ACCESSIBILITY ANALYSIS FOR NAKHON RATCHASIMA LIGHT RAIL TRANSIT STATION

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ABSTRACT

Nakhon Ratchasima Municipality has planned to develop and reform the basic infrastructure and transportation by constructing the Light Rail Transit (LRT) as an alternative public transport system. Moreover, are development to facilitate for public transport connections and the walkway safety are also included in the development plan. This present research aimed to identify catchment areas around LRT stations by referring to acceptable walking distances to LRT stations as follows - 324 meters, 400 meters, 500 meters, 648 meters, 800 meters, and 960 meters. These walking distances were used with Circular Buffer and Network Analyst Service Area techniques in order to calculate for the proportions of LRT accessibility. Employing ArcGIS 10.4 program for desktop to analyze spatial data, this research found that the areas around LRT stations in the urban area of Nakhon Ratchasima had higher accessibility level than the suburbs. The data indicated that the areas around the stations located in the urban area were suitable for pedestrian network development. In order to develop mass transit system within the area of Nakhon Ratchasima Municipality, it was suggested that feeder system in the suburbs should also be developed with less proportion of LRT accessibility than the urban area for users' convenience. It was expected that the more accessible the LRT stations was, the more job opportunities and residential space would be available.

KEYWORDS: Accessibility, Geographic Information System, Light Rail Transit, Spatial Analysis, Nakhon Ratchasima

1. Introduction

The urban area of Nakhon Ratchasima has been recognized as the high potential area for developing the connecting spot to the high-speed rail in the future. To prepare for the increasing need of travel, public transportation system in the area is required to be improved. Given this, Traffic Management and Public Transport Development master plan in Nakhon Ratchasima urban areas was studied in order to reform the basic infrastructure and transportation in the province. As a result, Light Rail Transit (LRT) is the project approved for offering an alternative public transportation choice in the province. The areas for public transport connections are also expected to be developed for the more effective transportation system. According to the strategy of Area Development [1], the development of feeder system helps expand catchment areas of LRT to cover all areas and enable users living far from stations to travel seamlessly to their destination without using their personal vehicles. The project emphasizes pedestrian safety and convenience. This concept agrees with Calthorpe's [2] notion that the goals of area development consist of accessibility, convenience of public transport users, and compact city. Such the compact city could create new pedestrians; therefore, the area development is considered to be the preparation for the city growth [3]. Similar to the notion of Transit Oriented Development (TOD), mixed-used communities, in which people are able to walk to the center of the high-speed rail system, are recommended to reduce users' dependence on personal vehicles and save more energy [4].

This current research aimed to identify catchment areas around LRT stations by referring to acceptable walking distances to LRT stations as follows - 324 meters, 400 meters, 500 meters, 648 meters, 800 meters, and 960 meters. These walking distances established the coverage areas around LRT stations. They could be viewed as indicators which could be divided into in two forms of distances: Euclidean distance and network distance. By calculating the proportion from the walking distances and area sizes, station accessibility was evaluated. In addition, a geographic information system (GIS), was used as an instrument for analyzing spatial data.

2. Previous Work

2.1 Transit Oriented Development (TOD)

Transit Oriented Development (TOD) is an integrated urban areas designed for maximizing the use of public areas with easy walking and cycling connections and convenient public transit service to the rest of the city [5]. The Next America Metropolis defines that Transit-Oriented Development (TOD) is mixed land use such as residential areas, commercial areas, or places in which people can be access to the central transit by walking to their workplaces [2]. This agrees with another work on assessing the social and economic effects of transportation projects [6] which found that the improvement of walkway was the key factor for enhancing better communities. The areas where TOD is promoted is considered as the center of mass transit and located near public transport stations within 10 minute walk or 500-800 meters from the stations [7, 8]. Factors influencing physical environmental development of TOD areas affect the number of public transportation users and help reduce dependence on personal vehicles. Furthermore, the improvement of transportation route conditions helps increase the use of a bicycle [9].

2.2 Typology of Transit Oriented Development (TOD)

TOD can be divided into different ways [2]. Types of TOD can be differentiated by locations and public transport connections. The term Urban TOD is defined as the TOD located on main transportation networks or the TOD that connects to urban public transportation systems. This type of TOD is collaboratively developed with business zones and high residential density zones. Different from Urban TOD, Neighborhood TOD is located in lower density areas. This type of TOD is located on Feeder public transport networks [8]. Also, Transit Oriented Development can be divided according to types of stations (Node) and areas around the stations (Place). Node indicates the main roles of areas. These areas are comparatively important because they connect to public transport networks. On the contrary, place demonstrates the roles of areas for various activities. It is necessary that the development of areas around stations or stops should balance the roles of node and Place in order to optimize the use of areas. Developing transit-oriented development (TOD) typologies is an effective strategy for urban sustainability [10]. The comparative analysis of TOD typologies, in terms of extending 'node–place' model, involves increasing dimension on node–functionality–place. This model was applied to five cities in China. It was found that all five cities adopted similar spatial pattern. This study contributed to planners and policymakers in performing strategic town planning.

