JUEE

Journal of Urban and Environmental Engineering, v.16, n.1, p.55-65

ISSN 1982-3932
doi: 10.4090/juee.2022.v16n1.055065

Journal of Urban and Environmental Engineering

www.journal-uee.org

THE URBAN'S PERCEPTION INVESTIGATED BY MULTIMODAL TRANSPORTATION THROUGH THE URBAN RAIL (TRAM) PROJECT

Wantana Prapaporn[1*], Takuro Inohae[2], Patiphan Kaewwichian[3], and Somsiri Siewwuttanagul[4]

[1]*Department of Civil Engineering and Architecture, Saga University, Japan*
[2]*Department of Civil Engineering and Architecture, Saga University, Japan*
[3]*Civil engineering Department, Rajamangala University of Technology, Isan Khonkean Campus, Thailand*
[4]*The Cluster of Logistics and Rail Engineering, Faculty of Engineering, Mahidol University, Thailand.*

Received 9 April 2022; received in revised form 14 June 2022; accepted 18 June 2022

Abstract: 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 this paper purposively illustrated the change in the accessibility performance of future transit network investment. This research presented the urban perception assessment with the accessibility index and the integration of rail urban motilities system throughout 2036 A.D.in which the principal investigation and interpretation were conducted on urban perceptions and the multimodal transportation modes (walkability, bus network, tram network) including 1) The changes of accessibility observed in various aspects as the population's accessibility to different transit networks in 2 different urban phenomena and 2) 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. The study outcome simplified the urban's perception mechanism that supports 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 in a productive supporting policy. This model represented the urban perception 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.

Keywords: Urban rail (Tram), Multimodal transportation, Accessibility índex, Urban phenomenon

* Correspondence to: Wantana Prapaporn, Tel.: +66 83 677 7796. E-mail: wantana.pa@rmuti.ac.th

INTRODUCTION

Public infrastructure is committed to urban life quality as it represents a country's capacity in terms of road, rail and air networks, as well as broadband and wide communications. Similarly, transport infrastructure capacity represents the increase of the network productivity, while the indicator of land transport was the total length of the road network and railroad normalized by the population density. Particularly, a country's investment in railroads can regularly be defined by three variables: 1) Total length of the railway route; 2) Goods transportation; and 3) Railway passengers, as presented in **Fig. 1** with the ranking trend determination between the total length of the railroad and the population per kilometer track classified by different countries (World bank, 2020).

Nowadays, as continuous urban growth has remarkably encouraged the ideas of urban's public transport to solve transport problems, there are many assessment models previously proposed to find the most effective model for urban livability and public transport in terms of Availability, Accessibility, Affordability, and Acceptability (Pulido *et al*., 2018). In the meantime, the increasing demand for transportation-economic growth was also a transport problem as congestion. In this regard, the railroad session proposes a function of connectivity and commute times using a whole network and the effect of urban policy, as the key issues, comprised of 3 related core components consisting Urban Strategies, Public Transportation, and Human Socialness. Most developing cities are challenging themselves by filling the gap between public transportation (such as bus and urban rail) and private vehicles. Hence, this research proposes 1) The investigation of the urban perceptions based on the urban rail project using different multimodal transportation modes including Walk Mode, Bus Mode, and Train Mode; and 2) The investigation and interpretation of the urban perception in 2036 A. D. based on the public transport plan (National Development Plan, 2017) through the human activities and perceptions toward the 3 building uses.

Exactly, the goal of sustainable urban transportation policy will provide a greater public transport service. In the case of Charlotte, North Carolina - the public planning and funding of 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 (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 total 115 km (Nehashi, 1998). In the cases of developing cities, many models and functionalities of public transportation were mentioned including 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 1** and **Fig. 2**.

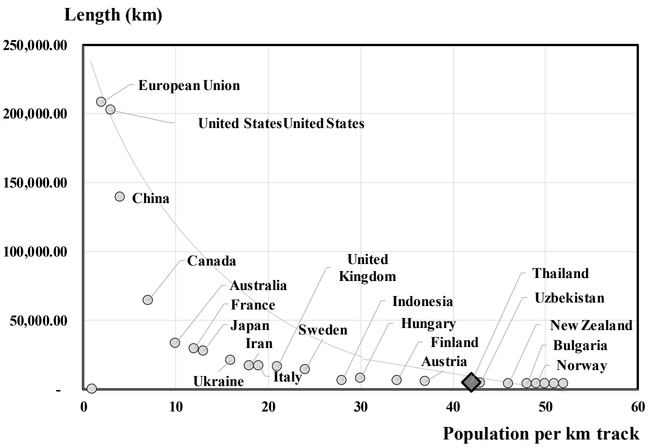


Fig. 1 Rail transport network size (population per kilometer track and total rail length).

