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Land Use and Transport Integration to Promote Pedestrian Accessibility in the Proximity of Mass Transit Stations

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LAND USE AND TRANSPORT INTEGRATION TO PROMOTE PEDESTRIAN ACCESSIBILITY IN THE PROXIMITY OF MASS TRANSIT STATIONS

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Abstract

Bangkok and its vicinity encounter traffic problems and air pollution that has been aggravating its situation due to traffic jams and high-density buildings in urban areas. Due to the previous development plan, the area is not aligned with the needs of area development particularly accessibility problem. Therefore, it is necessary to distinguish the area around the station of 500 meters from the centroid of each station. The design factor which was considered in this study include; design, diversity, density, destination and accessibility. The classification of destination in the different station was performed by using statistical analysis to distinguish the group of stations by using the Cluster analysis. The average of all cases was compared among all pairs and analyzed from the Dendrogram. It has found the result was classified into six groups which represent the main activity of the residential area, the mixed-use area, commercial area, recreation area, and central area. The government. It is an approach of the development around the station area following their context to alleviate traffic congestion with reducing air pollution to achieve sustainable development and promote activities surrounding transit station.

Keyword: Transit Oriented Development: TOD, Land use, Transit Stations

1. Introduction

Bangkok and the perimeter are expanding along with the main street network with an inconsistent of secondary road development. The congestion of traffic volume includes the problem of road safety and lack of public transport links, affordable housing and urban infrastructure are critical urban public which has continued to occur. From the statistics of TomTom, the famous GPS manufacturers rated the city with the most traffic jam in the world from the big city of 390 cities among 48 countries. It found that Bangkok represented the first ranking of congestion (BLT Bangkok, 2561) which might be due to the major cities in the developed countries such as Tokyo, London, Singapore, Hong Kong, Seoul and New York, use the rail mass transit system as part of traffic solutions and mitigate environmental problems. Stimulate the economic growth of the community as a result of government policy and the current national Economic and Social Development plan focuses on the development of transportation of people and goods by the rail system. Thailand's development is in the present lacking of development of sufficient public transport such as parking, bus, and transportation centres for a different community to link with existing development of housing, trade centres, employment areas and advance transport planning for the future.

From the last 15 years since it was opened to the BTS rail mass transit system, Thailand's lack of plans to develop an appropriate area around the mass transit station or Transit-Oriented Development (TOD), the design of the mass transit systems are lack of holistic planning which covers the development of the city to promote traveling with the public transport system. Traffic transport forecasting (transport modelling) often ignores key usage of land use, such as urban form or urban design factors contributing to all group of uses. (disadvantaged people), such as children, women and people. Non-motorized transport Mode (NMT), such as pedestrians and cyclists, has always been ignored as well as lack of capturing economic valuation, such as lack of consideration of the value of external social impacts. When designing of TOD projects, a high-density building block or high-density, land use will be employed in highest utilization (Highly-dense and mixed land use) such as a commercial centre, a government institution or a residential building in the area or around the public transport station. The density is dimmed when it is developed out of the centre. The traffic radius should be within walking distance (walking distance) with approximately up to 800 meters from the development centre or station.

The area around the station poses its different context. The large area of Bangkok comprises of 5 main areas which are; 1. Central business district, Bangkok city centre (CBD) 2. Urban Area 3. East Outer Ring Area (East Outer Ring Road) 4. West Outer Ring Road (Suburban) and 5 outer outside of Bangkok or the perimeter (TerraBKK, 2014), to provide specific development that responds to the context of the station area. This study aims to study the physical characteristics of the stations area and employ data from the use of land to classify different group stations according to the features of the mass transit station, promoting access to the TOD areas and suggest for appropriate guidance. To develop a space around the station to plan a spatial based area that responds to the local needs and preserve the unique development of the area to achieve sustainable mobility development.

2. Literature review

2.1 Transit Oriented Development: TOD

In the year 2016, Woraporn Poonyakanok discusses the concept of developing areas around the mass transit station (Transit-Oriented Development or TOD) (Figure 1) that means the development of the area surrounding the mass transit station to take advantage of mixed land use. High density and promotes the use of public transportation systems. The TOD concept aims to create a wide range of activities in the area around the public transport station, with a variety of building types; residential, commercial, office, and other types. This is to support users of the public transport system, as well as the environment conducive to pedestrian and use bicycles to provide a wide range of travel options while reducing reliance on private cars.

