also applied TOD concept, the impose compact city distributed that gathering with node-link especially rail sector responsively to be the main transport (Department of Urban Engineering, 1994) (Kwon, 2015) within station responsive area as seen from **Figure 3.10.**



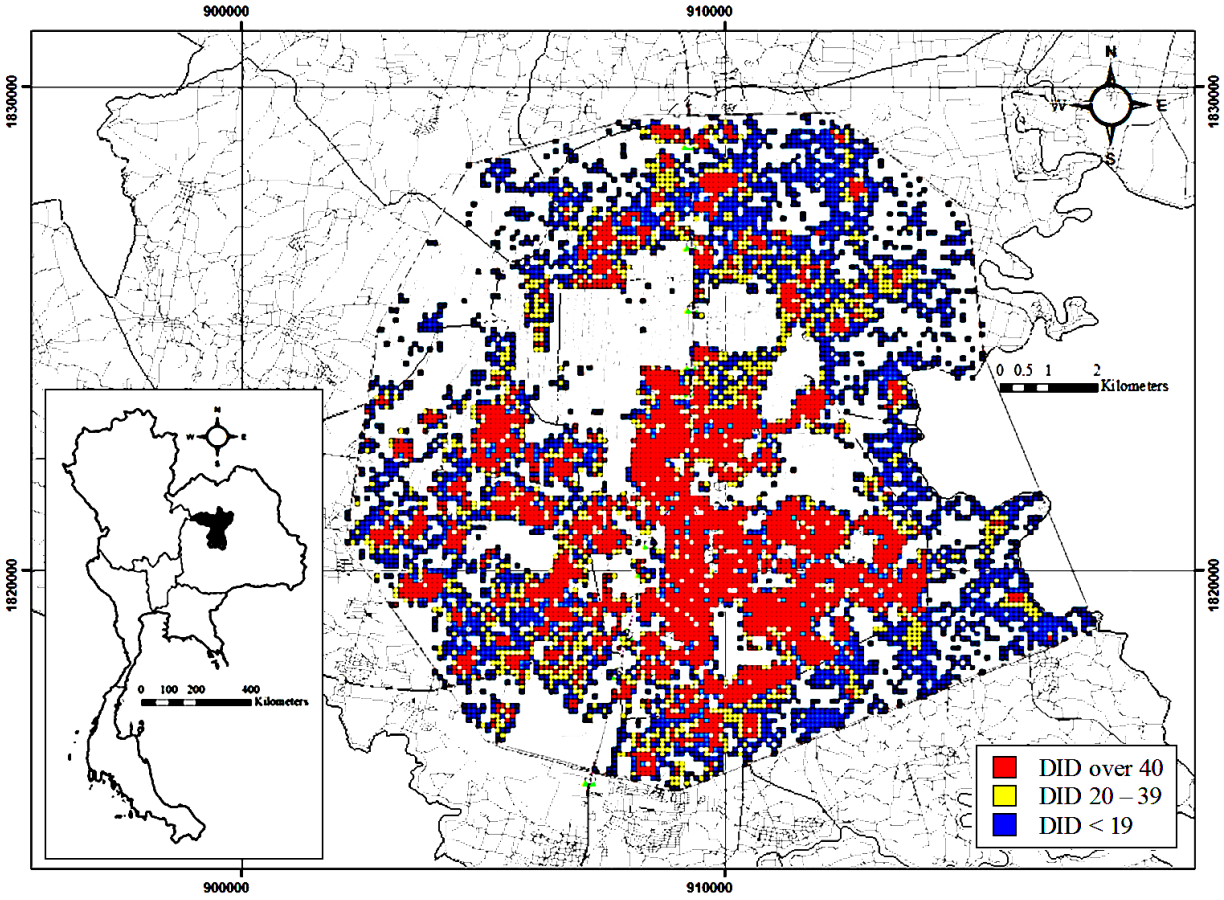
(A) Present situation (B) Future conceptual plan (C) The location of main facilities in Sejong, South Korea

Figure 3.10. Restructure plan for the capital region (A) Current (B) The polycentric model : the urban village version (Department of Urban Engineering, 1994) and the location of main facility in Sejong, South Korea (Kwon, 2015)

The fundamental concept belonged from demand responsive transport system (DRTs) is a flexible from public transport that adjusts the service based on traveler's needs. (Raveau, 2021.; FelipeMariz Coutinho, 2020.; Jaafar Berradaa, 2021). However, there were different by land use regulation as Thailand where controlled by boundary shade as mention above (Town Planning Act, B.E. 2562). Research exposed a Densely Inhabited Districts (DID) criteria that Japan were designated as the census units of basic unit blocks comprising: 1) The district containing the basic unit blocks, etc., with a population density of 4,000 or more per square kilometer and these unit blocks were bordered to each other within the municipality; and 2) The district consisting of those mutually bordered unit blocks, etc., with a population size of 5,000 or more, compared to the Population Census of Japan where the population size was 3,000 or more, but less than 5,000 so that they were designated as a "Quasi-Densely Inhabited District"(Statistics bureau of Japan, 2020). Besides, there were DID parameters (inhabitant/ha) indicating various levels of the classification. Likewise, there was a case in Semarang City, Indonesia, where the station areas and different densities cover 10 up to over 85 inhabitants/ha (R. A. Ramadhan & B. Pigawati, 2019). The urbanization with Grid Index Feature and DID legends of KhonKaen were presented in **Figure 3.11.** The research contribution with 3 case phenomenon that adopted DID in case of 1. No

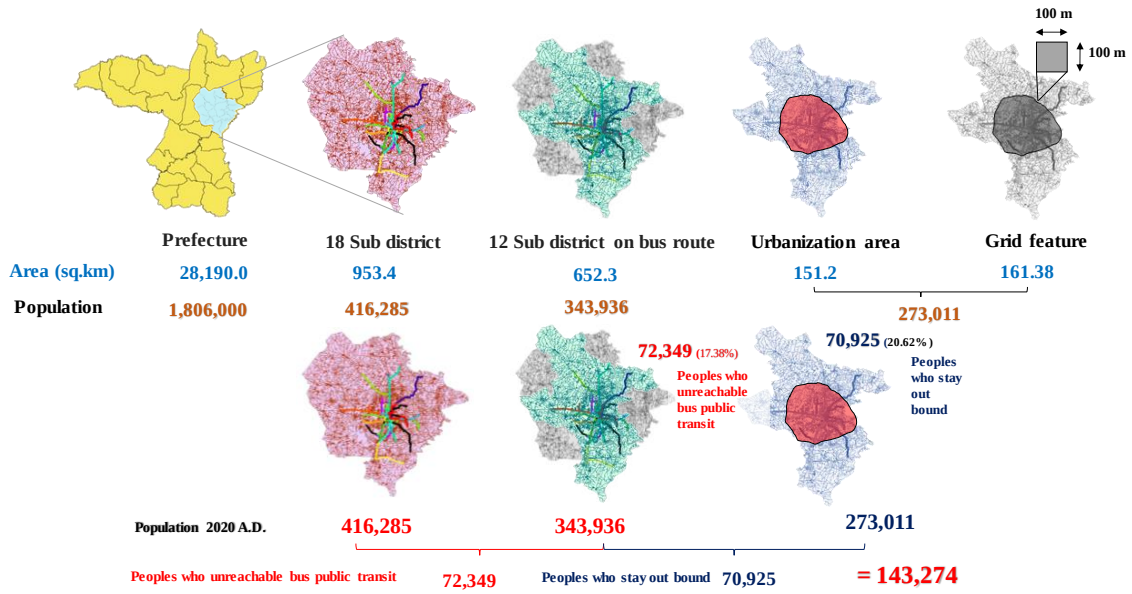
promote plan 2. Promote low density (DID lower 20) and 3. Promote medium density (DID 20 - 39) as seen from **Figure 3.12.**

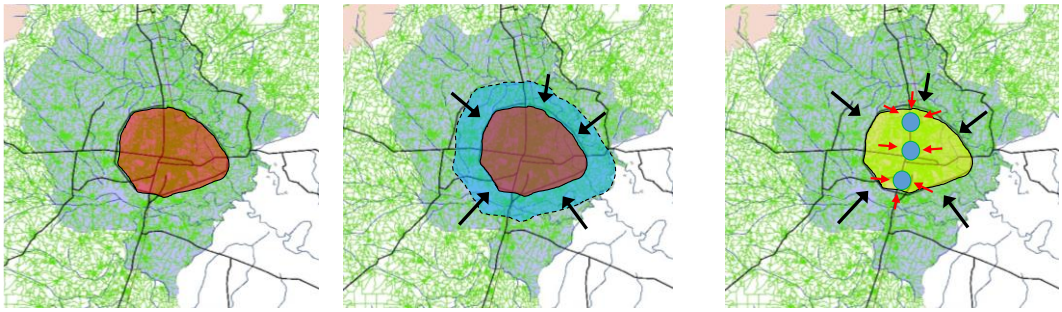
Figure 3.11. KhonKaen, Thailand is 10,890 km2 of Land Located with 12 Sub-Districts based on the Bus



Route Network presented by Grid Index (grid size 100x100 meter).

Moreover, the destination concept relied on the human character comprising educational, cultural, and recreational facilities (e.g. schools, shrines and athletic fields, etc.), industrial facilities as well as communal and social welfare facilities; Theses facilities are commonly linked to the basic unit blocks (Statistics bureau of Japan, 2020). Actually, accessibility was a fundamental aspect to assess the competency of accessibility through different proposes. This research adopted based travel times and residential building as perceived by the allocated travelers (National statistical office, 2020). In term of the measured mobility mode by average speed as mention previously, the study focused on the major types of building use (square meter unit) consists of different 3 building functions:1) Commercial Use: shopping malls and any retail shops run by private sectors; 2) Mixed Use: The buildings under the urban development with at least 2 functions (physically and functionality); and 3) Public Service Facility: The buildings used for public service and basic needs of the residents provided by government (Department of Public Works and Town & Country Planning : Thailand, 1979).

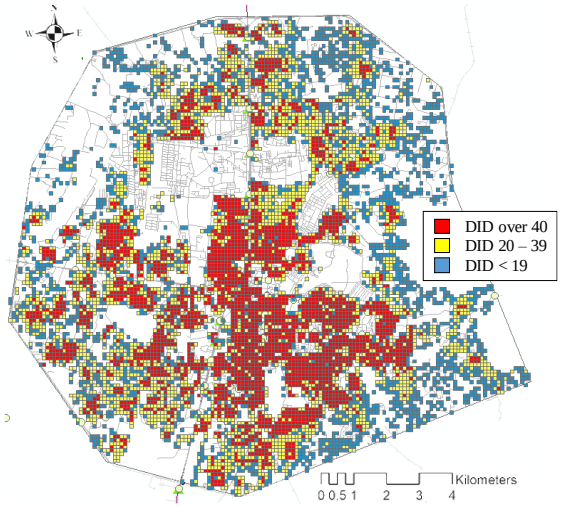




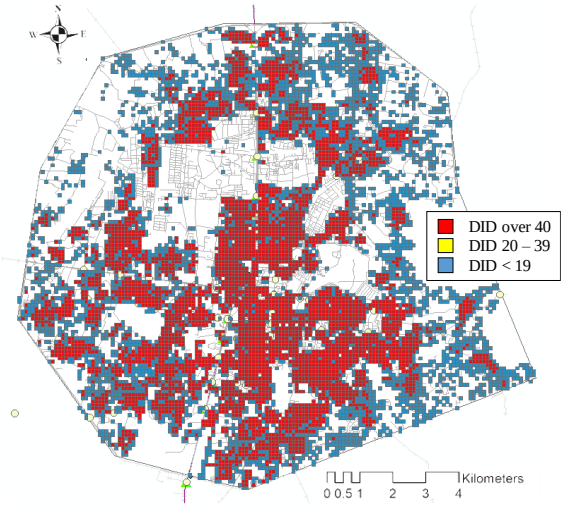
(A) Current situation

(B) Current situation and provide people outbound area to inside (Supporting Policy for Promoting Low Density)

(C) Promote medium density area to new urbanization zone (Supporting Policy for Promoting Medium Density)



(B) - Supporting Policy for Promoting Low Density (Population Density > 20 DID Grid Index) Scenario.



(C) – Supporting Policy for Promoting Medium Density (Population Density = 20 - 39 DID Grid Index) Scenario.

Figure 3.12. KhonKean, Thailand land use scenario by promote 2 scenarios (B) Promoting Low Density and (C) Promoting Medium Density

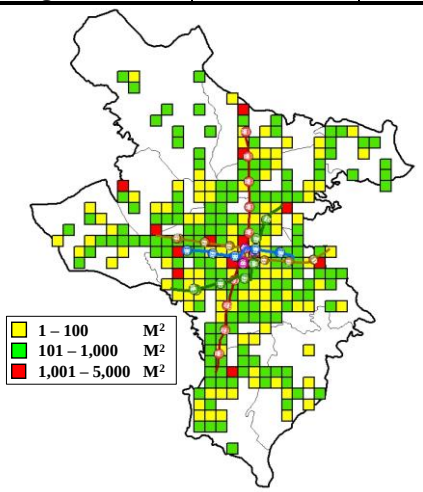
3.3.2 The Destination Units Represent by Grid Index

This research focused on the travel times and types of the residential building through the traveler's perspectives (Ceccato et al., 2020) following the National Statistical Office's forecasting data from the previous years and up to 2036 A.D. as seen by **Table 3.6.** The mobility mode measurement was conducted on the average speeds of Walks, Bus, and Train derived through the building use (square meter units) that grouped into 3 mode's presenting

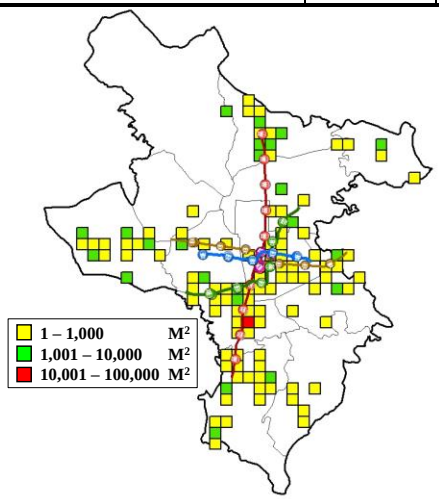
1. These buildings were classification in details into 8 types of building functions consisting of: 1) Commercial building; 2) Industries building; 3) Infrastructure building; 4) Education building; 5) Religious building; 6) Public service building; 7) Infirmary building; and 8) Recreational building (DPT, 2020). The data showing 1x1 square kilometer of grid units in 2018 A.D. as seen in **Figure 3.13**.
2. The 3 building modes (Commercial Use, Mixed Use and Public Facility) present separately. as seen in **Figure 3.14**.
3. The one map to present by 3 mode of destination designate as seen in **Figure 3.15**.

Table 3.6. The building function as destination unit classification in 3 types consist 1. Commercial units 2. Mixed use units and 3. Public facility units (see more detail in appendix)

No	Type of building		Description	Units	%
1	Residential building	Residential	Including private and public dwelling	168,264	88.87%
2	Commercial building	Commercial	Convenience store, Market, Local market. Hotel	11,102	5.86%
3	Industries building	Mixed use	Manufacturing	2,157	1.14%
4	Infrastructure	Public facility	Airport, Terminal, Railway station, Electrical hub	243	0.13%
5	Education building		Kindergarten, School, Technical college, University	3,740	1.98%
6	Religious building		Temple, Cemetery, Abbey	2,546	1.34%
7	Public service building		Town hall, District office, Police station, Museum, Library, Jail, Fire station	323	0.17%
8	Infirmary building		Hospital, Clinic, pharmacy, Department of Disease Prevention, Medical hub	731	0.39%
9	Recreational building		The football stadium, Sports club, Park	223	0.12%



Commercial building



Industries building

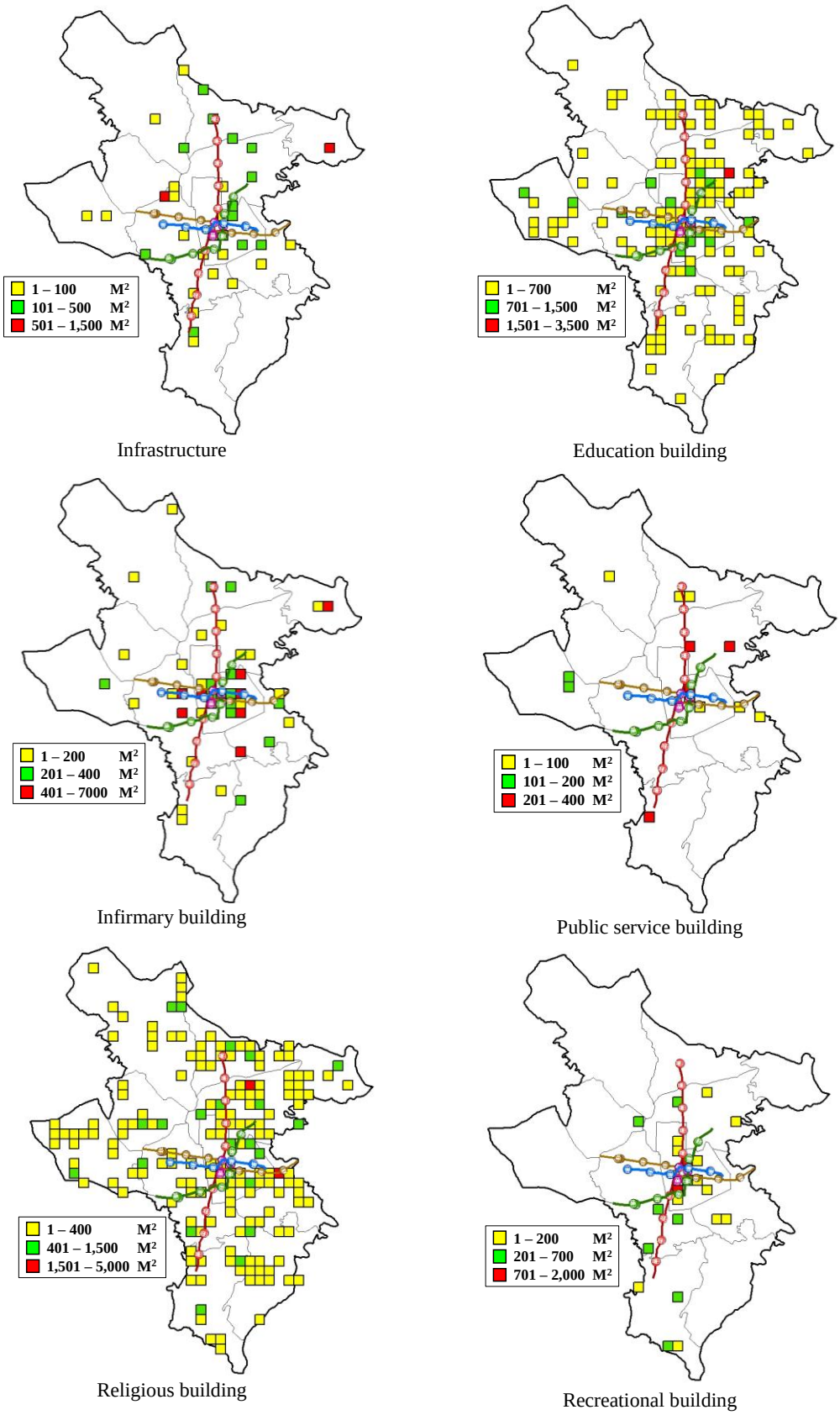
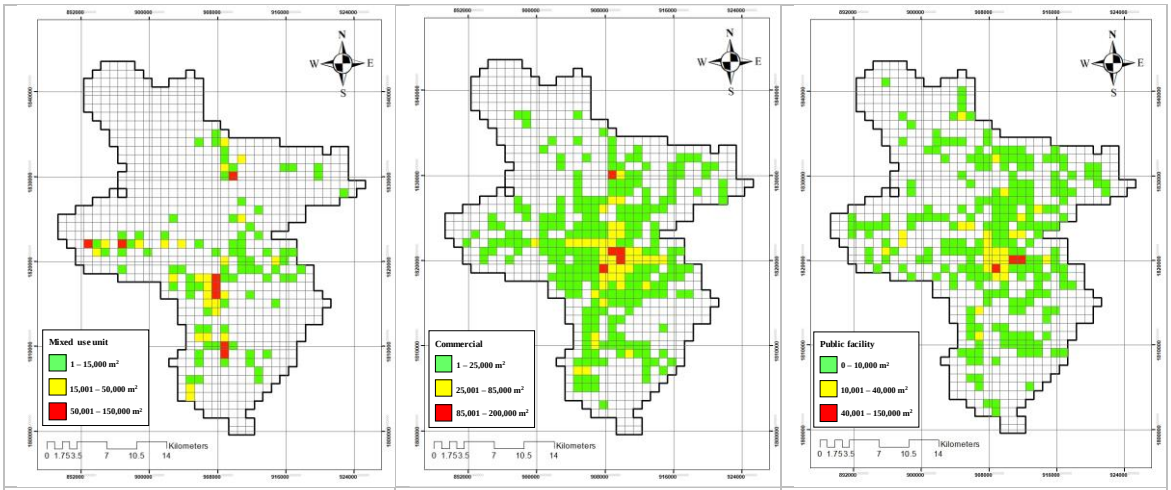


Figure 3.13. The location of different trips destination by grid density (1x1 square kilometre)



Mixed use | Commercial | Public facility

Fugure 3.14. Trip Proposals Present by Grid Index (1 x 1 sq.km.), KhonKaen, Thailand

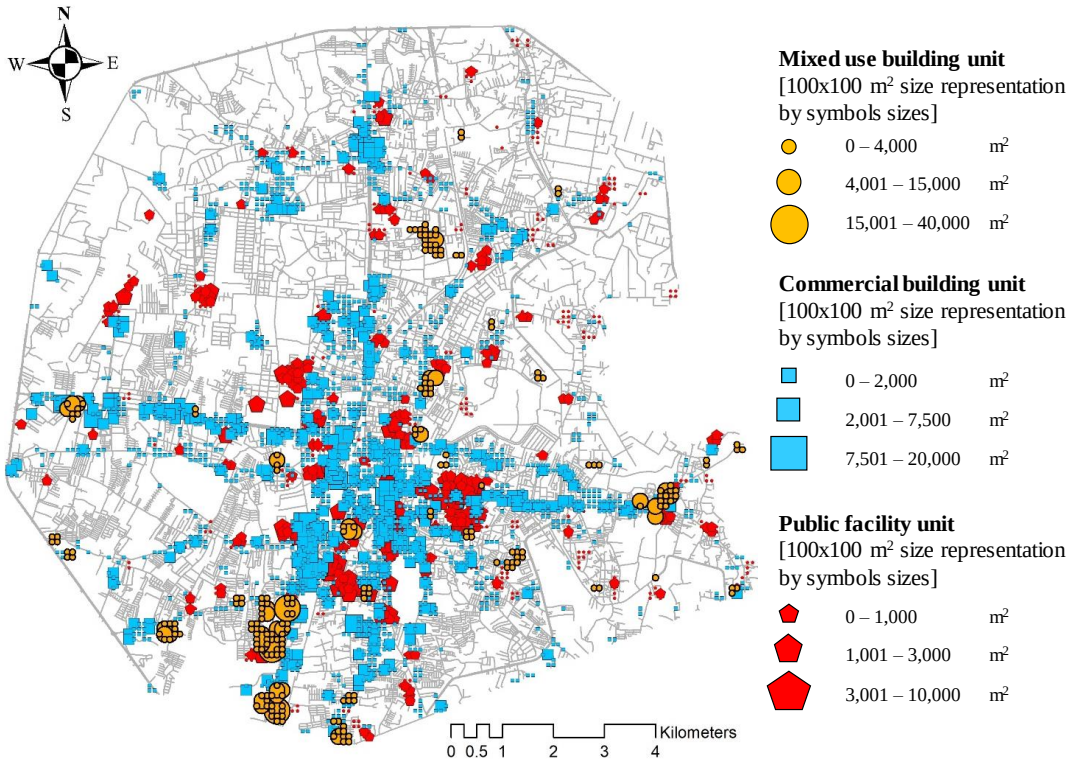


Figure 3.15. The locations of 3 types of destination designate building unit

3.4 URBAN POLICIES OPTIONS

The research express that detailing on 2 urban relative function is execution based on 1. the public transit feeder configuration and 2. Land use scenario. In this sections, the researcher presents an idea of conventional bus network transformation concept and the effected by TOD

strategy plan implementation while showing of 3 station's TOD plan in city case and effective trend by TOD action plan via presented term of accessibility in which indicated the performance of urban rail public transit as the first priority of urban mobility.

3.4.1 The Feeder Demand Responsive Feeder System (DRFs)

The demand responsive feeder system was established in USA. The mainly present is rethink the effective possible of public transport. While have been develop since 2004 (Brake et al., 2004), the service provided for demand that became filled gap between the private transport rental as Taxi and inaccessible of public transports. The demand responsive feeder service (DRFs) implemented cases confirm the successful in term of both cost-efficiency and sustainability. (Bryan David Galarza Montenegro, 2021.; Marie Harberinga, 2020). The overview of DRC experiences is seen in **Table 3.7.**

Table 3.7. Overview of Feeder and DRC Research Experiences.

Author (year)	Case	DRC	Transport Mode	Models Assessment
(Mageean and Nelson, 2003)	Europe	√		Telematics-based DRT
(Brake et al., 2004)	UK	√	Bus	Survey
(Quadrifoglio and Li, 2009)	USA	√	Bus	Costs and service quality
(Martínez and Eiró, 2012)	Portugal	√	Bus, Train	Vehicle Routing Problem (VRP) formulation
(Sun et al., 2013)	China	√	Bus, Train	Multi-objective model
(Deng et al., 2013)	China	√	Bus	Generation algorithm
(Chandra and Quadrifoglio, 2013)	USA	√	Link-node connectivity	Connectivity index
(Jiang and Guo, 2014)	China	√	Bus	Customer Satisfaction
(Calabrò et al., 2020)	Italy	√	Bus	Ant-colony optimization
(Giansoldati et al., 2021)	Italy	√	Walk, Bus, Train	Discrete choice model
(Sala et al., 2021)	Spain	√	Bus	Social network analysis
(Costa et al., 2021)	Brazil	√	Bus, Train	Simulation–optimization model
(Vansteenwegena et al., 2022)	Belgium	√	Bus	Optimization problem model with DON-PBS
(Gkiotsalitis, 2022).	Singapore	√	Bus, Train	Convex optimization
Research present	Thailand	√	Walk, Bus, Train	Accessibility index

Besides, the fundamental of urban inequality presented in assessment terms of accessibility, cost of transport, livability and safeness. The economic evaluation mostly present by Gross Domestic Product: GDP and Gross National Product GND investigate in different level, while the urban mobility perception presented by accessibility by various model assessment. As the present case in KhonKaen, Thailand, the research presents the multimodal assessment (Walk as the Non-driven automobile) – Bus (current public network) – Rail (Project plan)) that was explained the redundancy between conventional bus route and Urban rail project plan. The research was adopted the DRFs concepts for the bus public transport reformed to explore the possibility of effective urban rail's feeder position. In the analysis case, the preliminary survey found over 50% of the bus routes and urban rail are in line redundancy that become the new research statement by understanding the feeder performance for urban rail project as the reformation of the bus route redundant in each line. The survey data performed the possibility

reform in which 5 criteria based reform concept consisting 1. The route path is over 50 percentage of redundancy 2. The street regulatory of lane's reform possibility as the one-way and two-way public authorized 3. The reformed principle in each route was to cling to the Origin and Destination that undisrupted the conventional life aspects 4. The possibility of land authorities where covered in street network on route reform as public and private authorities 5. The reform route addressed to track perpendicular by limited of 800-meter station buffer as seen the simplified schematic diagram in **Figure 3.16**. The research survey found that 12 of 19 routes get to belonging to reforms criteria as present in **Figure 3.17.**

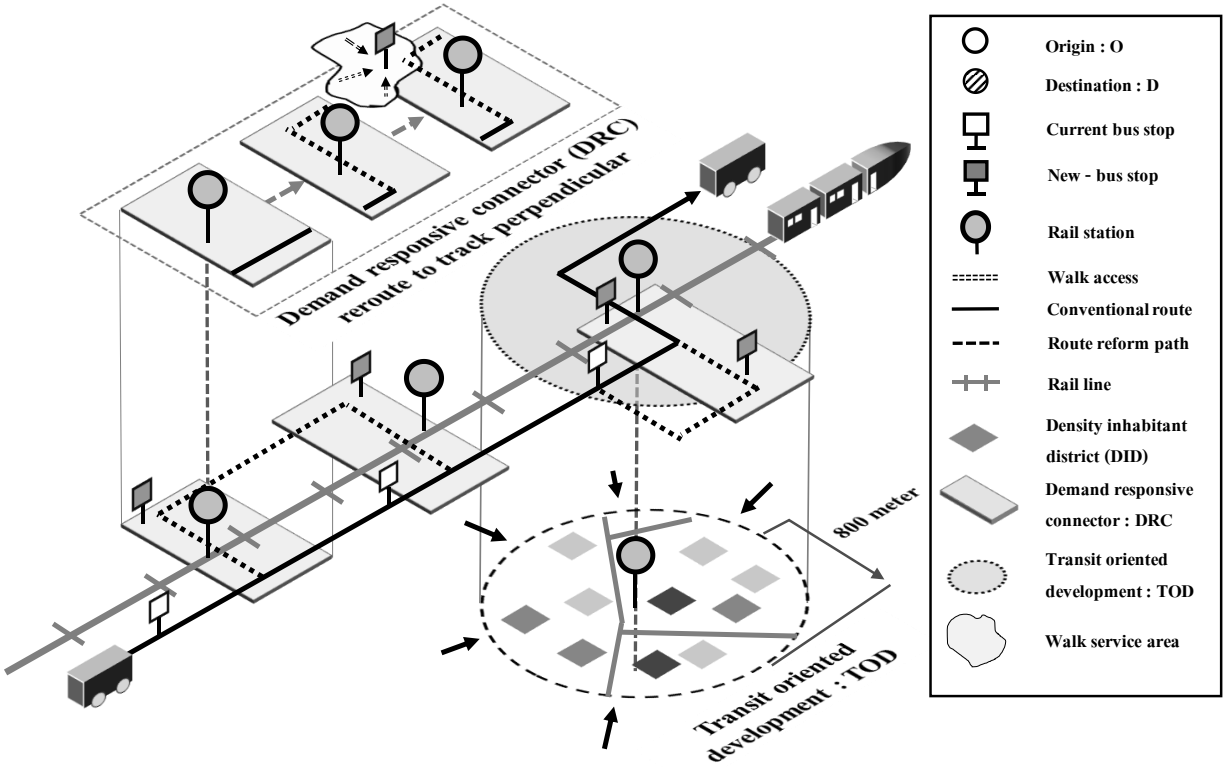
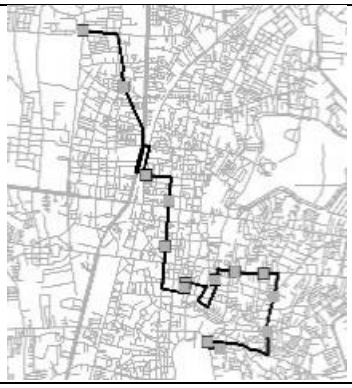
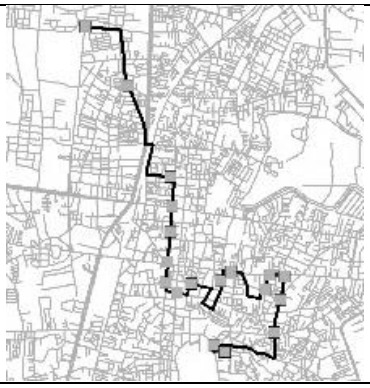
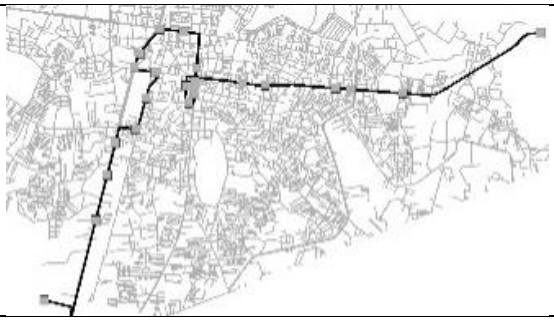
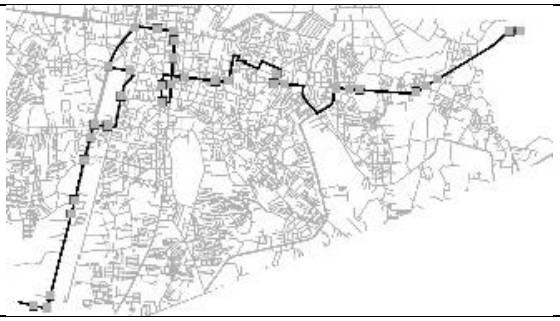


Figure 3.16. Schematic chart of Bus route reform concept followed by demand responsive connector (DRC) and Transit Oriented Development: TOD (Bryan David Galarza Montenegro, 2021)