Table 1. Comparative of Public Transit Capability (Pan *et al*, 2009; GAO, 2001; 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
	Line capacity: Typical peak hour passengers	1,000−3,000	2,000−10,000	3,000−18,000	13,000−41,000
2	Line capacity (passengers/direct/hour)		5,000–45,000	12,000−27,000	40,000−72,000
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

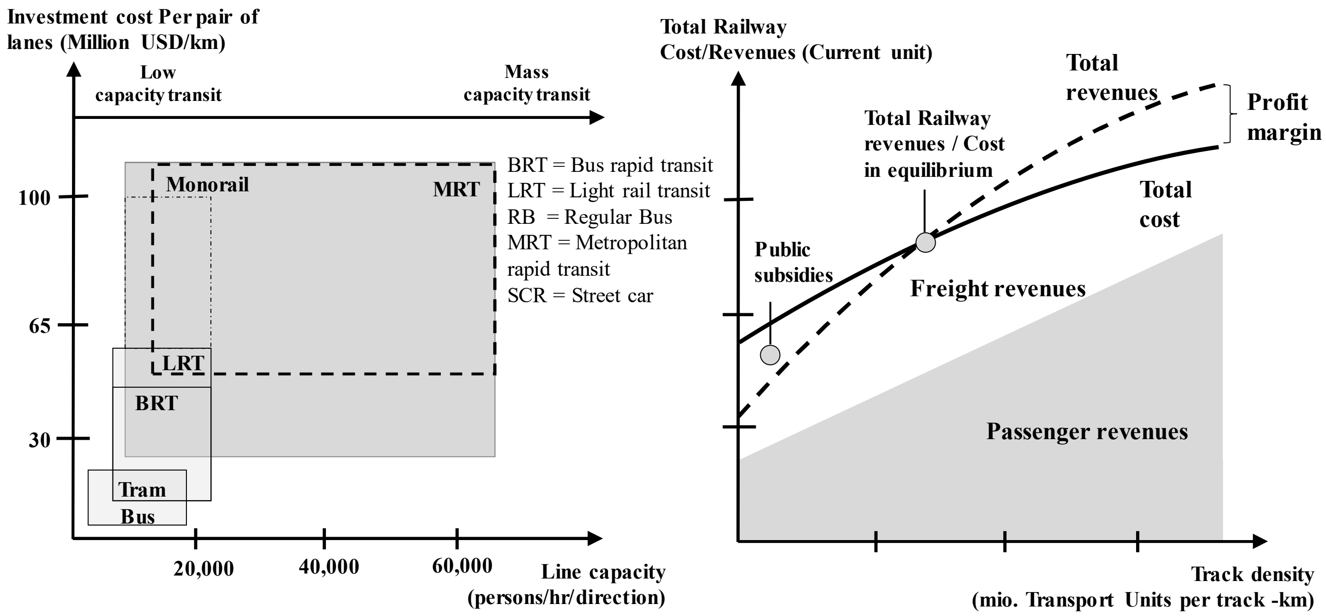


Fig. 2 Simplified Representation of Costs/Revenues of A Railway System and Bus Rapid Transit (BRT): An Efficient and Competitive, Mode of Transport (Cervero, 2013; Association, 2008; Kittelson and Associates, 2003; Vuchic, 2007; PCBK International Co., 2011; Daniel Pulido *et al*, 2019).

The effective urban rail case in London, England, presented the public infrastructure consisting of the Subway, Docklands Light Railway, and Tram from over 100 years ago through 1870–1939 A.D. (Fiona, 2020). The network represented the connectivity performance directly relying on transport quality (Li and Quadrifoglio, 2010); whereas, the urban rail investment cases confirmed the increasing cost of land-use around rail transit stations due to the growth of commercial land use; more growths were found in multi-family residential land use (Bhattacharjee and Goetz, 2016). Local employers also take an important role in travel demand management (TDM) efforts by influencing commuters' mode choice through financial incentives (Ghimire and Lancelin, 2019). Particularly, a Transit-Oriented Development (TOD) was an urban planning strategy for an urban development tram project at walking distance from mass public transport stations (Lamour *et al*., 2019) in which the rail-based accessibility was higher in the cities where a TOD degree was higher too (Papa and Bertolini, 2015). Most cities in China had put their effort into establishing a framework of TOD planning context that could be more applicable than the concept, suggested by planning experts and policymakers, on how to integrate TOD into land use planning in order to achieve sustainable transportation (Ling *et al*., 2020). On this point, the previous study suggested an incentive policy such as substituting subsidies with rewards and rural planning by realizing a rural revitalization towards post-productivism (Huang *et al*., 2020), and the TOD zone remarkably showed that the critical demands were in the range from 10 to 50 customers/mile^2/hr and that the policy was more favorable during afternoon peak hours (Li and Quadrifoglio, 2010).

Consequently, the urban transportation capacity relies on limited urban forms and a demand-supply consideration. The most effective public transit confirmed by railroad transit was safe, hazardless, and affordable properly due to the urban forms relocation (Knupfer *et al*., 2018). Consequently, this research proposed an evaluation model that was applicable to the public transport investment plan.