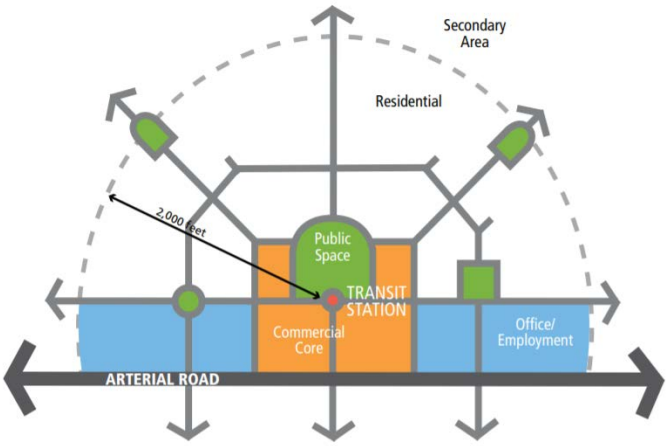

Figure 1. Rutul Joshi, et al. (2017). *Transit-Oriented Development.*

The community is mixed within the average pedestrian distance of 2,000 feet from the bus stop and the main commercial area. TOD blends residential office shops, open spaces and public transportation in a walking environment, making it convenient for residents and staff to travel by public transport, bike, foot or car. Also, the transport hub should be located in the centre of the neighbourhood, away from the residents of 500 meters or 10 minutes, this central location reflects the importance of transportation in the community and the overall region as of Figure 1 (Angela Brinklow, 2010).

The development of the area according to the TOD principle was successful, not just by the development of the area of TOD, but it should be developed into a unique TOD district and resulting in a reducing of travel volume. Several passengers can access public transportation and people in other areas may make the trip into TOD area with a private car rather than using public modes. It is developed according to TOD principles and creating a built environment to create a more TOD place in many areas to succeed by considering 5 dimensional of station area development as follows (Angela Brinklow, 2010):

- Density to create an area of TOD: It must have some houses with a lot of working-age population There should be several tourists high enough in the area and must be within walking distance. Tourist attraction plays a role as a trip generation to feed to the BTS Skytrain because these populations are the number of passengers who will enter the station and result in a reduction in private car travel.
- Diversity: Space utilization or land utilization in areas around TOD should contain a mixture of land use in a variety of types. There are many styles of housing with different architectural styles and connects the surrounding areas to provide access to various land use activities.
- Design of the physical environment of the TOD area: Facilities in the TOD area could assist commuters with walking trips or bicycle use to reduce travel by private cars and attract more people into the station area.
- Distance to Transit: The identification of the public commuters in access to TOD areas which represents the distance between the metro station, housing location and the employment area. To scope with travel behaviour of commuters in access to the city centre, it requires access to the various activities with fast and

convenient, which significantly reduces the time and cost of travel with the public transport system. Thus, the development of the area according to TOD is taken into account of the distance to the station to meet the preferences of the trip makers appropriately.

- Destination Accessibility: The ability to access area of the area development according to the TOD principle means to manage the connection of various areas to transit station such as shops, business centres, residential areas, and areas that attract people to connect conveniently and easily. The ability to access these areas is necessary to consider the level of accessibility of the mass transit system in which the area can be connected to the BTS (Skytrain) station.

To create an environmental dimension in the area, TOD can be applied to promote the development of a successful station area planning. The concept also helps to build social interactions between people who live in the city, with a lively atmosphere, then local people will have an opportunity to know each other more. This implies a reduction in the crime rate. It also helps to promote cooperation of the community, which help for public participation. The development of the TOD area is linked to the rail system. However, a different location should be designed to respond to a main activity in the city.

2.2 Node-Place Model

The area of development that utilizes the concept around the mass transit station will focus on an interchange of transportation made and land use, thus it leads to study the differences of the area around the mass transportation. Therefore, the Node-Place Model is used in the classification of TOD (Lyu, 2016) by using the factors of transportation. Or Node-Value that describes the different types of transportation, and can be divided into factors as follows:

1) The number of passengers using public transport services in the station area.
2) Types of train service in stations: In the station area that has various types of train or can be connected between the various railway lines will increase the value of the area with high land prices.
3) Car and bicycle parking lots: Development around the public transport station aims to reduce the number of private cars. If the public transport stations have suitable car and bicycle parking lots, it would be easier to access public transportation.