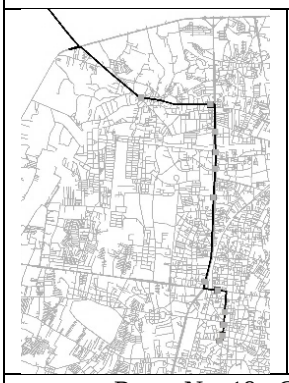
Route character	
	

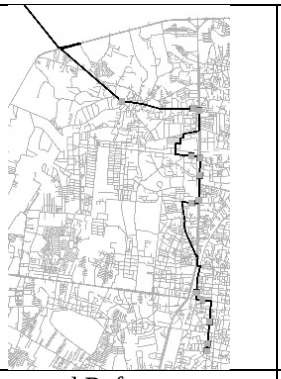
Route No. 16 : Current and Reform

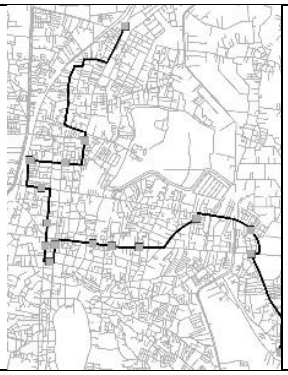


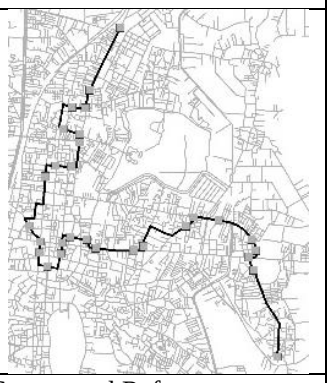


Route No. 3 : Current and Reform

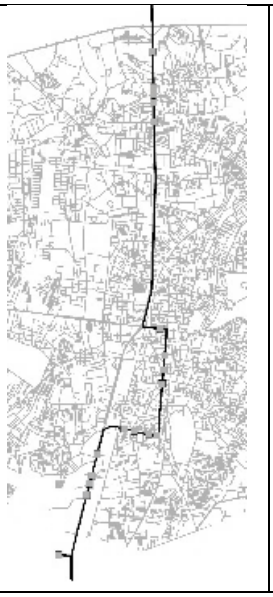




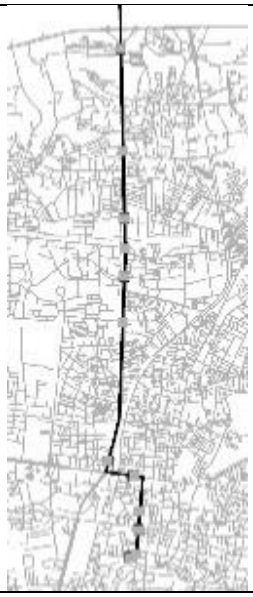




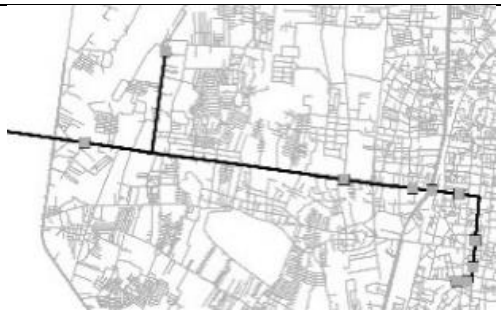
Route No. 19 : Current and Reform



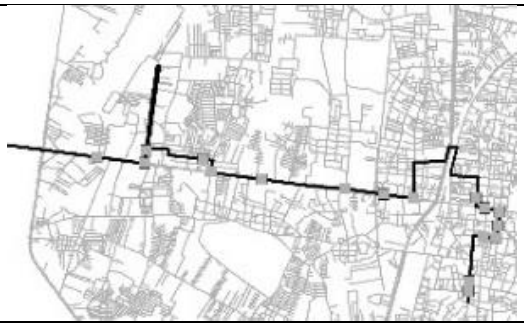
Route No. 22 : Current and Reform

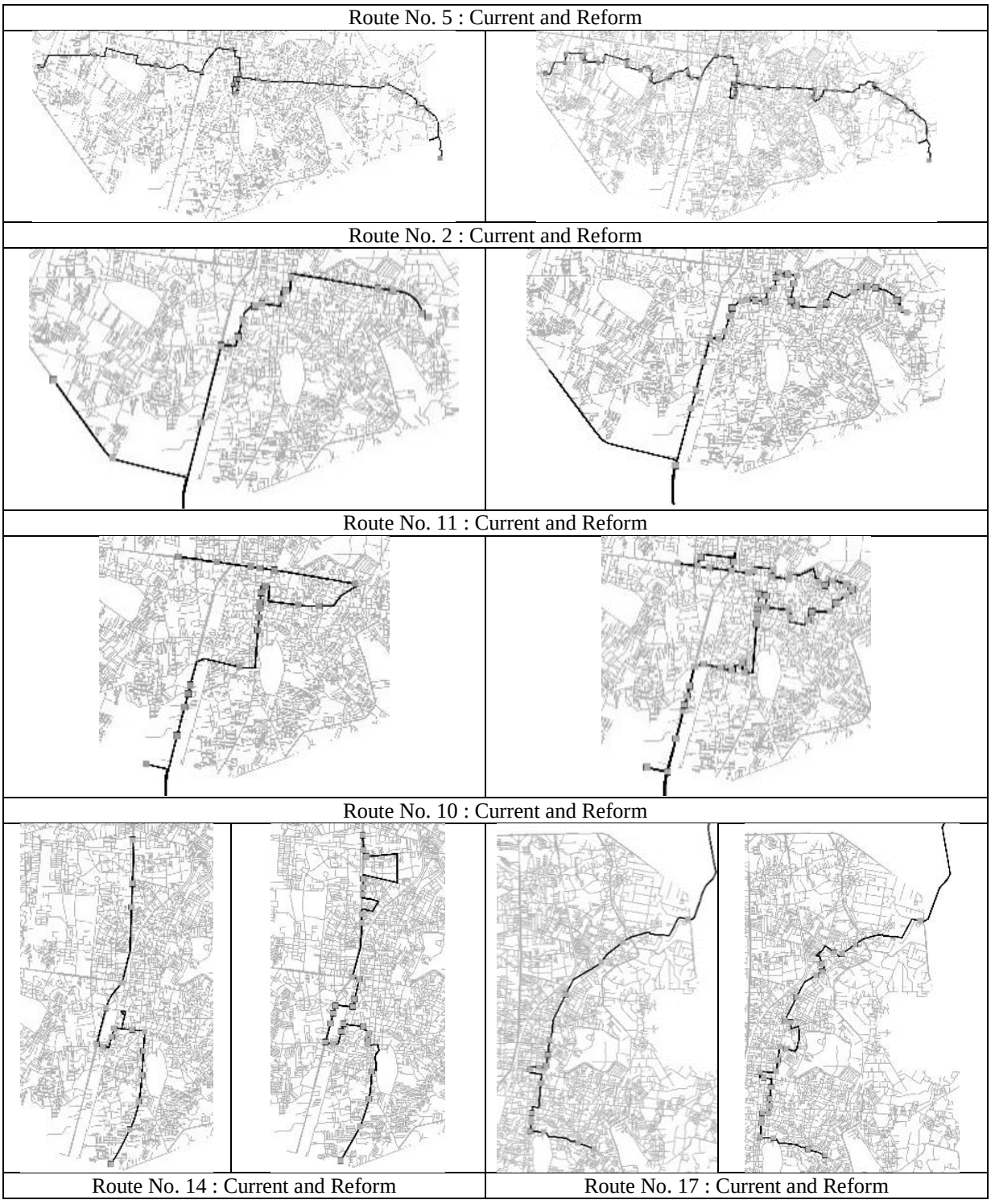


Route No. 4 : Current and Reform



Route No. 20 : Current and Reform



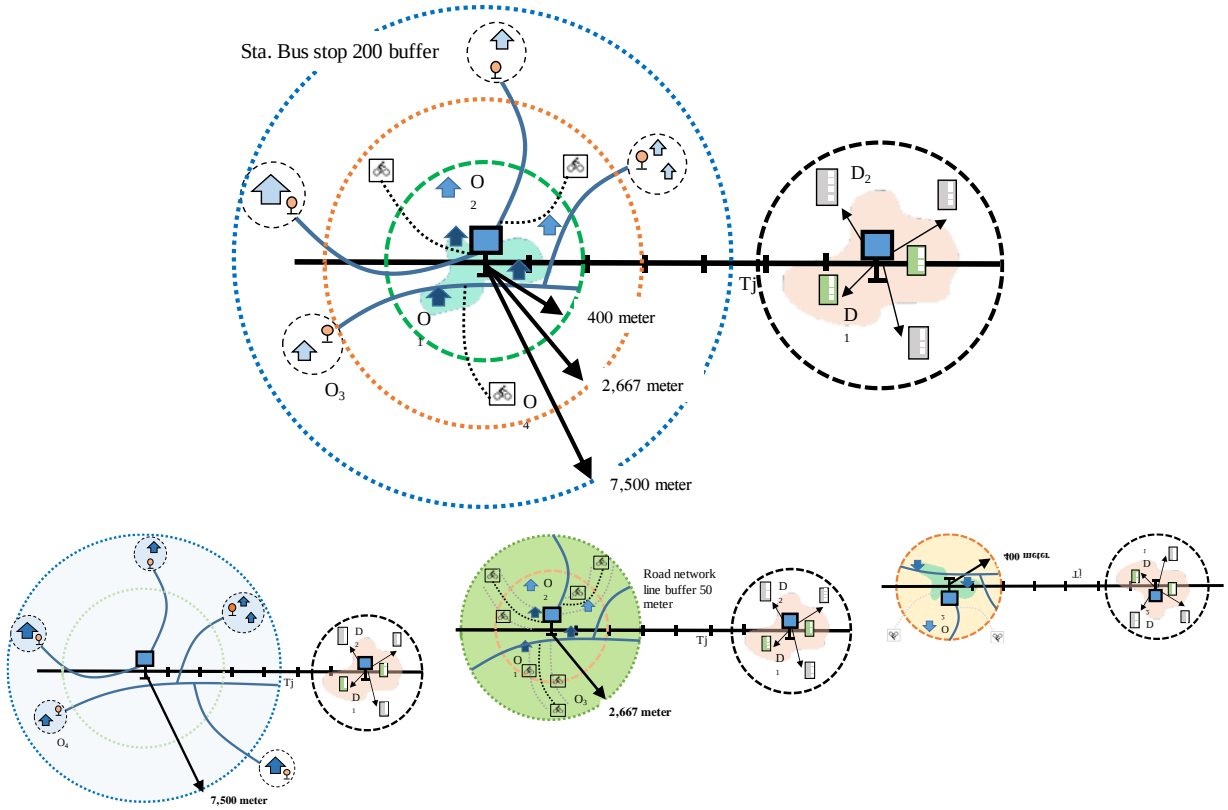


Figures 3.17. Bus Network Comparison on 12 Conventional Route and Reformed Route

3.4.2 Transit Oriented Development: TOD

The land use function descriptive as node that analysis through bus stop and rail station. The mainly relative represent distance and weight of considered parameters while imposes the various indicator as connectivity indicator : CI (Shailesh Chandra, 2013). Those analysis had pursue the effectively urban phenomenon investigated, TOD concept was started in late 20th century (Richard D. Knowlesa, 2020). In japan 1989 A.D., in capital city founded about 46 percentage of work based trip (Department of Urban Engineering, 1994). The TOD have been adopted in 4 stage by 1910 – 1950 A.D. is the beginning of TOD (The population growth in large cities and shift of urban transport to railway.), 1950 – 1980 A.D. is the New town development and TOD project (Rapid urban expansion and huge demand for housing due to rapid economic growth), 1980 – 2000 A.D. is the TOD's development along railway lines (correction of the structure of unipolar dependence on the city center and formation of business core sites), and 2000 – 2020 A.D. is TOD for a new era (Formation of smart cities and compact cities that respond to diverse social environment changes) (Japan TOD, 2021).

The effectiveness of TOD is directly affected with the economic represented by the land price. BRT service and pedestrian connections to the station with the high rise commercial development are gravitating to Guangzhou's BRT corridor, the resulted in real estate prices increasing by up to 30 percent during the first 2 years of BRT. (Robert Cervero, 2014). The Transit-Oriented Developments (TODs) claim to improve their residents' quality-of-life (Arefi, 2020) tandem with effectively public transit plan while achieved by 1. High density and mixed land use development support 2. Providing the variety of transport choice 3. Reduced the pollution 4. Promote walkability in transit hub 5. Strengthening local and regional economy. The TOD principal characters present 10 TOD category as 1. Urban commercial core 2. Urban mixed use core 3. Inner urban neighborhood 4. Urban neighborhood 5. Suburban neighborhood 6. Outer Suburban neighborhood 7. Suburban center 8. Outer suburban commerce park 9. Outer suburban industrial park 10. Airport (Christopher D. Higgins, 2016) within 5 steps strategies implementations (The World Bank, 2018). TOD planning framework has been established in China's context while applied concept as adopted the betweeness centrality index predictive powering by employment density and commercial floor area ratio (FAR) to maximize the benefit of improving transit accessibility. (Jianyi Li, 2020.; Yue Lianga, 2020.; Qifan Shao, 2020.; Lab, 2021). The TOD are dynamically effect through the local economic as represent by residential property prices effect (Olga Filippova, 2020) potential of TOD boosting in the development zones of real estate market and livable neighborhoods (Shiliang Su J. Z., 2021). This chapter presenting the shading of service area as the estimate demand use that extracted by 3 modes (Walk, bus and ride) based on morphology consideration As seem in **Figure 3.18.** In the closely relative area, the research executed by the Thiesson polygon techniques in ArcMap to images the station catchment area divided as seen by **Figure 3.19**. In term of station attractiveness, the model present 4 modes access to station by 1. walk mode by 1.1 400-meter of Un TOD station buffer: (A) and 1.2 800-meter of TOD station buffer (B), both cases represent the scenario of walk access in 10 minutes 2. Ride mode present the gentrification of 50 street offset within 2,667 meter of rail station buffer, the cases represent the scenario of ride access in 20 minutes (C), and 3. Bus access within 7,500 meter of rail station buffer (D), the cases represent the scenario of get the bus access in 30 minutes as present in **Figure 3.20.**



Population number that capability walk to bus stop in 200 meter, then bus stop accessed in 30 min (7,500 meter)

Population number that capability to ride (50 meter of street line buffer within 2,667 meter)

Population number walkable in 800 meter buffer of TOD and 400 meter buffer of Un-TOD

Figure 3.18. Catchment Area by Each Mode's Ability by Walk (TOD zone), Ride (street network ability) and Bus access.

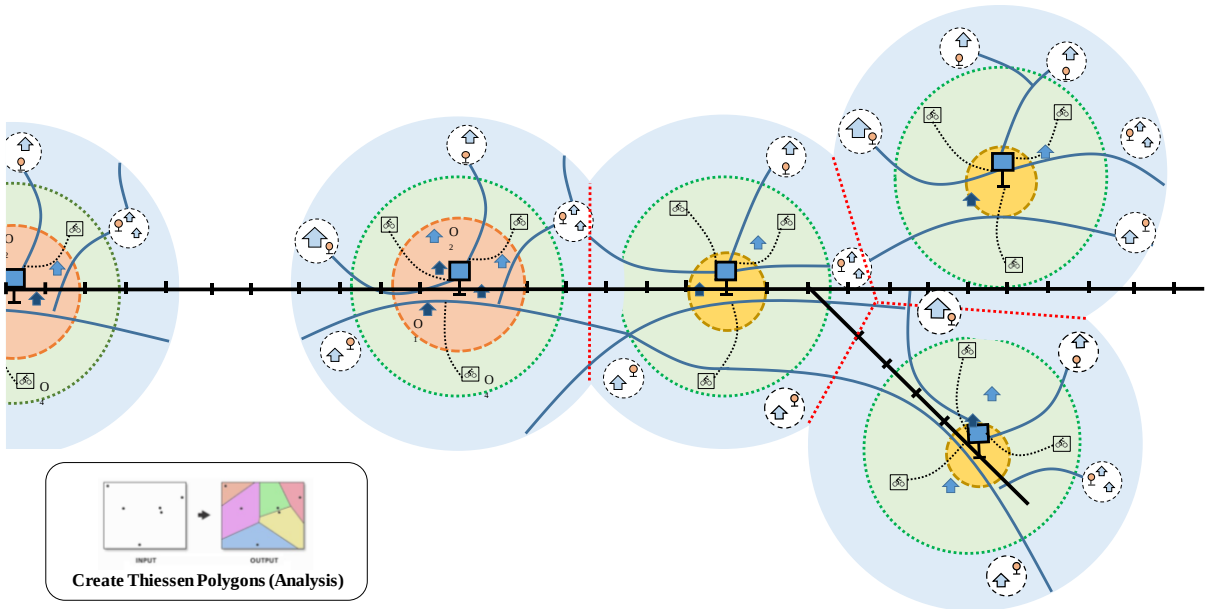
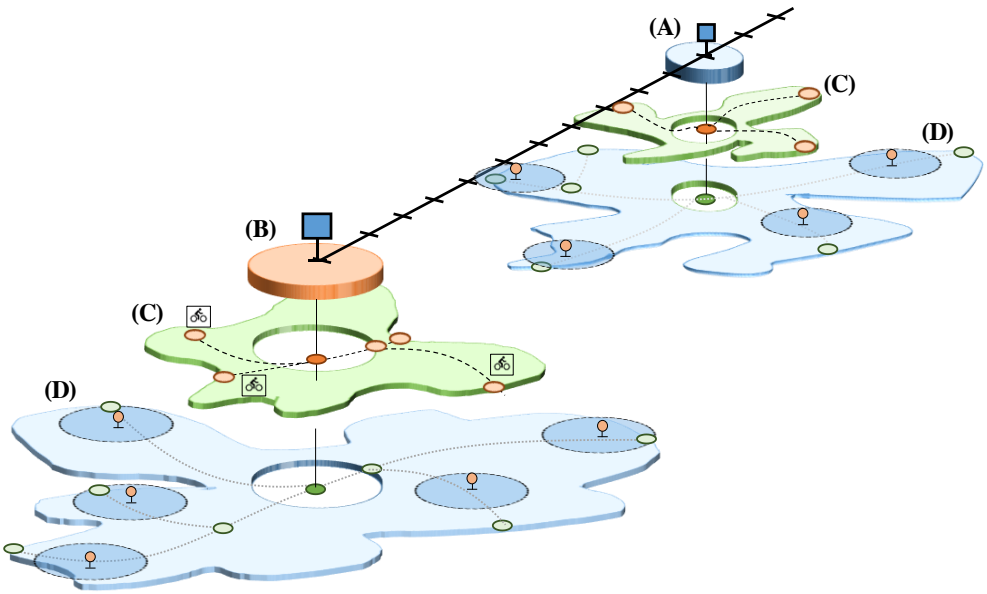


Figure 3.19. The catchment area by Thiesson polygon techniques in ArcMap. The shading of buffer present in 3 level 1. Walk 2. Ride and 3. Bus access.



(A) 400-meter walk access	(B) 800-meter walk access	(C) 2,667 meter ride access	(D) 7,500 meter bus access

Figure 3.20. The urban feeder (population) base station accessed, 3D simplification.

Railway remains a largely governance-owned vertical integrated system that tandemly the transit oriented development (TOD) is an increasing urban's density controlled with environment by improving. The urban capability relative directly with public transport sharing, gradient with distance by CBD (Central business district) (Di Huang, 2020.; Antonio Nigro, 2019). The fundamental concept belonged from demand responsive transport system (DRTs) is a flexible from public transport that adjusts the service based on traveler's needs. (Raveau, 2021.; FelipeMariz Coutinho, 2020.; Jaafar Berradaa, 2021) and the demand responsive feeder service (DRFs) (Bryan David Galarza Montenegro, 2021). Mostly implement cases confirm the successful in term of both cost-efficiency and sustainability. (Marie Harberinga, 2020)

In Thailand, the concept framework and approach to master planning the TOD area following 7 mains criteria's, 18 indicators and 11 sub-indicators as shown in **Table 3.8.** Moreover, the literature comparing on the factor of development presenting in the **Table 3.9.** and The classification of the design of the area around the station mass transit system shown in **Table 3.10.** In analysis case, based on the first line (red line) discussed implementation covered 3 TOD plan 1. Lotus station 2. Yaksamlieam and Central station and 3. Terminal 3 station as seen from **Figure 3.21.** The innovative TOD strategies had been study to present in various plan as Sustainable Urban Renewal (Pattamaporn, W, 2020) (Supattra, G and Sathaphon, Mt., 2019).

Table 3.8. Thailand Concept Framework of TOD Master Plan.

No.	Lists	Assessment hierarchy	
		Indicators	**Sub-indicators**
1	Understand area and community	• Building community involvement • Research information • Setting goals and creating a development plan that achieve urban proposes together	**The research presented a sections of parameter relative with the land use and public transport:**

2	Create an attractive, walkable place	• Clean and safety area • Public space • Encourage use of free and public spaces for short-term activities. • Facilitate long-term development • Transportation choice and options	• Public transit • Promotion of high-rise buildings or buildings that can combine commercial and residential activities in Same building or same area • Utilization of historical and architectural resources to stimulate habitats and the economy • Improvements and restoration of various types of buildings to facilitate living and working • Improvement of public regulations and processes
3	Diversify the downtown economy	• Promoting job position in the area • Construct and provide new habitat in the TOD area on both sides and the city center • Creating a diverse environment for businesses and retail groups.	
4	Build in equity	• Affordable housing • Driving economic opportunities	
5	Improve government regulations and processes	• Improvement of public regulations and processes • Create work processes that available for project developers and businesses contributions.	
6	Finance projects	• Investment Fund • Value capture	
7	Establish on-going place management		

Table 3.9. Factors to development (Pawinee Iamtrakul, I – Soon Raungratanaamporn and Pattiya Shinpiriya. (2017)

				Thailand current development	
No	**Factor**	**Station area success**	**Regional success**	**Station area**	**Regional success**
1	Number of TOD development		X	X*	
2	Quality of transport		X		
3	Transport technology		X		
4	Street network	X	X	X	X
5	Park around station	X	X	X	X
6	Habitat and Job density	X	X	X*	
7	The varies type of commercial district	X	X	X*	
8	The condition of shop location		X		
9	The structure of local economic		X		X
10	Regional consumption behavioural		X		
11	Transport demand		X		
12	The land use flexibility	X	X		
13	The habitat response of living	X	X		
14	The various of habitat types		X		
15	The affordable housing	X	X		
16	Policies support		X		X

Note: X means active/evolving, X* means existing development but is a development of the private sector that cannot be guided or controlled by the state.

Table 3.10. Classification of the design of the area around the station mass transit system (Pawinee Iamtrakul, I – Soon Raungratanaamporn and Pattiya Shinpiriya. (2017) (Yake, 2012)

No	TOD	Land use	Habitat types	Forms of commerce and employment	Sizes	Types of rail network link
1	Capital	Office building, shops, residences, entertainment and public space	Big family and Loft house	High-value offices and commercial source	Over 5 floor	Transportation System center that is the destination of traveling in a city level with a high-quality transport system.
2	Regional center	Office building, shops, residences, entertainment	Big family and townhome	Focus on creating an employment area of more than 50,000 sq. ft. in order to development for the shops or office buildings over 250,000 places	Over 5 floor	The secondary hub of regional travel has a park and walk building and a traffic network at the district level. Emphasis on having a transportation system to provide service at the district level.
3	City center	Office building, shops, residences		The office area that less 25,000 sq. ft. or the shop over 50,000 sq. ft.	Over 3 floor	
4	Community level city	residence, shop community level	Big family townhomes, and residential building small (single family)	The shop that provides community-level needs sizes less than 50,000 sq. ft.	2-7 floor	The station transfers travelers into the city. There is a large parking lot and buses.
5	Center community level city	Office building, shops, residences				Walkability to stations, there is a small car park. and there may be a bus system
6	Main street	residence, shop community level	Big family	Provided the solution of "infill" by shop		Emphasis on the walk to station. There are bus system along the way and no have car park
7	University	University and others	Big family (small amount)	Limit the amount of office building and shop	varies	Focus on use during specific periods and have a large parking lot to accommodate.

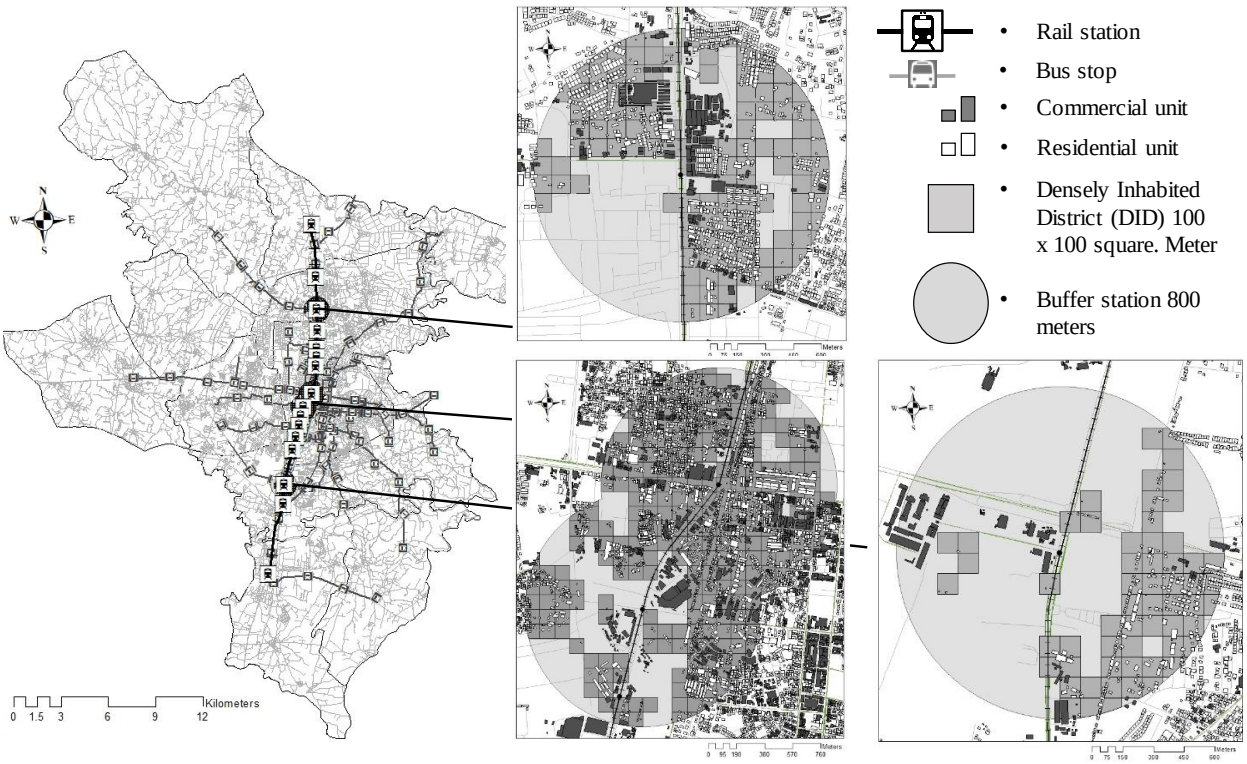


Figure 3.21. The 3 station of TOD plan in KhonKaen, Thailand

3.4.3 The Gentrification of TOD Level

There was presenting the context of TOD plan, explained based the size and impact of consideration including 1. City-region level 2. Corridor level 3. Station area and 4. Site level. The research fills the gap of urban planning focuses on dense, compact, mixed-use neighborhoods with vibrant streets and safe public spaces for social interaction. In the TOD station plan with grid 100x100 meter size, which grid is effective promoted for the case of KhonKaen was revealed as seen from **Figure 3.22.**

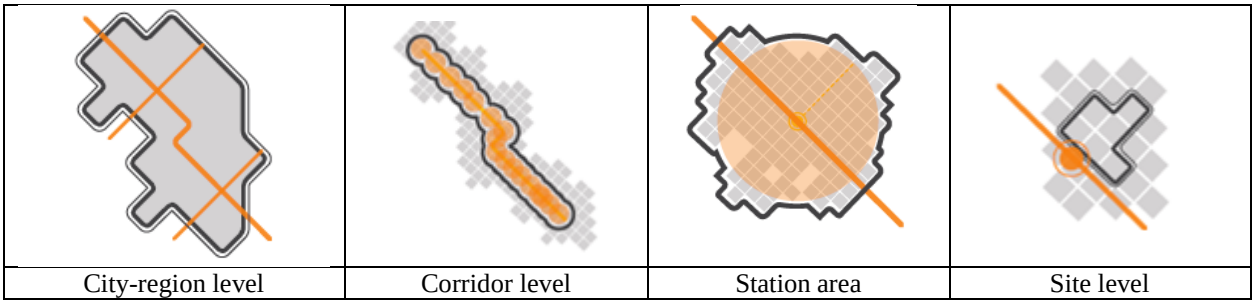


Figure 3.22. Determine the context of a TOD plan (Scale implementation) (The World Bank, 2018)

3.5 Conclusion

The list consists of relative parameters which is included in this chapter: 1. Urban public transportation network 2. Morphology, while gathering data to visualize urban mobility in various modes. The research focuses on urban mobility, which is represented in Chapter 4 by the accessibility index. All of these accessibility measures in an urban forecasting scenario will depict the competency of a public transportation network based on urban mobility perception for a future plan.

CHAPTER 4

THE FRAMEWORK OF ACCESSIBILITY INTEGRATED ANALYSIS

4.1 INTRODUCTION

This chapter covered the general development of accessibility models, starting with four-step models of transportation planning. The goal of the model creation was to better understand network capability within the context of reachability. All of this has been increased up by the destination unit, which was divided by the number of people who passed those boundaries. The factor determines the feasibility of an urban public transportation network, as well as accessibility, policy scale, and trend. The assessment models proposals are 1) The changes of accessibility observed as the population's accessible in different transit networks and 2) A comparative cases within public transport network (Walk, Bus and TRAM (project plan)) while commuted based on the unimodal (conventional bus route and urban rail project periods) and multimodal transportation models (linking the transport connected as walk – bus and train) through trip's capability that represented by three different building uses 3) The study outcome simplified the urban's mobility perception which was notably essential of the urban rail infrastructure understanding. The trip distribution and traffic assignment to address the determination and calibration for the mathematic models (B.Potts and M.Oliver, 1972)

4.2 TRADITIONAL LANDUSE AND TRANSPORTATION PLANNING

The fundamental principal of travel demand analysis pursued the 4 steps of models transport method including: 1) Trip Generation; 2) Trip Generation; 3) Model Split; and 4) Route Assignment as seen in **Figure 4.1.** The main proposes are finding the behavioral character of traffic that address for the stake holder authority to do the effective management. As a result of land use, household demographics, and other socioeconomic characteristics, trip generation affects the frequency of origins or destinations of trips in each zone, per trip purpose. Trip distribution connects origins and destinations, frequently using a gravity model– a computation that considers relative activity at the origin and destination, as well as the cost of travel between them. The percentage of trips between each origin and destination that utilize a specific mode of transportation is determined. (This modal model might be in the logit form). Route assignment assigns journeys between an origin and a destination to a route using a specific mode. The principle of user equilibrium is frequently used (for highway route assignment), in which each driver chooses the shortest (travel time) path. The problem is that travel times are a function of demand, and demand is a function of journey time, which is known as the bi-level problem.

The models contribution of Trip distribution connects origins and destinations while linked the frequency of origins or destinations by cumulative population and destination unit designate

utilizing land use scenario. The route assignment session adopted the journeys between an origin and a destination to a route in the whole public transit network considering.

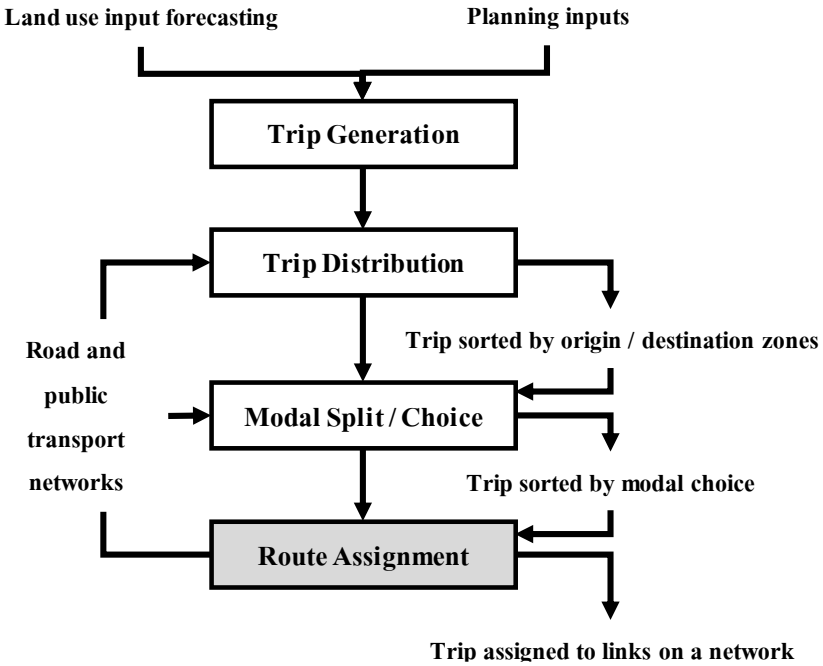


Figure 4.1. Traditional Four-Step Transport Model (Rick Evans, 2007.; Márton Tamás Horváth, 2017.; Carolina Souza da Conceição, 2019)

4.3 RESEARCH DESIRES

The principal of research profound the relative parameter of urban's mobility evaluation that cumulative the number destination unit designate of trip divided by population in network. Excluded the minimum population require as the demand of system, the aim of public transit is a promote the effective accessibility with declining of cost of transport and deplete the inaccessibility. The mainly corresponded structure is 1. Urban morphology as urban density and urban shape 2. Urban public transport currently and planning including 2.1 conventional bus 2.2 urban rail investment plan 3. Urban socialness (this research perceived as destination by 3 main classifications 3.1 Mixed use 3.2 Public facility and 3.3 Commercial units). The Research scope design and Accessibility approach schematic flow diagram shown in **Figure 4.2.** This concept usefully adopts to investigated the public transit network.

The techniques present in various investigates that integration between Demographic, Land use and Public transport network gathering by 2 aims is The accessibility index of Unimodal transportation investigated between "Walk", "Bus" and "Urban rail". And 2. The accessibility index of Multimodal transportation investigated between "Walk", "Walk – Bus - Walk" and "Walk – Bus - Urban rail "TRAM - Walk". As the results, 1. The public transit capability reaches and 2. Accessibility by over 2 modes connected is considering the clarity of the urban mobility competency which visualize the functions and capabilities of the transportation system.

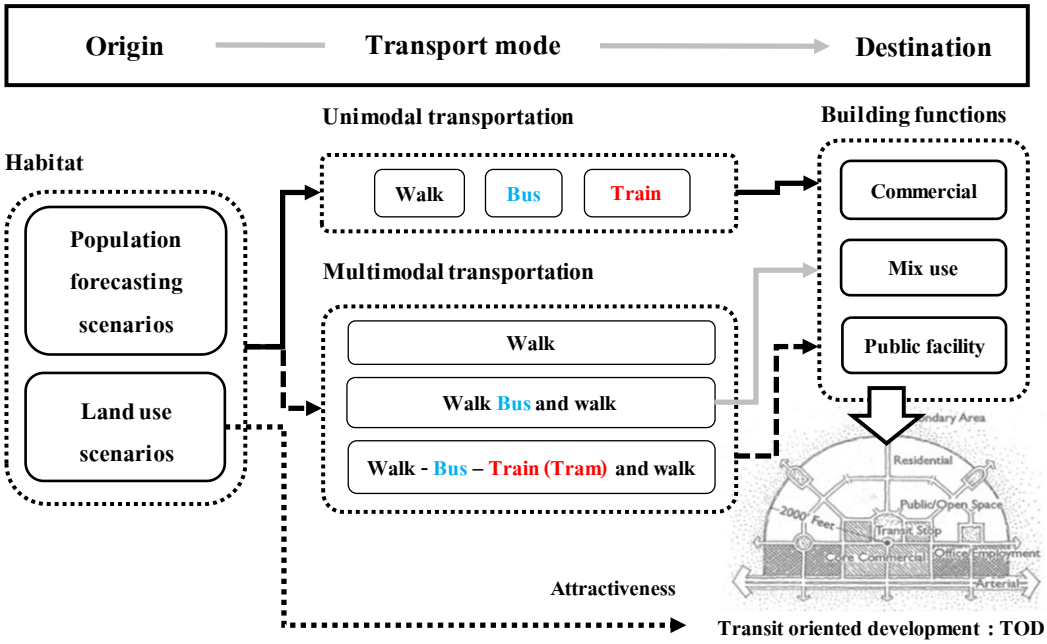


Figure 4.2. Research scope design and Accessibility approach schematic flow diagram.

4.4 ACCESIBILITY MEASURE

There are many possible categories of accessibility measurement but only four basic perspectives are majorly distinguishing (Geurs, 2018; Geurs & Wee, 2004). In term of planning, accessibility index has been broadly applied to solve the problems in public transport and land-uses; meanwhile, it has been also used to evaluate several alternative bus systems of a proposed commuter rail line for transport planning. Practically, the accessibility analysis often focuses on the people's physical quality concerning their socioeconomic factors in various indicators (Bhat et al., 2000). The research progressively presents the demand of transport perceived by the habitat unit commuted to the destination in various modes of transport mode comparative. This notion deeply visualizes the public transport performance tendency and capability.

The accessibility measure presented here is the intended to be used in statewide transportation planning, as well as other planning efforts for two specific proposes 1. Measure the current condition in area 2. Alternative method to evaluate conditions before and after project implementation. While many accessibility measure provide information at a disaggregate level (at a particular time of a day for a particulate mode and trip purpose), a key innovation in the work present here is the ability to aggregate over any combination of four dimensions. The four dimension are: 1. Trip propose 2. Mode 3. Time of days and 4. Spatial level (U.S. department of Transportation. Develop of an urban accessibility index formulation, aggregation and application) as shown in **Table 4.1.** Conventional forms of accessibility measures.

Table 4.1. Conventional forms of accessibility measures.

No	Conventional forms	Description	formulary
1	Distance measure	The simplest accessibility is the distance	$A_i = \frac{\sum_j d_{ij}}{b}$
2	Opportunities measure	The simplest accessibility measure that take account of both distance and objective of a trip is the cumulative – opportunities measure.	$A_i = \sum_j O_{jt}$
3	Gravity measure	The gravity measure includes an attraction factor as well as a separation factor	$A_i = \sum_j \frac{O_j}{t_{ij}^{\alpha}}$
4	Utility measure	The method of calculating accessibility for an individual n, is the expected value of the maximum of the utilities (U_{in}) over all alternative spatial destinations I in choice set c .The utility is determined by ranking the logsum of V_{in}	$A_n = E\left[\underset{i \in C}{Max}\, U_{in}\right] = \ln \sum_{i \in C} \exp(V_{in})$
5	Time space measure	Time – space measures add another dimension to the conceptual framework of accessibility corresponding to the time constraints of individuals under consideration.	
6	Composite Accessibility measure.		