2.3 Accessibility

The main role of transportation system is to offer convenient accessibility between people and business and to facilitate exchanges of product information and services [11]. The accessibility is an essential element of transportation. It exhibits the agility of product or information transportation [12]. According to article about classifying sky train stations by building use and accessibility In Bangkok, the use of high- density buildings and the accessibility to the areas around stations from the feeder transportation system were correlated with the number of sky train users [13]. Hence, these factors have become the significant factors for its catchment area development concept (TOD) [2]. The research investigating the measurement of land usage accessibility development [14] underscored that passenger behaviors depend on their accessibility to areas and forms of land usage [15].

2.4 Measuring Accessibility

Accessibility is the measure of the capacity of a location. Basic infrastructure management has become the key for accessibility which helps indicate spatial inequality [12]. Accessibility to many types of facilities has been widely recognized in the field of sustainable city planning [16]. The public transit accessibility to educational facilities was evaluated in India using spatial techniques [16]. The study compared Euclidean and network distance, also known as detour indices. Descriptive statistics and regression analysis were two main tools for evaluation. The analysis identified local obstacles and network problems which have impacts on the public transit accessibility [17]. Accessibility to amenities, services, and facilities (ASF) from public transit was measured by employing two types of spatial distance accessibility measures. In the early stage, the Euclidean distance was compared using Google API along with other mobile applications. After that the study focused on network distances using Open Street Map (OSM). At the second stage, Indicators (Euclidean vs. network) helped identify the local barriers and problems with network access that affect the actual network distance. This also helped policymakers identify gaps in public transit coverage and accessibility to the ASF. Detour Index reveals the relationship between transport networks and straight distance. The higher the Detour Index value is, the more transport networks inclined toward straight distance [18]. The efficiency of transport networks can be measured by the Detour Index. That is, transport networks will have more spatial efficiency when the Detour Index is close to one [19]. Two types of distances, namely Euclidean and network distances, are compared from the station to a fixed destination.

$$DI = \frac{D(S)}{D(T)} \qquad (1)$$

where D(S) and D(T) refer to Euclidean and network distances respectively.

Accessibility measurement using the Circular Buffer method considers all areas around the targeted spot based on distance selected for studying. Network Analyst Service Area can also be adopted to identify geographical environment around the targeted spot and distance selected for studying. A public transport research in Denmark borrowed detour index to show catchment areas by using proportion analysis between Circular Buffer and Network Analyst Service Area. Detour Index (DI) is equal to length of the route divided by the geographical distance between the origin and the end [20]. This technique helps measure accessibility. If the proportion is close to 1, it indicates good accessibility.

2.5 Walkability

Walkability is significant for planning highly effective cities. A walkability research in Italy explored techniques for measuring the quality of walkway and walkability toward the railway station. The research considered key factors influencing walkability in urban areas [21]. Other studies about analysis of transit service areas using by GIS, it was reported that walking distances to reach public transit, bus stops and railway stations, from starting points are 550 meters and 1,200 meters respectively [22]. Sangsila [23] studied pedestrians' behaviors in using Bangkok Mass Transit System skytrain at a distance of 500 meters. It was found that pedestrians were less likely to use public transit every 100 meters father from stations. People preferred walking at a distance of 200-300 meters according to studies of Sakdasak [24] and also investigate catchment areas around Talad Bang Yai station. He highlighted that areas in Bang Yai were appropriate for undertaking TOD because rail users were able to reach the station within 5-10 minutes or 500 meters. The 500 meter radius determined according to studied Sangsila [23, 24] conformed to a study in Nakhon Ratchasima urban areas which was included in the Area Development Plan for Integrating Public Transportation Connections. Moreover, Kho-oomklang [25] studied about acceptable walking distance to reach the public transit system in Nakhon Ratchasima Municipality by applying Price Sensitivity Meter (PSM) in her research. Her research revealed that the longest walking distance that passengers would decide to walk to the LRT stations was between 324 – 648 meters in normal climate. Duncan et al [26] studied about inspected the accuracy of Walk Score and Transit Score by using the data gathered from GIS and divided the ranges of road networks into 400 meters and 800 meters. The correlation analysis reported significant values for bus stops and subway which related to Walking Score at a distance of 400 meters and Transit Score at a distance of 800 meters. Thus, it could be concluded that Walk Score is the accurate indicator for measuring walkability. Similar to research of Carr et al [27] studied was, the accuracy and the reliability of Walk Score used for estimating walkable access to facilities were testified. The results confirmed that Walk Score was a reliable and accurate measurement for estimating walkable access to facilities. Walk Score could be one convenient option for researchers who would like to investigate a relationship between walkable access to facilities. Transport for London [28] highlighted transportation and public transit connectivity dealing with Public Transport Access Level (PTAL) that it was a measurement for public transit system connectivity in London which related to walkability. The measurement referred to the distance to the nearest station, waiting time and service frequency, and the nearness of the main railway station. To measure accessibility, a Point of Interest (POI) and Service Access Points (SAP) needed to be determined. The average walking speed reported in Transport for was 4.8 kilometers per hour. The walking time to reach the nearest bust terminal was within 8 minutes or 640 meters. The walking time to the railway station reported was 12 minutes or 960 meters.