For the development factors in the land area or Place-Value, it will be mainly explained based on the land use and economy around the public transport station that can be divided into the following factors; (Lyu, 2016)

1) The population density in the area around the public transport station;
2) The number of employees within the stage of development surrounding the public transport station.
3) Characteristics of land use.

It can be seen that using the Node-Place Model to measure the different types of bus stations will use the relationship of existing development and land usage development around the mass transit station. Lyu (2016) described that if there is development in the area of transportation or Node to access easier, the land or Place Value will be more diverse (Figure 2).

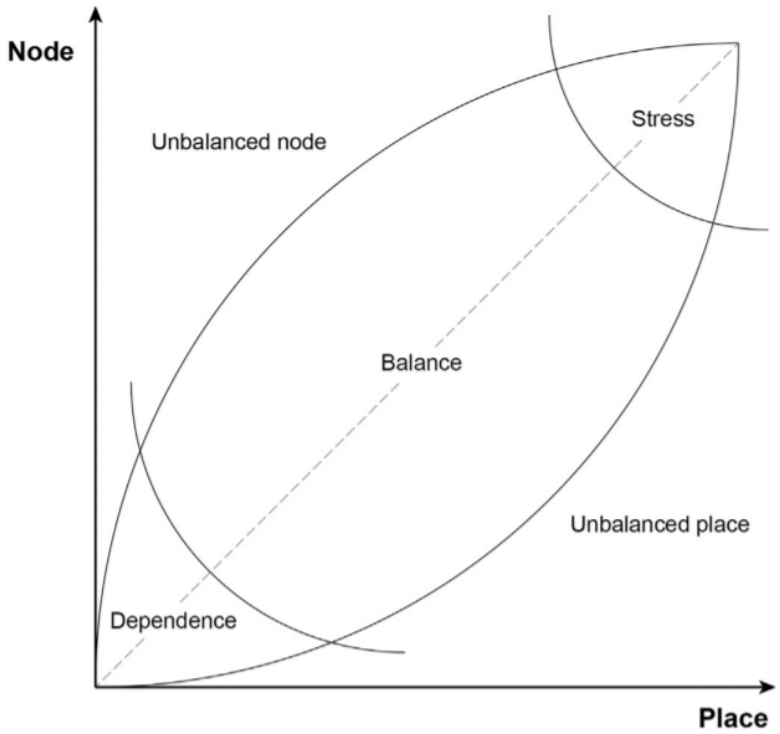

Figure 2. Guowei Lyu, et. al. 2016. The node-place model as defined.

Figure 2 is a classification of dimensional of transit station area development which consists of 5 characteristics by using the Node-Place Model. The following detail is explained about its relationship (Lyu, 2016):

1) *Balance area* is an area with Node-Value and a moderate level of Place-Value. It can be explained that in this area, both the mass transportation system and the beneficial land usage are appropriate.
2) *Stress area* has a high Node - Value and Place - Value which can be explained that in this area, there is both mass transportation development and intense beneficial land use development which causes land prices in this area to be high, and there is less vacant space due to the significant development.
3) *Dependency area* has a Node-Value and low Place-Value. It can be explained that in this area, the mass transportation system is developed and there is less land use development which is a low-density suburban area.
4) *The Unbalanced Node area* is an area where the Node-value is greater than the Place-Value value described in the area. It develops a high mass transit system but does not have the development of taking advantage of land to be consistent with the development.
5) *Unbalanced Place* is an area with less Node-Value than Place Value. It can be explained that this area has high land use development but the public transport system is not appropriately provided.

The Node-Place Model is used to distinguish the characteristics of each mass transit station, which will use the development of transportation and development of land, and the use of the Node-Value and Place-Value may not be sufficient to classify. Station features or even in areas where the transportation and development of taking advantage of the high level

of development, but there is no access or no proper road structure. There are not enough pedestrian or bicycle paths to make the area not fully developed as it should be.