Remark

- i = index of origin locations
- j = index of destination locations
- w_j= a set of weights associated with destinations e.g. the number of jobs in a traffic analysis zone
- C_{ij} is a cost of travel from i to j and
- $f(C_{ij})$ is an impedance function on the travel cost giving the utility of a destination

4.5 EXPERIMENTAL STUDY

Previously, the studies on the urban morphology where the public transit accessibility was a common topic of measurement and the key success of the urban public transport system (Deboosere & El-Geneidy, 2018; Jayasinghe & Munshi, 2014). According to the extensive academic literature on accessibility measurement as job employment to interpret and quantify the job employment accessibility (Cheng & Bertolini, 2013). By the way, there were depending on activity cases. On the contrary, the Gravity-based Accessibility Measurement techniques was weight and determine the reachability from point to point in an urban transit system where either the distant or the less weighted area has a slighter impact of the consideration. Belo Horizonte City, the literature presenting the relationship between the bus accessibility and the levels of urban mobility (Lessa, Lobo, & Cardoso, 2019) in which the levels of bus accessibility determine different modes of transport and destinations that within the costs consider of internal travel time.

In fact, the accessibility assessment had been previously studied and applied in Lisbon, Portugal, with a variety of significant components; for example, urban planning, mobility patterns, the point of services, and availability of public transportation represented through the local economic activities (Vasconcelos & Farias, 2012). Similarly, the public transport accessibility measurement considers various factors such as the needs of all the residents should be necessarily considered (Verseckienė, Meškauskas, & Batarlienė, 2016). In Lovos, Greece, these spatial areas and infrastructure's location including hotels, restaurants, bank, and gas stations were delicately described and compared with the bus routes. Practically, the data analysis utilized the findings from the geographical measurement, the metrics, and the spatial analysis in which the results describe the constraints between spatial geographical, affected the people's liveability in the urban economic activities, urban mobility and competency for economic development (Tsiotas, Kalantzi, & Gavardinas, 2016). In Amsterdam, Netherlands, the job accessibility and opportunity were measured by accumulating the effects of the competition, distance decay, and job diversity (Cheng & Bertolini, 2013). Additionally, it was noted that an urban area with a higher GDP was generally allocated with higher capacity and more public transport infrastructures which in turn support reducing their congestion.

The research considering 3 main structures consisting of 1. Urban shape (Morphology and Demographic) 2. Public transit (conventional bus routes and Urban rail investment plan) 3. Policies options that imposes TOD investigates. The accessibility investigated parameter within 5 structure consideration 1. Transport model assessment (Walk, Bus and Urban rail) 2. Rail transit investment plan (especially in 3 times frame 2021, 2026 and 2036 A.D.) 3. Land use function that present in 2 phenomena (multiply with 3 access models present 9 cases accessibility values) 4. The population structure by 2 age range 1. 10 – 64 years and over 65 years and 5 Trip destination by 3 main group, detailing by 8 type by building functional as described in chapter 3, the experimental study simplify as seen from **Figure 4.3**. The research explores the possibility of land use function by present 2 cases as promote low and medium density grid unit as mentioned in chapter 3. The result explained the access competency. Therefore, the research reveals the hidden abilities of feeder function that become to be the notion of the feeder reformation study. As the multimodal investigated diagram seen by **Figure 4.4.,** the result presents the low performance accessible by rail network, the urban sprawling along the bus route network were significant. The research conducted with the point of feeder transform while was adopted based on the demand responsive connector (DRC) idea. Although, most of the city's effective mobility was promoted with the city plan. The options to fill the gap in developing city that is strongly strict on urban policy regulation is needed to study and explore the possibility of policy innovation. In the case of urban rail implementation, the possibility of feeder transformation is an alternative for gathering and measuring feeder performance. Both options were confirmed in various case, the research notion fill the gap within the accessibility model, multimodal transport, and secondary transport mode consideration. All accessibility presenting separately analysis sections that simplifies the research scope design and accessibility approach schematic flow diagram as seen by **Figure 4.5**. The last session, the author carries on the node function in rail transit by focusing on the tendency of policy as The walk, ride and bus access to rail station which have been effect to the demand estimation of public transit system. The policies tendency will be guiding, shaping and trending the notion of innovative policies.

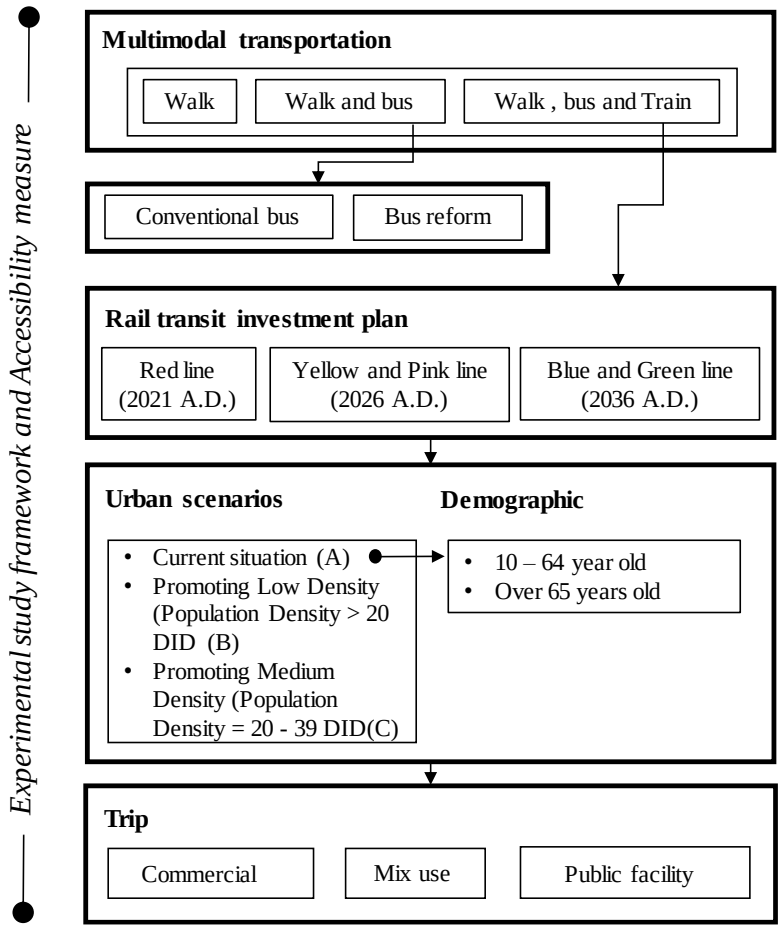


Figure 4.3. Experimental Structure by Multimodal Transport, Land use scenario, Age structure, and Trip.

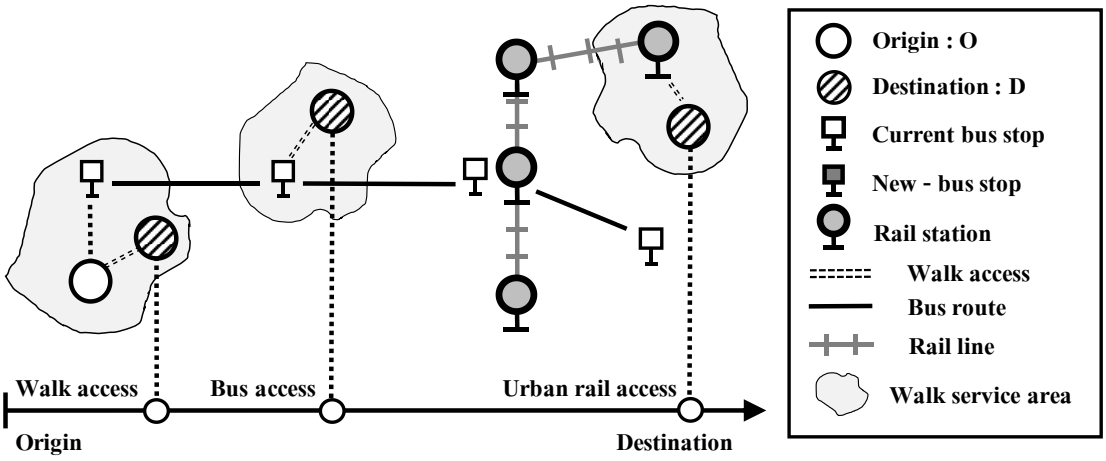


Figure 4.4. Multimodal Transportation schematic chart.

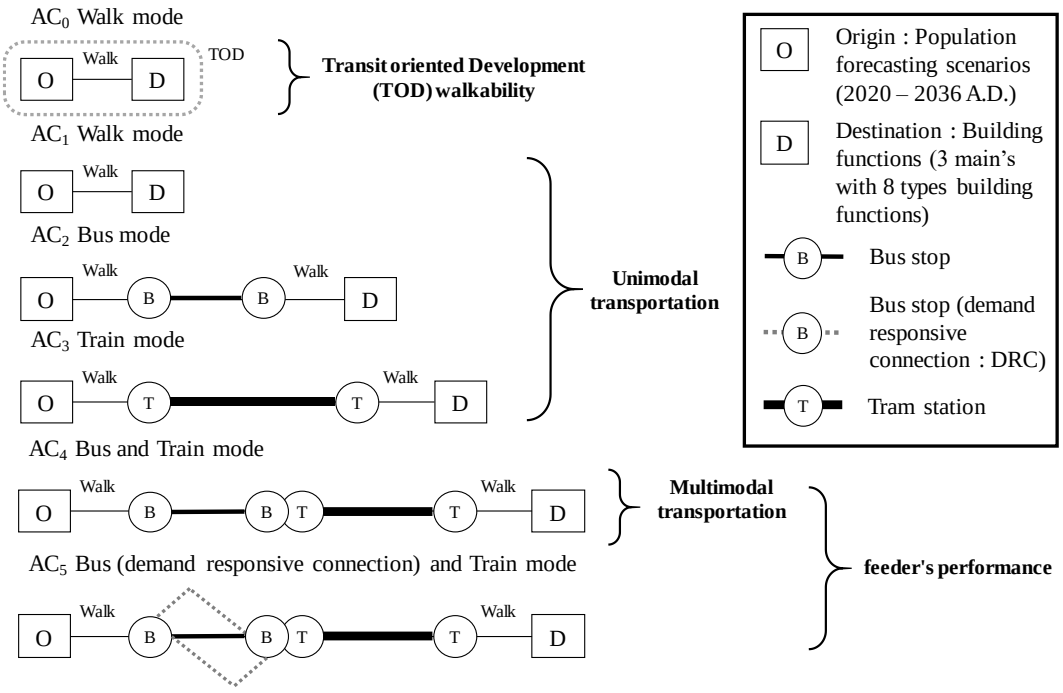


Figure 4.5. Research scope design and accessibility approach schematic flow diagram.

4.6 ACCESIBILITY INDEX AND DEVELOPMENT MODEL

The accessibility levels by bus were researched in the Belo Horizonte city discussing its relationship with the levels of urban mobility (Daniela Antunes Lessa et al, 2019). The accessibility assessment methodology was conducted by applying the significant differences in many urban planning cases, mobility patterns, the point of services, and the availability of public transportation (Filipe Moura et al, 2017) and the dimensions of public transport accessibility measurement were correlated to travel cost, options, constraints, quality, etc (Biermann et al, 2017). In fact, the decision making for public transport accessibility improvement was involved with the authorities in several areas so the final decision should be made through the collaboration amongst all related sectors as well as the consideration on the resident's needs. In addition, Urban Network Analysis (UNA) was assigned to quantify the pedestrian enumeration using the network to reach public facilities (Morimoto, 2015). In this regard, there are the effective factors on the urban accessibility including: 1) Transport Demand; 2) Mobility; 3) Transport Option (Mode); 4). Integration; 5). Affordability; 6) Mobility Substitutes; 7) Land Use factor; 8) Transportation Network Connectivity; 9) Transport Management; 10) Prioritization, and 11) Inaccessibility (Litman, 2020). Practically, this research adopted the accessibility concept in different levels of 3 integrated transportation modes as the consumer demand perceived by job employment revealed the interpretation of human activities, notion definition, and quality. The research also indicated trip activities by building the areas for different uses. This so-called accessibility index (2), (3), and (4) presented: Walk Total Time = 10 min (AC_1) as seen in **Eq. (2)**, Walk and Bus and Walk Total Time = 30 min (AC_2) as seen in **Eq. (3)**, Bus, Train and Walk Total Time = 40 min (AC_3) as seen in **Eq. (4)**, respectively. More details were depicted in **Fig. 4**. Previously, there was a study

suggesting that a total time use was less than 60 min (Daniel Pulido, 2018). The simplification calculation by mode of transport presenting in **Table 4.2.**

The accessibility categorizations apparently distinguished the four basic perspectives (Geurs, 2018) and at the planning stage, it has been widely used as a tool to solve both transport and land-use problems and to evaluate several alternative transportation systems by discussing both advantages and disadvantages (often focusing on the basic accessibility in physical, economical, or social aspects). Previously, commonly accessibility measurements presenting concepts has been a path of transportation between mobility and associability and the effective measurement defined the general concept of graph theory and spatial separation (Chandra Bhat *et al*, 2000) as a weighted average computation of travelling time for all the zones of consideration where d_{ij} was the distance between i and j, and b was the general parameter given in **Eq. (1)**

$$Ai = \sum_{n=0}^{\infty} \frac{dij}{b_n} = \frac{(\text{Zone x Weight average})}{\text{sample size (n)}} \tag{1}$$

$$A_q = \sum_{i \varepsilon Ni} A_s P_{it} \Big/ \sum_{i \varepsilon Ni} P_{it} \tag{2}$$

$$AC_i^m = \sum_{j \in [t_{i,j}^m < T]} D_j, D_j = LogA_j \tag{3}$$

$$\overline{AC} = (\sum_p N_1 AC_1 + ... + N_n AC_n) \tag{4}$$

$$AC1 = \Sigma_{k=10\,min}^{SA} (P_n \, x \, T_n) / \sum P_n \tag{5}$$

$$AC2 = (\Sigma_{k=10min}^{CFbus} (\Sigma_{k=10min}^{SA} (P_n))) \, x \, (\sum_{k=10min}^{SA} (T_n)) / \sum P_n \tag{6}$$

$$AC3 = (\Sigma_{k=10min}^{CFtrain} (\Sigma_{k=10min}^{CFbus} (\Sigma_{k=10min}^{SA} (P_n)))) \, x \, (\sum_{k=10min}^{SA} (T_n)) / \sum P_n \tag{7}$$

$$AC4 = (\Sigma_{k=10min}^{CFtrain} (\Sigma_{k=10min}^{CFbus} (\Sigma_{k=10min}^{SA} (P_n)))) \, x \, (\sum_{k=10min}^{SA} (T_n)) / \sum P_n \tag{8}$$

$$AC5 = (\Sigma_{k=10min}^{CFtrain} (\Sigma_{k=10min}^{CFbusreform} (\Sigma_{k=10min}^{SA} (P_n)))) \, x \, (\sum_{k=10min}^{SA} (T_n)) / \sum P_n \tag{9}$$

Abbreviation description

A_q = Average number of opportunities of type “m” available to origin of “j” in area “i”

A_s = Cumulative opportunities of type “m” available to zone “i” up to limit “k”

P_{it} = Origin in zone “i” of types “t”

Pn = The demand of transport (person unit) in zone “i” present by grid index as seen in **Figure 4.6.** The building by ArcGIS execution allocated by residential building unit)Persons)

T_n = Destination perceived by building functions) : Square meter unit, calculated in *logarithm* form .(The destination perception executed by grid feature index as 100 x 100 Square meter. as mention in chapter 3. and seen in **Figure 4.7.**

i = Residential mesh (DID) number. The research address within 3 levels classifications as 1. Low density (DID is 1 – 19 population /ha) 2. Medium density (DID is 20 - 39 population /ha) and 2. High density (DID is over 40 population /ha) as mention in chapter 3.

m = Traffic modes. This research mainly present public transport network that covered 1. Bus network and 2. Urban rail network project plan.

T = Travel times radius.

D_j = Facility (evaluated values) in logarithm form.

$t_{i,j}^{m}$ = Transport mode "m" from residential "i" to facility "j"

AC_i^m = Accessibility of resident "i" to to facility "j" by traffic mode "m".

$\overline{AC}$ = Average accessibility of whole transport network considered.

AC_i = Accessibility of resident "i" to destination considered.

N_i = Population in residence "i" executed by Service Area GIS function within street network.

SA = Service area is the area execution the mobility function in their network .as seen in **Figure 4.8.**

CF = Closest facility is the route execution by their network with the units 'transmissions) the bus stop and rail station

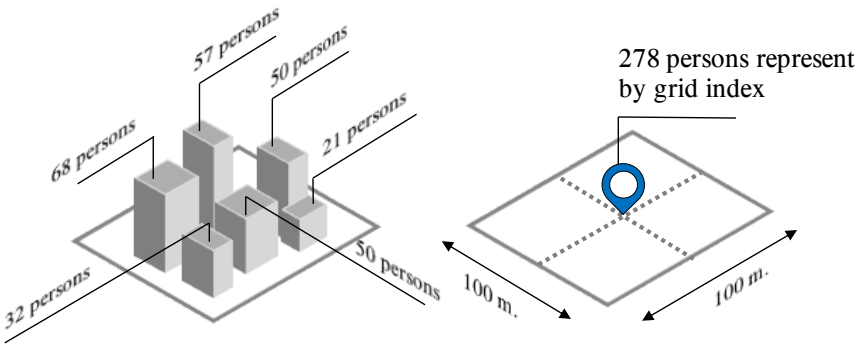


Figure 4.6. The demand of transport (person unit) in zone "i" present by grid index

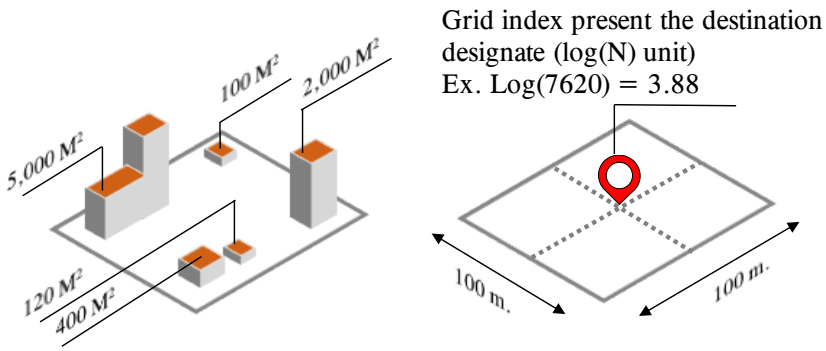
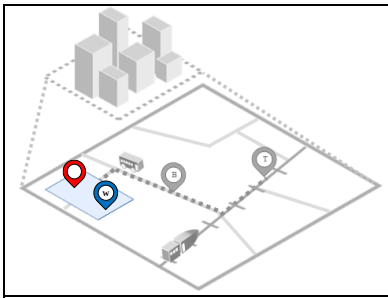
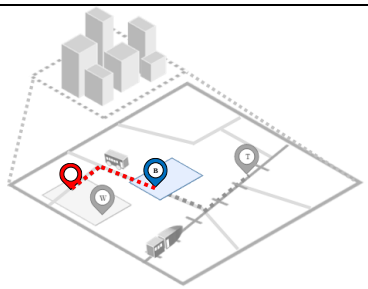
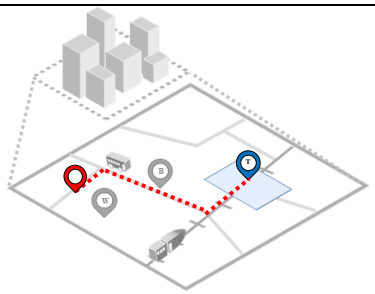


Figure 4.7. The destination (square meter) in zone "j" present by grid index

Table 4.2. The simplification calculation by mode of transport.

		
(A) Walk access	(B) Walk and bus access	(C) Walk, bus and rail access
Calculated by		
• Cumulative every grid of population density executed by the service area function when intersecting with the designated destination • Present the accessibility index	• Cumulative every grid of population where accesses to bus stop by service area function • After that link the bus stop to next bus stop as the destination by closest facility functions within fixed time consideration. • The bus stops destination merge with the walk service area of unit destination designate. • Present the accessibility index.	• Cumulative every grid of population where accesses to bus stop by service area function • After that link the bus stop to next bus stop where achieved transit to rail network by closest facility functions • Then, link the rail station to next rail station within fixed time consideration • The rail destination merge with the walk service area of unit destination designate. • Present the accessibility index.

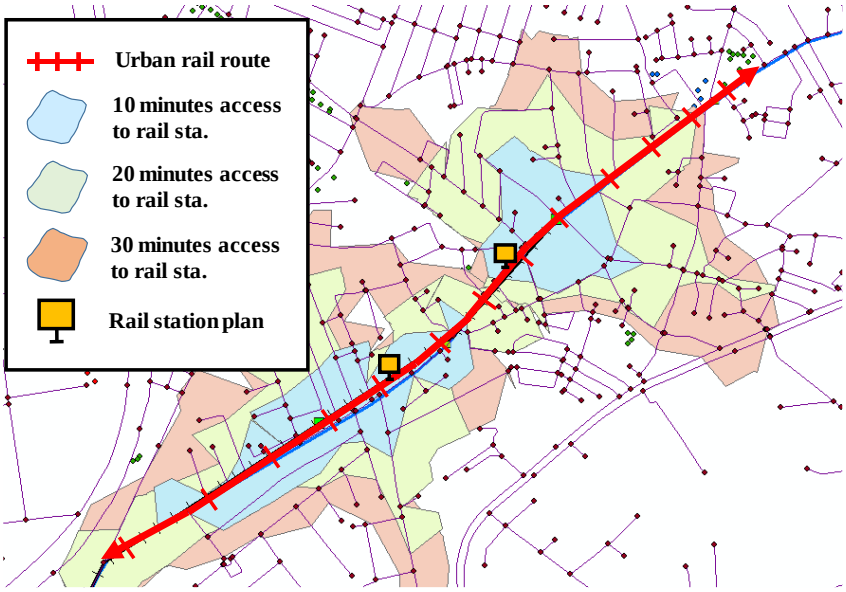


Figure 4.8. Service area is the area execution the mobility function in rail station accessed 3 times use (10, 20 and 30 minutes).

4.7 OPTIMIZATION MODEL IN TOD

The optimization model utilizing by the GRG model in excel, mathematical optimization is the process of selecting the optimal element from a group of variables based on certain criterion. All quantitative disciplines, from computer science and engineering to operations research and economics, have optimization problems, and the development of solution methods has been of interest in mathematics for centuries. The Transit-Oriented Development zone which was compiled by grid index (100 x 100 sq. meter) had been focused on the restricted parameter consisting of 1. The walk accessibility model in 3 zones (Urban core, Urban neighborhood and Transit core) of the TOD plan separately, 2. The grid density variable controlled (example grid finding by 40 DID while freely determining in grid slots but not over top up than 20 DID), and 3. The TOD population target, this concept related by land use promote regulation as permit for the mixed use in residential zone and promoted the high rise unit as presenting in **Figure 4.9.** All controlled parameters presenting in **Table 4.3.** Lastly, the integration of the technique of the population target based walkability formulary with the effective grid finding would present the effective grid location.

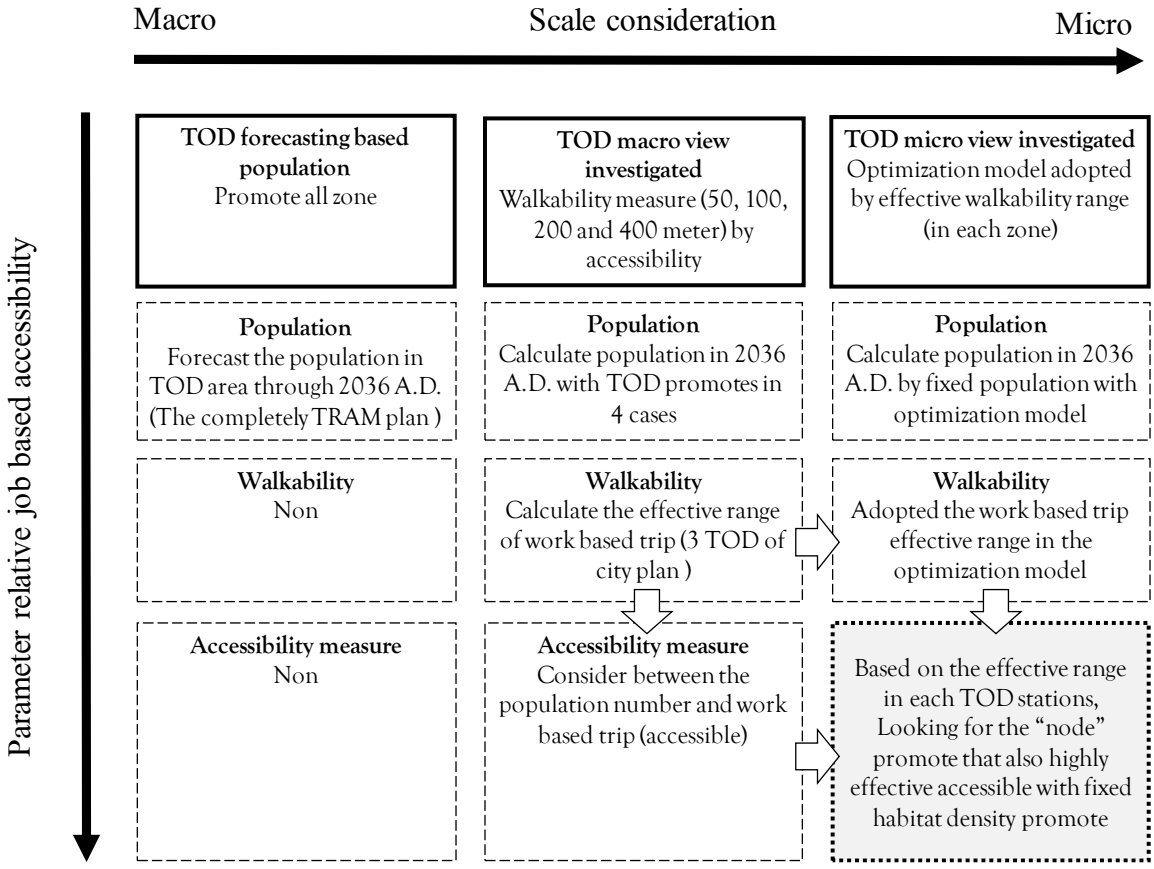


Figure 4.9. The concept framework by optimizations and scale intensity and parameter relative in TOD zone

The optimization techniques adoption was predicting of possibility relative livability by economic scale represented by commercial access by walk in TOD.

P_n : Area of population unit (person) by grid 100 x 100

A_n : Area of commercial unit (m^2) by grid 100 x 100

Optimization constrain

Variable (X) : Grid point [n = 1, 2 …. 126 points of SU (Lotus station)]

Objective function : Maximum of accessibility in effective range by walk

Constraint : Cumulative population (persons) with Cumulative commercial location

Accessibility index : AC = $$\frac{\sum_1^n[(N_1\ xD_1\ )+(N_2\ xD_2)\ldots+(N_n\ x\ D_n)}{\sum(N_1+\ \ldots..\ +N_n)}$$

N_i = Grid node of population (persons), Trial with cumulative population propose $\geq N_i \geq$ current population number.

D_i = Grid node of commercial unit (m^2), Trial with fixed commercial unit $\geq D_i \geq$ current population number.

Table 4.3. Comparative 3 location of TOD with GRG optimization model

No	Station / effective range	Optimization model		Condition added	Number of grid
1	Sub urban core (Lotus station) / 200 meter effective walkability index	$\overline{AC} = \sum_{n=1}^{k} \frac{(P_1A_1 + \cdots + P_kA_k)}{(P_1 + \cdots + P_k)}$	Objective function	-	126
		P_n : Area of population unit (m^2) by grid 100 x 100 A_n : Area of commercial unit (m^2) by grid 100 x 100	Variable		
		1. $P_n + X_1 < P_n < P_n + X_2$, $X_1 = 1$, $X_2 = 20$ 2. $P_1A_1 + \cdots + P_kA_k < X_3$, $X_3 < P_1A_1 + \cdots + P_kA_k + 100{,}000$, depended on the scale of location indicated 3. $P_1 + \cdots + P_k < P_1 + \cdots + P_k \; x \; 1.3$	Constrain condition		
2	Transit Core (Terminal station) / 400 meter effective walkability index	$\overline{AC} = \sum_{n=1}^{k} \frac{(P_1A_1 + \cdots + P_kA_k)}{(P_1 + \cdots + P_k)}$	Objective function	Provide the scenario of Mixed use unit (10,000 m^2) that distributed all TOD zone.	66
		P_n : Area of population unit (m^2) by grid 100 x 100 A_n : Area of commercial unit (m^2) by grid 100 x 100	Variable		
		1. $P_n + X_1 < P_n < P_n + X_2$, $X_1 = 1$, $X_2 = 20$ 2. $P_1A_1 + \cdots + P_kA_k < X_3$, $X_3 < P_1A_1 + \cdots + P_kA_k + 100{,}000$, depended on the scale of location indicated 3. $P_1 + \cdots + P_k < P_1 + \cdots + P_k \; x \; 1.3$	Constrain condition		
3	Urban core (Central station) / 400 meter effective walkability index	$\overline{AC} = \sum_{n=1}^{k} \frac{(P_1A_1 + \cdots + P_kA_k)}{(P_1 + \cdots + P_k)}$	Objective function	-	264
		P_n : Area of population unit (m^2) by grid 100 x 100 A_n : Area of commercial unit (m^2) by grid 100 x 100	Variable		
		1. $P_n + X_1 < P_n < P_n + X_2$, $X_1 = 1$, $X_2 = 20$ 2. $P_1A_1 + \cdots + P_kA_k < X_3$, $X_3 < P_1A_1 + \cdots + P_kA_k + 100{,}000$, depended on the scale of location indicated 3. $P_1 + \cdots + P_k < P_1 + \cdots + P_k \; x \; 1.3$	Constrain condition		

4.8 CONCLUSION

The relationship between urban mobility and public infrastructure would be productively modified by policy support. The accessibility index by public transit accessed development offers the notion of competency to destination by unit function in network while relying on time based measure as a fixed time comparison measure (45, 60 and 90-minute time consume). The

effectiveness of network integration mobility and inaccessibility was also revealed by the assessment based public transit in different modes investigated. Although promoting the TOD zone was a necessary consideration for supporting the urban mass transit implementation project, the visual of the city scale that has been proposed to provide public service equality is required to guide in setting for the city plan paradigm.

CHAPTER 5

MODEL DEVEOLOPMENT IMPACTS BASED PUBLIC TRANSPORT INVESTIGATED

5.1 INTRODUCTION

The model assessment of the impacts-based public infrastructure project was presented in this chapter. The two layers of public transportation integration sensibility are described in the conclusion. The research aims on the connection between land use and public transit. The study's purpose is to find a new knowledge area based on the fundamentals of transportation engineering development and to look into novel solutions that support city plans by planning and projecting the urban rail network.

5.2 MODEL DEVELOPMENT REPRESENTATIVE.

The principal transport model followed by 4 steps model, the research contribution to develop the accessibility model that addressed the public transport network performances, also was perspective urban motion by public transit access. The research notion adopted the accessibility measure while were commuting between 1. urban policies and structure and 2. Public transport network hierarchy. In Brussels, the urban accessibility and mobility revealed the two main danger are 1. The deterioration of general accessibility and 2. The excess of automobile mobility, these reacted to selective improvement of accessibility by public transport and selective restrictive of accessibility by private car (Martine, L., Gibert, L., Katalin, T. & Philipe, T, 1997). In this regard, the research carries out within 3 structure component of urban beneficial proposes consist of 1. Urban accessibility 2. Policy trend and 3. Model assessment. The urban accessibility index which presenting by 5 indicators, as above mentions in chapter 4. The policy trend affects the accessibility based on the urban rail investment plan assessment. The model assessment comparative by the Unimodal and Multimodal model development investigated. Moreover, the feeder transform consideration is also present.

5.3 THE FUNDAMENTAL OF TRIP ACCESSIBILITY BY UNIMODAL ASSESSMENT.

The analysis on the bus-network and urban rail investment plan currently implemented revealed that the urban mobility reflected the available levels that an individual person can get an access toward the utility units. In a city, the tendency of urban density was explicitly related to the public transport together with the bus public transportation line. Accordingly, the distributed building utility was related to the accessibility measure as illustrated in **Figure 5.1.** in which the accessibility by rail destination was found to be partly low in cases of the commercial, infirmary,

religious and public service units. The comparison on the accessibility index with the fixed periods of time (60, 75 and 90 minutes) of the designated destination determination have been slightly growing firmly validated by the regression analysis as described in **Figure 5.2.** and **Table 5.1**. Apparently, the accessibility measure suggested that the current bus public transit was more effective than the rail transit without the urban plan initiatively promoted.

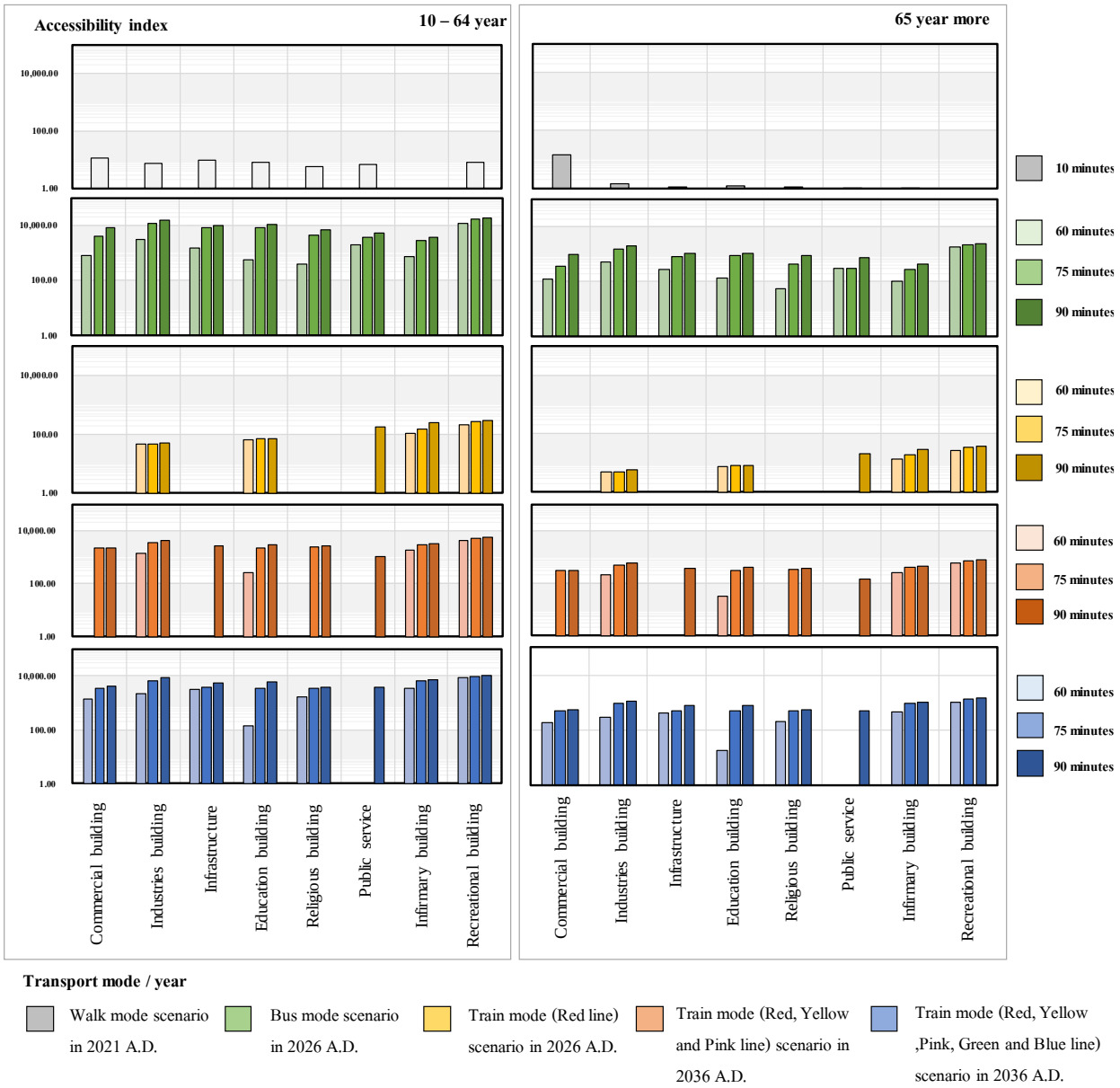
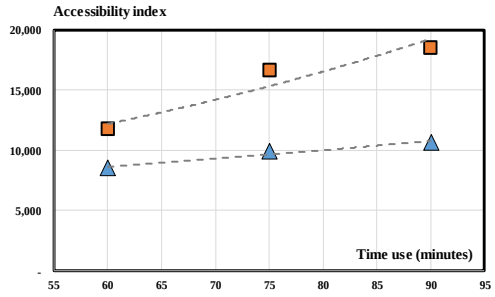


Figure 5.1. Accessibility Index Comparison of Different Public Transport Modes and Types of Building; the 2 different sample groups with age ranges 10 to 64 (Left) and over 65 (Right).