MATERIAL AND METHODS

Multimodal transportation

Multimodal transportation is referred to the combination of different transportation to create a unimodal road network plan and to design a transportation model on a tactical level (Elbert and Muller, 2020) including both static and dynamic simulations. Individually, the mobility patterns from urban sensing data (mobile tracking) were supportive of the understanding of urban mobility variation for overall mobility (Calabrese *et al*., 2013). Notwithstanding, a static simulation is proper for those developing cities incorporating data from the investigation on the impact of the new project on the multimodal transportation systems (Azucena *et al*., 2021). Multimodal transportation traced the passenger's carriage by combining two different transportation modes from a place where the network was connected to the designated areas. In this research, three multimodal transportation modes were discussed: (1) Walk Mode (W): Origin; a 10-min walking link to a service area to destination via walkable road network; and (2) Walk, Bus, and Walk Mode (WBW): Origin; a

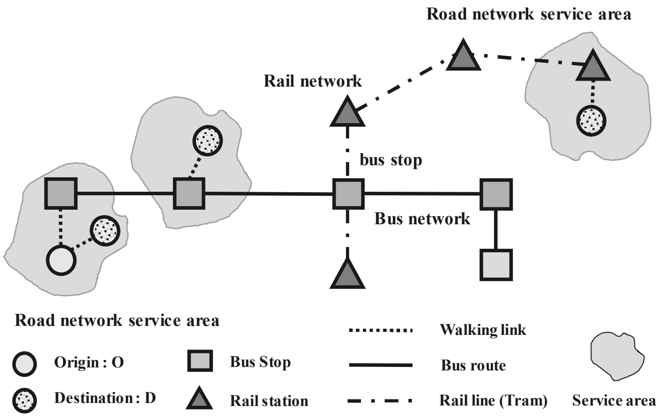


Fig. 3 Multimodal transportation schematic chart.

10-min walking link to the service area via a bus stop (based on the road network) connected to the next bus stops in 10 minutes; Destination: 10-min accessibility to the service area via walkable road network from the station, and Walk, Bus, Train and Walk mode (called WB1TW for the first implemented rail line, WB3TW for three rail lines and WB5TW for 5 rail lines): Origin; a 10-min walking link to the service area via a bus stop (base on the road network), connected to next bus stop in 10 minutes, transmitted to train network, and ride on rail route in 10 minutes; Destination: 10-min accessibility to the service area via walkable road network from the station as shown in **Fig. 3**.

Accessibility measures

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 people's basic accessibility in physical, economical, or social aspects). Previously, various types of measurements (Bhat et al., 2000) commonly presented the accessibility 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 as a weighted average computation of traveling time for all the zones of consideration where dij was the distance between i and j, and b was the general parameter given in Eq. (1):

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

The accessibility levels by bus were researched in Belo Horizonte city discussing its relationship with the levels of urban mobility (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 (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 involved the authorities in several areas; then, the final decision should be made through the collaboration amongst all related sectors as well as the consideration of the resident' s needs. In addition, Urban Network Analysis (UNA) was assigned to quantify pedestrian enumeration using the network to reach public facilities (Morimoto, 2015). In this regard, there are effective factors in 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 the total time used was less than 60 min (Pulido *et al.*, 2018).

$$AC_1 = \sum_{k=10\,min}^{SA} (P_n \, x \, T_n) \qquad (2)$$

$$AC_2 = \left(\sum_{k=10\,min}^{CF\,bus} \left(\sum_{k=10\,min}^{SA} (P_n)\right)\right) x \left(\sum_{k=10\,min}^{SA} (T_n)\right) \qquad (3)$$

$$AC_3 = \left(\sum_{k=10\,min}^{CF\,train} \left(\sum_{k=10\,min}^{CF\,bus} \left(\sum_{k=10\,min}^{SA} (P_n)\right)\right)\right) x \left(\sum_{k=10\,min}^{SA} (T_n)\right) \qquad (4)$$

- Population (P_n): The building by ArcGIS execution allocated by residential building unit (persons)
- Trip proposes (T_n): Destination perceived by building functions: (Square meter unit, calculated in logarithm form)
- Service area (SA): The area execution the mobility function in their network.
- Closest facility (CF): The route execution by their network with the units' transmissions (the bus stop and rail station).

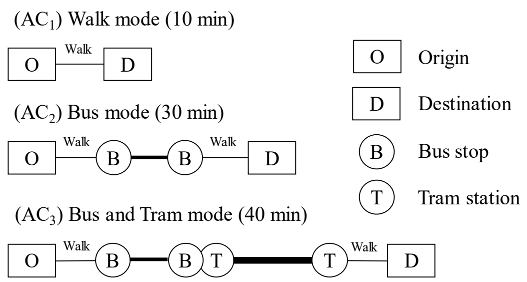


Fig. 4 Accessibility approach schematic flow diagram

Area of Study and Population Representative

Khon Kaen prefectures, Thailand, is one of the six prefectures where the Twelfth National Economic and Social Development Plan (2017−2021 A.D.) was imposed e.g. a tram project plan. The population data were taken from the Statistics, Population, and House Statistics for the year 2020 A.D. (Khonkaen Provincail Statistic Office, 2020) and Thailand Human Development Report 2014 by UNDP. Research exposed a Densely Inhabited Districts (DID) criteria that Japan 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 (Ramadhan and Pigawati, 2019). The urbanization with Grid Index Feature and DID legends of Khon Kaen are presented in **Fig. 5**.

Land Use Scenarios

The principle of compact city affirmed the fact that urban land density had decreased outward from the urban center in an inverse S-shape rule (Jiao, 2015). Accordingly, this research discussed 2 scenarios of land use following the principle of the compact city that was commuted and to agglomerate the population who were relocated to the urbanized area. In Khon Kaen, the predicted population was 380,577 up to 571,703 people so the urbanization zone should support 339,754 to 509, 814 people from the year 2021 to 2036 respectively (National statistical office, 2020). Firstly, the current land use scenario was shown by a 100 × 100 grid. Secondly, the scenario was a supporting policy to promote a low density (less than 20 DID) in 3,736 grid feature unit allocation. Thirdly, the scenario's principle was to promote a medium-density (20–39 DID); both cases were a cumulative population living out of urbanization called (A), (B), and (C), as seen in **Fig. 6**, respectively. This was consistent with a previous study stating that the state-support Amtrak stations had a significant effect on the local population in the long term (Ahmadreza Talebian et al., 2018). The examination was utilized based on the ArcGIS approach.