3. Study area

The mass transit system had started its operations since December 5th, 1999 and it was operated by Bangkok Mass Transit System Company with a total of 22 BTS stations from Morchit to Bearings. The Metropolitan Rapid Transit: MRT operated by Bangkok Mass Transit system, Thailand Public Company Limited, received the concession from the mass transit BTS Skytrain and has been activated in 2004, with 18 stations from Hua Lamphong Station to Bang sue. In this study, the area of 500 meters around two mass transit system which is the BTS and MRT was focused for the 35 stations which has been activated for more than 10 years since it covers the major zones of trip generation. This study will group the typical character of the feature of the mass transit station while promoting access to the TOD area to reduce road traffic problems in Bangkok area (Figure 3).

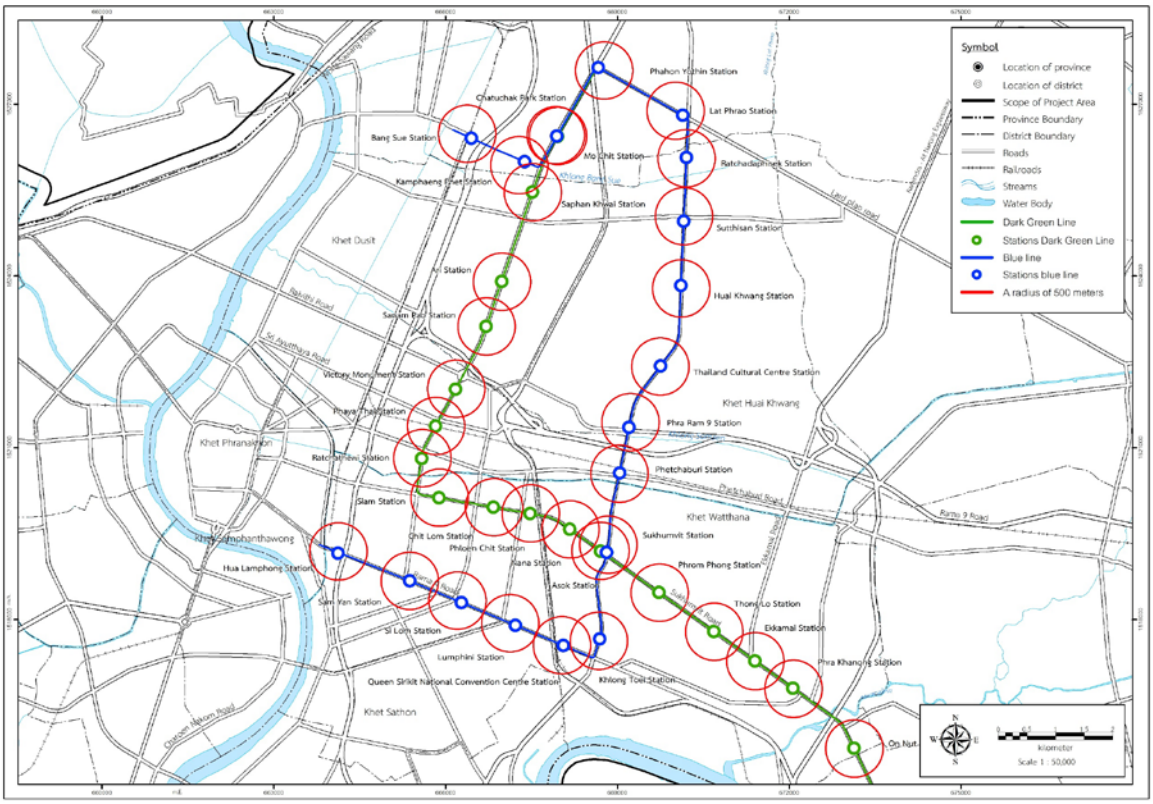

Figure 3. Study area with radius of 500 meters around BTS and MRT stations

4. Methods

In the study of the land use integration and transportation to promote pedestrian access to the mass transit system, the method can be divided into 4 main steps as explained in the following detail (Figure 4);

1. Literature review to study factors used in the characterization of mass transit stations.
2. Gathering data of surrounded area nearby the Mass Transit Station under 5 variables of classification: Density, Diversity, Design, Destination Accessibility, Destination diversity. There were 35 stations both BTS and MRT chosen for this study.
3. Classifying the characteristics of each station by using the cluster analysis technique to classify the groups of the mass transit stations with statistical analysis data.
4. Summarize the results from the study and discussion about the classification of the 35 stations (Blue Line and Green Line) for finding the way out to improve the surrounded area of TOD.