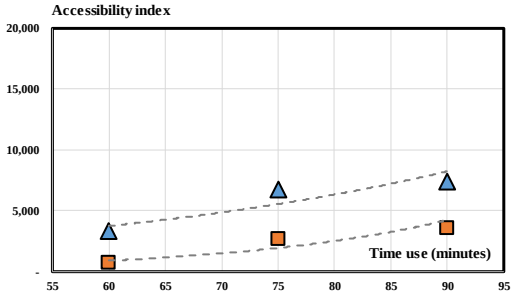
The fundamental principle of travel demand analysis was to investigate and manage the travel demand behavior. While a complex relationship between the land use and the transport planning efficiently provided a social perspective on the transport planning (Boisjoly, & El-Geneidy, 2017), the accessibility investigation demonstrated the urban phenomena in terms of the

urban attractions and spatial development. The data analysis based on public transit accessibility evaluation affirmed that the developing cities with an investment on the urban rail project similarly suffered from the unequal accessibility and low accessibility performance. Moreover, the model visualized the insight of urban perception that were confronted by the aging demographic and urban sprawling. The model analysis usefully explained the urban mobility accessibility performance that addressed the primary mode of urban mobility. The comparative resulted between current bus network and train network investment plan presented the block plot styles (60-95 minutes' times use) as seen by **Figure 5.3.** Evidently, the urban rail project in the developing cities necessarily supported in order to shape up the city plan using an effective urban innovation such as the Transit Oriented Development (TOD). As previously mentioned, the research notion presented the comparative study on public transport accessibility investigation between bus and urban rail in different timeframes and sort by destination functional units.

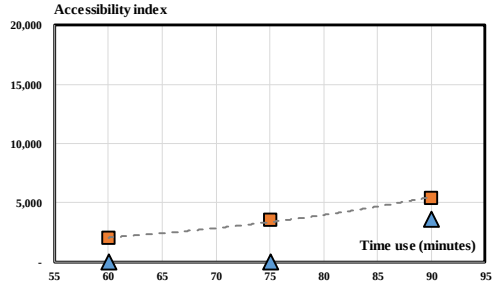
This section was presenting on the International review for Spatial Planning and Sustainable Development (Japan).



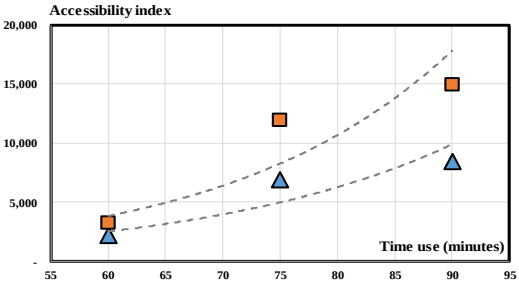
Commercial building



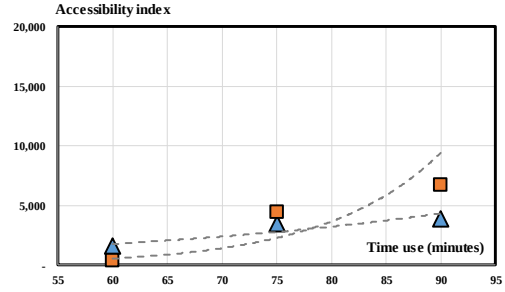
Industries building



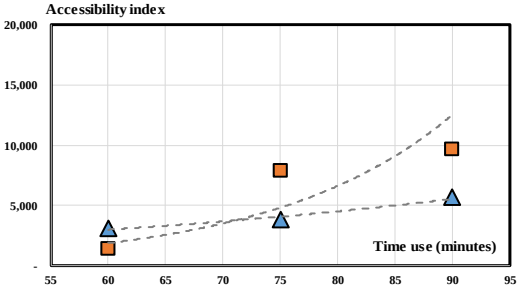
Infrastructure



Education building



Religious building



Public service

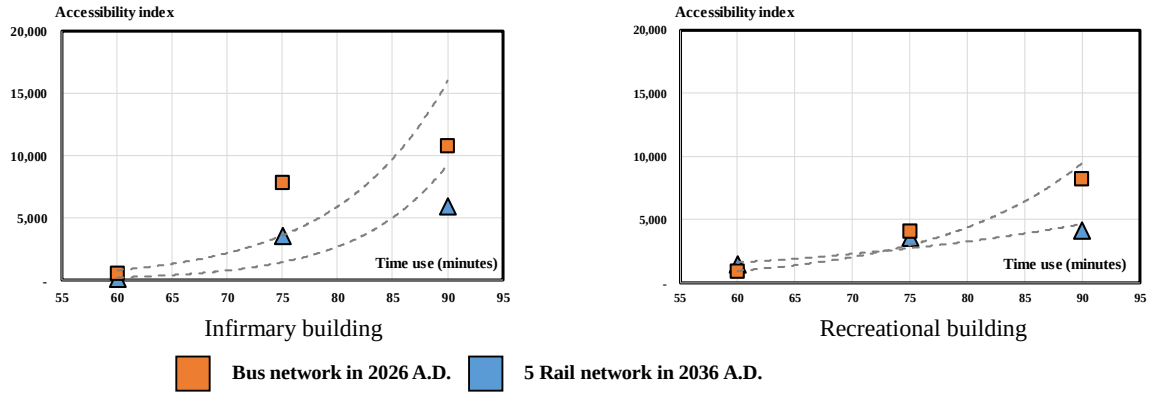


Figure 5.2. 8 Comparison Charts between Bus and Train Transit from 2021 A.D. to 2036 A.D. by Destination Functional Units within Fixed time (60, 75 and 90 minutes use)

Table 5.1. Accessibility index and time consume (60, 75 and 90 minutes) by regression analysis

		Y : Accessibility index, X: time consume			
		Commercial building	Industries building	Infrastructure	Education building
Bus (2026 A.D.)	Y	$4{,}884.7e^{0.01x}$	$38.4e^{0.05x}$	$282.2e^{0.03x}$	$176.1e^{0.05x}$
	R^2	0.91	0.88	0.99	0.85
Train (2036 A.D.)	Y	$5{,}549.7e^{0.01x}$	$762.9e^{0.03x}$	N/A	$160.9e^{0.05x}$
	R^2	0.94	0.83	N/A	0.86
		Religious building	Public service	Infirmary building	Recreational building
Bus (2026 A.D.)	Y	$1.9e^{0.09x}$	$39.6e^{0.06x}$	$2.1e^{0.09x}$	$9.2e^{0.08x}$
	R^2	0.85	0.82	0.83	0.95
Train (2036 A.D.)	Y	$300.4e^{0.03x}$	$855.0e^{0.02x}$	$0.1e^{0.12x}$	$188.5e^{0.04x}$
	R^2	0.84	0.96	0.85	0.84

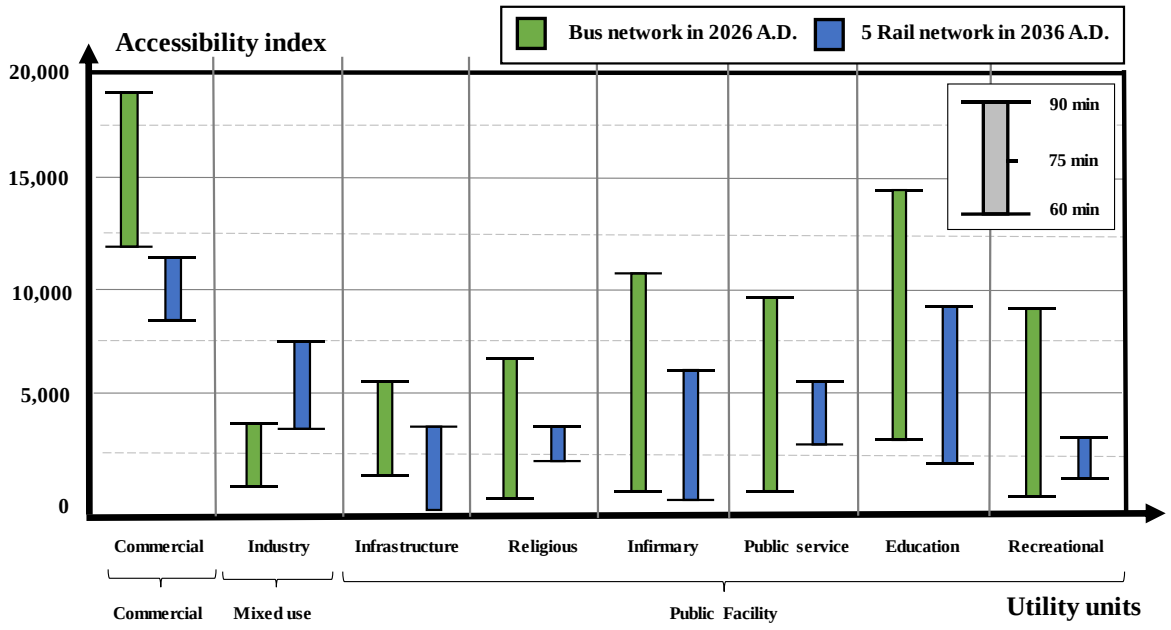


Figure 5.3. Block Plot of Time- use between Bus in 2026 A.D. and Urban Rail project in 2036 A.D. Comparative by Accessibility Index and Trip Destination.

5.4 THE FUNDAMENTAL OF TRIP ACCESSIBILITY BY MULTIMODAL ASSESSMENT.

The figures below highlighted the relationship between Accessibility Index and those 5 multimodal transportation modes and it was affirmed that the most effective mode during a period of 2021 to 2036 A. D. was Walk and Bus mode (WBW). The trip purposes similarly exposed that the supporting policy for low-density areas was improved for approximately 0.87 – 0.58%, 0.35 - 0.24%, and 0.36 - 0.24% in cases of Mix-Use, Commercial Use, and Public Facility Use respectively, and that for the medium density area was improved for 0.45 - 0.34%, 0.34 - 0.27%, 0.34 - 0.35% in cases of Mix-Use, Commercial Use, and Public Facility Use respectively. In the aspect of the supporting policy for the urban phenomena, there was the tendency of rapid increase in 2026 and 2036 A.D. in both supporting policies as presented in **Figure. 5.4**.

Although rail transport was an urban development strategy to improve mobility, the study of urban mobility between rail system and urban perception showed that without city plan promotion policies, there were a concentration of the district and the disorderly sprawling of urban. The characteristics of public buses were a considerable part of a feeder in a system that could improve or reform a route, i.e., enhancing redundant paths with railways or improving a way to be perpendicular to the railway at the station stop. According to the study, it was found that the current bus routes were redundant with the rail routes plan by more than 50% (12/19 of all bus routes in the study area). The bus routes-pattern had essentially developed to a feeder at the urban rail transport system, which was a fishbone diagram structure. The purpose of the route remained the same, that is to say, the origin and destination of each route remained the same. Besides, the model defined a bus stop node as a foundation for assessing social equality. The results revealed the mechanisms of public transport networks and urban perception, as well as investments in urban railways needed trying to keep a balance between urban policies, support, city management via city plan machines, and development plan of rail transportation as a principal system in conjunction with feeders by the bus network and urban socialness. This research represented several models of continuous transport assessment, especially walking – bus and train.

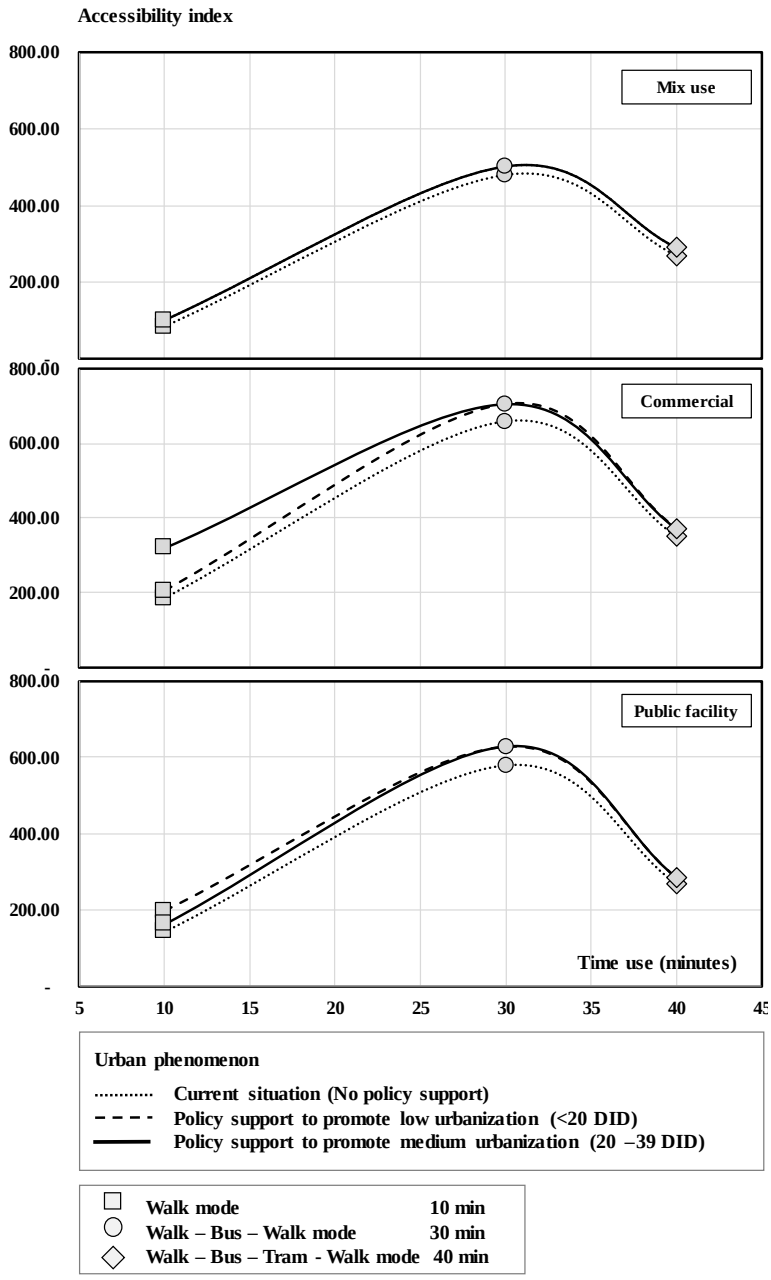


Figure 5.4. Accessibility index by Multimodal Transport Represented by Trip Purposes in 2036 A.D. (40- min time use)

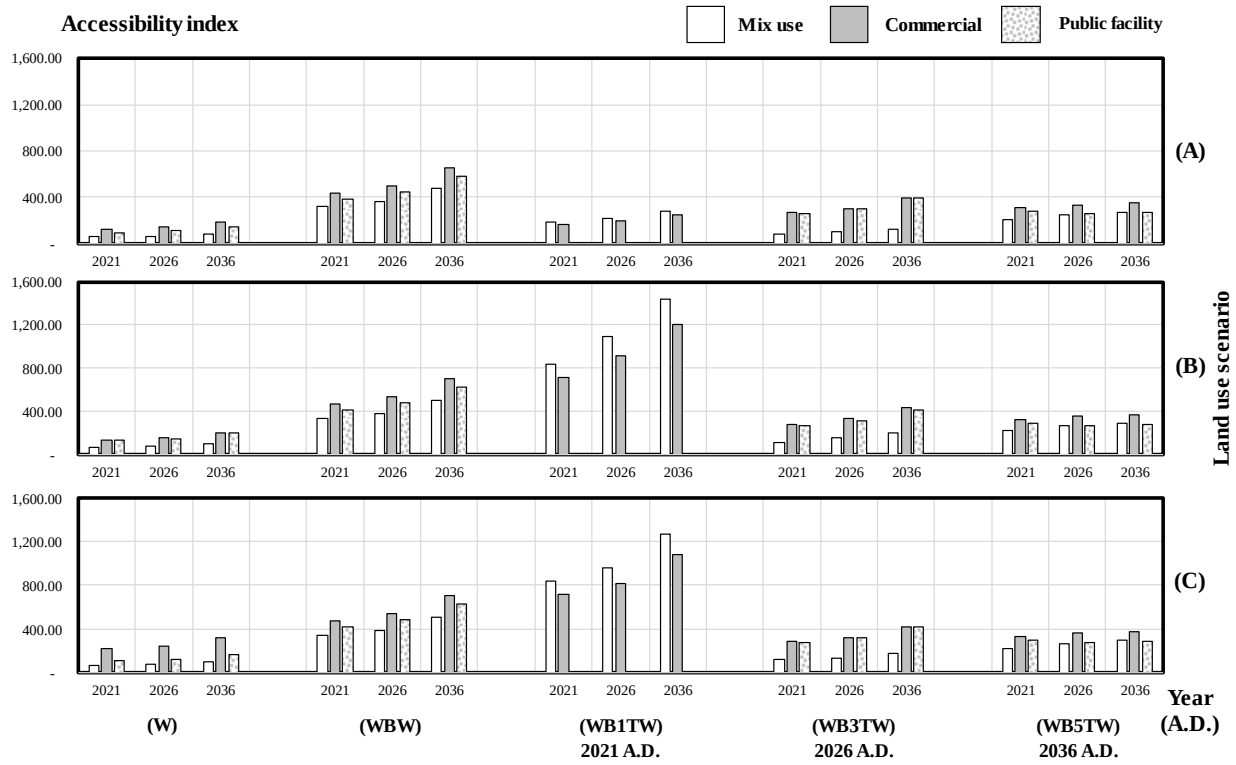


Figure 5.5. The 5 Multimodal Transportation Mode in Different Land Use Scenario

Regarding the trip purposes in the rail investment plan (2021 – 2036 A.D.), the data analysis presented 3 multimodal transportation modes in different time uses (10 min to 40 min by different multimodal transportation modes computed by Accessibility Index) as depicted in **Figure 5.5.** The comparative result presented the completion of the urban rail plan (5 routes) in 2036 A.D., while the trip destination by Walk – Bus and Train (40 minutes) presented the findings with an accessibility index of 131.58 to 839.69, 168.31 to 716.84 and 0 to 314.78 in cases of Mix Use, Commercial Use, and Public Facility Use respectively; these findings were apparently lower than what was found in Bus Mode (30 min).

The population who capable to reach public transit network shown in the **Figure 5.6.** The Population Reach in Those Multimodal Transportation. A comparative study on the population's accessibility and multimodal transportation modes in three different building uses: Mixed Use, Commercial Use, and Public Facility Use present the mobility within network while proposes the urban rail to be the primary mode and bus network as the secondary mode to reach the destination designated. The study outcome simplified the urban's perception mechanisms that supports a non – driven virtualization while the urban rail infrastructure was notably essential for understanding the relationship between the urban perception and public infrastructure that would be resulted as a productive supporting policy. This model discussing based on the light rail transportation

investment plan to understand and develop a more efficient approach for city-level cooperation in both the public and private sectors. By walkable accessed, the number of population reached from approximately 180,000 persons to 300,000 people for all of policies plan (2021 – 2036 A.D. timeframes) that confirm the level of intensity needed to focuses on the station gentrification area while discussed in chapter 3. Therefore, the bus and train network reachable was slightly growth but no have significantly different by term of population reachability.

This section was presenting in the Journal of Urban and Environmental Engineering (Brazil).

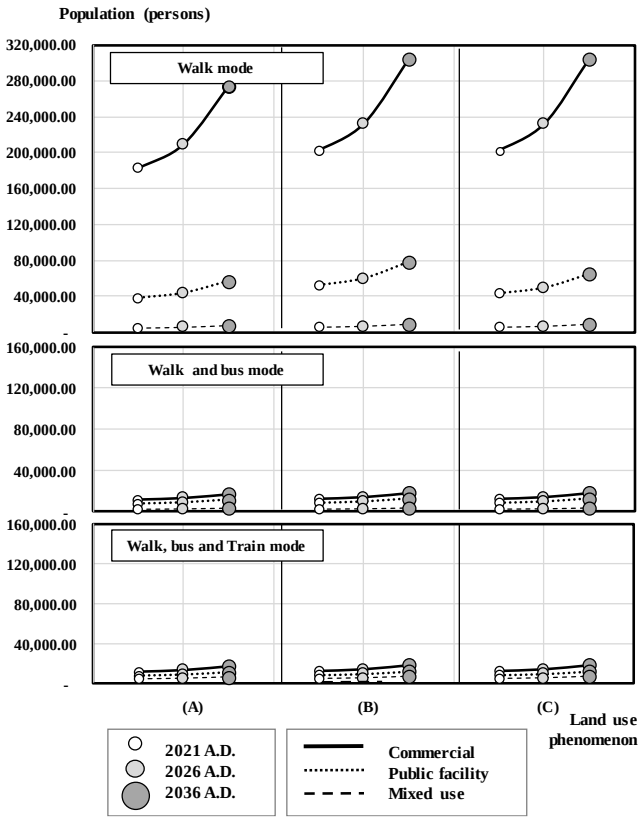


Figure 5.6. The population who capable to reach public transit network

5.5 THE FUNDAMENTAL OF TRIP ACCESSIBILITY BY MULTIMODAL ASSESSMENT, COMPARATIVE BY CONVENTIONAL AND REFORM OF BUS NETWORK.

The analysis focuses on the distinct and fundamental prospect of route transformation . The ideal buffer distance between tram stations and established new bus stop in 300-meter range .The 4 of 6 route trip by mixed use unit, 6 of 12 route trip by public facility unit and 6 of 12 route trip by commercial unit of route reform are lower accessibility index than conventional route . Mixed use increases 40. 37 and 43. 38 percentages, public facility reduces 0. 43 and increases 40. 37 percentages and 43. 38, and commercial increases 4. 40 and 8. 35 percentages, according to each route side effect determination by time usage 10 to 40- minute evaluation, by route reform and conventional route, respectively . The route reform extends the route to about 11 percent of the conventional route (12 of 19) bus route reform consideration as seen in **Figure 5.7** and **Table 5.2.**

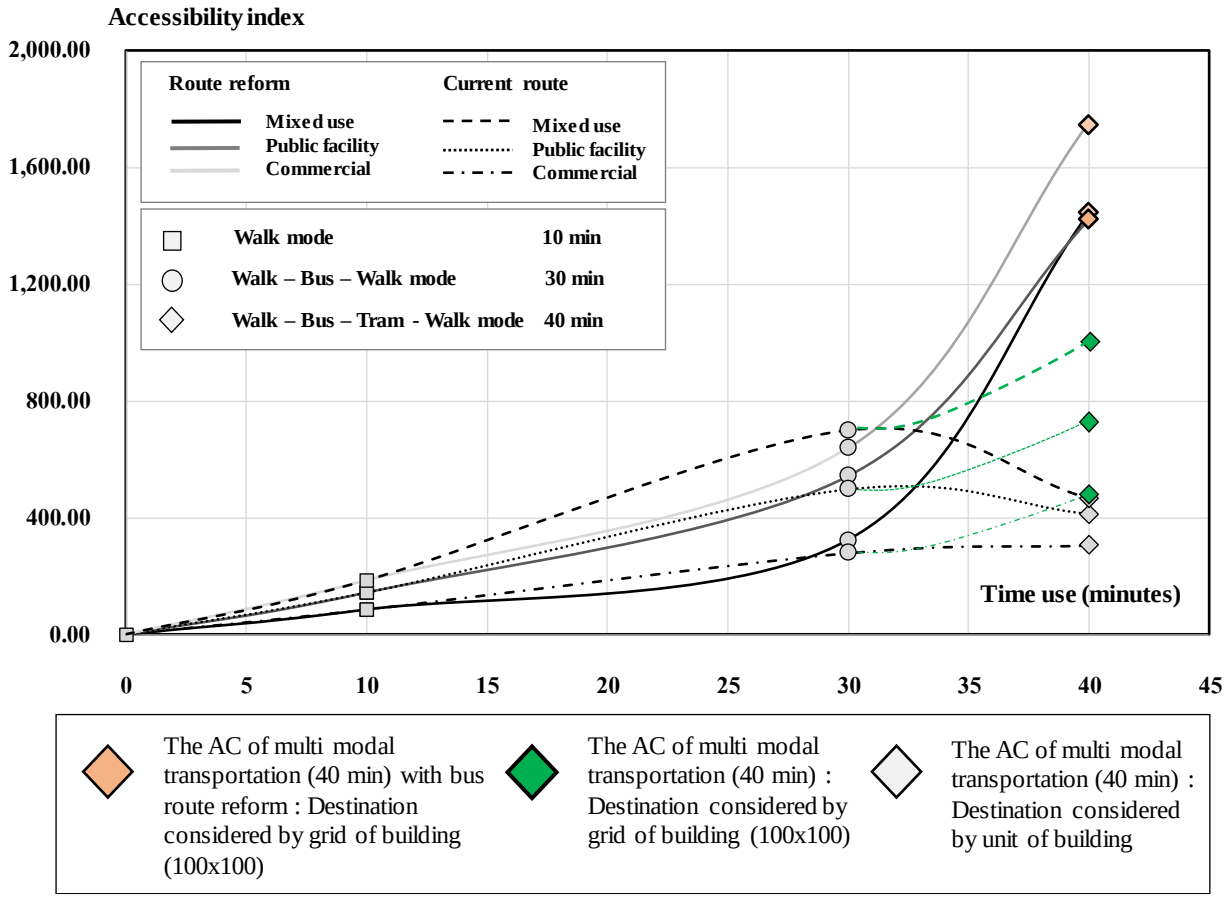


Figure 5.7. Three modes of multimodal transportation are represented in the accessibility index

Table 5.2. Accessibility index with multimodal transportation.

Time use (minute)	Multi transportation	Accessibility index					
		Mix use		Public facility		Commercial	
		Reform	Current	Reform	Current	Reform	Current
10	Walk	85.05	85.05	143.20	143.20	184.77	184.77
30	Walk–Bus–Walk	323.14	279.26	541.99	498.02	638.31	697.62
40	Walk–Bus–Train-Walk	1,443.03	465.43	1,420.43	740.04	1,748.78	984.91

Firstly, the framework of precondition route consideration was discussed in **Table 5.3.** while contributed in the travel distance and marginal trip as the distance amongst rail stations, the secondary-street connection, and intensity levels of urban rail promotion with the city planning policy. The practical implementation in real situation suffered by: 1) The performance of routes connected within different road network authorities; 2) The real case of physical infrastructure as unprovided for new bus-stop point; and 3) The pre-designed bus route returning point is over than a 300-meter rail station buffer area.

Table 5.3. Route Reform Consideration Framework

No.	Network	Assessment	Concept reform	Impact
1	Bus Network : Primary Mode	Accessibility Index by the Individual Route	1. Gentrification 1.1 Perndicular Track 1.2 Rail station's Buffer. 2. Route physical and Regulation 2.1 Route Conectivity 2.2 Route Authority 2.3 Physical and Infrastructure. 2.4 Redundant Rate. 3. Social contribution 3.1 Fixed Origin and Destination.	Urban transit mobility Inaccessibility Opportunities Accessibility capability
2	Bus and Train Network : Feeder and Primary Mode	Accessibility Index by the Whole Network		

The data analysis focused on the distinct and fundamental prospect of route transformation as the ideal buffer distance of rail stations had established 169 new bus-stops. It was resulted as 4 of 6 route trips by mixed-use unit, 6 of 12 route trips by public-facility unit, and 6 of 12 route trips by commercial-use unit; the accessibility index of the reformed route was lower than that of the conventional route. In case of the individual route consideration, the side effects from both cases were presented by accessibility values within a 30-minute evaluation as seen in **Figure 5.8.** However, the reformed route had extended the route length by average 11% of the conventional route with some effects on the time consumed for the whole network.

This section was presenting in the Journal of Regional and City Planning (Indonesia).

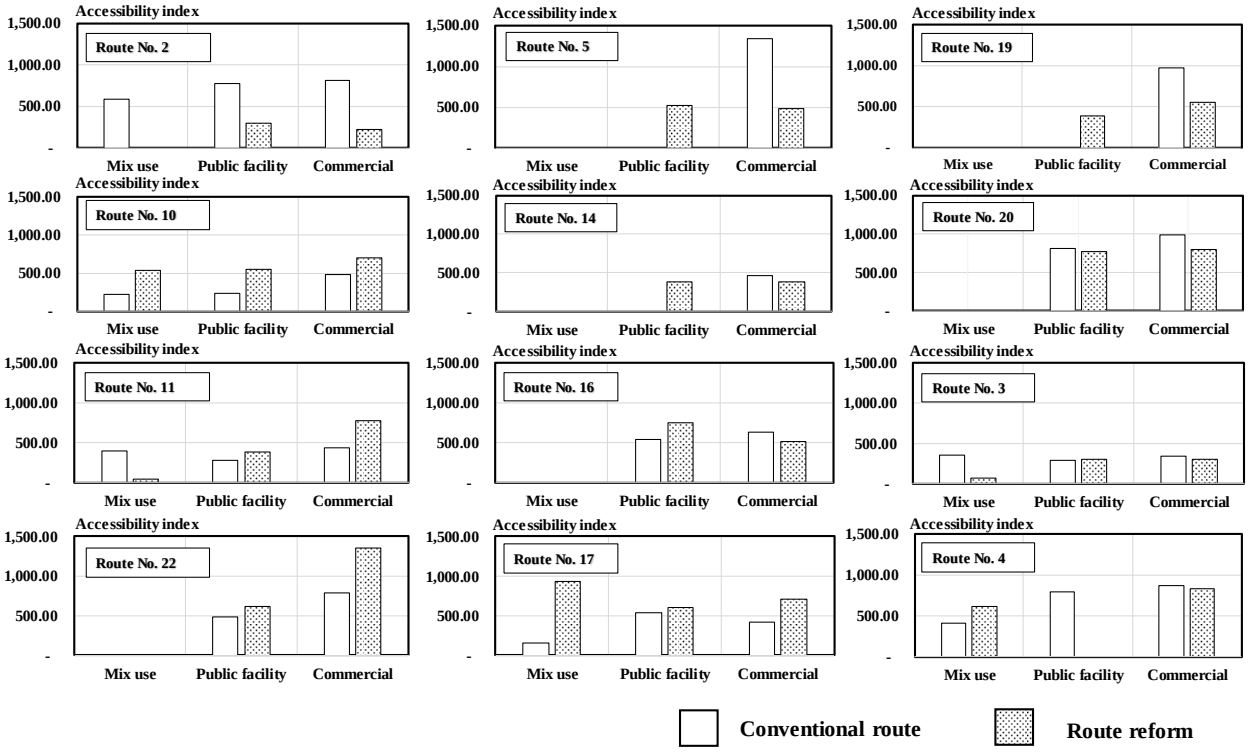
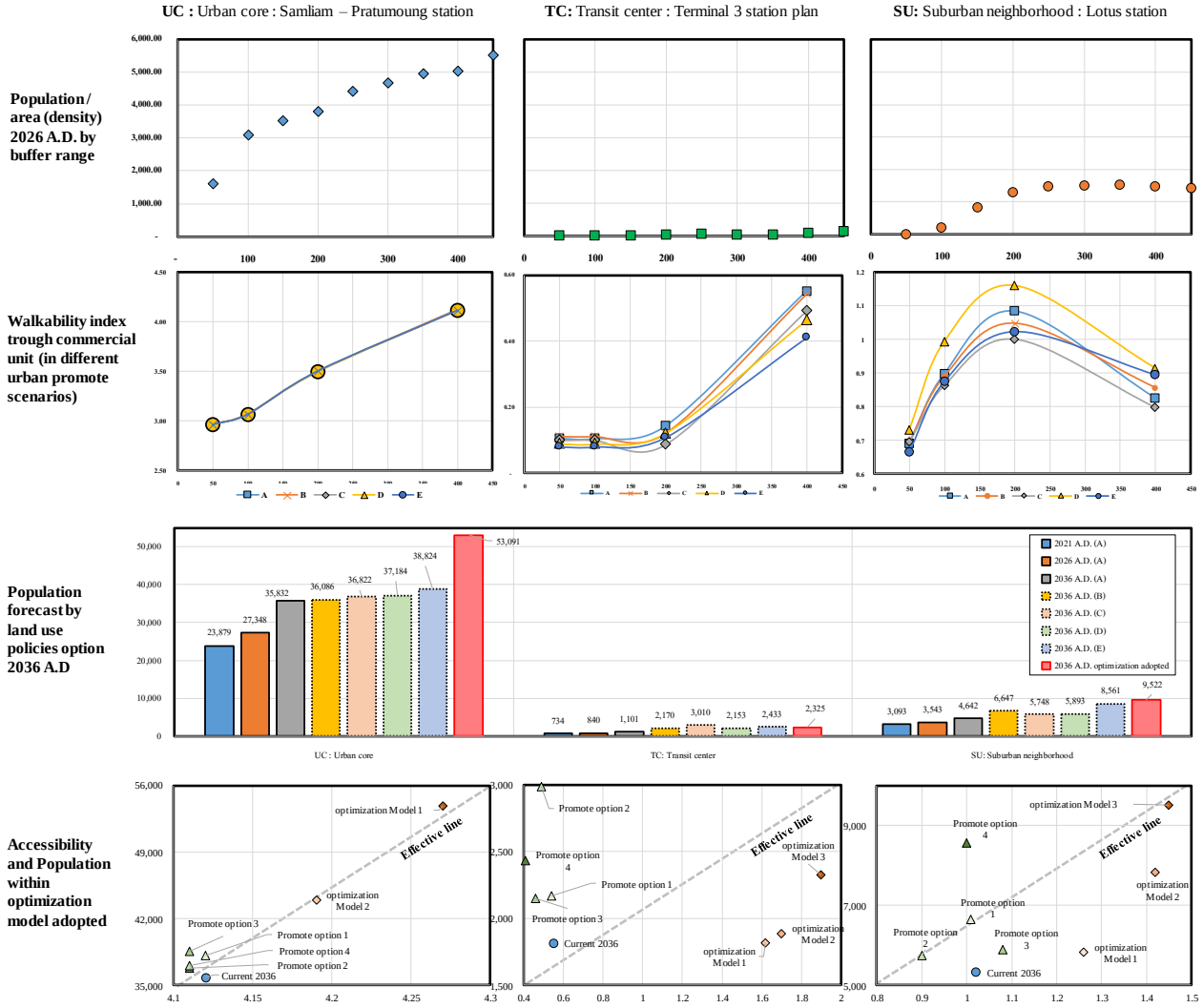


Figure 5.8. Each route has an accessibility index comparative.

5.6 THE FUNDAMENTAL OF TRIP ACCESSIBILITY BY URBAN RAIL NETWORK CONSIDERATION, COMPARATIVE BY TOD POLOCIES AFFECTED.

Basically TOD principal are urban policy maker equipment which fulfilled the customer demand density of 800-meter station's catchment area. The TOD district options was successful development within various parameter, definition and environment. Basically, the capability of walkable is most important that including satisfaction, safety, parking, side walk environment, cycling ETC of walkway. This chapter carries on by adopted the objective based optimization concept to specific restrictive condition that explore the visualizers the location of effective promote. The research notions integrate and images the phenomenon in advance that shown the affected of policies options based population compose which comparative between walk accessibility and population expected. The result shown in **Figure 5.9 -5.10**.