3. Materials and Methods

3.1 Area of Studies

The area of Nakhon Ratchasima Municipality, Muang district, Nakhon Ratchasima has an area around 37.5 square kilometers.

Nakhon Ratchasima LRT network consists of two phases as shown in figure 1. Phase 1 comprises the orange and green lines. The orange line runs through the economic growth area with the entertainment area, the hospital, and the old town for a total distance of 9.81 kilometers with 19 stations. The green line runs from a large market of the municipality through and the city's main railway station. This route provides access to government offices, schools, and Suranaree monument, with a distance of 11.17 kilometers and 20 stations. Phase 2 includes the purple line which connects Nakhon Ratchasima Bus Terminal with large shopping centers. This line is 7.14 kilometers long and contains 17 stations [1].

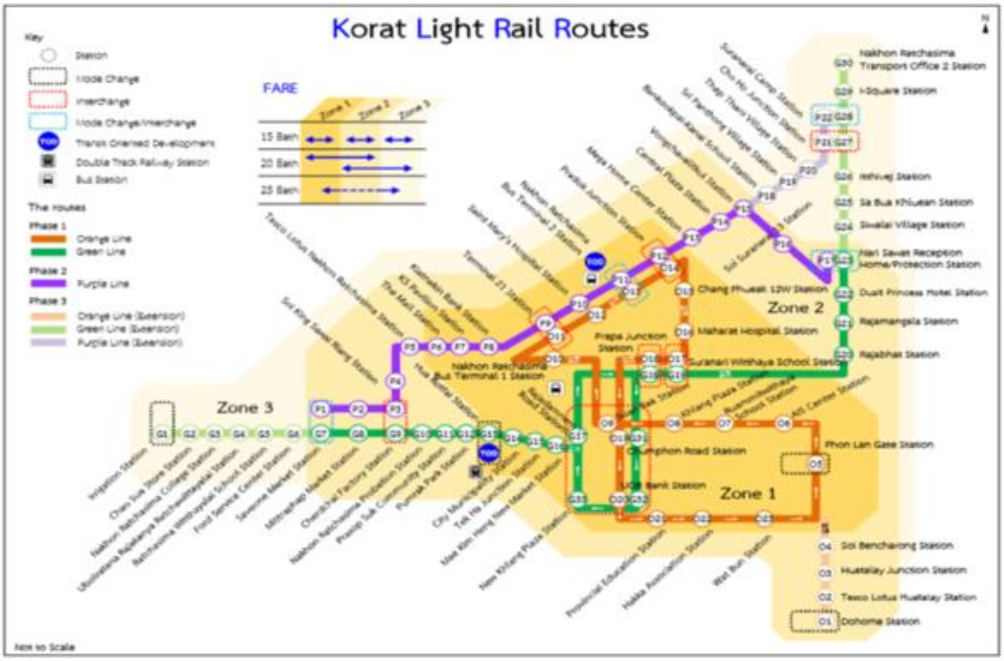

Figure 1 The light rail transit (LRT) station [1]

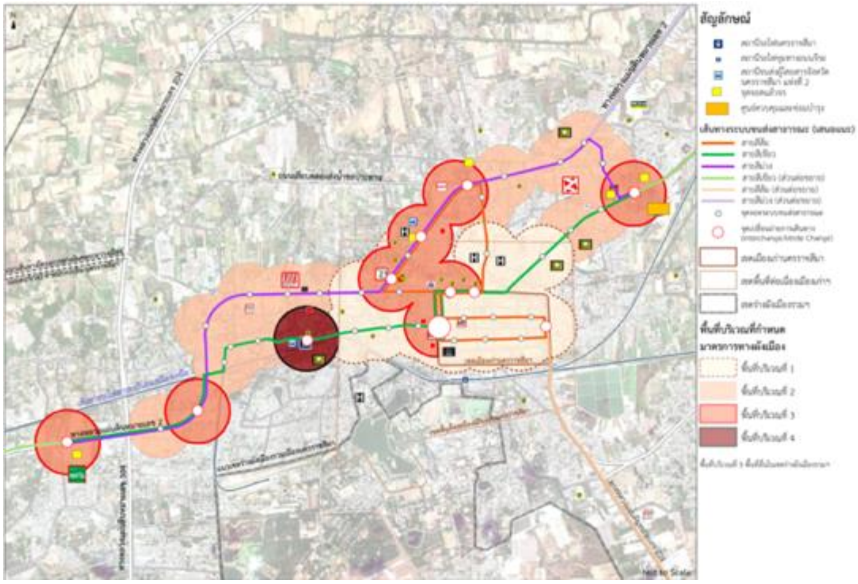

Figure 2 Area classification [1]