Public transport

The area of study was a place where the public urban rail transportation project was promoted following the 12th National Economic and Social Development Plan (National Development Plan, 2017). According to transportation planning, concentrated households and non-driver households represent the total user's demand based on public transit service to reach their trip purposes (Litman Todd, 2020). The study also proposed the indicators for the city and a set of desirable conditions for the city's mobility system; meanwhile, three different timeframes were considered comprising: (1) 1-5 years up to 2021 A.D.; (2) 5-10 years up to 2026 A.D.; and 10-20 years up to 2036 A.D. following the 12th National Economic and Social Development Plan.

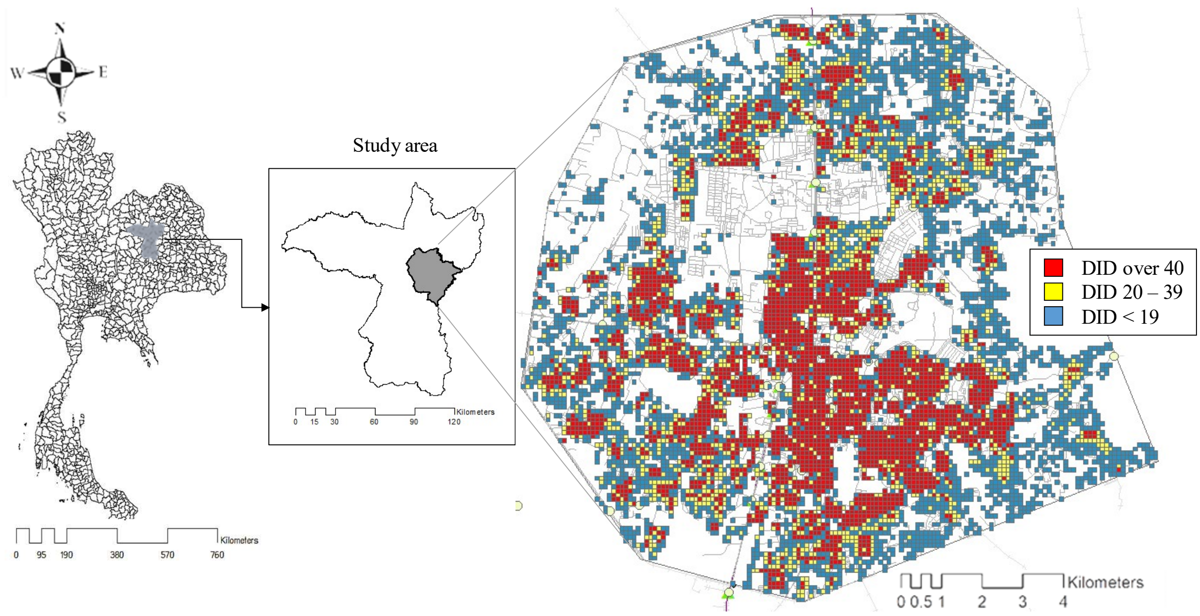
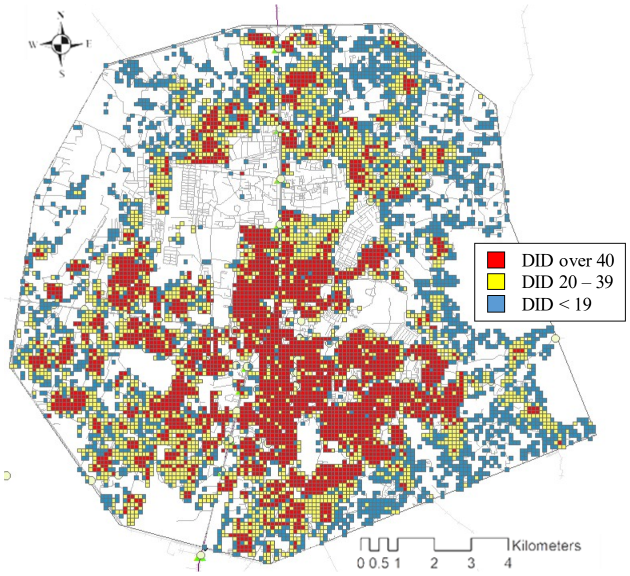
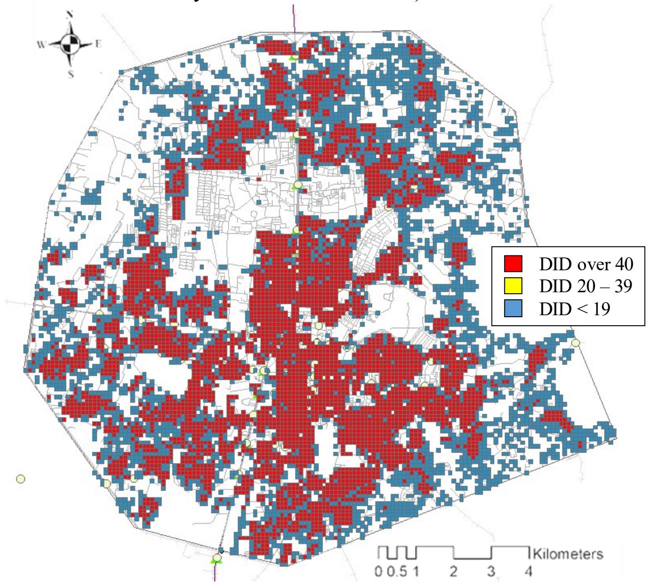


Fig. 5 Thailand Khon Kaen Prefectures, Urbanization Grid index (grid size 100 × 100 meter) Present. (A) - Current Situation (urbanization) in 8,065 grid feature units.