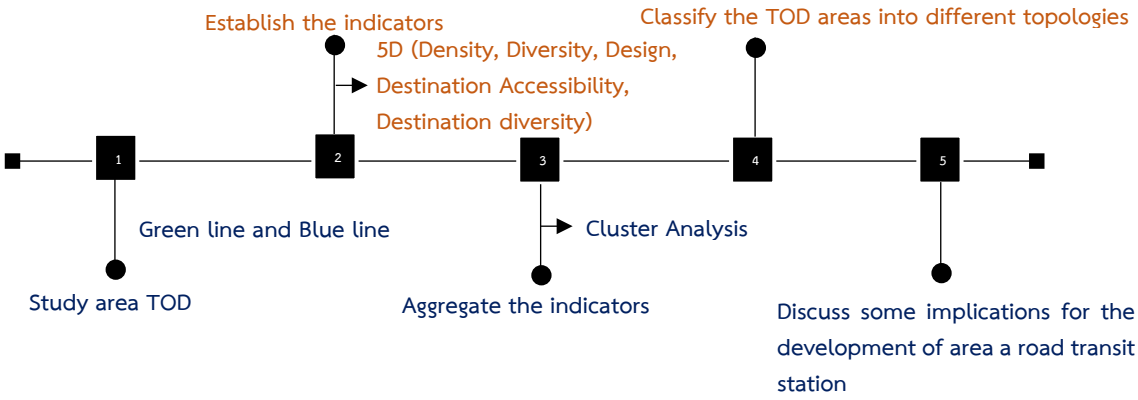

Figure 4. Methodological framework

Table 1. The indicators for evaluating TOD in different stations.

Indicator	Measures	Definition	Unit of Analysis
Design	Connected node ratio	Number of road connections	Position
	Ped-shed ratio	500 meters walking distance by road line	meter
Diversity	Land use mix	Average value of land use rate at 500m	square kilometers
Density	Gross dwelling density	Floor Area Ratio: FAR	FAR 0.0 – 0.5 0.5 – 1.0 1.0 – 2.0 2.0 – 3.0 More than 3
Destination accessibility	Accessibility	Number of nursing places Number of Post Office Number of schools Number of supermarkets, shops, markets. Number of police stations Number of hospitals	Number of points
Destination diversity	Services	A summary of the presence / absence of the 10 areas: 1. The number of schools 2. Supermarket 3. Post Office 4 parking spots by the public 5. Police 6. Hospitals 7. Measurement 8. Hotel. 9. Marketing 10. Hospitals	
	Transit accessibility Bus stops	Public transport point	

5. Result of analysis

Due to the study of influencing factors effected on TOD typology to classify the characteristics of the mass transit stations, it was found that the factors can be divided into 5 areas according to the 5D principles of TOD: consisting of design diversity density destination accessibility and destination diversity.

5.1 Indicator of analysis

5.1.1 Design

Design variable was analyzed from the connected node ratio and Ped-shed ratio by using a tool of GIS to find the intersection of road and distance from the path in 500 meters from the centre of the station. It was conducted by using the Network Analyst to examine the connection areas of stations and traffic routes (Figure 5 and Figure 6).