The study project of Traffic Management and Public Transport Development in Nakhon Ratchasima urban areas identified the area development along with the construction of LRT routes. The development can be divided into 4 areas: (1) the old town areas around LRT stations and the continuous areas; (2) the areas outside the old town and continuous areas; (3) the areas around LRT stations which are expected to be LRT interchanges and transport mode change; and (4) the areas around stations at the Transit Oriented Development (TOD) zones.

3.2 Data collection instruments

The ArcGIS 10.4.1 program for Desktop was employed for saving digital data and determining Universal Transverse Mercator (UTM). The mapping control followed Indian 1975 reference. Therefore, the coordinate systems on the map used in this research were Indian 1975/UTM Zone 47 and Indian 1975/UTM Zone 48 [29].

3.3 Data analysis and interpretation

3.3.1 Point data layers of 19 orange-line stations, 20 green-line stations, and 17 purple-line stations were created by ArcGIS 10.4.1 program for Desktop as shown in figure 3 in order to analyze Circular Buffer and calculate area sizes based on Euclidean Distance within 324 meters, 400 meters, 500 meters, 648 meters, 800 meters, and 960 meters.

3.3.2 To create Polygon data of 19 orange-line stations, 20 green-line stations, and 17 purple-line stations, the researcher used GIS Application together with Network Analysis [30] and Service Area at of distances of 324 meters, 400 meters, 500 meters, 648 meters, 800 meters and 960 meters. The buffer distance is taken as the service area distance. The area sizes were calculated by adopting Network Distance.

3.3.3 The Euclidean Distance and Network Distance data were used for analyzing proportion.

3.3.4 Then, the GIS application is used for analysis via Inverse Distance Weighted (IDW) method. The proportions values are taken with the IDW. The methods mentioned above are Interpolate a raster surface from points.

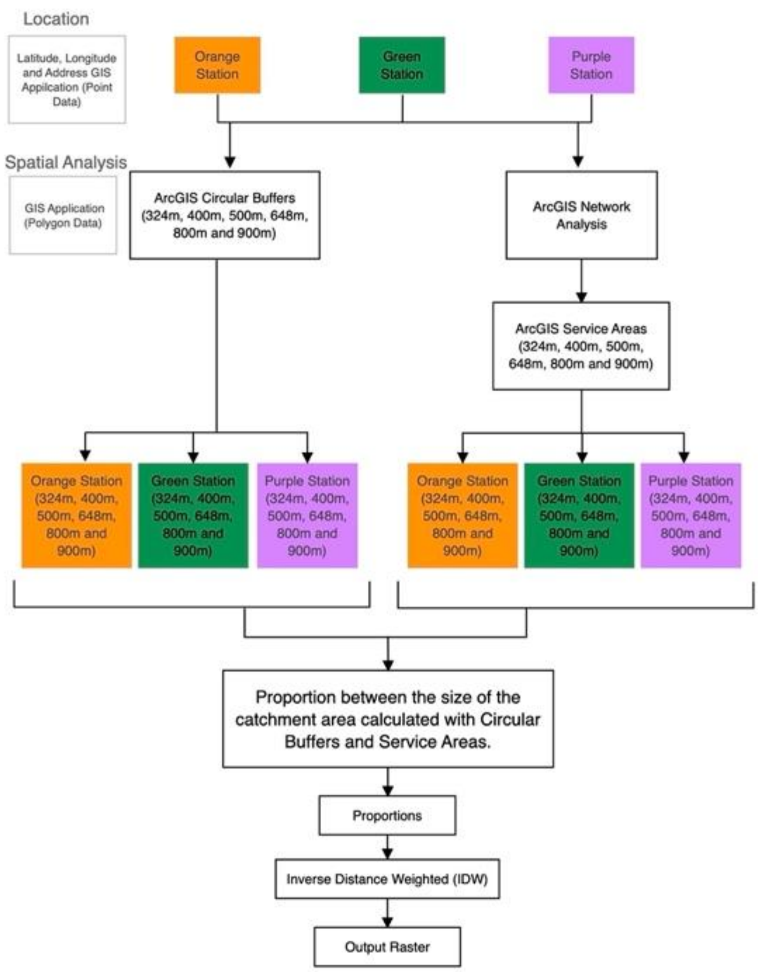

Figure 3 Method adopted in ArcGIS 10.4.1 for Desktop

4. Results

After calculating IDW and Euclidean-Network distance proportions were calculated and compared among stations and transit lines. Shown in figure 4 to figure 14 and table conclude the key indicators findings of the analysis.