No promote

Non-range, present DID limit by 40 DID for promote **low DID** (lower 20) to 40

Non-range, present DID limit by 40 DID for promote **medium DID** (20-39) to 40

In 0 - 400 radius of rail station, promote **medium DID** (20-39) and **low DID** (lower 20) to 60 DID

In 401 - 800 radius of rail station promote **medium DID** (20-39) and **low DID** (lower 20) to 60 DID

Currently scenario - No promote

TOD promote by zone, Non-range, present DID limit by 40 DID for promote low DID (lower 20) to 40 called promote option 1

TOD promote by zone, Non-range, present DID limit by 40 DID for promote medium DID (20-39) to 40 called promote option 2

TOD promote by zone, In 0 - 400 radius of rail station, promote medium DID (20-39) and low DID (lower 20) to 60 DID called promote option 3

TOD promote by zone, In 401 - 800 radius of rail station promote medium DID (20-39) and low DID (lower 20) to 60 DID called promote option 4

Location optimization by GRG model in TOD 800 meter buffer. 1 constrain (Limit population)

Location optimization by GRG model in TOD 800 meter buffer. 2 constrain (Limit population and expect accessible index value)

Location optimization by GRG model in TOD 800 meter buffer. 3 constrain (Limit population and expect accessible index value and control grid population in each grid)

Figure 5.9. The charts of population, effective range of walkable in different TOD promoted options cases

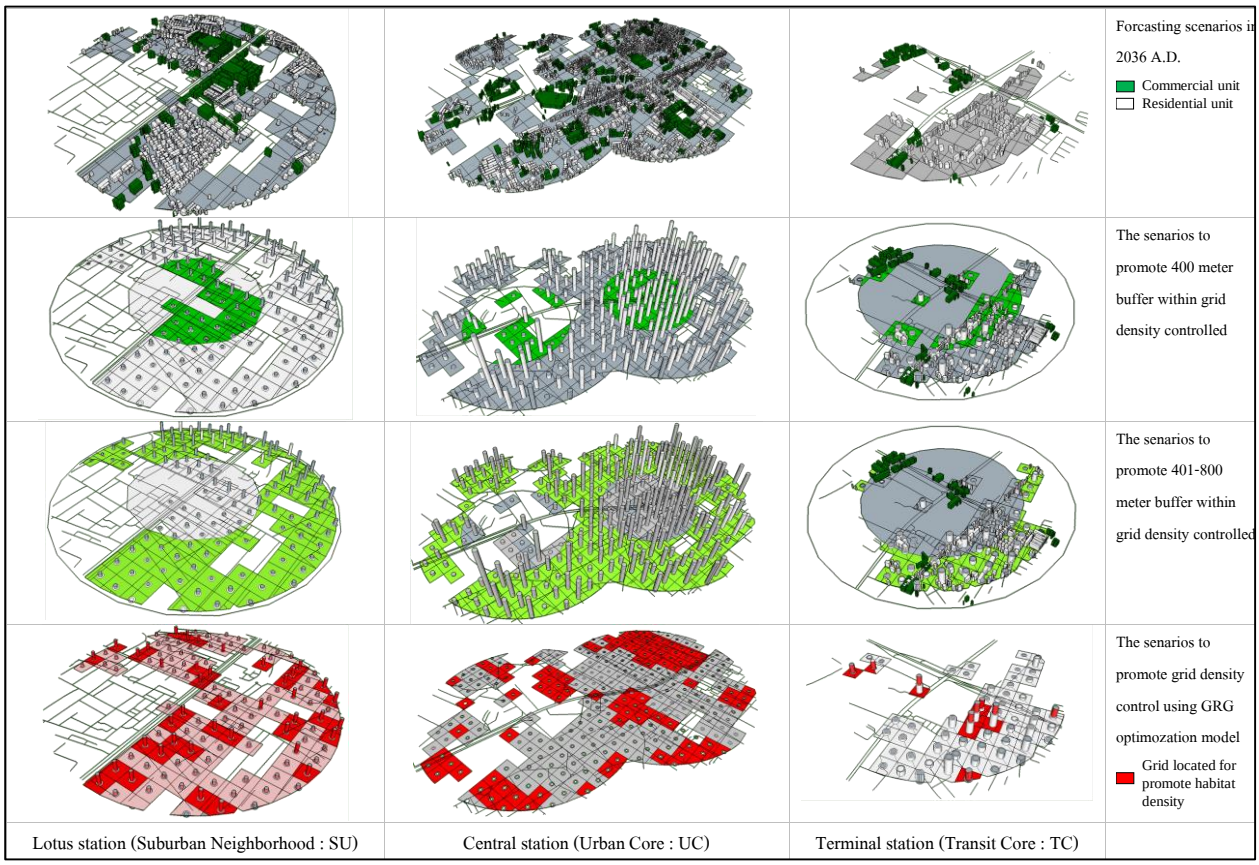


Figure 5.10. The 3 urban morphology cases present by DID grid index

A high density that was allowable for residential zone could firmly promote the attractiveness in the area with the corridor level of bus network along the route. However, the TOD city plan promotion could suffer from the immigration phenomenon while it was typically relying on the economic encouragement promotions. In KhonKaen, the TOD plan had been launched in 3 station areas (an 800-meter buffer zone of rail stations) (Huang, R. et al., 2018) including: 1) Urban Core (UC); 2) Transit center (TC); and 3) Suburban neighborhood (SU) as seen by **Figure 5.11.** The TOD promotion in 2036 A.D. with land acquisition, high rise building permit and financial encouragement within 3 TOD location plan was required for the possible population expectation by Grid density index promoted by GRG modes as seen in **Figure 5.12.** Meanwhile, the TOD promotion support around 6 % of the total population on the city scale. The fundamental concepts of the compact city would to provide the effective land use around stations that effective for bus access and the feeder performance indicate that it was effective to get in to rail network, both are critical issue of concerns for the city planning issue.

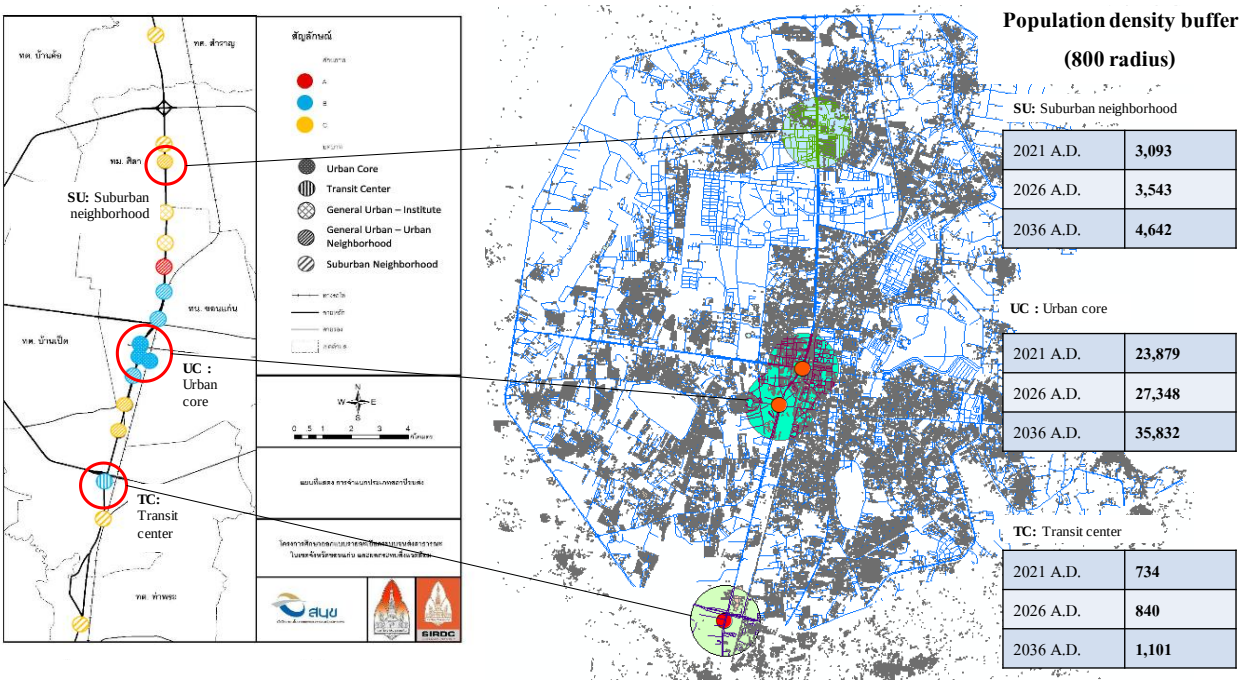
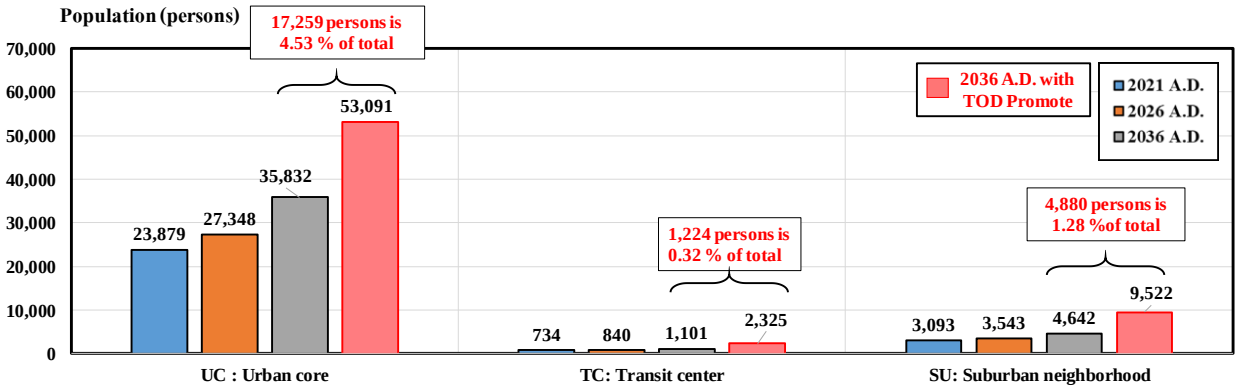


Figure 5.11. Population Number in an 800-meter Buffer Zone of Rail Stations from 2021 – 2036 A.D. (EIA report. (2018)



Remark : Population forecast in 2036 A.D. in urbanized zone is 380,577 persons

Figure 5.12. The population forecast in TOD zones (2021 – 2036 A.D.)

5.7 CONCLUSION

The analyses from the previous four chapters would be consolidated and presented in Chapter 6. This chapter is divided into sections, the first of which explains the relationship of urban demographics with the conventional public transit (bus network). The urban rail mass transit investment plan was also required to be supported by the city plan considerably. The multimodal transportation session will explain both of the two network integrations that prominently display feeder performance and rail station performance as perceived by destination elements. Those studies found the hidden performance of bus feeder networks in cities that are encountering sprawling cases, as seen by economic growth along main streets in comparison to the traditional bus route mentioned above. According to the three hierarchy's analyses represented, the research investigates the viability of feeder change policy and conservation effect points for all stakeholders in those networks. Finally, the policy's scale intensity of the city directly affects urban mobility; the urban plan is a milestone for gathering all associated characteristics based on practical measurement in order to develop effective urban mobility proposals.

CHAPTER 6

DISCUSSION AND CONCLUSION

6.1 INTRODUCTION

This session would discuss the parameters fragile, sensibility and scale consideration risk, based on the accessibility model by transport modal that have been discuss in chapter 3 and 4. The multimodal transport link over two mode calculated that define the sample sizes different from the single level consideration. In urban aspect, the catchment area presents the walkable performance to public transit accessed. The research presents the sensibility in research conducted in 3 leveling by 1. The sample definition risk 2. Cumulative represented 3. Grid size and consideration scale as the service area function within varies grid size presented that represent direct of demand transport in accessibility measure. Understanding the degree of suitability of the considered dataset size is therefore very important. Especially when the stakeholder applying multimodal transport interpreting the sum of that sample in many forms, such as sum of all populations, sum of paths possible, or sum of mean paths traveled. The summarize of dissertation was an integration 4 parts, presenting by 3D visualizes as the principle of urban rail public transport development project represented by Accessibility Index, Modes of Transport (Unimodal and Multimodal evaluation model), Scale Intensity (as the urban recognize and promoting scale), and Policies Trends.

6.2 THE SAMPLE DIFFINITION RISK

The definition of Origin demand transport perceived by habitat units. Based on the accessibility model investigate that was adopted the population in different definition as shown in **Table 6.1.** and **Figure 6.1.** The meaning of associability in the definition of accessibility measures is the relative between the urban land use consideration and public transport network measurement while commuted the reachability is based on times-temporal examined.

Table 6.1. The sample definition risk

Model / Assessment index	Conventional form	Accessibility measure parameter
Unimodal transportation / Accessibility index	$AC_i^m = \sum_{j \in [t_{i,j}^m < T]} D_j, D_j = LogA_j$	D_j is cumulative population by Service Area walkability to bus stop.
Multimodal transportation / Accessibility index	$Ai = \sum_{n=0}^{\infty} \frac{dij}{b_n} = \frac{(\text{Zone x Weight average})}{\text{sample size (n)}}$	Zone x Wight average is cumulative population by grid 100 x 100.

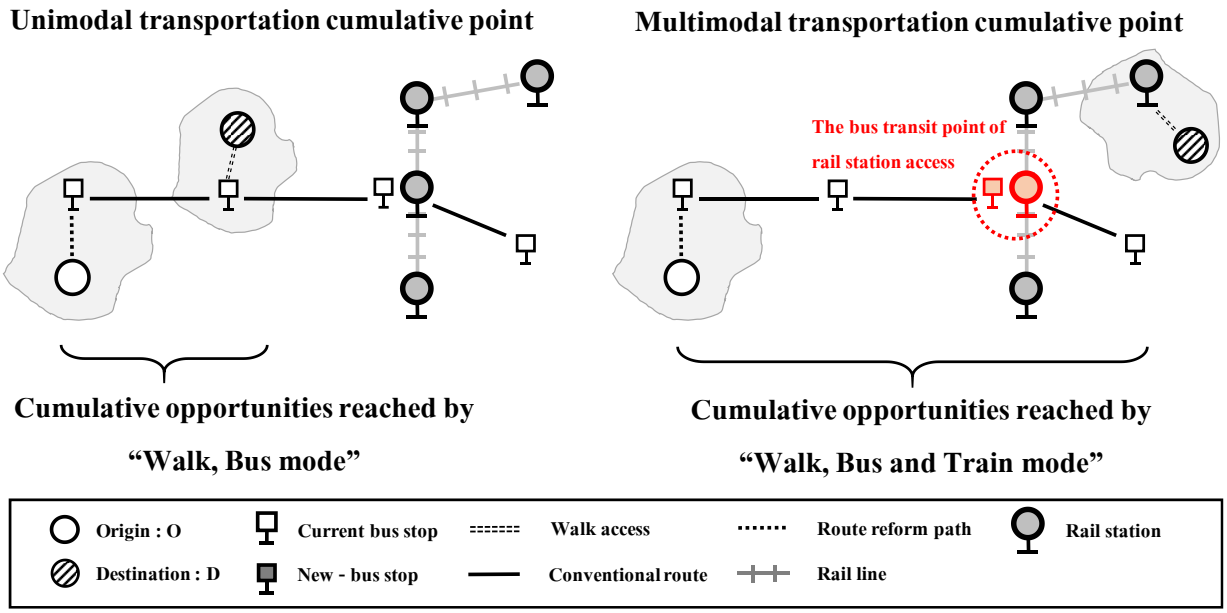
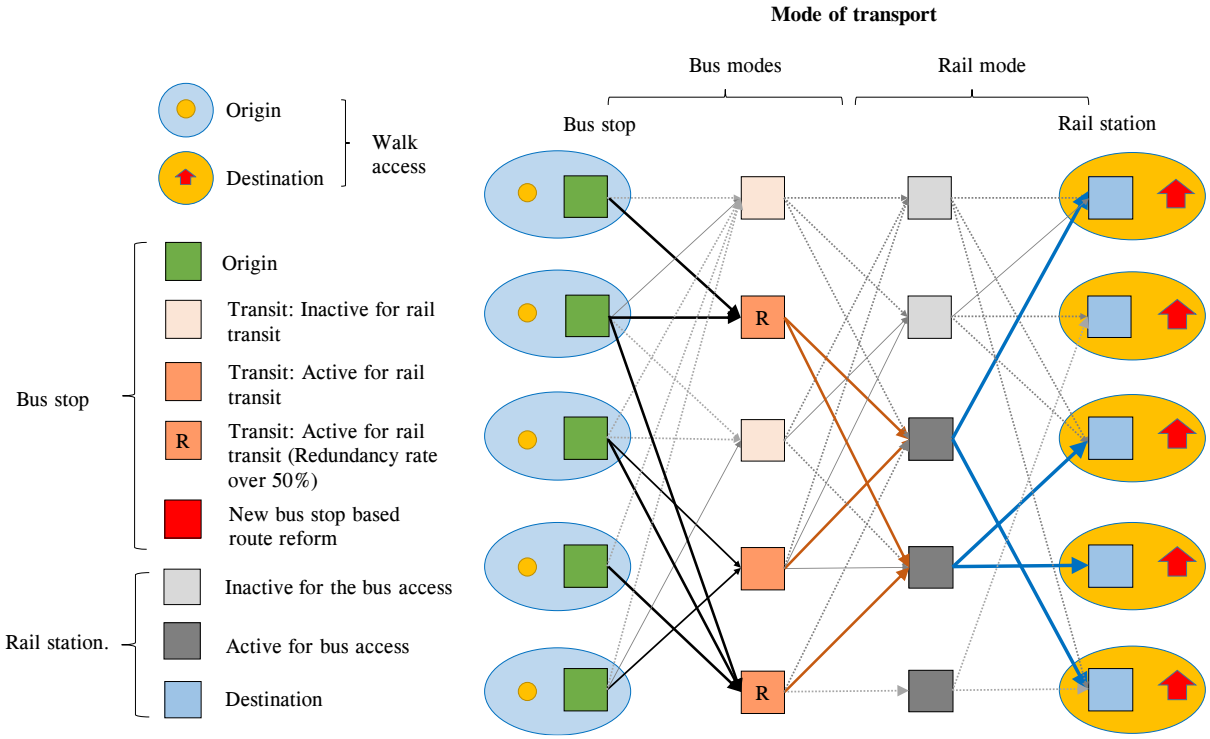
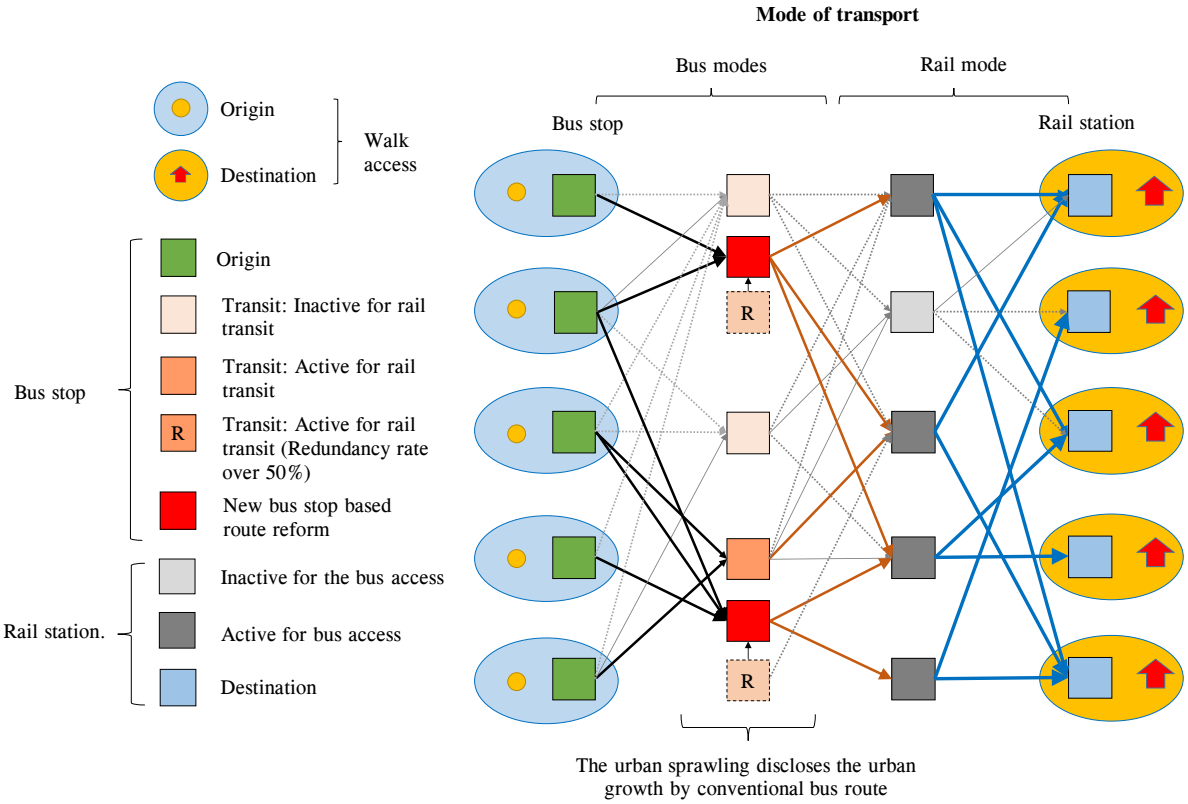


Figure 6.1. Unimodal and Multimodal transportation critical cumulative point.

Network-based metrics meaning is deploying the population by habitat units transfer to destination that execute by grid index, which active link of 2 mode transport determination. The simplification flow diagram of the application of Demand Responsive Connection and network-based metrics as **Figure 6.2**.



(A) Multimodal transport assessment based 'conventional bus route" schematic flow diagram



(B) Multimodal transport assessment based "bus route reform" schematic flow diagram

Figure 6.2. The application of Demand Responsive Connection and network-based metrics simplification schematic flow diagram. (A) is conventional bus route and (B) bus route reform

6.3 CUMULATIVE REPRESENTED

The definition of sample in different session. Based on the accessibility model investigate that was adopted the ratio divided in different definition as shown in **Table 6.2.**

Table 6.2. Cumulative represented

Model / Assessment index	Conventional form	Divided parameter
Unimodal transportation / Accessibility index	$\overline{AC} = (\sum_{p} N_1 AC_1 + ... + N_n AC_n)$	Sample sizes; Not consider.
Multimodal transportation / Accessibility index	$Ai = \sum_{n=0}^{\infty} \frac{dij}{b_n} = \frac{(\text{Zone x Weight average})}{\text{sample size (n)}}$	Sample sizes; Number of population access new bus stop access to rail station.

6.4 GRID SIZE AND CONSIDERATION SCALE.

The size of consideration as comparative by 4 level presenting 1. 500x500 m^2, 2. 250x250 m^2, 3. The 100x100 m^2 and 4. 10x10 m^2. The research contribution within 100 x100 m^2 grid size which was fit and test in 4 different grid size that is effective population and area present. Besides, there were DID parameters (inhabitant/ha) indicating various levels of the classification. As the analysis result, the 500x500 m^2 grid size cover all the land use considering but the size of grid doesn't fit on bus stop service area. Besides, the 10x10 m^2 are effective for bus stop service area determined but the population lost along the boundary line are low performance than 100x100 m^2. The comparative result shown in **Table 6.3.** and **Figure 6.3.**

Table 6.3. Grid size comparative by population, population lost and area lost

		Grid size (m x m)			
No	**Parameters**	**500 x 500**	**250 x 250**	**100 x 100**	**10 x 10**
1	Total area (square. Kilometer)	174.25	166.00	161.37	158.77
2	Livable (square. Kilometer)	155.50	116.43	81.2	8.04
3	Total population	274,824	274,824	274,824	274,824
4	Total population (by grid)	274,824	256,417	273,060	272,832
5	Population lost	0	18,406.61	1,764.11	1,992.03
6	Parameters	500 x 500	250 x 250	100 x 100	10 x 10

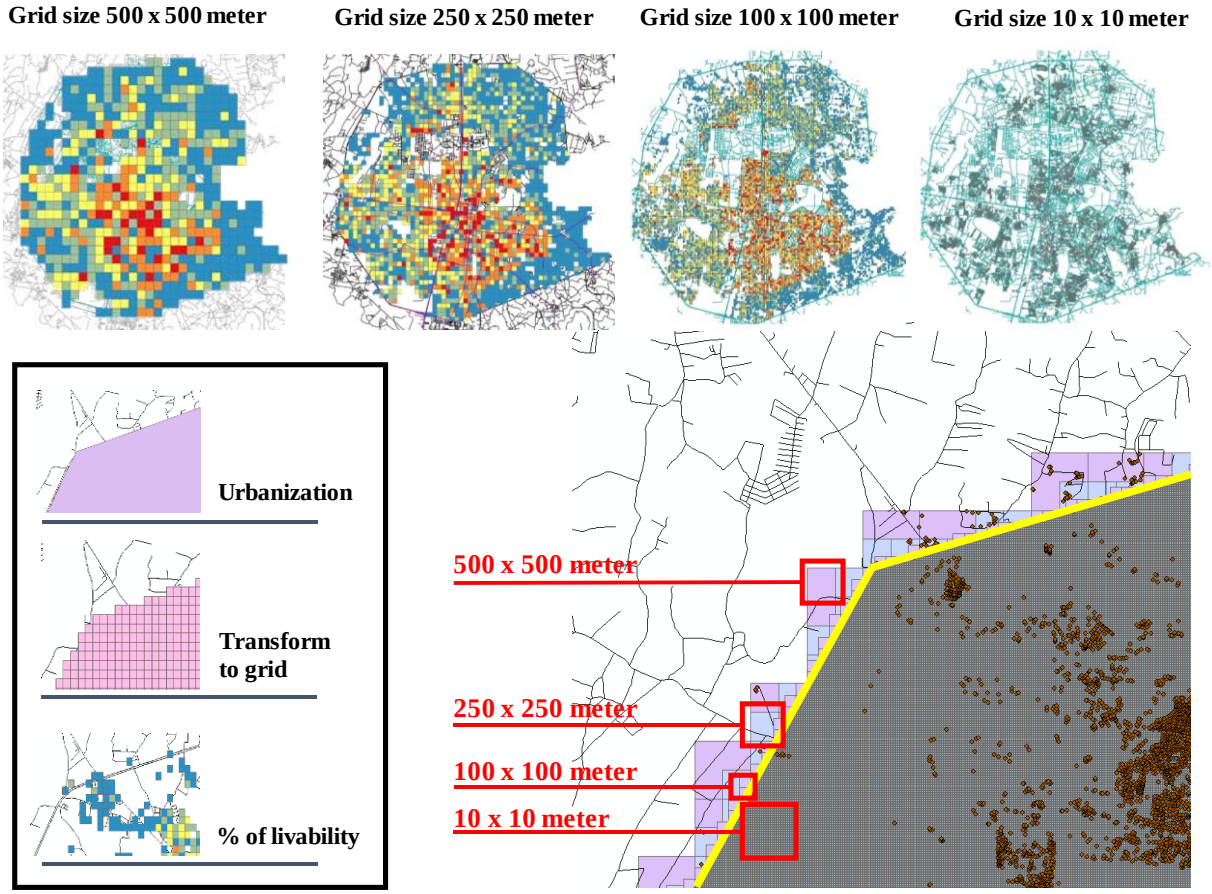


Figure 6.3. Grid size comparative

The author adopted the grid index scale techniques for cumulative the building facility destination number in grid 100x100 that impose the meaning of access expanding the meaning of reachable. Besides, the policy maker must realize the sample size analysis while were effected the boundary of considering as the gentrification regulation, the authority and so on. This explained by **Table 6.4.** and **Figure 6.4.** The grid size and consideration scale effect.

Table 6.4. Destination Grid consideration

Model / Assessment index	Destination Grid
Unimodal transportation / Accessibility index	Cumulative area (logarithm form) by Service Area walkability.
Multimodal transportation / Accessibility index	Cumulative area (logarithm form) in grid 100x100 meter by Service Area walkability.

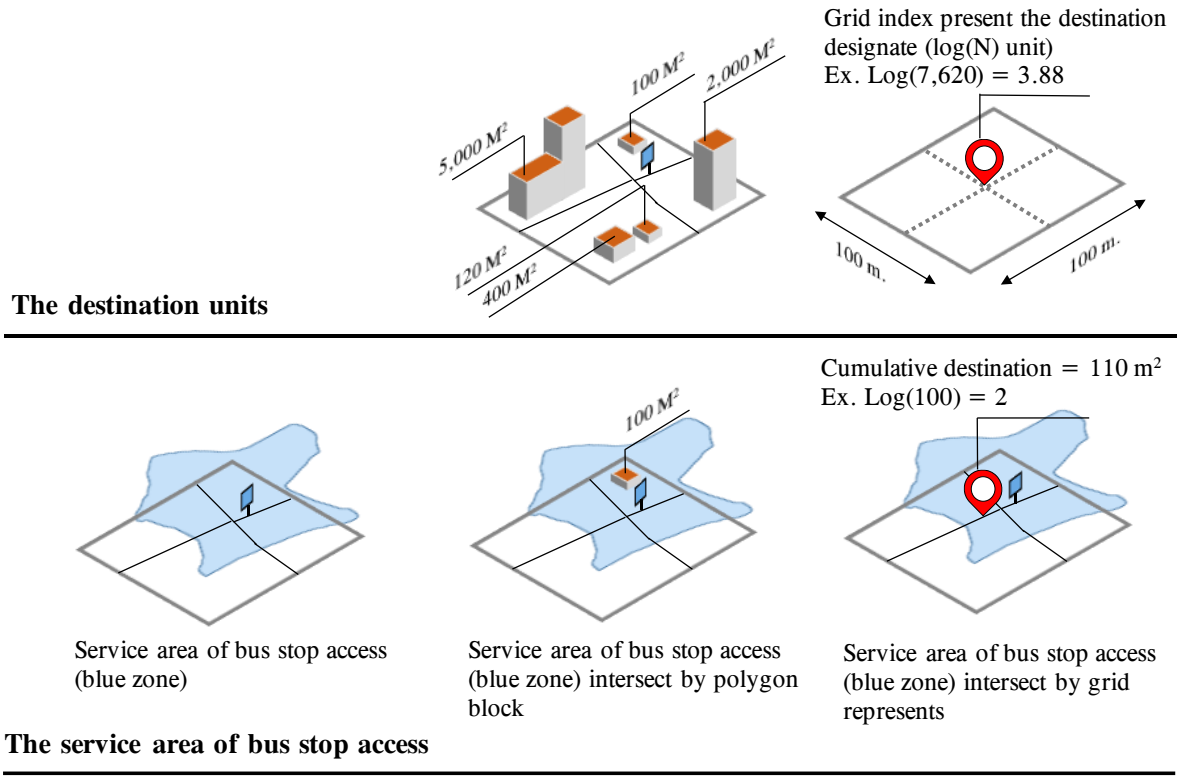


Figure 6.4. Grid size and consideration scale effect.

6.6 THE PRINCIPAL OF URBAN RAIL PUBLIC TRANSIT DEVELOPMENT PROJECT REPRESENTED BY ACCESIBILITY INDEX, MODE OF TRANSPORT, SCALES INTENSITY AND POLICIES TRENDS.

The result was representing ideal concept while support the urban guidance and measurement the city plan that proposed urban rail public transport project. The multimodal

transportation presents a well-studied model of traveling. The smallest urban rail as the TRAM project position's to be the primary mode of transit with the bus system functioning as a feeder, and the zoning compaction concept was applied as a Transit Oriented Development: TOD and locality (District zone) has been reveal the relative connections. Firstly, the results exploring the natural character while significantly present the relative of the urban accessibility index and modes of transport network integration, the modes link by addressing the primary mode as urban rail network and secondary mode supporting as bus network called feeder, those relative present the effective scenario which presenting in green line and worth scenario by red line as seen by **Figure 6.5.** The natural character while significantly present the relative of the urban accessibility index and modes of Multimodal transport assessment.

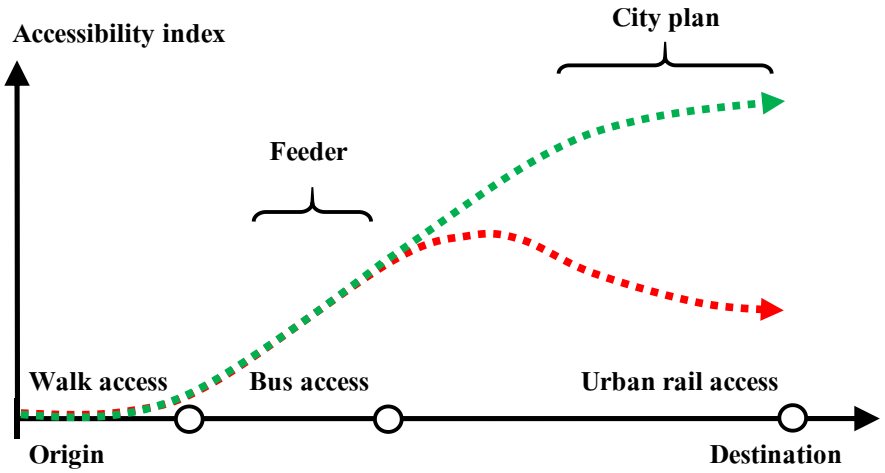


Figure 6.5. The natural character while significantly present the relative of the urban accessibility index and modes of Multimodal transport assessment.

Urban rail infrastructure utilizing enormous budget while was essentially needed for spatial interaction understanding the relationship between urban perception and public infrastructure. The knowledge profoundly leading to be guide and shape policies during the land use and infrastructural policy such as; the management of a city planning overview, high–density zone policy, and Transit-Oriented Development (TOD) and adopted the urban heritage zone promoting etc. The model clearly represented the urban perception mobility model based on the urban rail transportation investment plan. In KhonKaen Thailand sample cases were obviously efficient approach for city-level cooperation in both the public and private sectors to be tandemly integration of innovative polies as from the top view by city plan paradigm to bottom up as the creative economy district.

The research investigated present model for universal usefully cases where plan to invest the Urban rail transit. Furthermore, the 4 path of research are strongly present the relative parameters development comprising between 1. The urban intensity levelling scale, 2. Accessibility index and 3. Mode of transport as presenting 3D visualizes as seen in **Figure 6.6.**

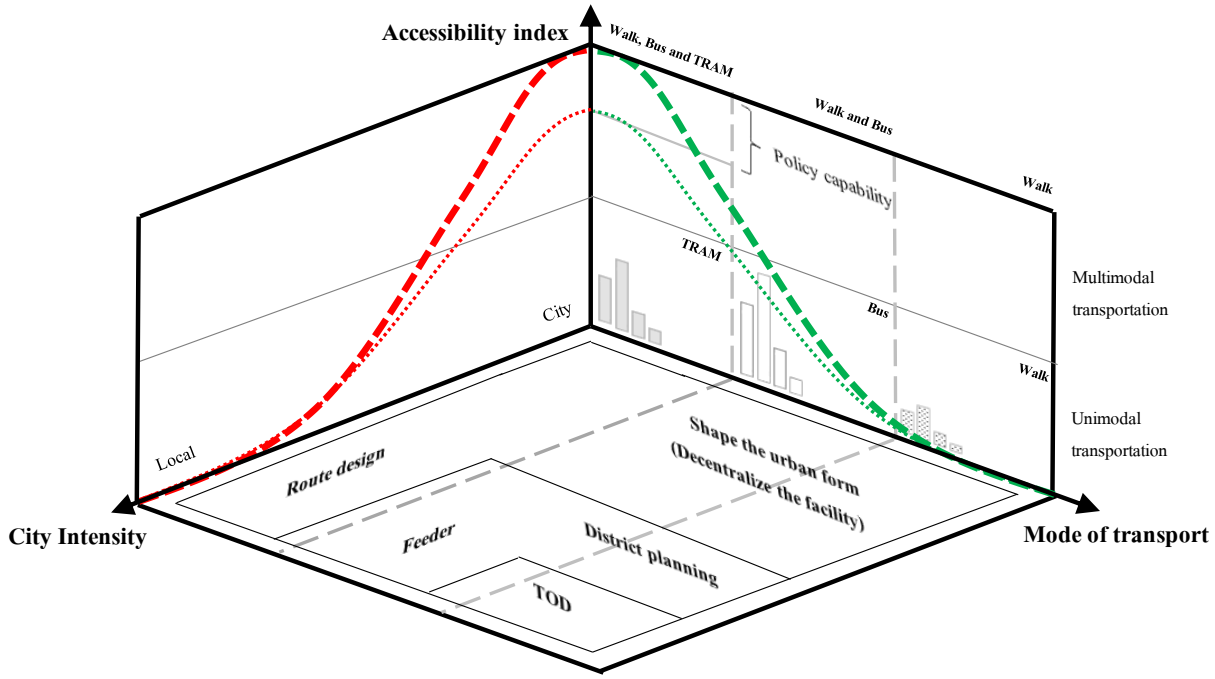


Figure 6.6. The principal of accessibility index, mode of transportation (Urban mobility) and intensity of city scale

The analysis case discloses the mechanics of public transportation, particularly bus network transformation in relation to urban economic, where the main street runs parallel. The study found that a bus route reform policy that preserves the route proposal on the train station attractiveness is achievable to reveal the hidden performance of bus network while consider in term of feeder. Although, the urban innovative policies as transit oriented development: TOD promote was an options to intended the urban densely but the multimodal transport assessment revealed choices of the urban innovative policies initiating that exploring the widely perspective of innovative policies. The effective urban mobility doesn't have been performed without the initiated shape of urban form and plan, also the urban mass transit was needed. These shifts might be an effect to difficulties enforcing regulations on operators. The results indicate that existing regulations in those regions may be altered, both structurally and in terms of the organizations' rules. The expressly define of urbanism's effective linkages and rerouting opportunities as the regional center, urban center, transit town center, urban neighborhood, transit neighborhood, special use, employment district, and mixed use centroid were all involved in the urban creative methods. In the developing countries, the intensity of urban form has hardly been mentioned since the route possibility seems to be the more applicable factor. Still, the reshaping of the conventional bus route is likely an alternative approach to complementarily support an effective feeder-bus network. In the meantime, the development of a public transit network such as DRC is increasingly becoming crucial especially within the sprawling residential areas. Lastly, the developmental models are elaborating on the relationship of the city from the local scale to global scale that effectively arranging base on public transport mobility.