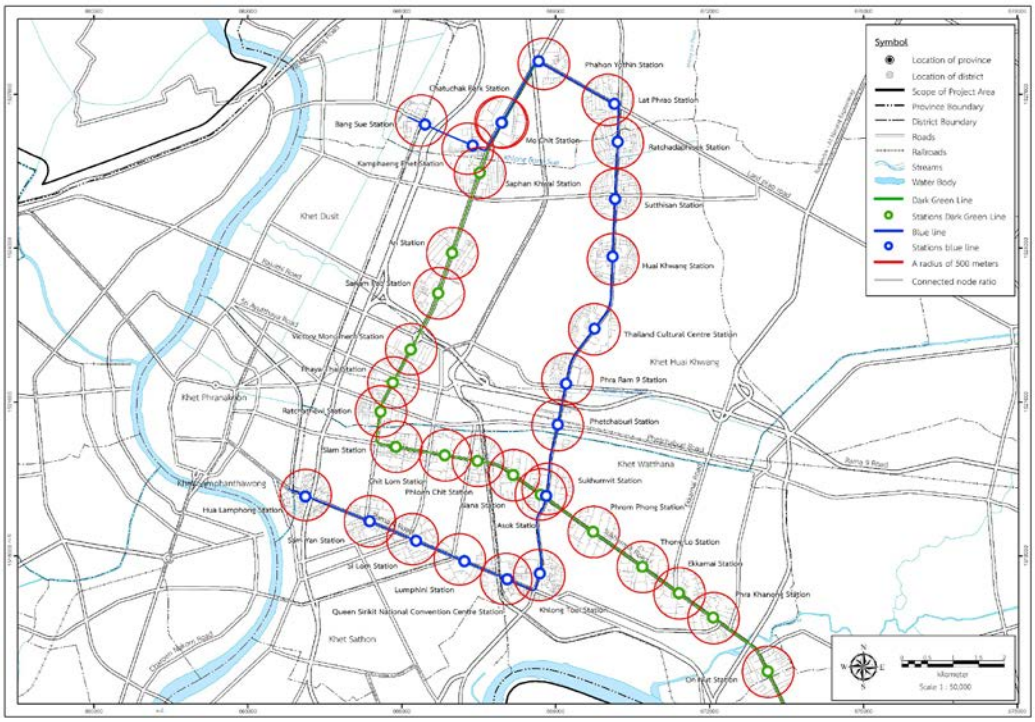

Figure 5. Connected node ratio (Intersections / all Intersections.)

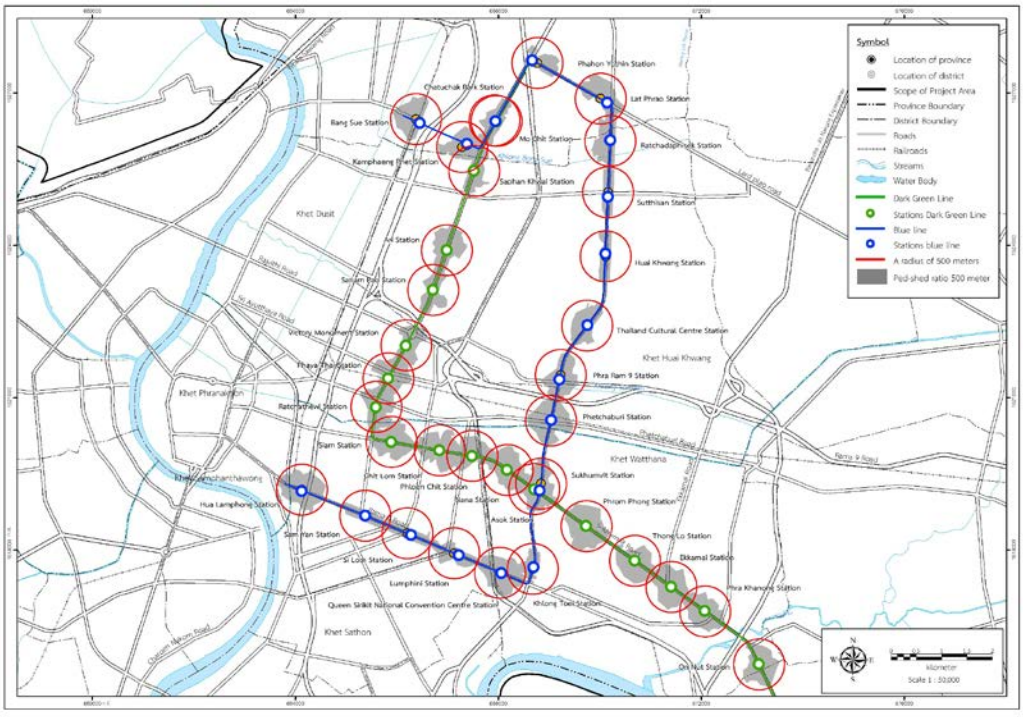

Figure 6. Pedshed ratio of the walkability of a neighborhood.