Figure 4 The result generated from ArcGIS 10.4.1 for Desktop is Catchment area of Korat Light Rail Route (Orange Station) in Nakhon Ratchasima Municipality. Circular Buffer Approach and Service Area Approach.

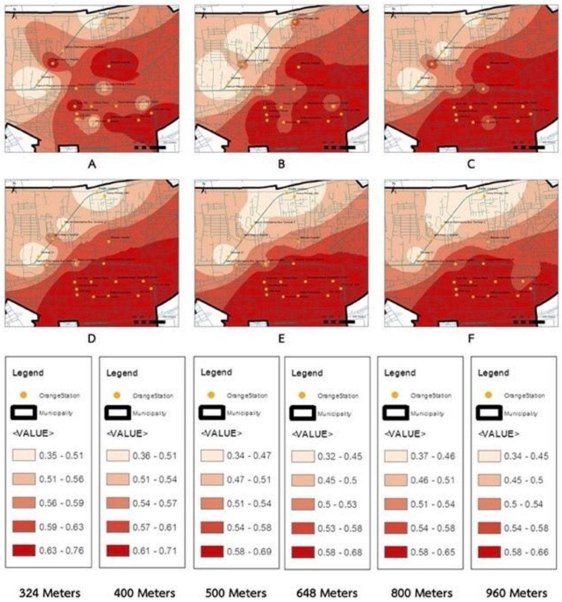

Figure 5 Inverse Distance Weighted (IDW) of Orange Stations: picture A 324 meters, picture B 400 meters, picture C 500 meters, picture D 648 meters, picture E 800 meters, and picture F 960 meters.

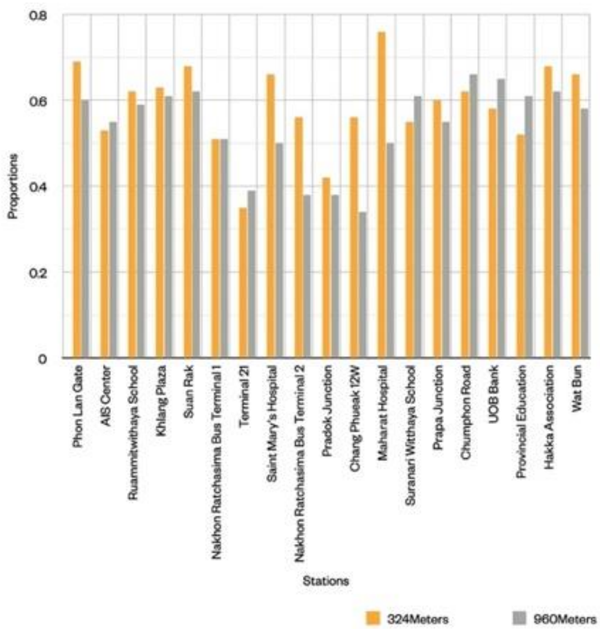

Figure 6 Proportion around LRT stations (Orange line) at distances of 324 meters and 960 meters.

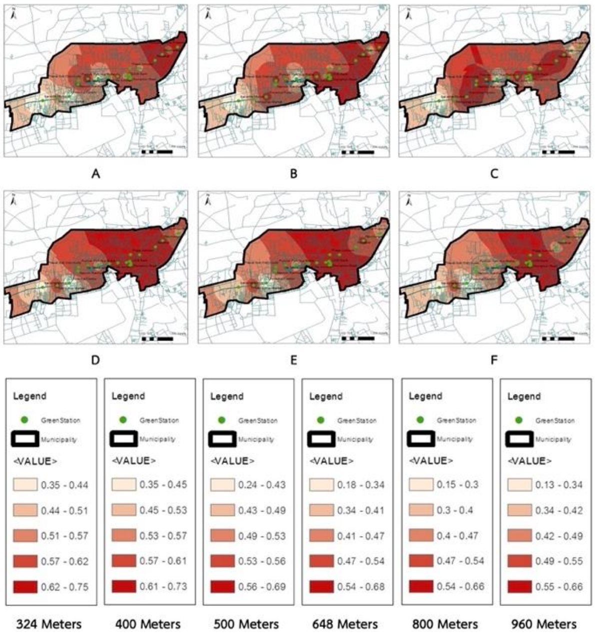

Figure 7 **Inverse Distance Weighted (IDW) of Green Stations: picture A 324 meters, picture B 400 meters, picture C 500 meters, picture D 648 meters, picture E 800 meters, and picture F 960 meters.**