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



(b) – Supporting Policy for Promoting Médium Density (Population Density = 20 - 39 DID Grid Index) Scenario**.**

Fig. 6 Land Use Phenomenon.

Besides, the transport demand forecast suggested that the demands had increased rapidly from a total of 656,500 trips per day to 1,146,400 trips per day from 2018 to 2036 A.D. (National Statistical Office, 2020; Office of Transport and Traffic Policy and planning, 2016;), respectively. In the same vein, the previous research showed that 4 transportation modes including (1) Minibus; (2) Bus; (3) Taxi; and (4) Motorcycle, could be classified by the operation patterns into the regular route and non-regular route service and the dominant transportation modes in the area of study were motorcycles (53.6%) and private cars (32.1%). Only 14.3 %of trips were covered by public transportation (Planning, 2016). In fact, the urban rail public investment plan covered 5 routes: (1) North-South Route, (2) East-West Route (2 lines) with a plan completion in 2026 A.D., and (3) East-West Route and Northeast-Southwest Route with a plan completion in 2036 A.D. consisting of totally 31 stations through 122 km as shown in **Table 3** and **Figs 7–8**.

Trip Proposes

The accessibility 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; These facilities are commonly linked to the basic unit blocks (Statistics Bureau of Japan, 2020). Actually, accessibility was a fundamental aspect of assessing the competency of accessibility through different proposes.

This research adopted based on travel times and residential buildings as perceived by the allocated travelers (National statistical office, 2020). In term of the measured mobility mode by average speed, the study focused on the major types of building use (m^2 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 the government (Department of Public Works and Town and Country Planning: Thailand, 1979). This research was discussed and presented as the Geo-Information System (GIS) data showing the numbers of building units in 2018 A.D. as given in Table 4 and Fig. 9.

Table 4. Building Types (Trip purposes) , Thailand Khon Kaen prefectures.

No.	Mode of building	Total unit	Total Area (km^2)	Urbanization unit	Urbanization Area (km^2)
1	Public Facility	4,570	1.38	2,886 (63.2 %)	0.95 (68.5%)
2	Mixed-use	1,848	1.68	770 (41.7 %)	0.62 (36.8%)
3	Commer cial Use	10,615	3.68	8,082 (76.1 %)	2.59 (70.3%)

Table 3. Public transport information

No.	Mode	Number of routes	Total length (km)	Speed (km/h)	Stations (number)	Year
1	Walk	-	-	4.8 km/h (80 m/min)	-	-
2	Bus	19	294.39	15 km/h (250 m/min)	314	2020
3.1	Tram project	1	22.68	60-80 km/h in outbound and less than 60 km/h inbound.	16 up to 31	2021
3.2		3	46.38			2026
3.3		5	73.13			2036

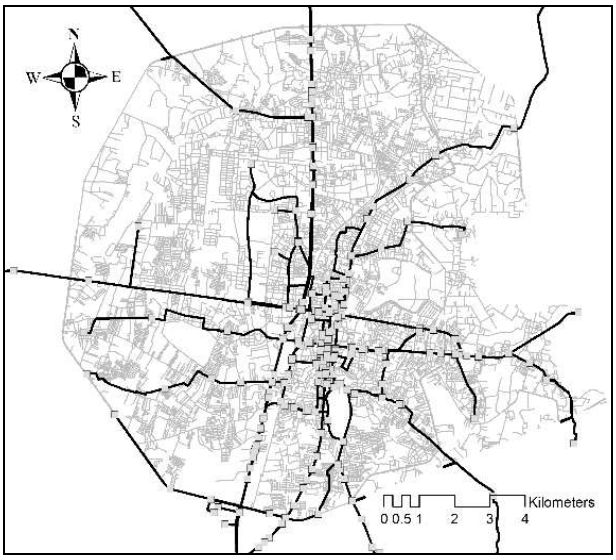


Fig. 7 19 Bus Network (2020 A.D.)

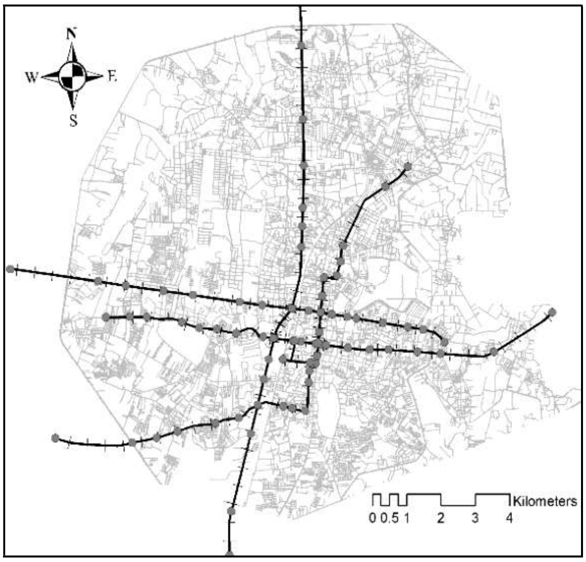


Fig. 8 Rail Investment Plan (2021−2036 A.D.)