This section will be presenting in Fifth International Conference on Railway Technology: Research, Development and Maintenance 2022. (Monday, 22nd August, 2022 - Thursday, 25th August, 2022) - Le Corum, Montpellier, France.

The dissertation present the policies framework amongst walk, bus, and rail network transit and the policies intensity levels. The practical implementation reveals the concepts in different scope consideration such as : 1. Walk & Local scale policy : needed to promote job-employment (Mixed-use promote) ; 2. Bus & Local scale policy: needed to determining the secondary layer readjustment and effective bus access territory and 3. Train and City scale: needed to apply the compact city (City-region level) to due the make an appointment between timeframe of the Urban shape development and Route of construction plan as seen from **Table 6.5.** All those accessibility index integration indifferent aspects combining the image of Urban rail network modeling evaluation method development which able to adopted for the universal case where purposively imply the core of urban transport to be the Urban rail mass transit.

Table 6.5. Policies Consideration Framework of Urban Intention for Urban Rail Mass Transit Project.

	Policies framework					
	Modes of transport					
City plan vision	**Walk (Times focus 10 minutes)**		**Bus (Times focus 30 minutes)**		**Train (Times focus 40 minutes for Multimodal mode)**	
Local scale	**Transit oriented development: TOD**					
	Concept	**Indicator**	**Concept**	**Indicator**	**Concept**	**Indicator**
	○ Promote Job-employment (Mixed-use unit promote)	○ Job employment / sq./km ○ Gross Domestic Product: GDP	○ District zone (rely on the bus route) – (Corridor level)	○ Bus inaccessibility (persons) ○ Bus accessibility index for entire trip	○ Urban rail route design ○ The walkability (In TOD zone) – (Station area) ○ Pop-dense controlled of Rail stations buffer.	○ Route linked (High – Low density) / Area (km^2 unit), opportunity (Node and Place index) ○ Residential unit opportunities, promotion, investment, and encouragement.
			Feeder			
			Concept	**Indicator**	**Concept**	**Indicator**
			• Secondary layer adjustment • The effective bus territory.	○ The criteria of route reform ○ Bus accessibility index of reform network	• Transition zones • Facility provided	○ Investment budget
City scale	**City plan**					
	Concept	**Indicator**	**Concept**	**Indicator**	**Concept**	**Indicator**
	○ Compact city (City-region level)	○ The walk accesbility (Accesibility index) for City level. ○ Inaccessibility persons	○ Compact city (Corridor level)	○ Job employment / Pop-dense / Corridor level territory	• Guidances and timeframes for the project relating to the Urban shape and Route construction plan. • Urban facility management such as utility unit relocating and distributing	○ Milestone between the Urban plan and Urban rail investment plan

6.6 CONCLUSION

The land use scenario analysis with mass transit contribution required innovative strategies at the city region, corridor, station, and site levels (Daniel Zimny-Schmitt, Andrew R. Goetz. 2020). (Somsiri, 2018). Without the city plan paradigm based consideration, the urban will suffer the ineffective policies which according on urban rail mass transit plan. Therefore, anticipating geographical effective capacity in conjunction with the public transit service network is a necessary precondition for a city's competency. Through a time-temporal examination, the accessibility model development obviously shows the capability between land use and public transportation network. Finally, through the urban rail network, the dissertation creates a model for investigations in multiple forms of transportation in order to establish a comprehensive urban mobility approach.

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APPENDIX

Table 27. The Unicode reference by City tow and planning regulation. KhonKaen data (2018 A.D.).

Code	Code unit	Detail	Unit
Code 1 : Residential	1100	Private Housing	167,968
	1300	Governance housing	296
Code 2 : Community zone	2210	Market	202
	2220	Hotel high rise Building	1,519
	2230	Big mall	200
	2240	Petrol station	462
	2280	Local shop	7096
	2300	Bank	119
	2420	Club house	71
	2800	Retail car shop	1,,433
Code 3 : Industrial zone	3110	Industrial Community hall	459
	3120	Food manufacturing	13
	3300	Commercial building	217
	3800	Local big market	1,468
Code 5 : Public infrastructure	5130	Airport	62
	5150	Transport office 1	18
	5160	Railway station	23
	5180	TV Station	44
	5220	Television hotspot	26
	5310	Electrical hub	36
	5410	Provincial Waterworks Authority	34
Code 6 : Public facility	6110	Kindergarten	27
	6120	School	594
	6130	School inbound	868
	6141	School outbound	63
	6150	Technical school	128
	6160	University	1,833
	6180	Special school	227
	6210	Temple	2,314
	6220	Abbey	59
	6250	Small temple	16
	6260	Cemetery	4
	6280	Monk university	147
	6310	Town hall capital	83
	6320	District Office	38
	6330	Sub District Office	57
	6340	Police Station	77
	6350	Fire station	13
	6360	Unknown governance office	55
	6370	Jail	77
	6500	Small medical hub	6
	6510	Commercial building	154
	6520	Clinic pharmacy	17
	6530	Hospital	494

	6620	Museum	4
	6630	Library	2
	6650	Small medical hub 2	17
	6830	Maternity house	43
Code 7 : Recreation area	7200	Forest temple	6
	7322	Football stadium	22
	7340	Water park	11
	7380	Sport club	112

The bus route detail. KhonKaen data (2018 A.D.).

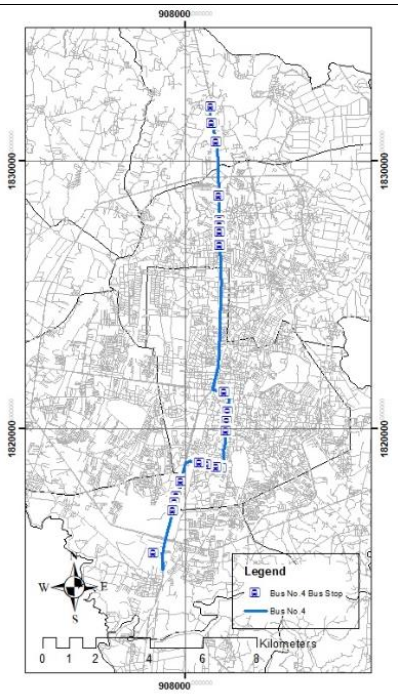

Figure A-1. Bus No.4 (Khonkaen terminal 3 - Ban nong nam kliang)

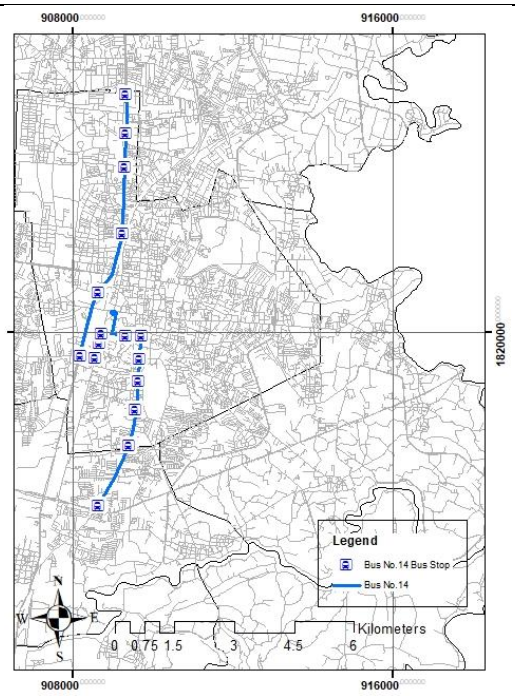

Figure A-2. Bus No.14 (Ban none tun - Police station 4)

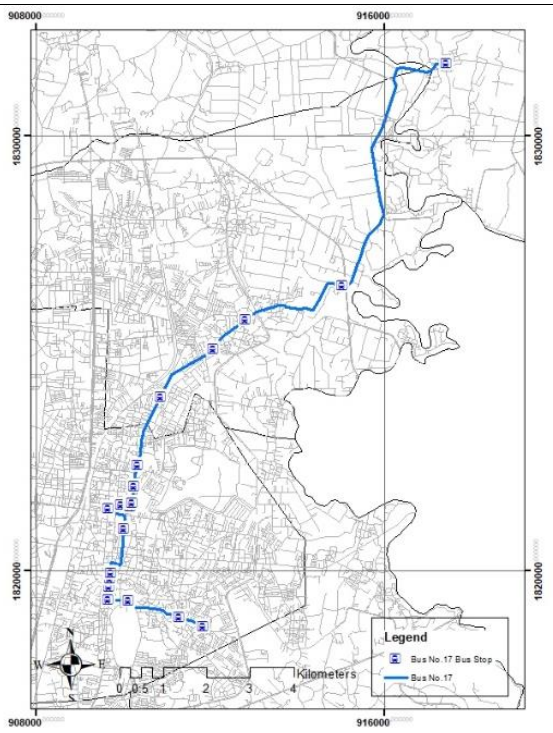

Figure A-3. Bus No.17 (Ban none tun - Ban khoktha)

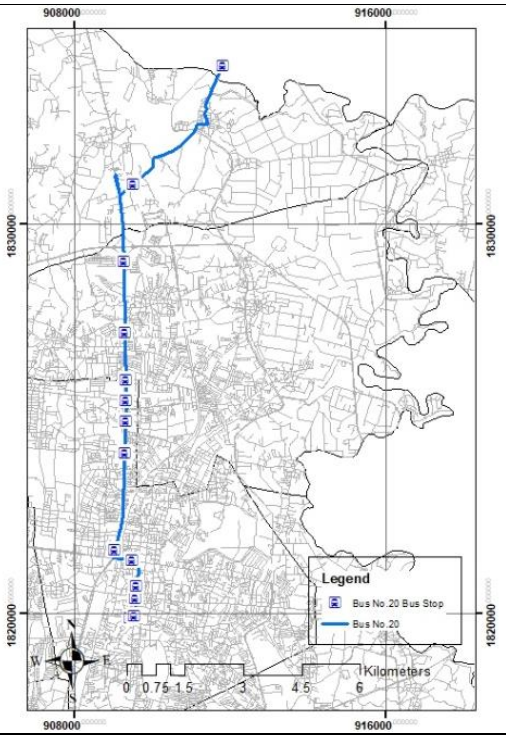

Figure A-4. Bus No.20 (Nong phai lom market - Klanghoong)

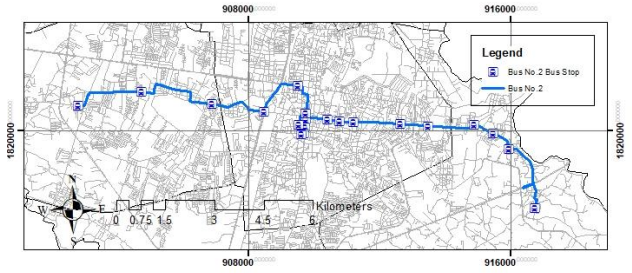

Figure A-5. Bus No.2 (Ban kok fan pong - Ban khok noi)

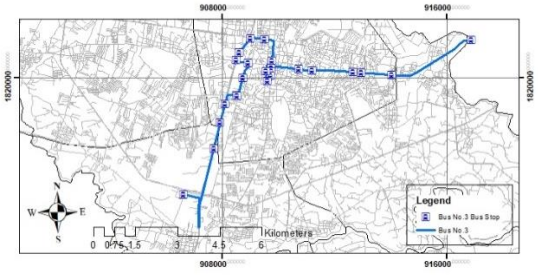

Figure A-6. Bus No.3 (Khonkaen terminal 3 - Ban pron nimit)

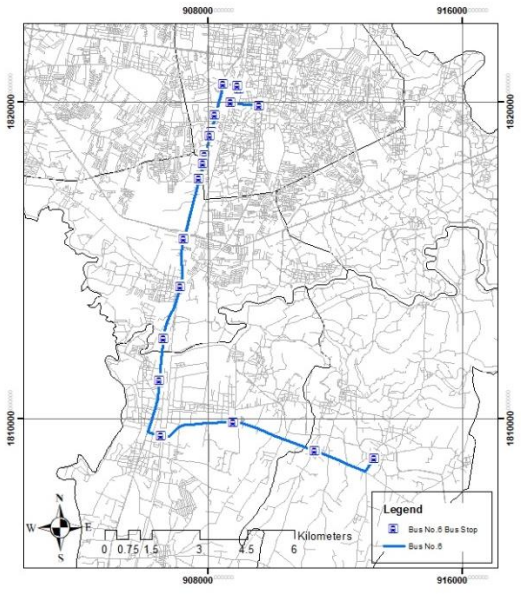

Figure A-7. Bus No.6 (Municipal 1 Food market - Ban lao nok chum)

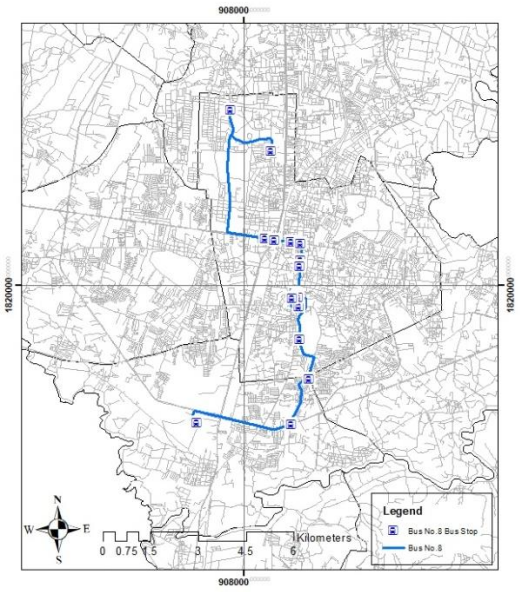

Figure A-8. Bus No.8 (Khonkaen University - Ban donbom)

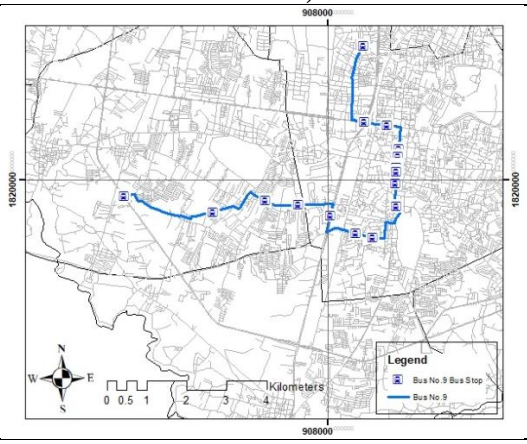

Figure A-9. Bus No.9 (Ban Sam Lieam - Ban sa at)

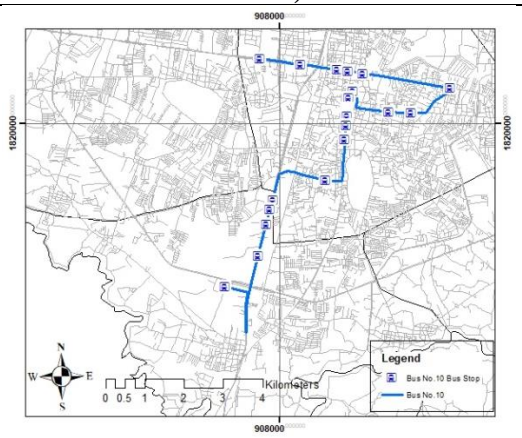

Figure A-10. Bus No.10 (Khonkaen University - Khonkaen club race course)

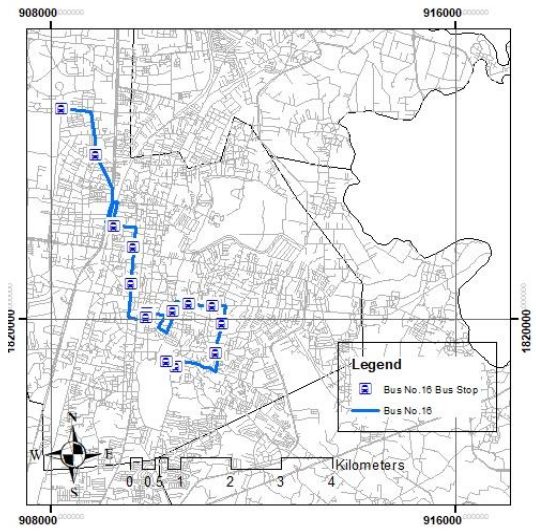

Figure A-11. Bus No.16 (Ban none tun - Adulyaram Temple)

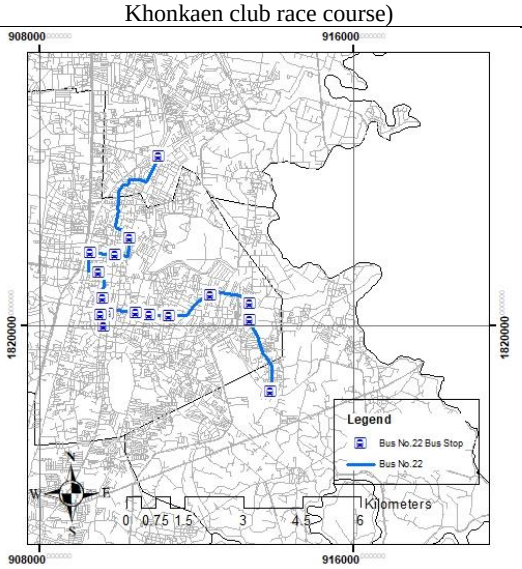

Figure A-12. Bus No.22 (Ban nong hai - Ban nong yang)

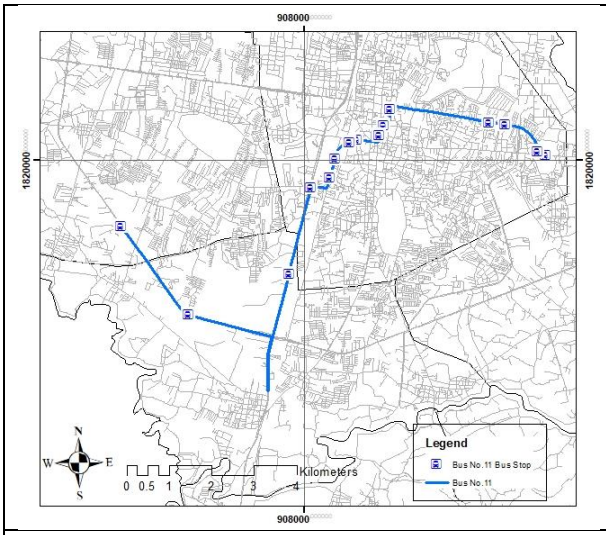

Figure A-13. Bus No.11 (Ban Non sawan - Ban kam Charoen – Maliwan Rd)

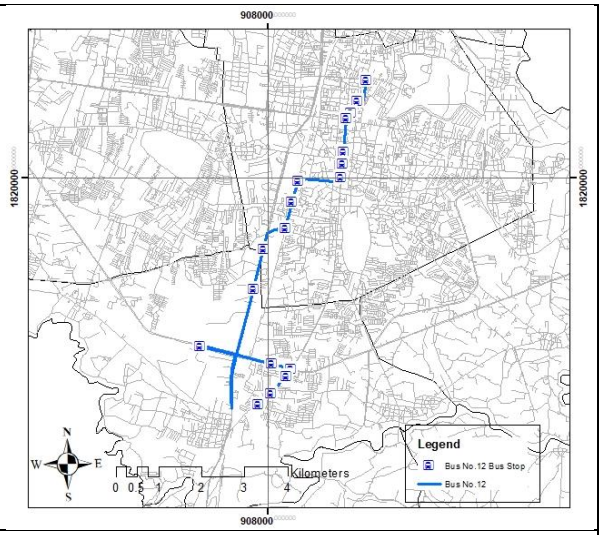

Figure A-14. Bus No.12 (Khonkaen national museum - Thepra wittayaon school)

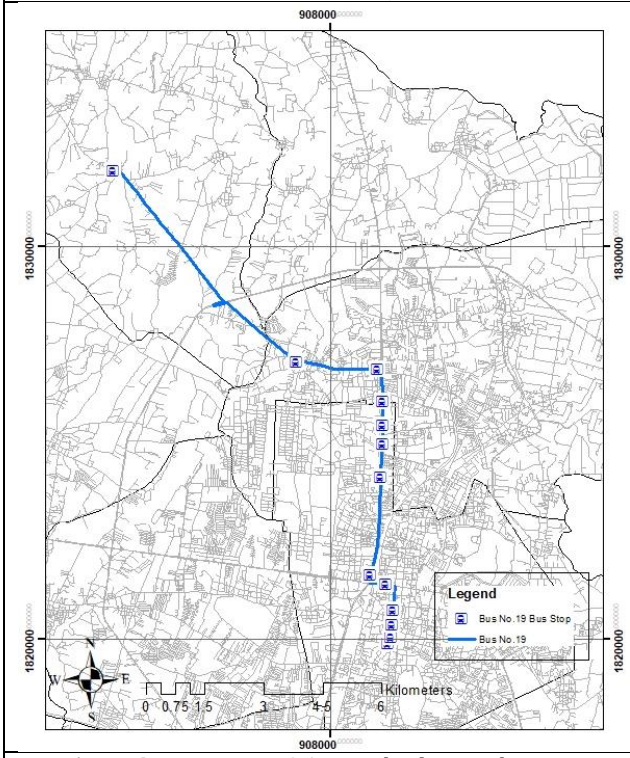

Figure A-15. Bus No.19 (Nong phai lom market - Ban noneruang)

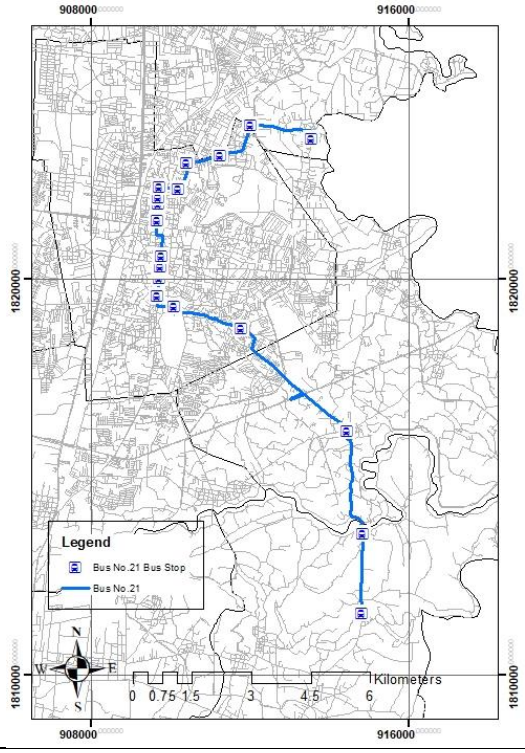

Figure A-16. Bus No.21(Ban none khawao - Ban donyang)

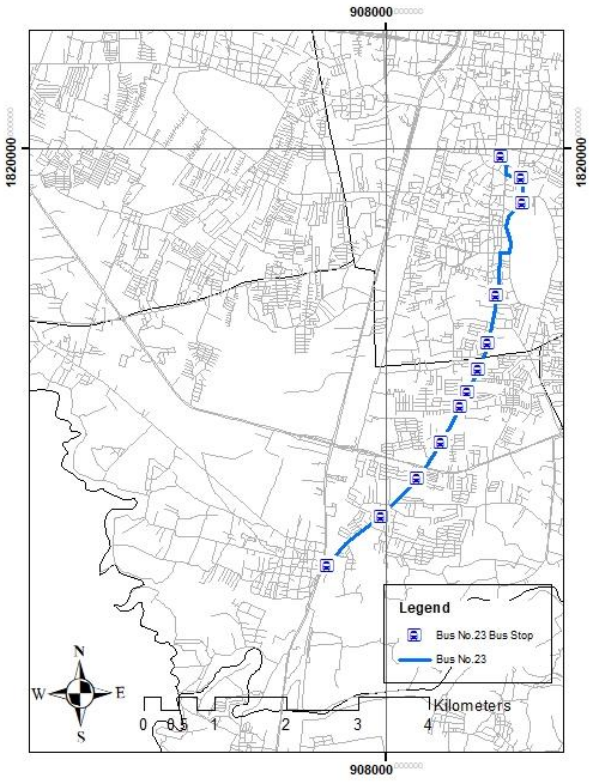

Figure A-17. Bus No.23 (Municipality 1 Food market - Ban huatoey)

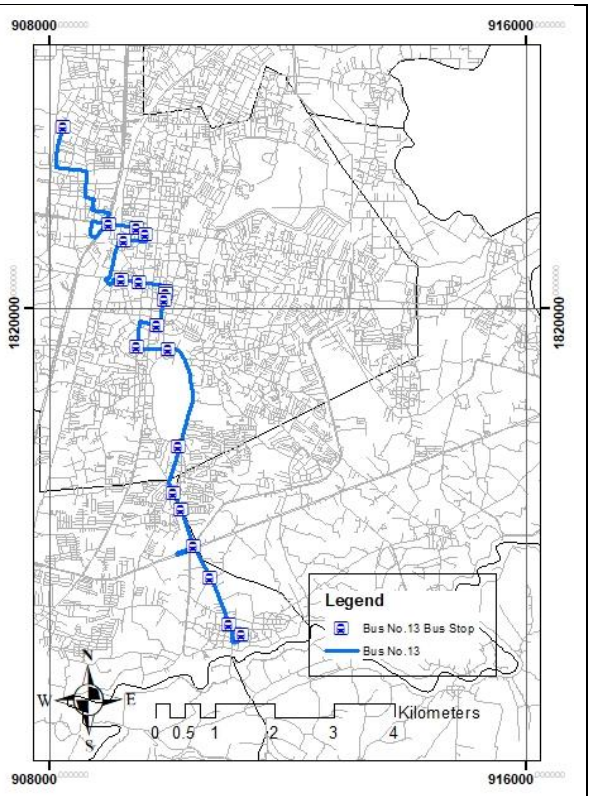

Figure A-18. Bus No.13 (Noi Nivet village - Sawang Mukana Co.Ltd)

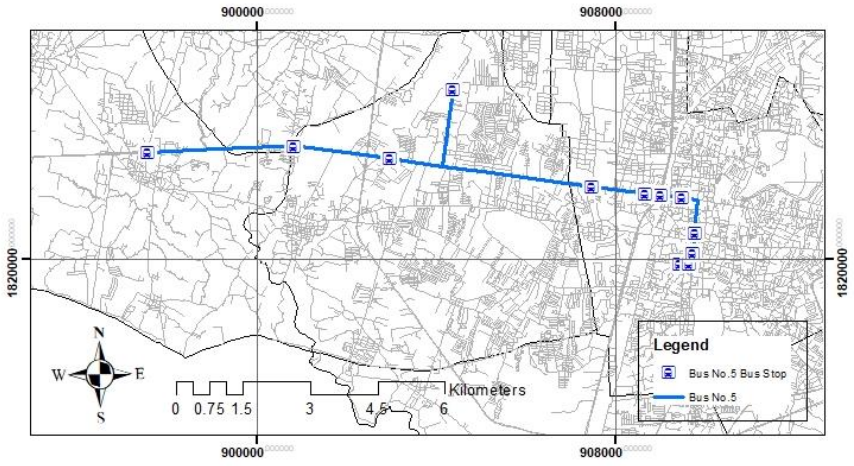

Figure A-19. Bus No.5 (Nong phai lom market - Ban tum)

The 800-meter buffer of rail station. KhonKaen data (2018 A.D.).

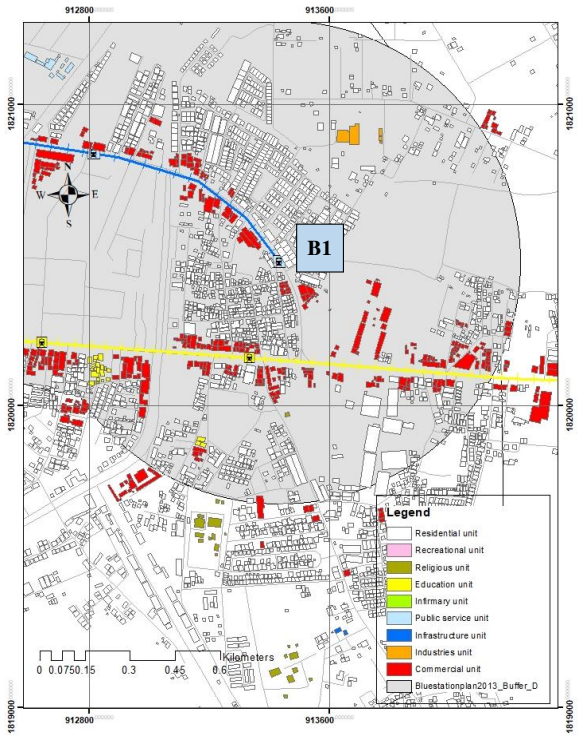

Figure A-20. Mitre Sampan (B1)

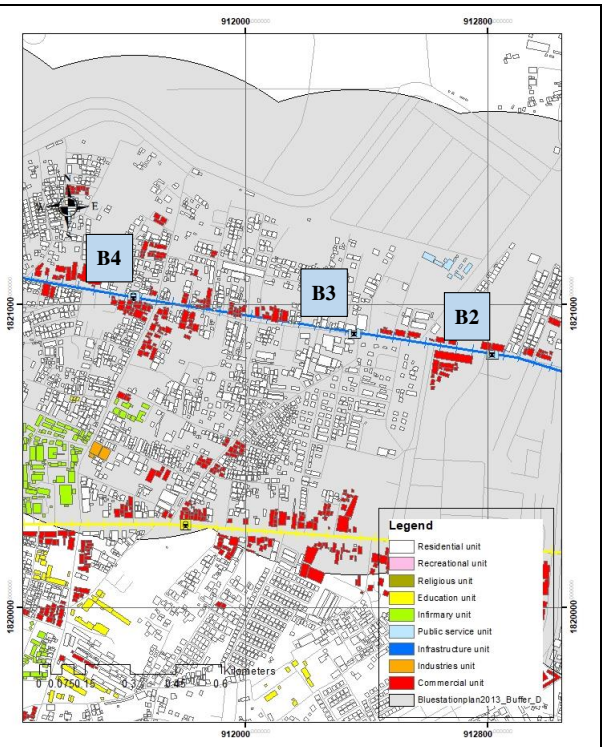

Figure A-21. RMUTI KKC (B2) - Bandit asia Uni (B3) - Chata phadung (B4)

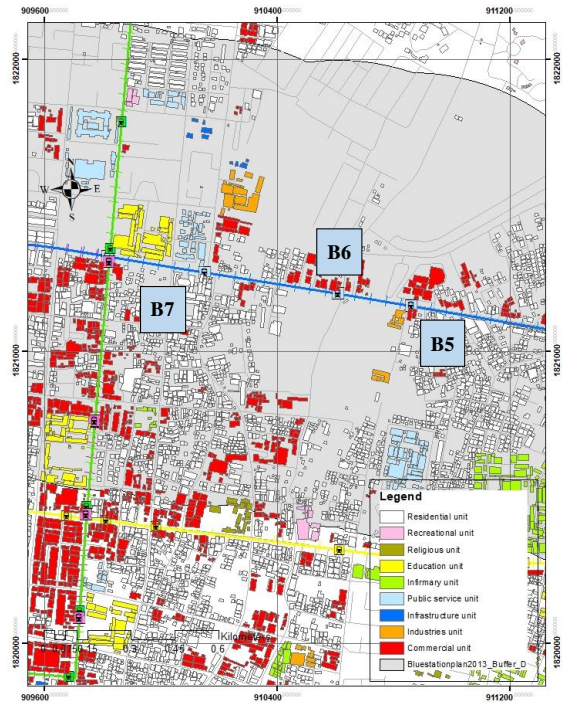

Figure A-22. Centrara (B5) - Intersection (B6) - KK City hall 2 (B7)

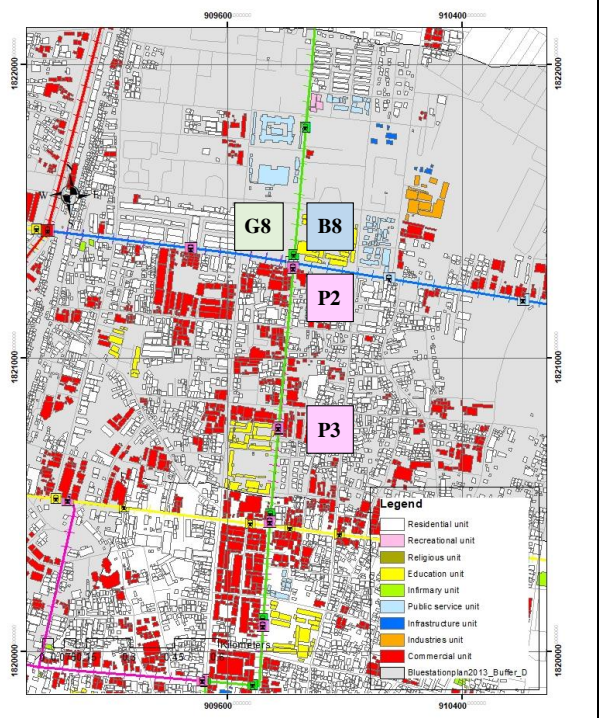

Figure A-23. KK Kidergarden (B8) - Terminal 2 (P3) - KK Kindergarten (G8) - Kindergarten (P2)

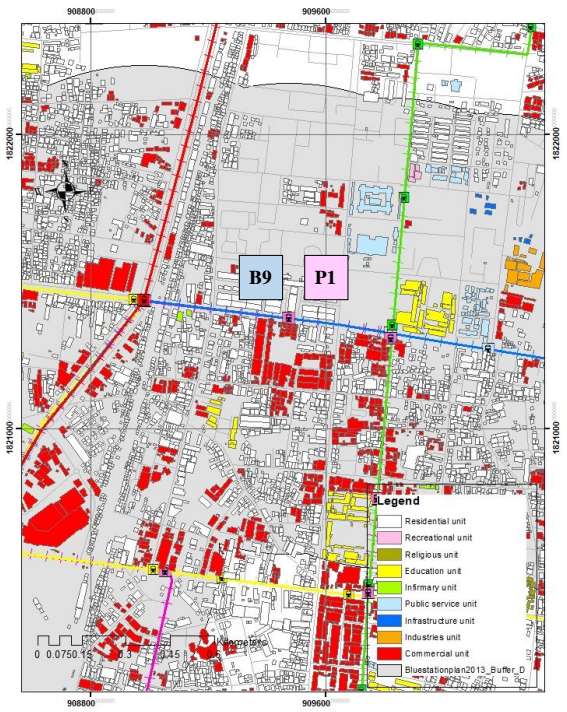

Figure A-24. Terminal 1 (B9) - Terminal 1 (P1)