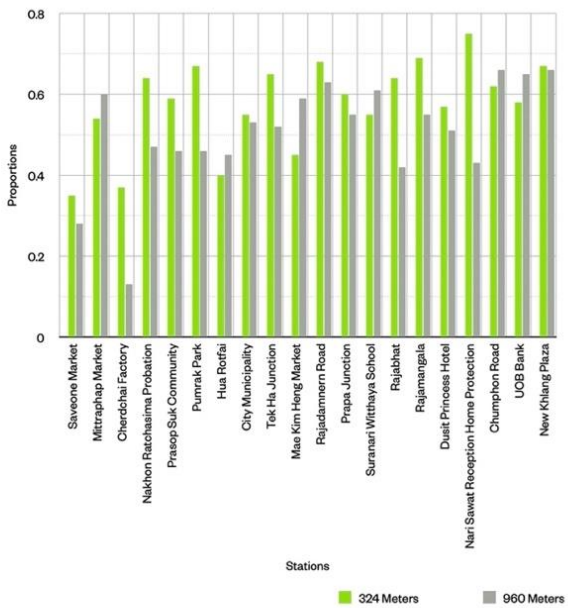

Figure 8 **The proportion around green-line LRT stations at distances of 324 meters and 960 meters.**

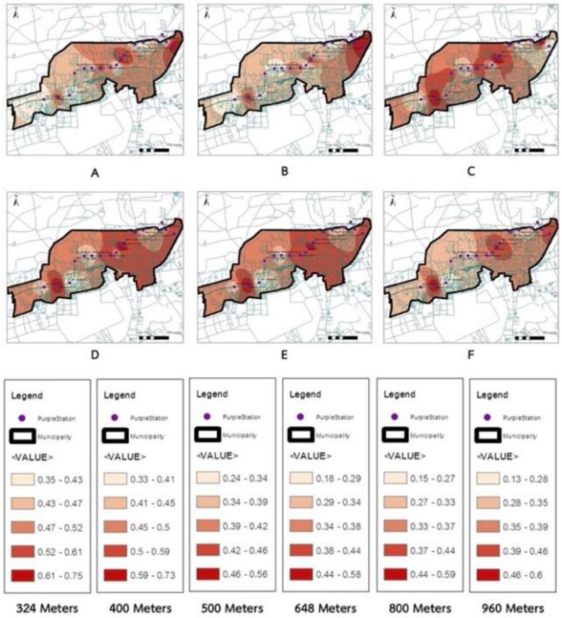

Figure 9 **Inverse Distance Weighted (IDW) of Purple Stations: picture A 324 meters, picture B 400 meters, picture C 500 meters, picture D 648 meters, picture E 800 meters, and picture F 960 meters.**

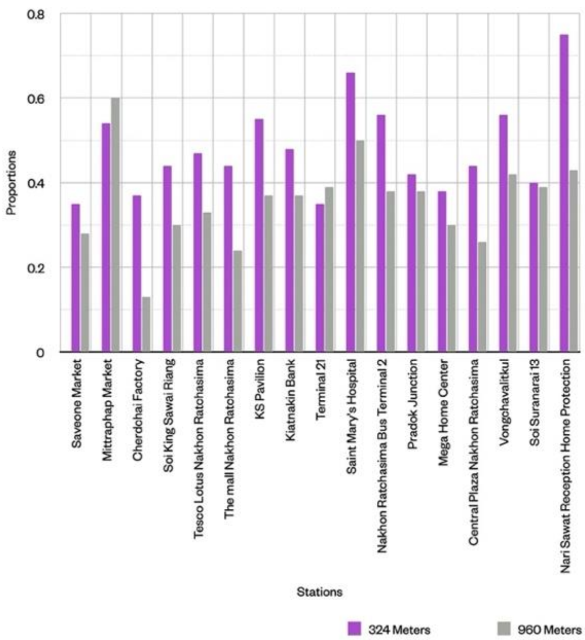

Figure 10 **Proportion around LRT stations (Purple line) at distances of 324 meters and 960 meters.**

Table 1 The Range of Proportion of catchment area around Korat Light rail Transit Stations.

Light rail Transit	Average	S.D.	Maximum	Minimum
Orange Line	0.56	0.10	0.76 (Maharat Hospital station)	0.32 (Terminal 21 station)
Green Line	0.54	0.12	0.75 (Nari Sawat Station)	0.13 (Cherdchai Factory station)
Purple Line	0.41	0.11	0.75 (Nari Sawat Station)	0.13 (Cherdchai Factory station)

These stations were selected to represent the accessibility of various area types such as urban, suburbs, central business districts (CBD), and Transit-Oriented Development (TOD). The CBD areas were located near 7 orange-line and green-line stations, while a few presented for purple line. The urban area had the highest average proportion of accessibility. The suburban area had far less accessibility than the urban area. Finally, the results show the proportion of the catchment area for each station, which was expected to become a TOD, as shown in figure 11-14.