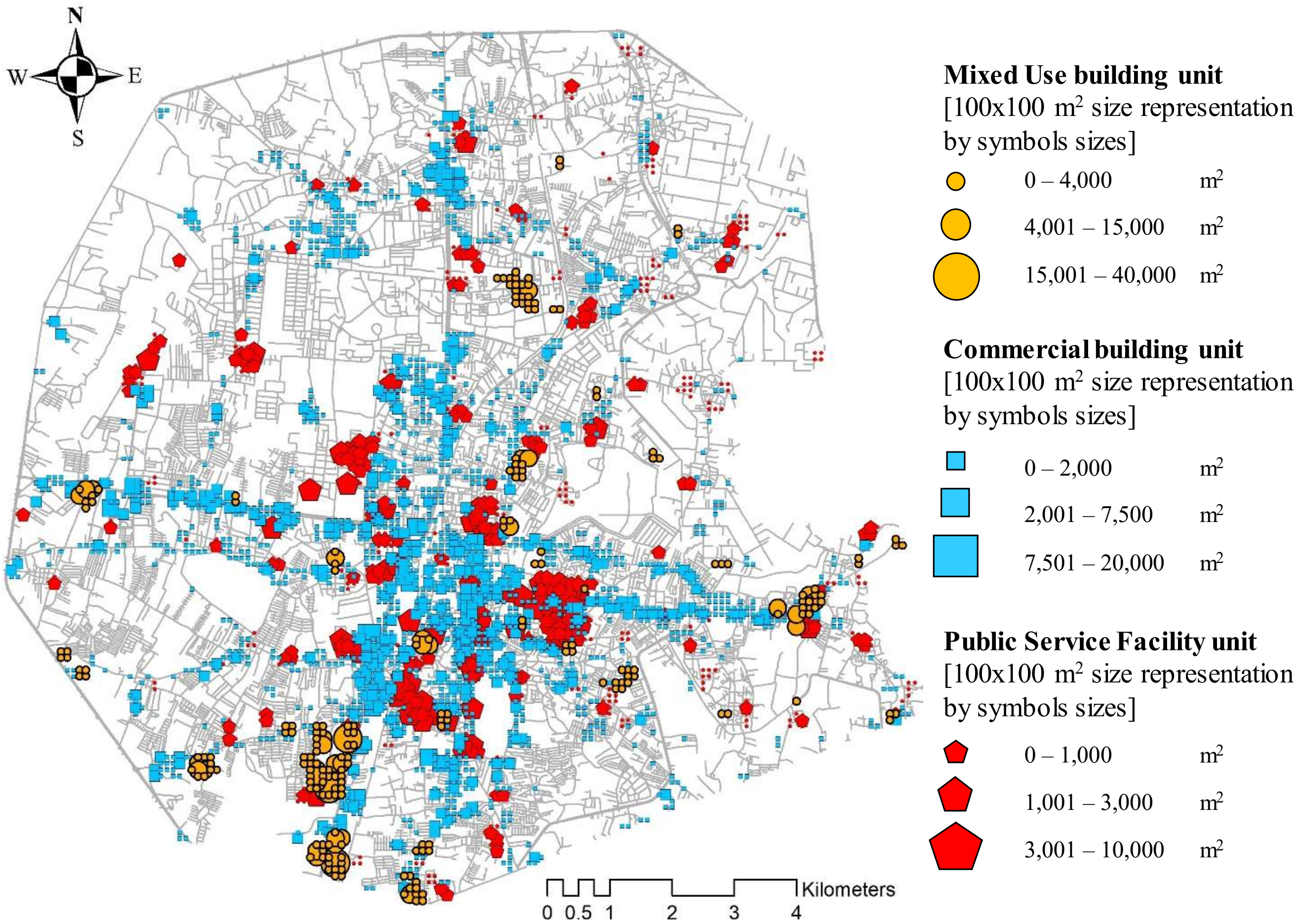


Fig. 9 The locations of 3 types of building unit.

RESULT

According to the abovementioned, the data analysis presented, firstly, the urban perception perceived by Densely Inhabited Districts (DID) scenarios showing the investigation on the population's accessibility through the multimodal transportation modes in which the results were interpreted by Accessibility Index varied by different land-use phenomenons. Secondly, the trip for urban mobility comparatively discussed 3 transportation modes, including Walk Mode, Bus Mode, and Urban Rail (Tram), based on population ratios (person unit) with their accessibility via that multimodal transportation as illustrated in **Fig. 10**. Namely, the bus stop node as a travel's mode connecting that exanimating was totally 314 units, only 120 of bus stop were walkable in 10 minutes via the road network;

whereas, a Bus - Train network modeling practically analyzed the data in 3 different timeframes including 2021, 2026, and 2036 A.D. According to the bus network computation, the numbers of reachable bus stops were 56 out of 314, 237 out of 314 and 251 out of 314 respectively. The data analysis also found that there was less than 10% of the total population with 10-min walkability to bus stops via the Walk- Bus - Tram mode. Consequently, the implications from cases study and the urban public transport (bus network) were directly related.