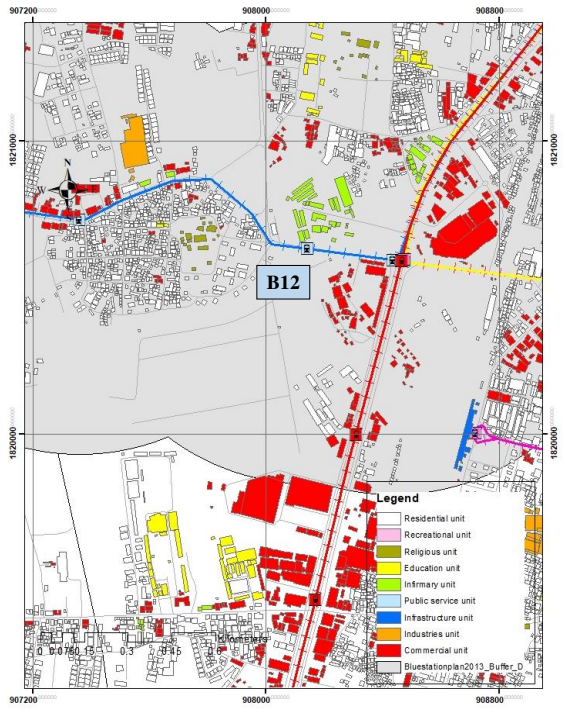

Figure A-25. KK Ram Hospital (B12)

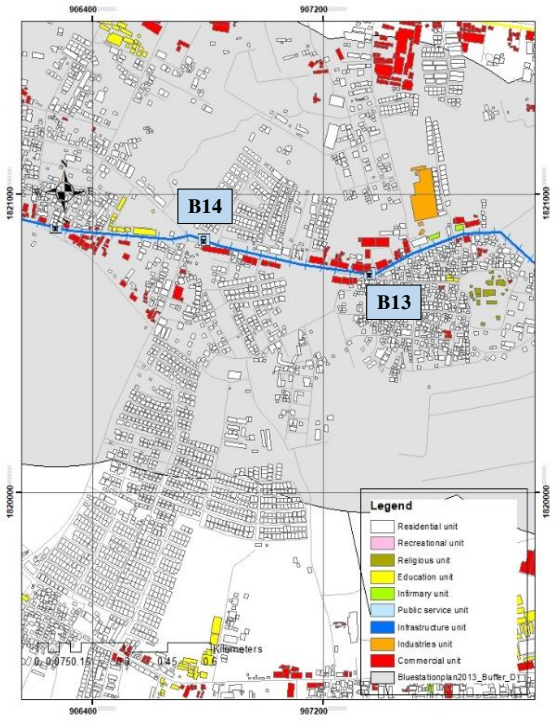

Figure A-26. Sri-Than (B13) - Boodsarin (B14)

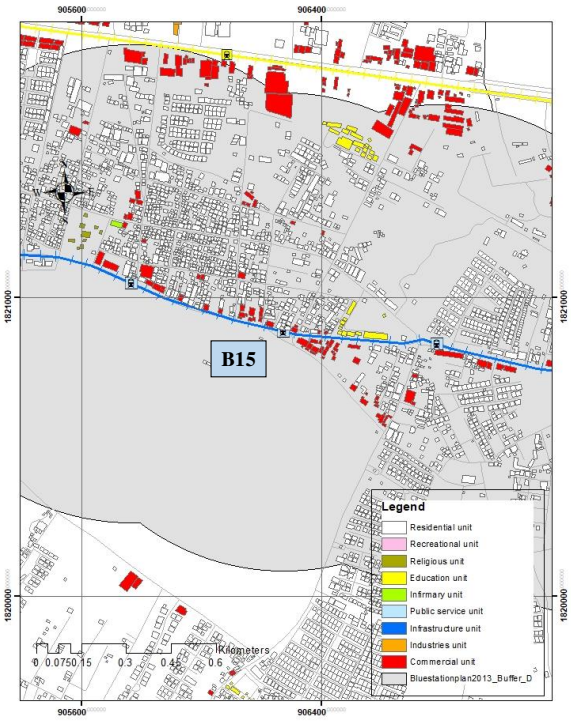

Figure A-27. Boung Nongkod (B15)

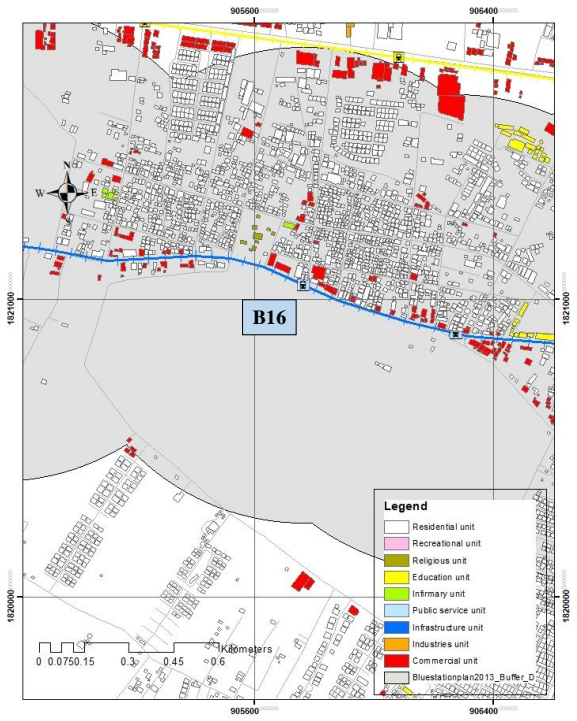

Figure A-28. Kamhai (B16)

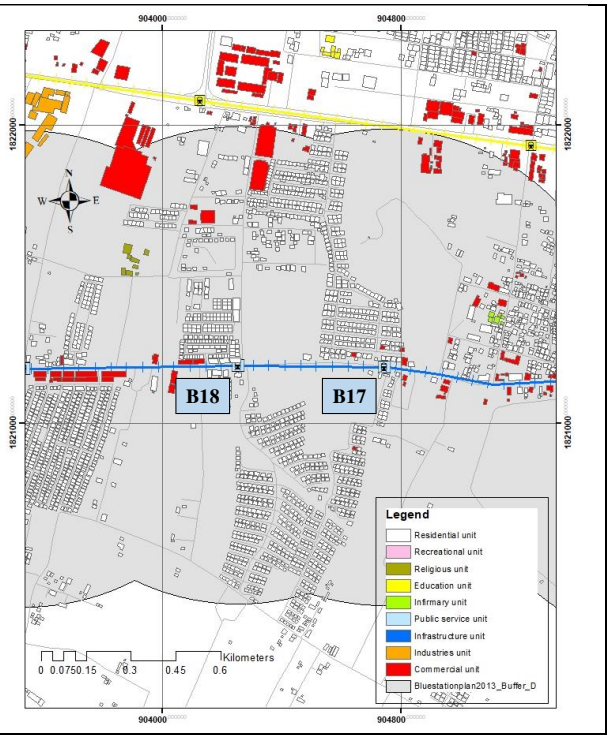

Figure A-29. Chonlapruk (B17) - Siwalee (B18)

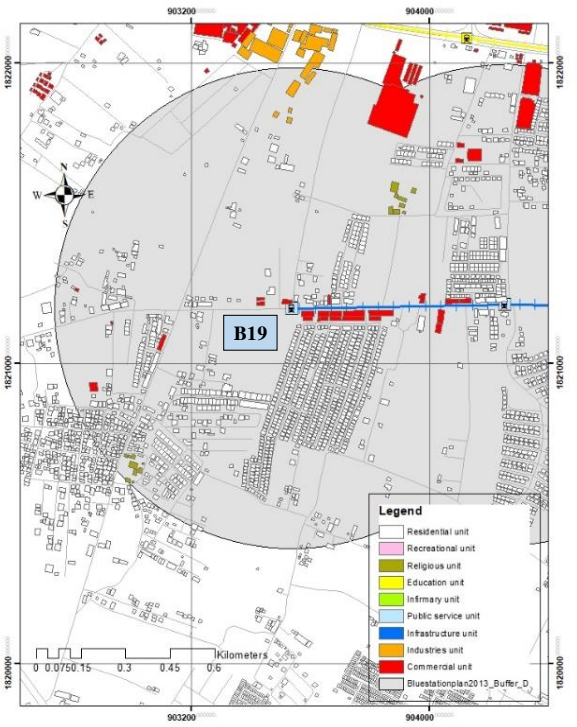

Figure A-30. VIP Home (B19)

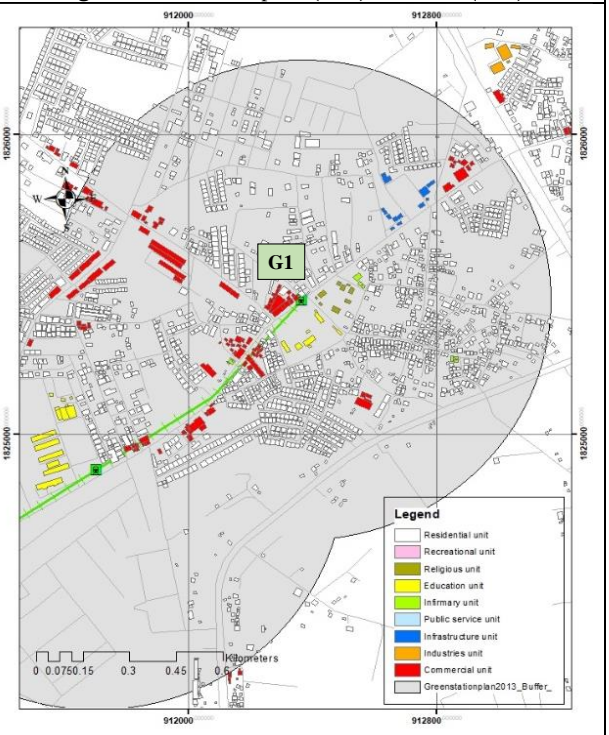

Figure A-31. Sila (G1)

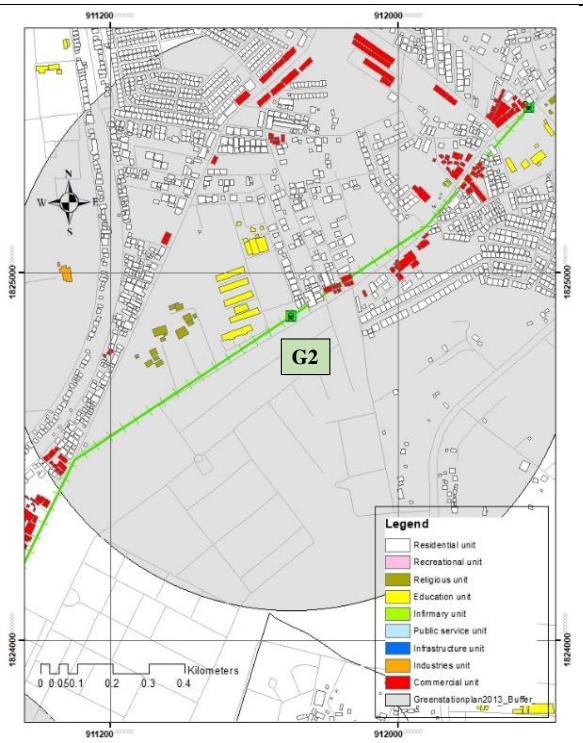

Figure A-32. Khamkaen School (G2)

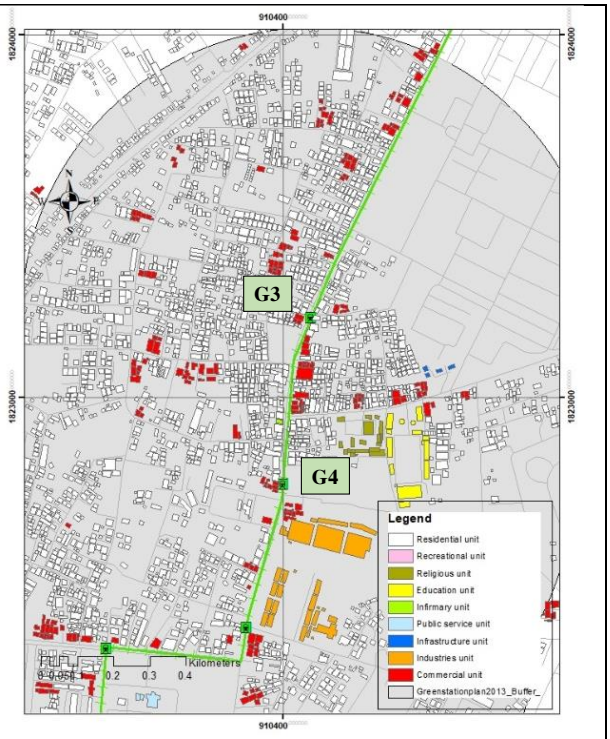

Figure A-33. Sripatcharin military (G3) - Ratchkanoung (G4)

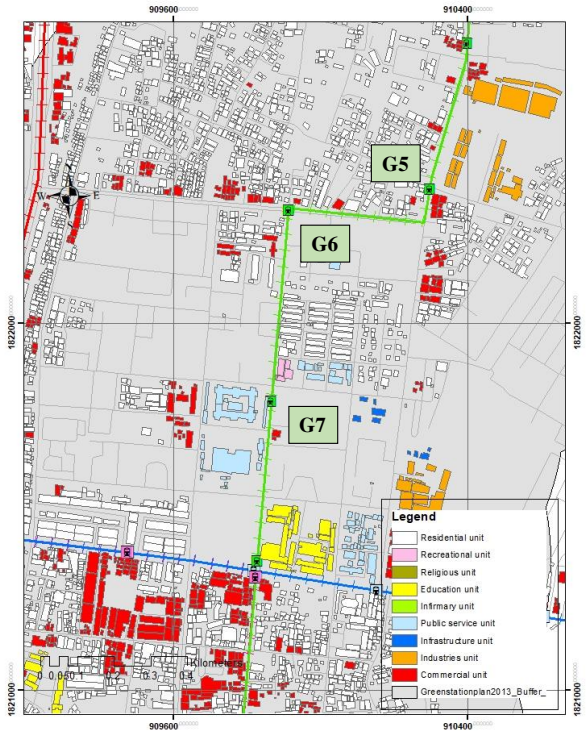

Figure A-34. Jomphol (G5) - City hall 3 (G6) - City hall Monument (G7)

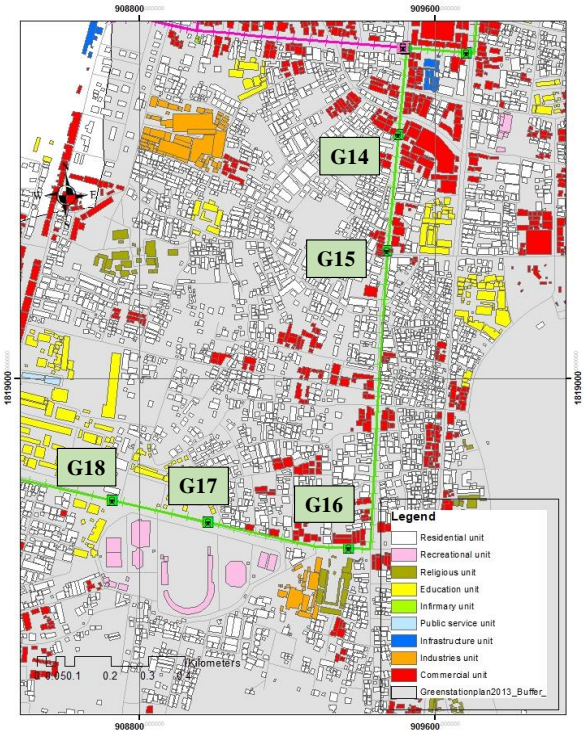

Figure A-35. Fairy Mall (G14) - BBL Bank (G15) - Watkraung municipal (G16) - KK Stadium (G17) - Kaennakorn school (G18)

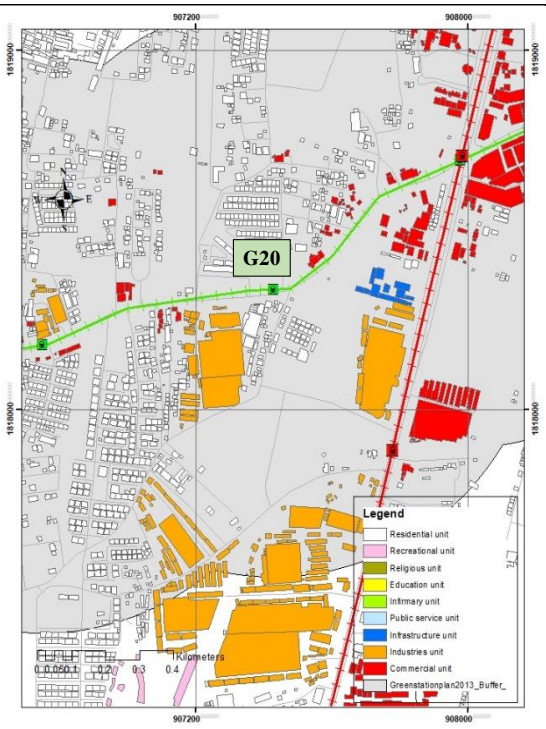

Figure A-36. PEA station (G20)

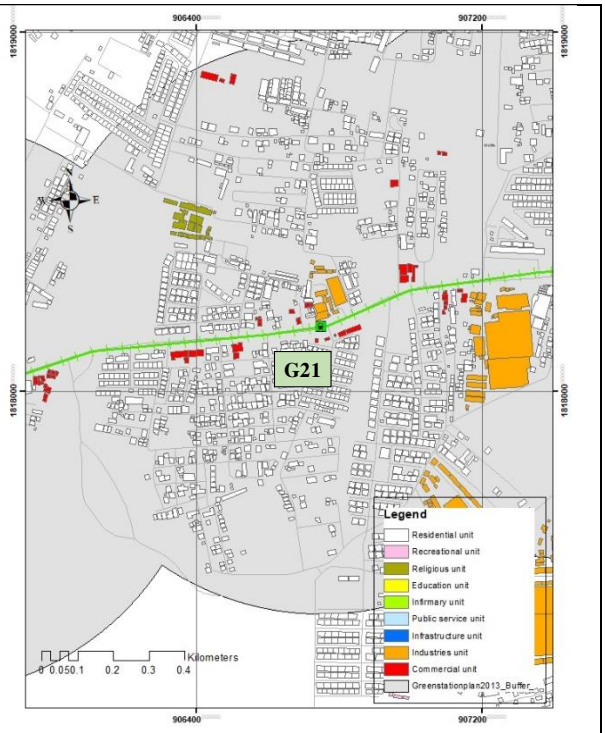

Figure A-37. Haeoun (G21)

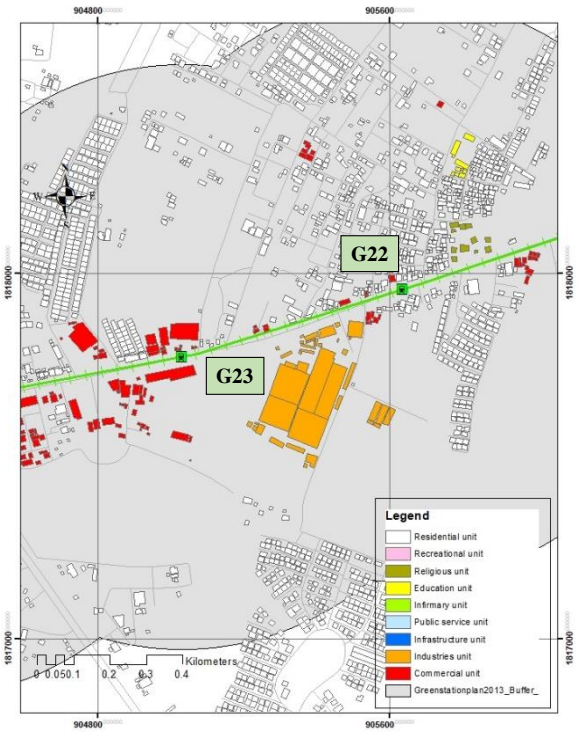

Figure A-38. Kham chareon (G22) - Nongkham (G23)

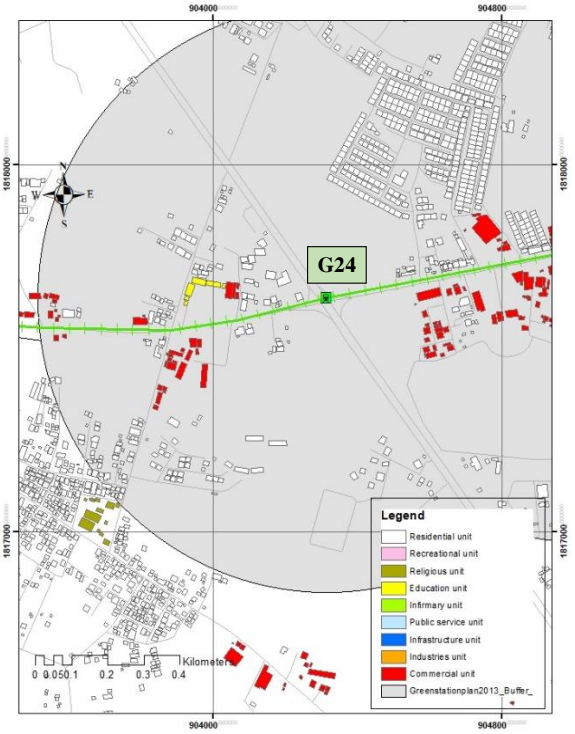

Figure A-39. Yak leangmoung (G24)

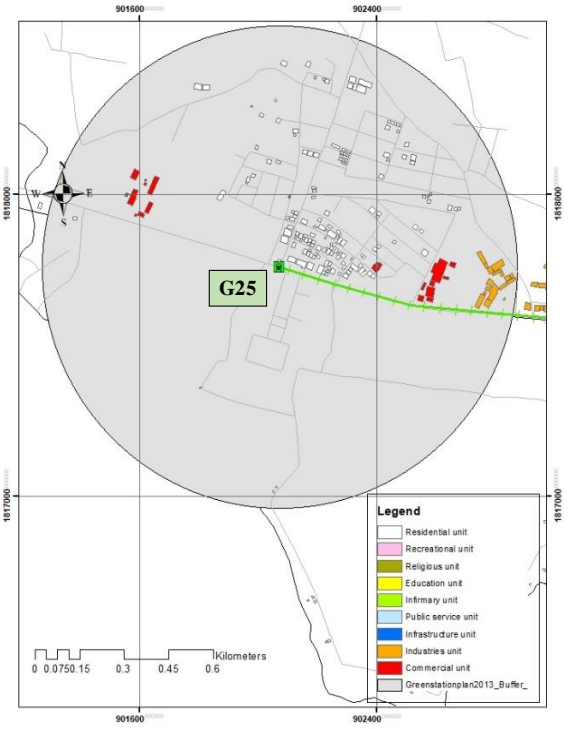

Figure A-40. Namton (G25)

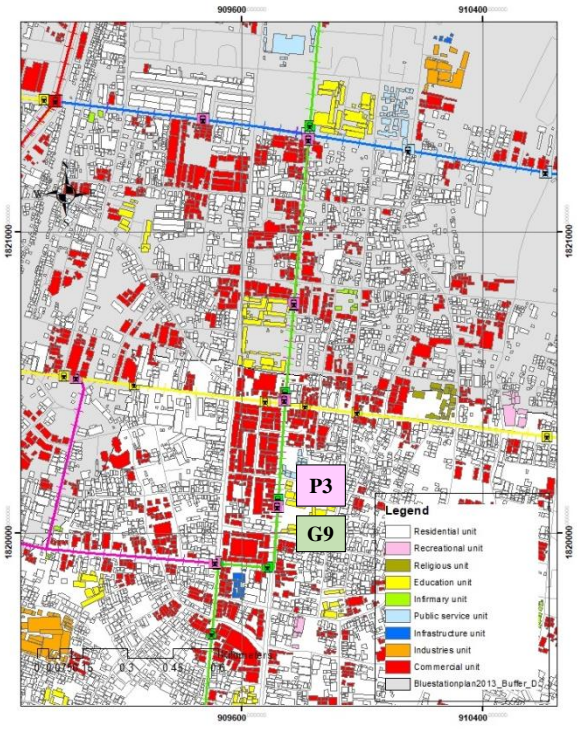

Figure A-41. Terminal 2 (P3) - Terminal 2 (G9)

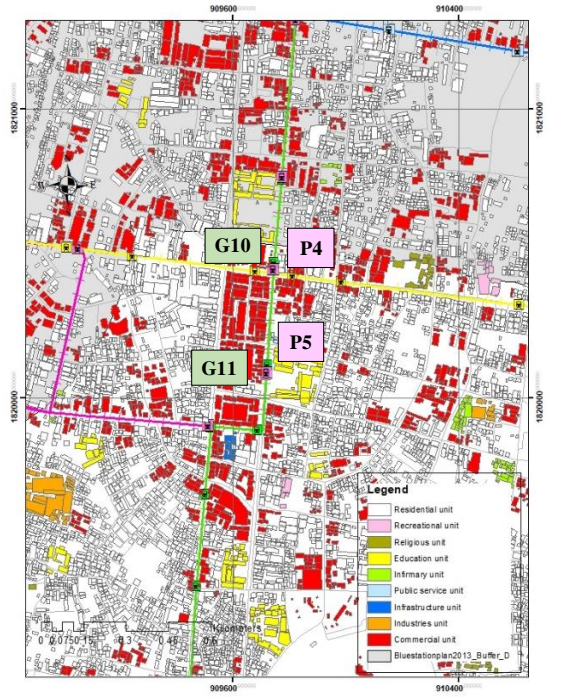

Figure A-42. Police station (P4) - Kalaya school (P5) - Police station (G10) - Kalaya school (G11)

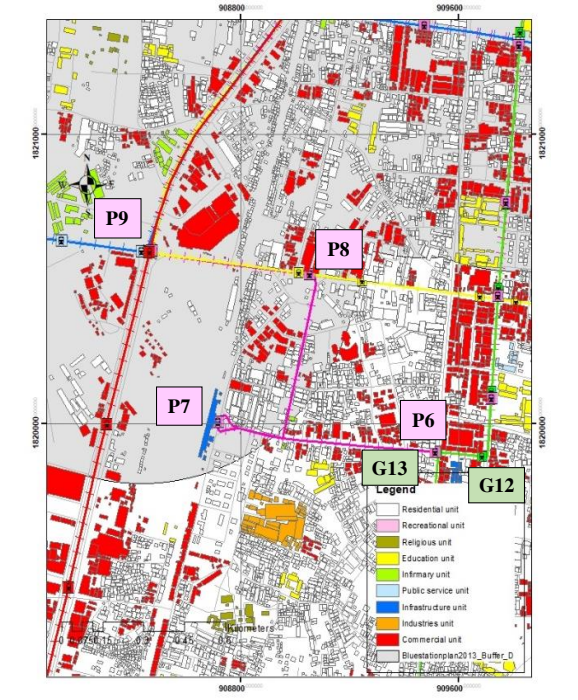

Figure A-43. Ruenrom Hotel (P6) - Railway station (P7) - City hall (P8) - Central mall (P9) - Market 1 (G12) - Ruenrom intersection (G13)

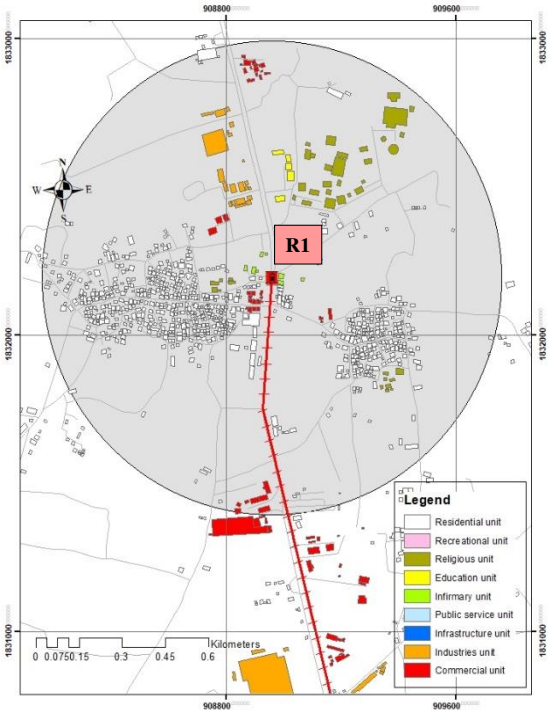

Figure A-44. Samran (R1)

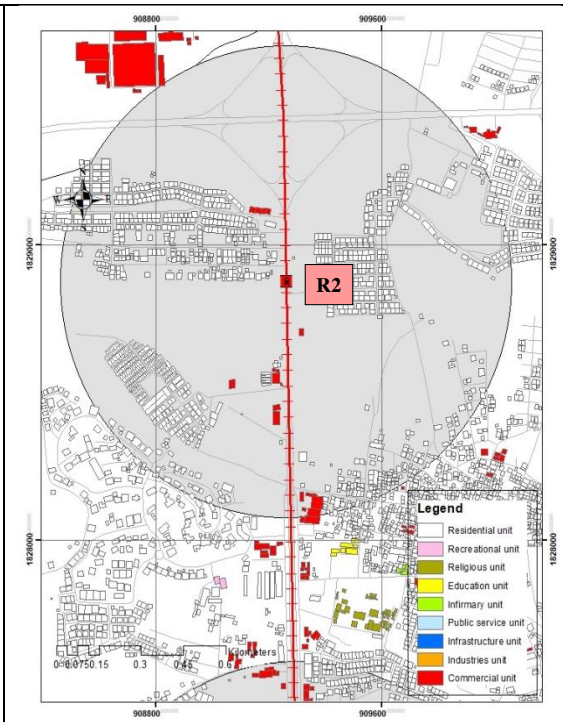

Figure A-45. Nongkung (R2)

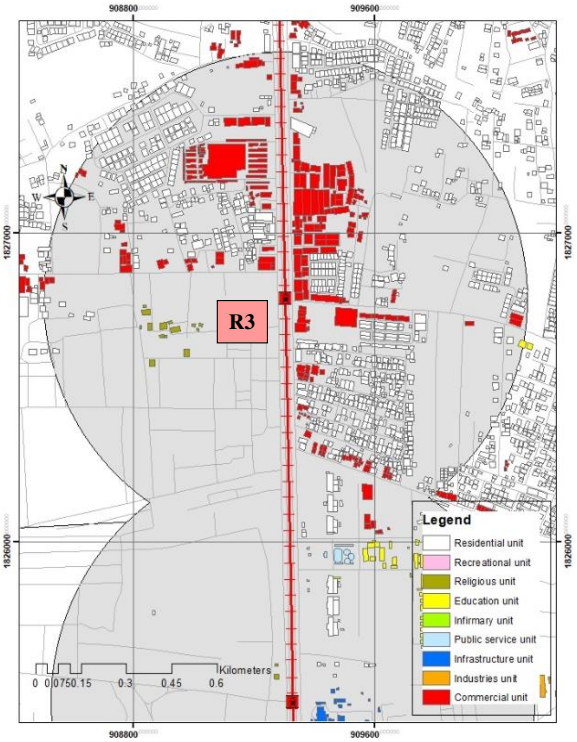

Figure A-46. Lotus sila (R3)

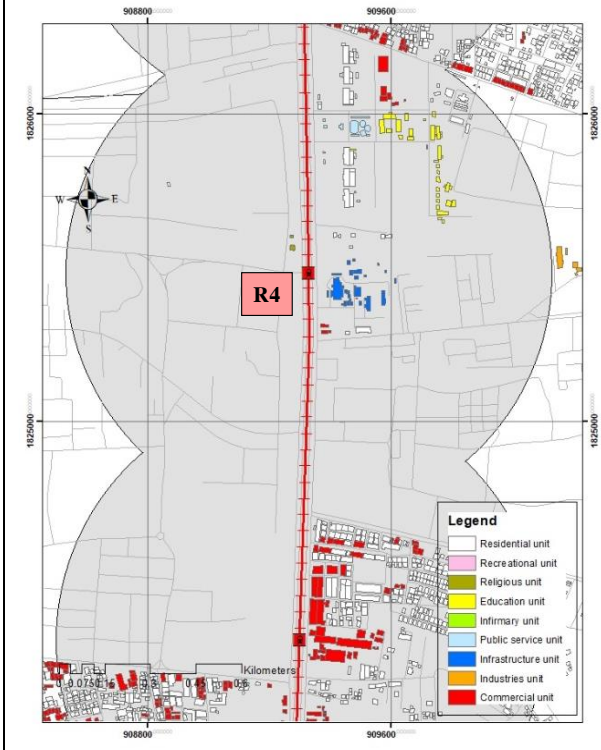

Figure A-47. Triangle KKU (R4)

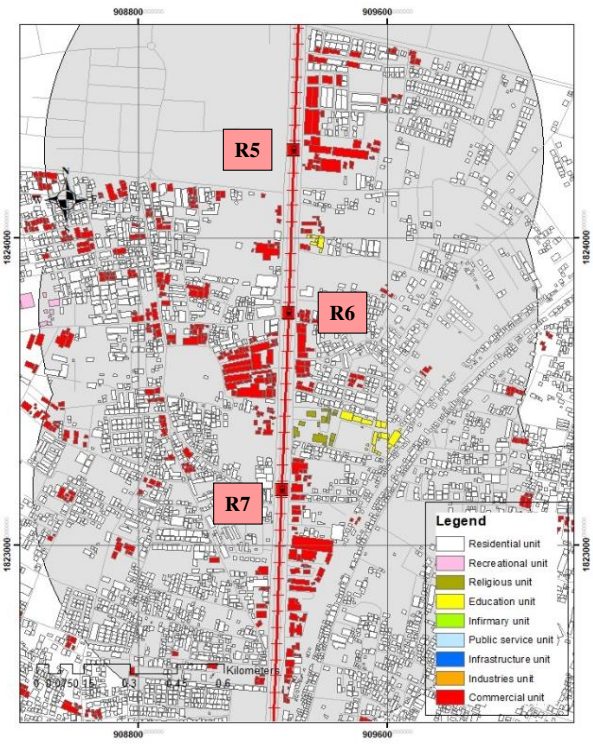

Figure A-48. Heart hospital (R5) - Toyota (R6) - Rachpruk 2 Hospital (R7)

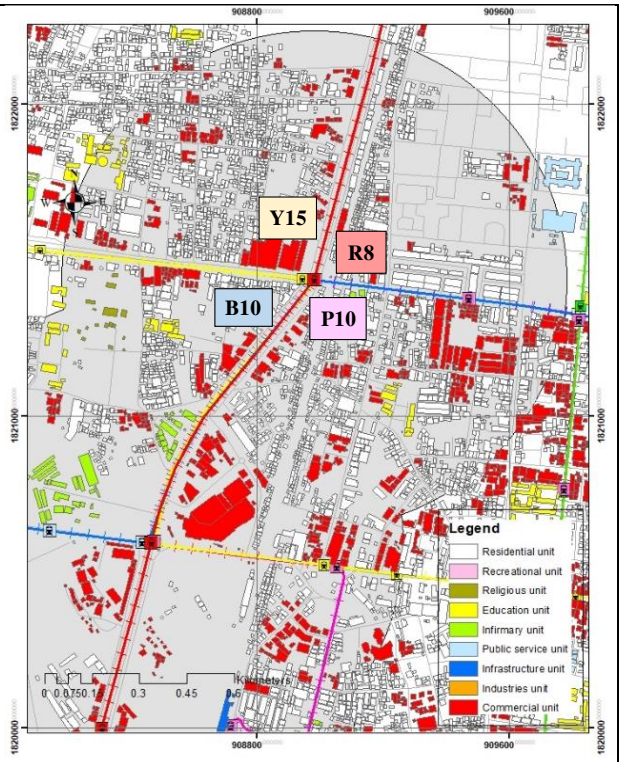

Figure A-49. Samlearm station (R8) - Samlearm station (P10) - Samlearm station (B10) - Samlearm station (Y15)