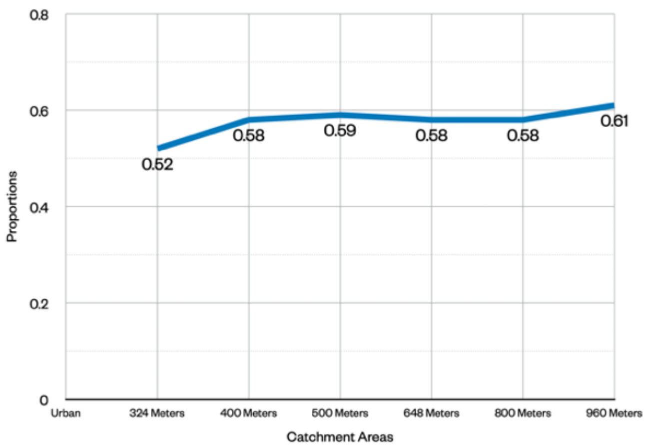

Figure 11 Proportion of the urban area: Provincial Education station (orange line)

The average proportion was 0.57 (S.D.=0.09). The highest proportion was 0.76 and the lowest proportion was 0.32.

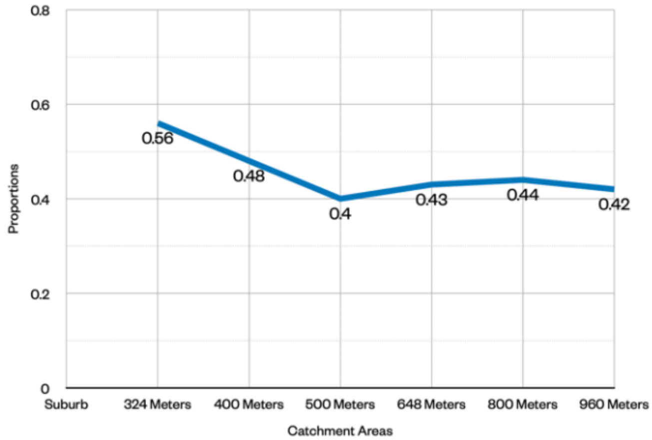

Figure 12 Proportion of the suburban area: Vongchavalitkul station (purple line)

The average proportion was 0.44 (S.D.=0.13). The highest proportion was 0.75 and the lowest proportion was 0.13.

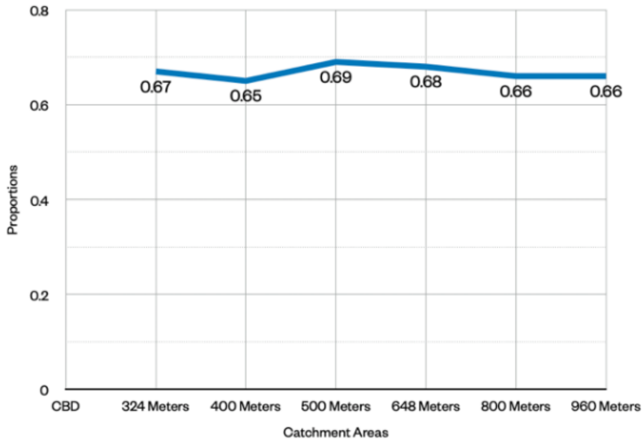

Figure 13 Proportion Central Business District: New Khlang Plaza station (green line)

The average proportion was 0.65 (S.D.=0.03). The highest proportion was 0.71 and the lowest proportion was 0.58.

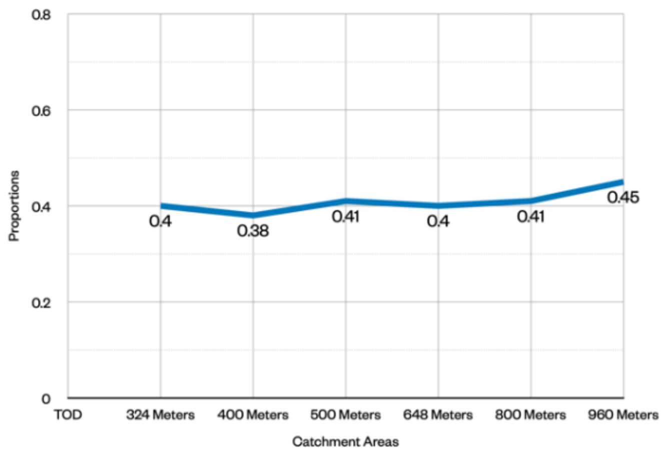

Figure 14 Proportion Transit Oriented Development (TOD): Hua Rotfai station (green line)

The average proportion was 0.43 (S.D.=0.05). The highest proportion was 0.56 and the lowest proportion was 0.38.