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 the 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 by 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 a tendency of a rapid increase in 2026 and 2036 A.D. in both supporting policies, as presented in **Fig. 11**.

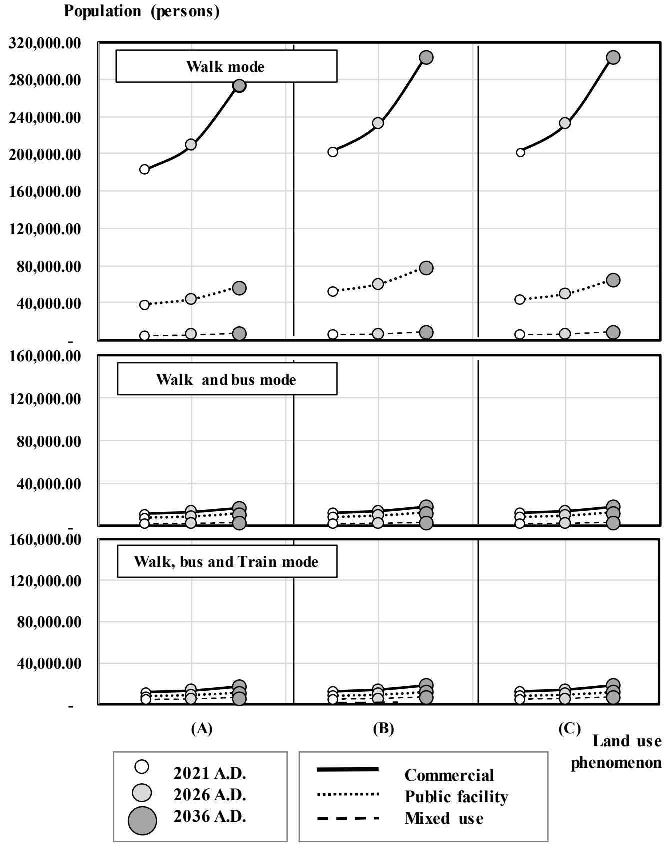


Fig. 10 The Population Reach in Those Multimodal Transportation.

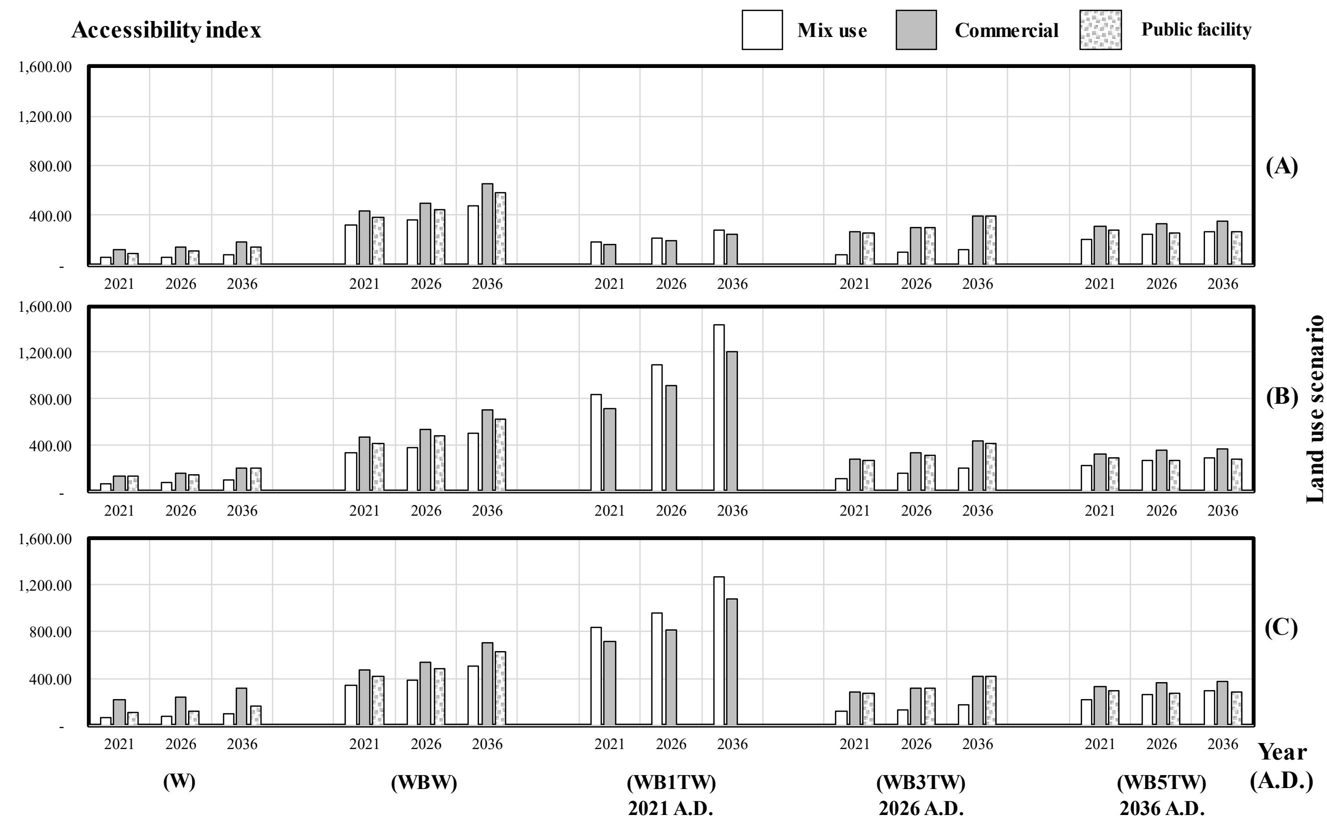


Fig. 11 The 5 Multimodal transportation mode in different land use scenarios.