5.1.2 Diversity

Diversity was analyzed from the average of mixed land use in a 500-meter radius around the station. The area with the most mixed land use is Kamphaeng Phet Station, which was 0.79 square kilometres.

As for the least mixed land use, there were 2 stations which are Thong Lo Station and On Nut Station. The result showed only 0.10 square kilometres. Apart from that, Thonglor and On Nut have Commercial areas located on the roadside and most are residential space, actually (Figure 7).

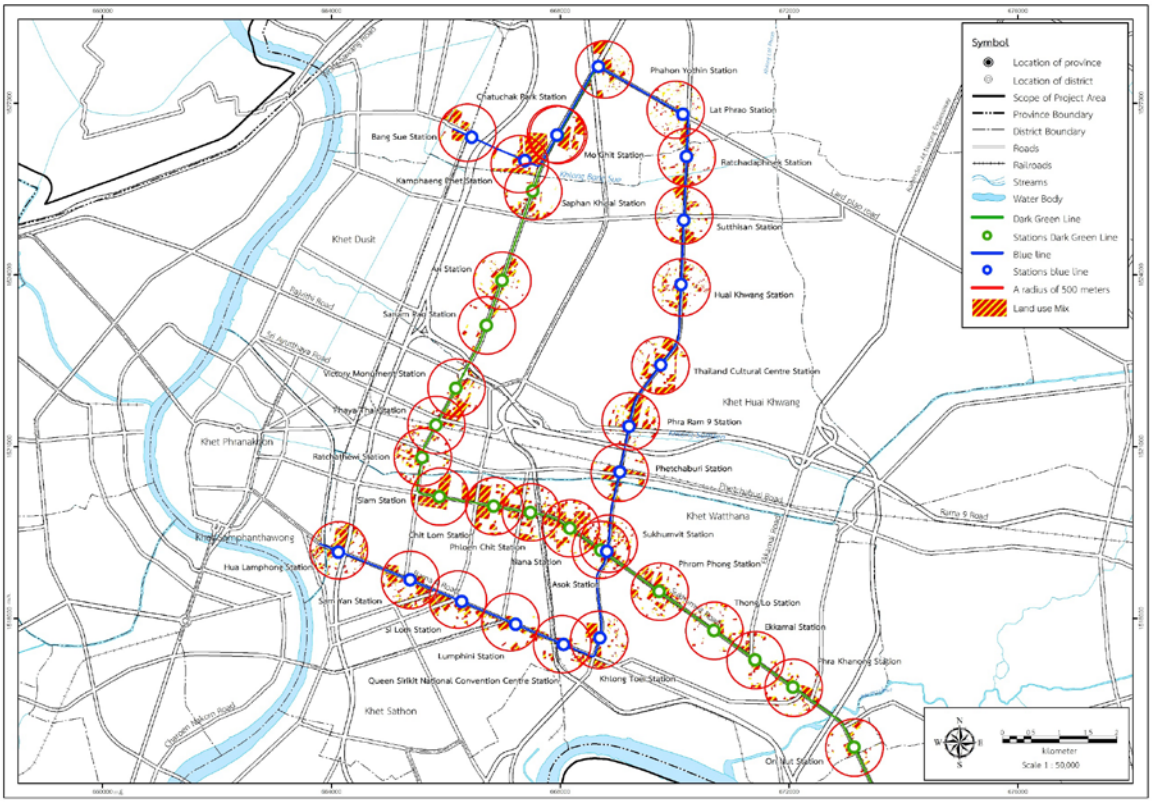

Figure 7. Land use Mixed

From the characterization of the area (Figure 8) when combined with land usage, it is found that there is significantly demonstrated different patterns of activity. According to land usage within 500 meters around the station area consisting of several types, this analysis attempted to classify the different pattern of residential, commercial, industrial, warehouse, mixed land use, public utilities, educational institutions, religious institutions, government institutions and other public utilities, agriculture, recreation, and others. To development the area to meet the needs of development and improvement while maximizing the utilization, it needs to look at the main physical context of the area as well.