5. Discussion and Conclusion

The accumulated evidence indicated that the analogy of distance types show that Cartesian distances (Euclidean and Manhattan distances) are strongly correlated with more precise network distances [31]. In 2017 Suber [32] studied public transportation accessibility impact. The findings indicated that accessibility measures for educational facilities are largely concentrated on the number of facilities within certain metres or minutes to the closest service. These distances are calculated based on several types (1) Euclidean distance, (2) Manhattan distance (3) Network distance and (4) Minkowski distance method [31]. Furthermore, revealed show that Euclidean (near) distance and network distance are reasonable in context to accessibility measures [33]. This study aimed to conduct general last mile mode choice behavior for Nakhon Ratchasima's potential LRT users with no specific origins and destinations.

The method used in this current research helped measure area accessibility which could be easily applied in the actual areas. The spatial analysis around LRT station at distances of 324 meters, 400 meters, 500 meters, 648 meters, 800 meters, and 960 meters within the area of Nakhon Ratchasima Municipality was undertaken by ArcGIS 10.4 for Desktop. The author uses the official shapefile from Nakhon Ratchasima Municipality and the school of remote sensing, institute of science, Suranaree university of technology. Both of them use Universal Transverse Mercator (UTM) system, Indian 1975/UTM Zone 47 and Indian 1975/UTM Zone 48 most importantly, in 2017 Jirakajohnkool wrote in ArcGIS desktop 10.5 that Thailand commonly uses Universal Transverse Mercator (UTM). The above system is accurate in terms of shape, area, distance, and direction most close to reality [30]. The accessibility to the areas around the LRT stations in Nakhon Ratchasima Municipality can be concluded as follows.

1) The urban areas had higher average proportion than the suburban areas. This is because the urban area had road networks around LRT stations or 68% of Grid Network. The characteristics of roads in the area are connected. Moreover, there are numerous local streets which help support the area accessibility. It is also the Central Business District (CBD) the urban area had the highest average proportion of accessibility. Given this, quality walkway as well as slope ramps for disabilities can be further developed along with the LRT system. Facilities and environment should also be improved. More streetlights and a security camera system should be installed to create reliable services for users. This could urge service users to walk to the public transit instead of using personal vehicles.

In the urban area, several lines of minibus stop at almost every LRT station. This indicates that the feeder system within the area is efficient enough to support public transport users in the future. However, the feeder system still needs to be further developed in some stations, such as City Municipality station, Provincial Education station, and Hakka Association station, because there is only one line of minivans stops at those stations. In the future, when the LRT system operates, there will be higher demand of travel in those areas. This could lead to inadequate public transport services in the areas. Hence, in those stations, an increase in the number of minibuses should be adopted as those stations are in the old town area with dense communities, however, based upon future demand.

2) The suburban area has Linear-Network roads around stations. This type of roads cuts through communities and separates into local streets. Mittraphap Road or Highway 2 passes through 17 stations and Transit Oriented Development (TOD) zones which is Nakhon Ratchasima Bus Terminal2. This is the spot for public transport mode change for all modes of public transport services: category 1-4. Moreover, Suranarai road or highway 205 passes through 4 stations and communities with 6 stations. 1 of 6 stations, Hua Rodfai station, is

the Transit Oriented Development (TOD) spot connecting both high-speed and double track railway projects. It is possible that there will be higher demand of transportation in the future. The average proportion of accessibility in the suburban area is less than the proportion in the urban area because the main intercity highway is in the suburban. The areas around stations are far from communities and has low population density. Therefore, the walkway development might not be necessary in some stations because service users are not able to walk to these LRT stations. The priority should be given to the feeder system development which better supports the service users. This could lead to the accessibility to job opportunities, residential areas, or basic infrastructure. More importantly, to create eco-friendly communities, the areas around Nakhon Ratchasima Bus Terminal2 and Hua Rodfai stations need to be developed according to the principles of Transit Oriented Development (TOD). To reduce the use of personal cars, walking and cycling should also be promoted. This is recognized as the effective public transport development for the increasing urban area accessibility. Also, the measurement for Compact City planning needs to be promoted with various kinds of activities. Eventually, it will become the center attracting more people with convenient public transport connectivity.

The development of the feeder system in the suburban area is profoundly significant because of the low accessibility of the stations especially outside the CBD area. It is also necessary to improve public transportation modes in this area to support public transport users.

The suburban area consists of a number of residential zones, communities, and economic activities in Nakhon Ratchasima. It is suggested that the feeder system station that should be developed for Chang Phueak 12W station. This is because there are numerous communities in this area with only one line of minibus available. Additionally, it is necessary to provide the users with paratransit to fill the gaps where public transport cannot successfully operate.

6 Recommendations

6.1 The study of accessibility to catchment areas around LRT stations can be further developed and improved for planning traffic policy in the future.

6.2 In the future, the development of area accessibility to LRT stations will increase users' demand for public transportation. This could help reduce traffic density resulting from the use of personal cars.

6.3 The study of area accessibility is useful for selecting appropriate LRT stations which will be suitable for developing quality walkway in the future.

6.4 The study of area accessibility helps develop connectivity of all kinds of transportation in order to create seamless travel.

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