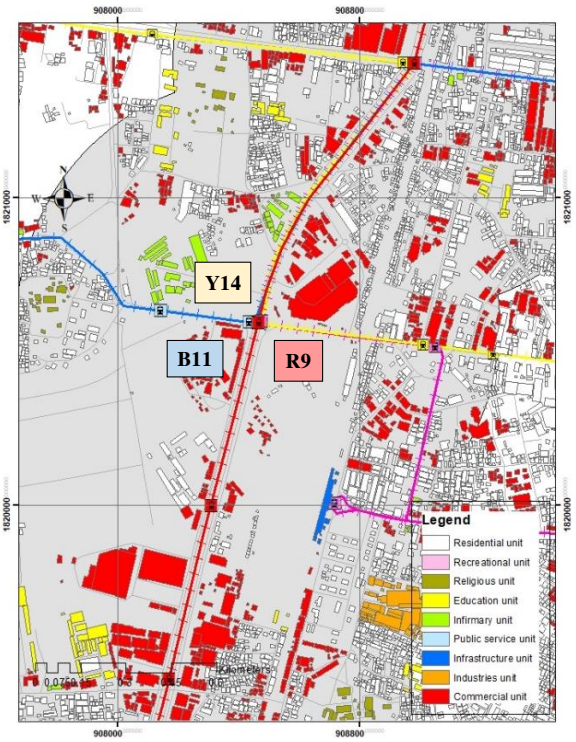

Figure A-50. Central mall (R9) - Central mall (B11) - Central mall (Y14)

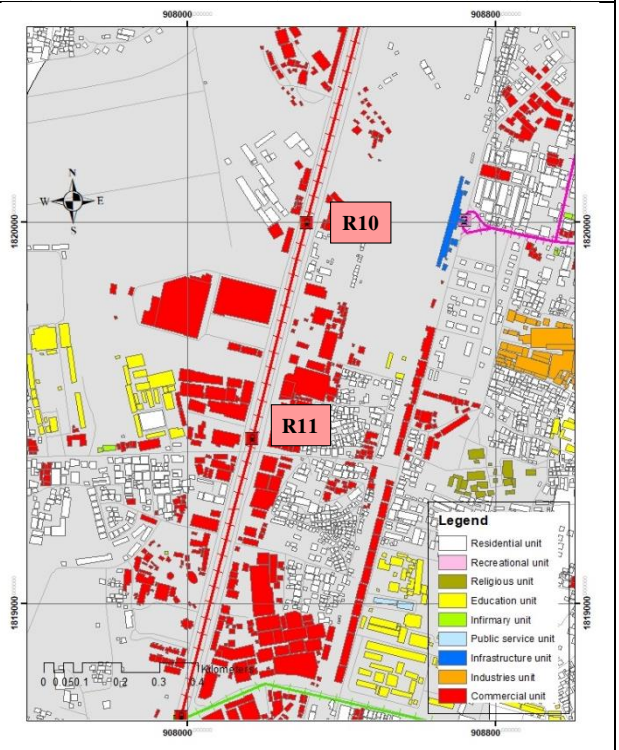

Figure A-51. Makro (R10) - Big C (R11)

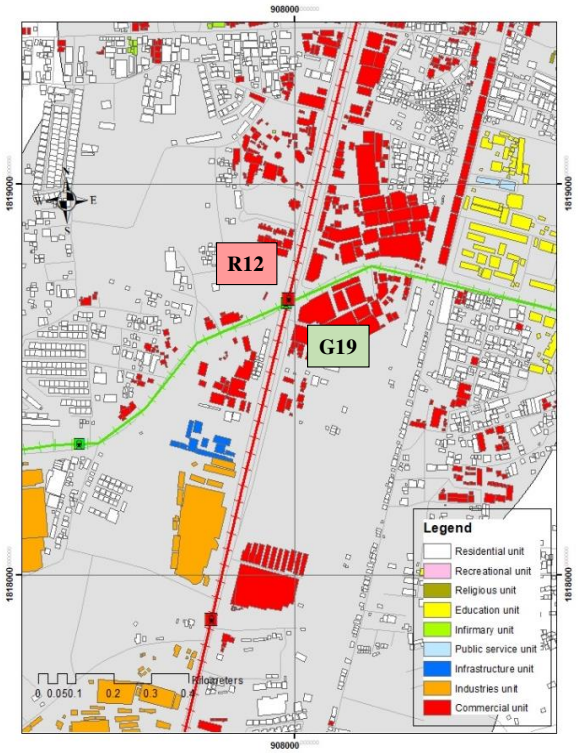

Figure A-52. Chroensri intersection (R12) - Chroensri intersection (G19)

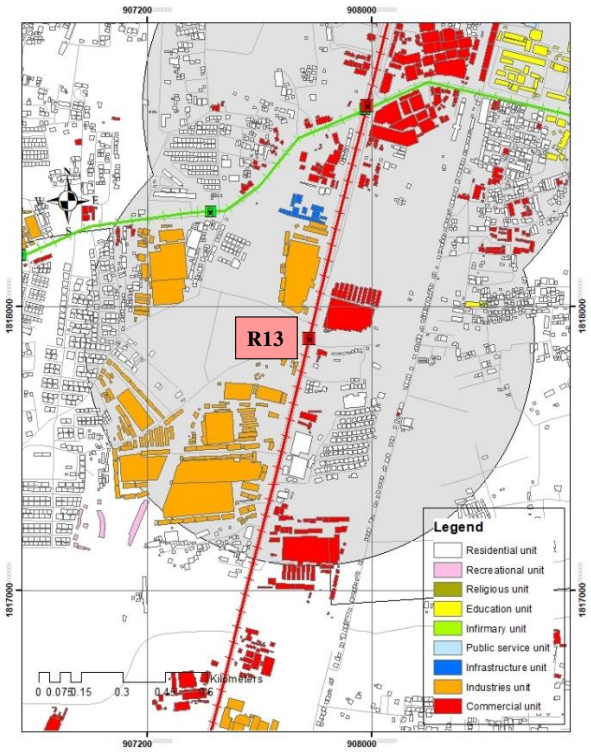

Figure A-53. Pratunam (R13)

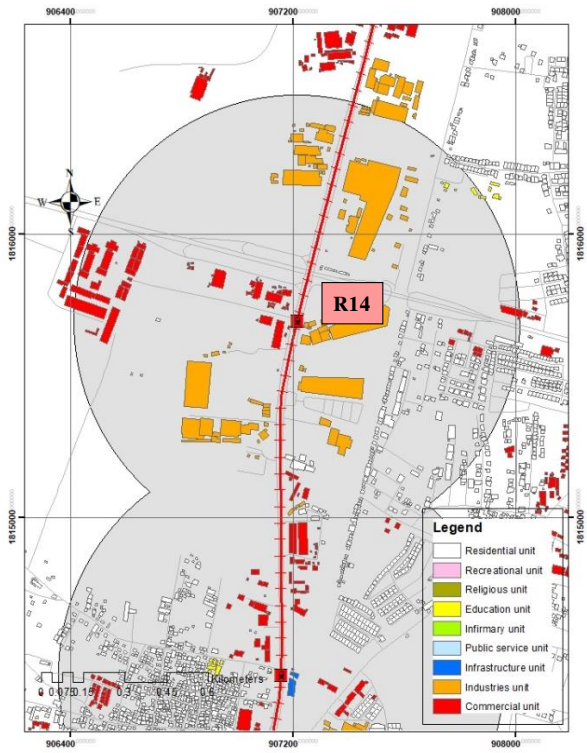

Figure A-54. Terminal 3 (R14)

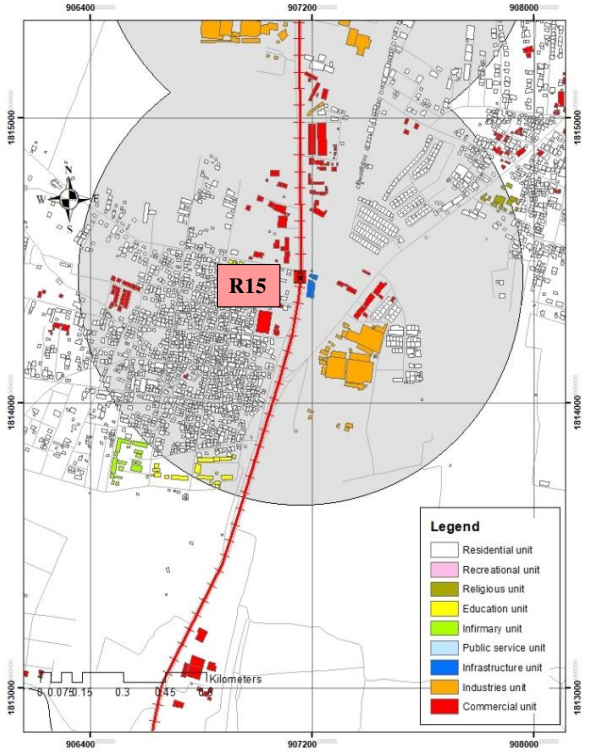

Figure A-55. Kudkuang (R15)

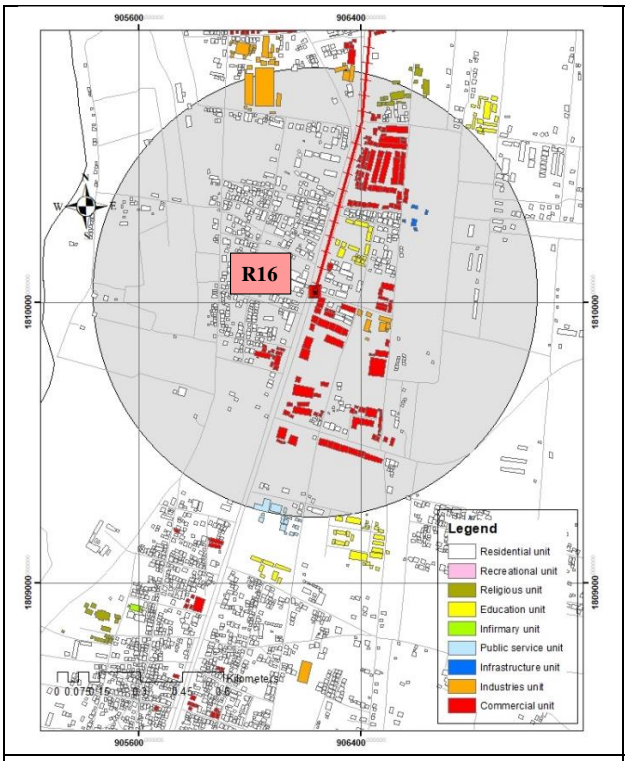

Figure A-56. Trapra (R16)

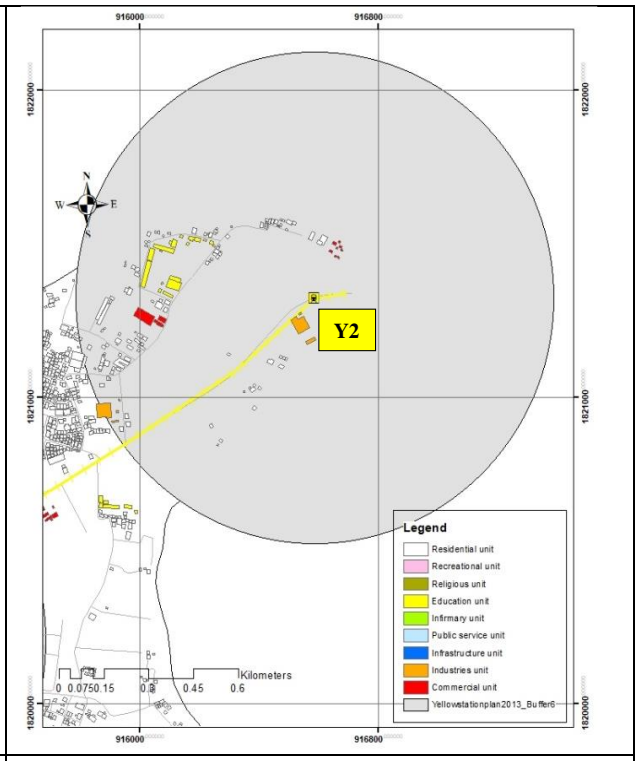

Figure A-57. Boungnieum (Y1) - Dondu (Y2)

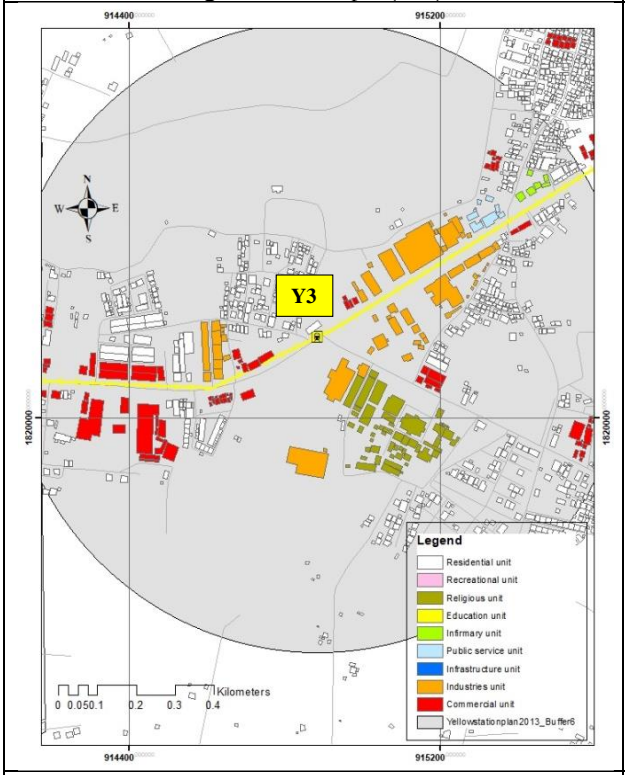

Figure A-58. Seang-aroun temple (Y3)

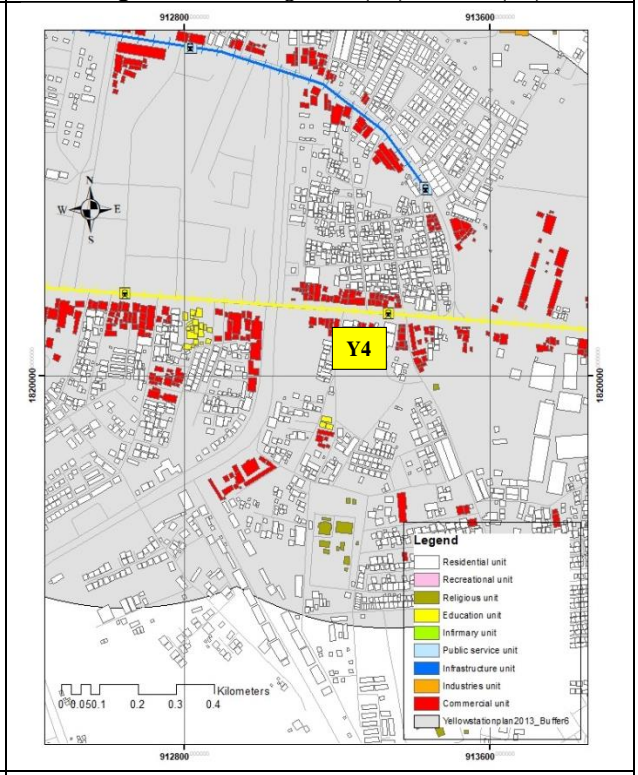

Figure A-59. Nongyai market (Y4)

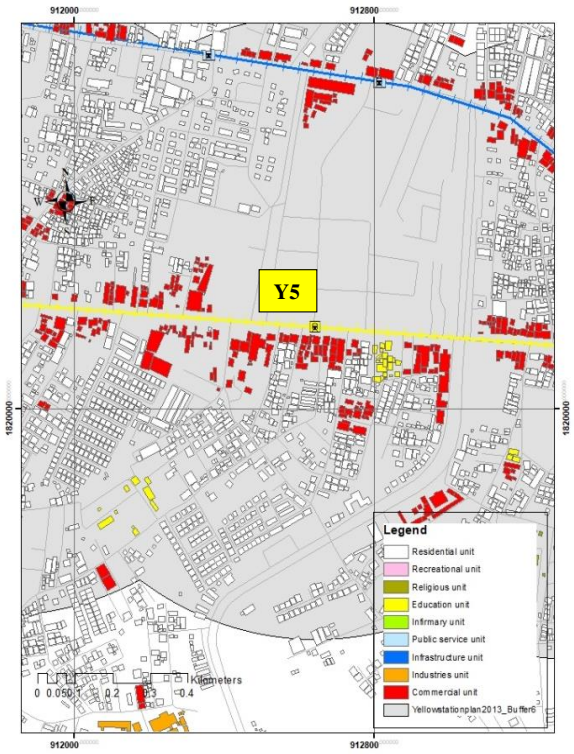

Figure A-60. RMUTI KKC (Y5)

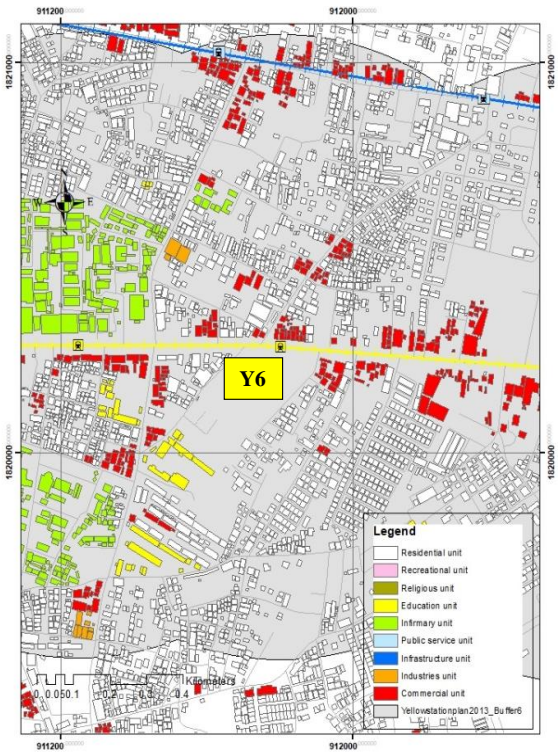

Figure A-61. Chata phadung (Y6)

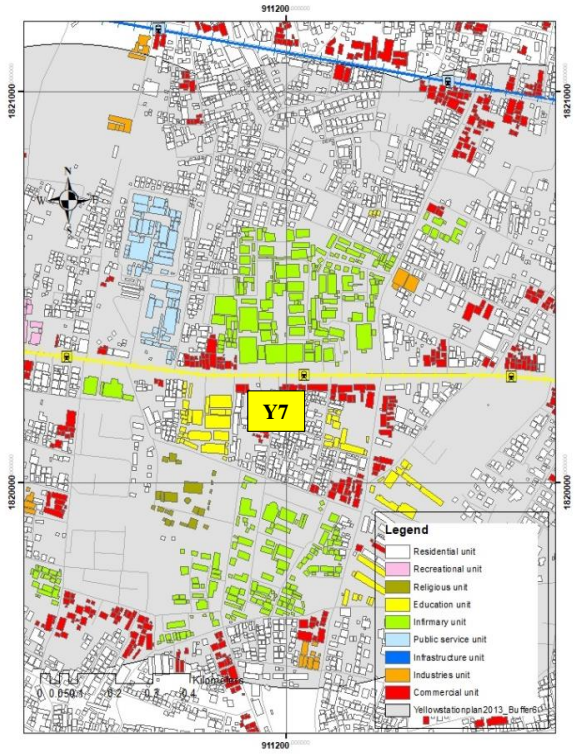

Figure A-62. KK hospital (Y7)

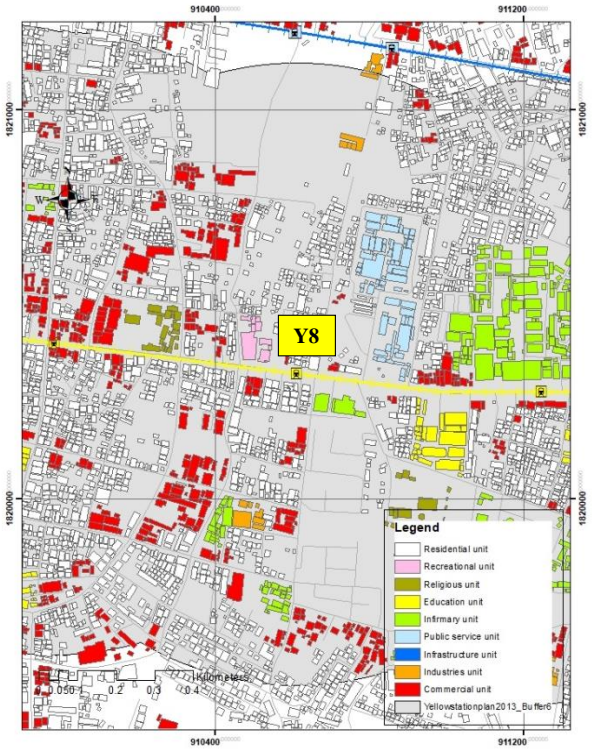

Figure A-63. Kaen kam (Y8)

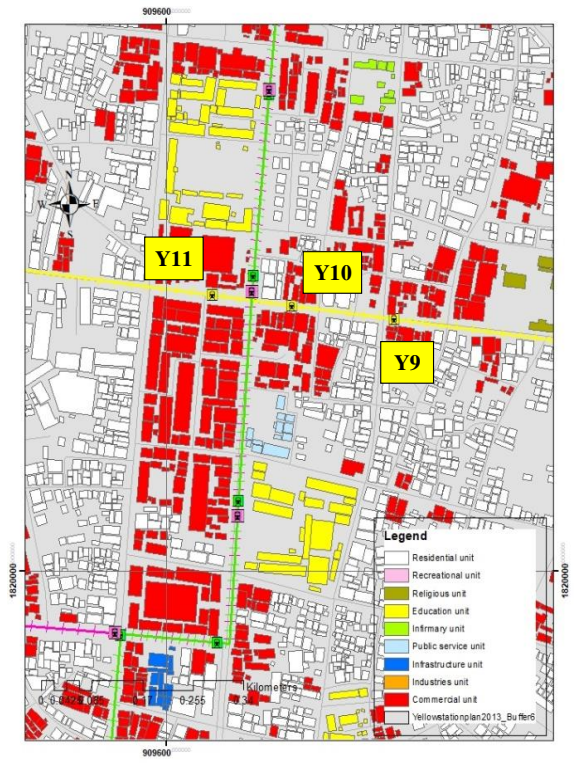

Figure A-64. Yak lung moung (Y9) - Police station (Y10) - Yak Na moung (Y11)

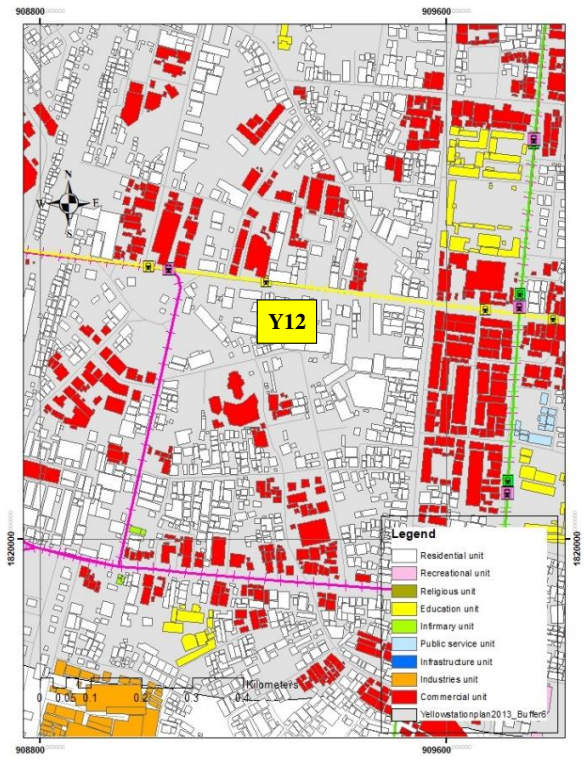

Figure A-65. Hug mall (Y12)

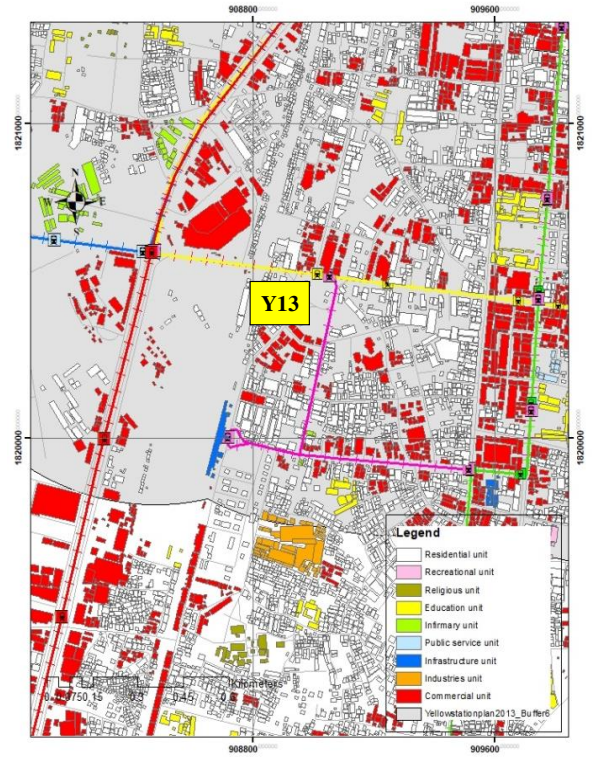

Figure A-66. San-lug moung (Y13)

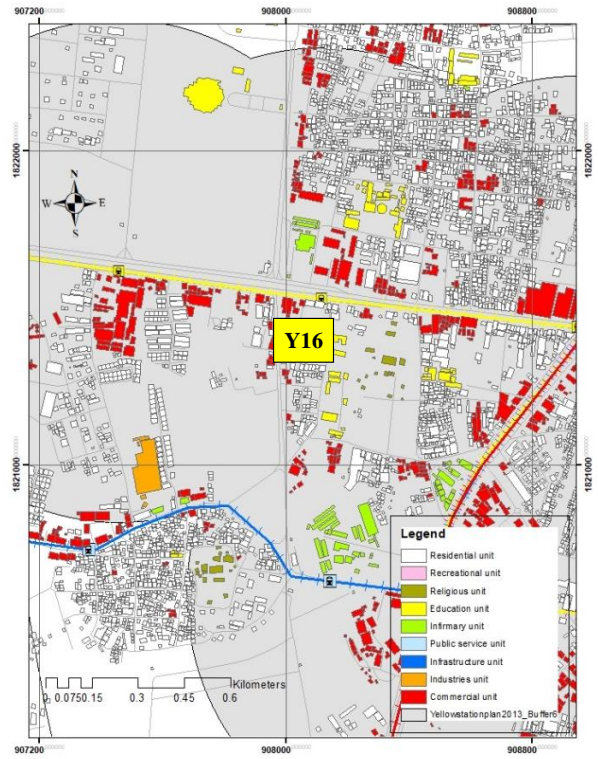

Figure A-67. Sentosa samliam (Y16)

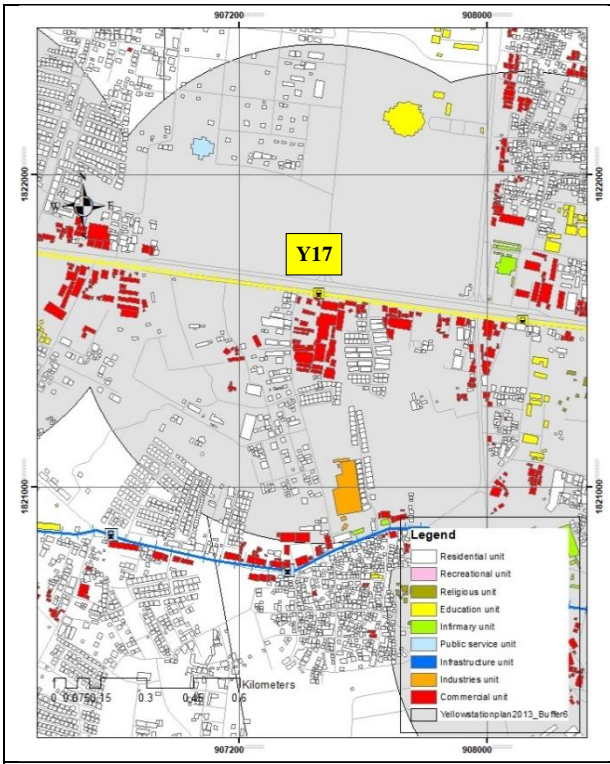

Figure A-68. Kanjanapisek convention center (Y17)

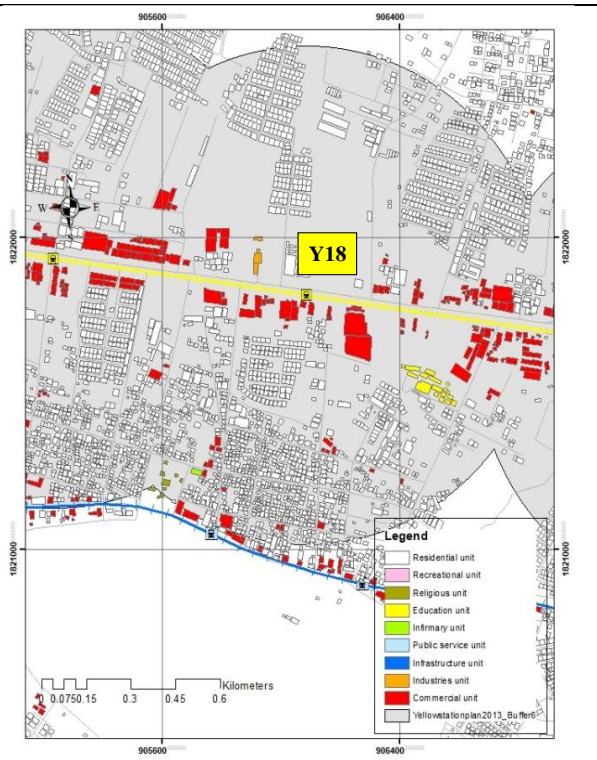

Figure A-69. KKU east (Y18)

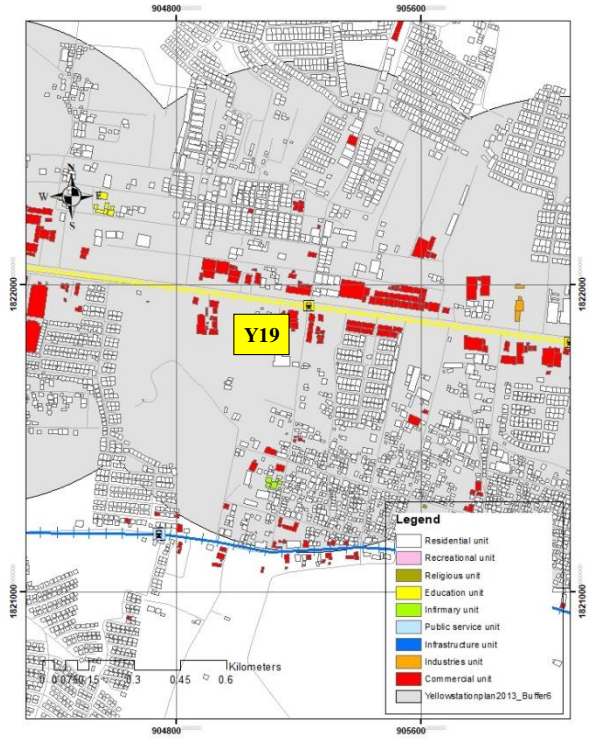

Figure A-70. PPT maliwan (Y19)

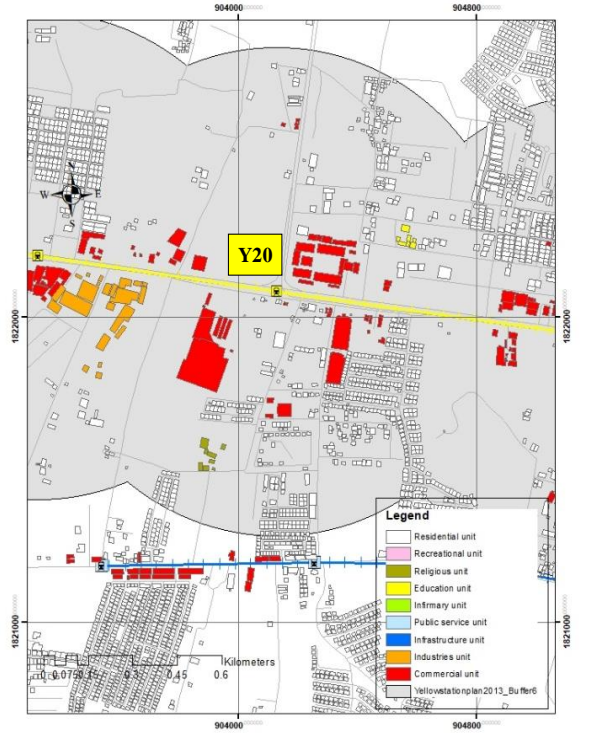

Figure A-71. Row-8 intersection (Y20)

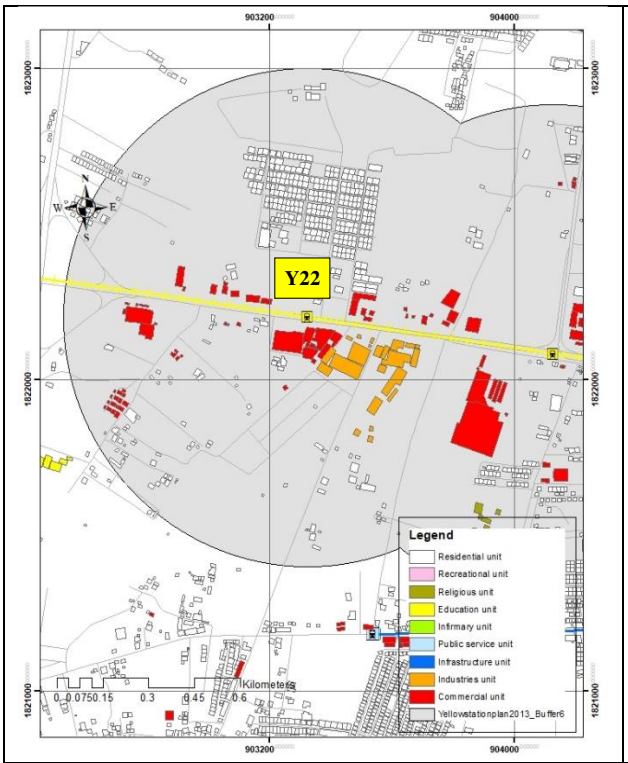

Figure A-72. Secha village (Y22)

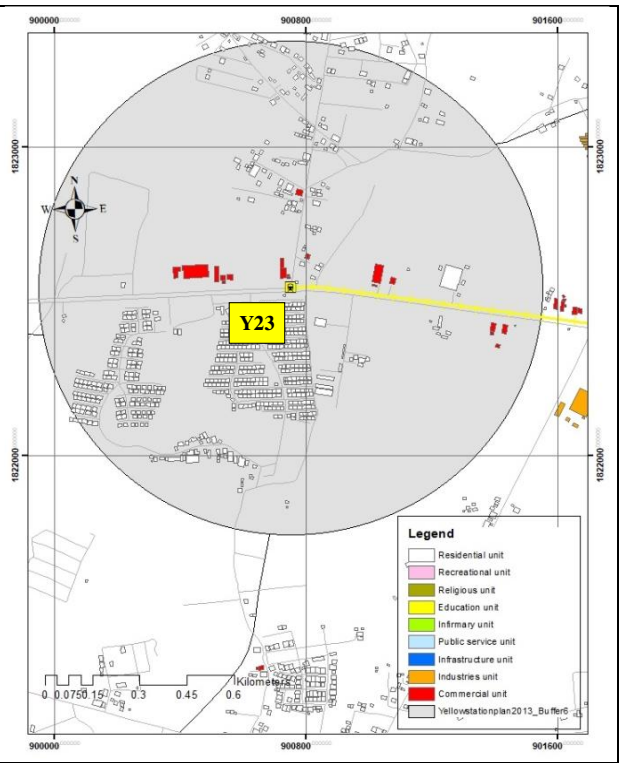

Figure A-73. Ban toom (Y23)

Remark: Yellow station 21 is an Air port