Regarding the trip purposes in the rail investment plan (2021–2036 A.D.), the data analysis presented three multimodal transportation modes in different time uses (10 min to 40 min by different multimodal transportation modes computed by Accessibility Index) as depicted in **Fig. 12**. The comprarative 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).

DISCUSSION

This research presented the phenomenon of urban perception using a multimodal transport assessment technique; it was explained by the period of a light rail transportation investment plan (TRAM project; 2021-2036 A. D.). The multimodal transport assessment is significant considering the urban composition, especially the urban morphology, urban form, district, density, and public transport network data. This research applied a multimodal transport model focused on light rail infrastructure investment perception in the accessibility index. The integral database about the bus network was used as the system's feeder and the stopping points (bus stop or railway station) as a travel mode connecting point, especially the awareness of traveling by sidewalk from the origin to the destination. It was in line with the promotion of public transportation policies, that is, to reduce private car use.

Considering the accessibility index of urban perception, the results of the analysis of three urban population models showed that the promotion of medium and low-density residential areas (40 < DID <= 20 and DID < 20) was in line with the 2021 A.D. North-South Railway Development Plan. Besides, it could be seen that for other train routes, there was a low urban perception, especially when compared to the mode of traveling by bus. The characteristics of urban perception explained that the development along the bus route had the highest accessibility, i.e., the public bus network and the city morphology had important mutually related implications. The multimodal transport assessment model on a walk-bus and tram (40 minutes) in 2036 A.D. described that the tram accessibility in such areas was lower than the bus accessibility (30 minutes).

Urban rail infrastructure was essential for understanding the relationship between urban perception and public infrastructure leading to policy productivity during the urban perception to infrastructural investment policy, such as, the management of a city planning overview, high–density zone policy, guidelines for Transit-Oriented Development (TOD), etc. This model represented the urban perception model based on the light rail transportation investment plan (tram project) to understand and develop a more efficient approach to city-level cooperation in both the public and private sectors.

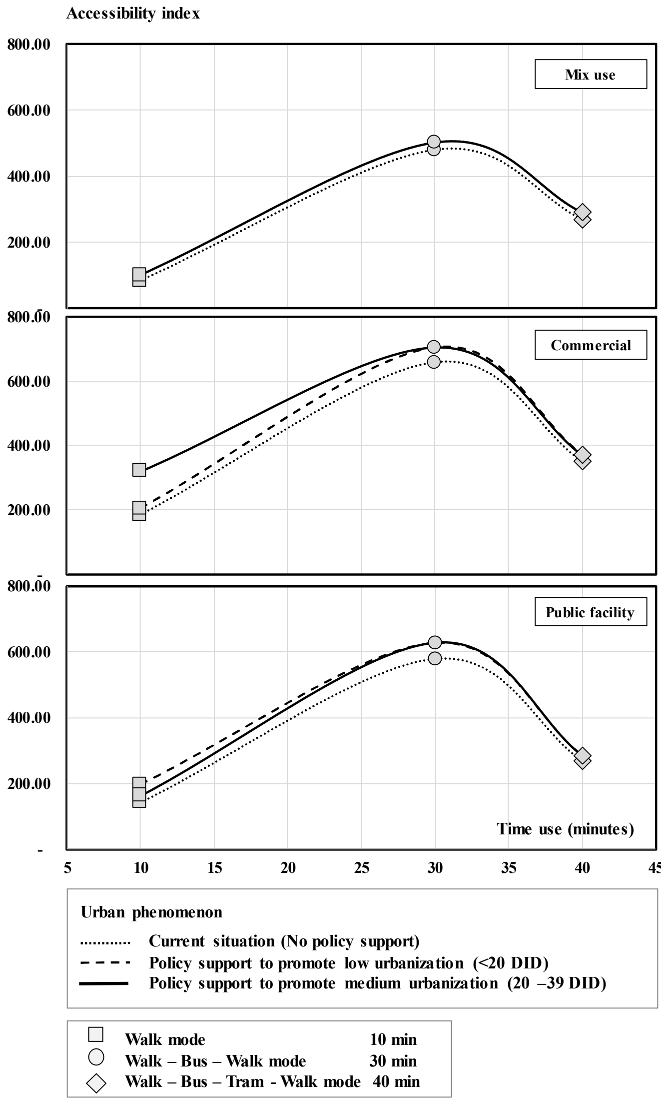


Fig. 12 Multimodal Transport Represented by Trip Purposes in 2036 A.D. (40- min time use)

CONCLUSION

Although rail transport was an urban development strategy to improve mobility, the study of urban mobility between the 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.

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