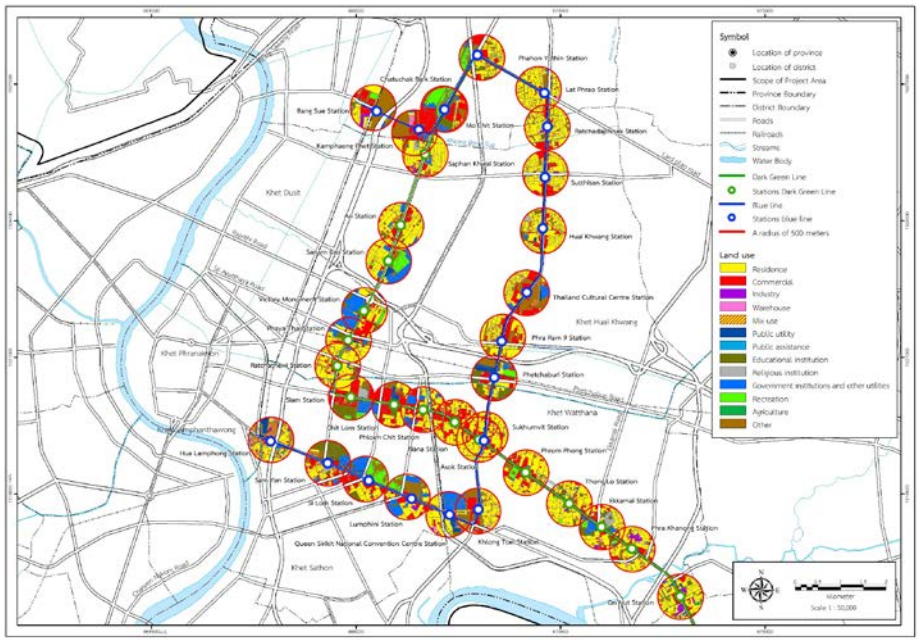

Figure 8. The land use within 500 meters of the 2 station Metro Line.

5.1.3 Density

Density was calculated from the floor area ratio (FAR) around the area of 500 meters within the total 35 stations. It revealed that Hua Lamphong was the station with the highest FAR at 1.72 due to the high density of buildings per land plot. A lot of land use are in the major use of commercial buildings, and some are general buildings. It was found that Phetchaburi was the station with the lowest FAR at 0.59 because there were less building density and some are generally opened space and vacant land (Figure 9, Figure 10 and Figure 11).

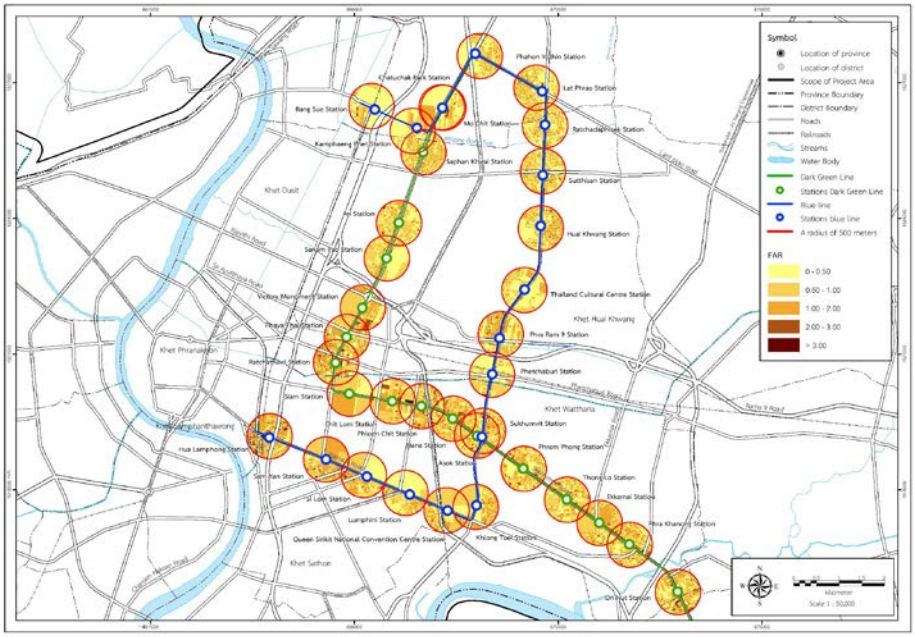

Figure 9. Floor Area Ratio: FAR

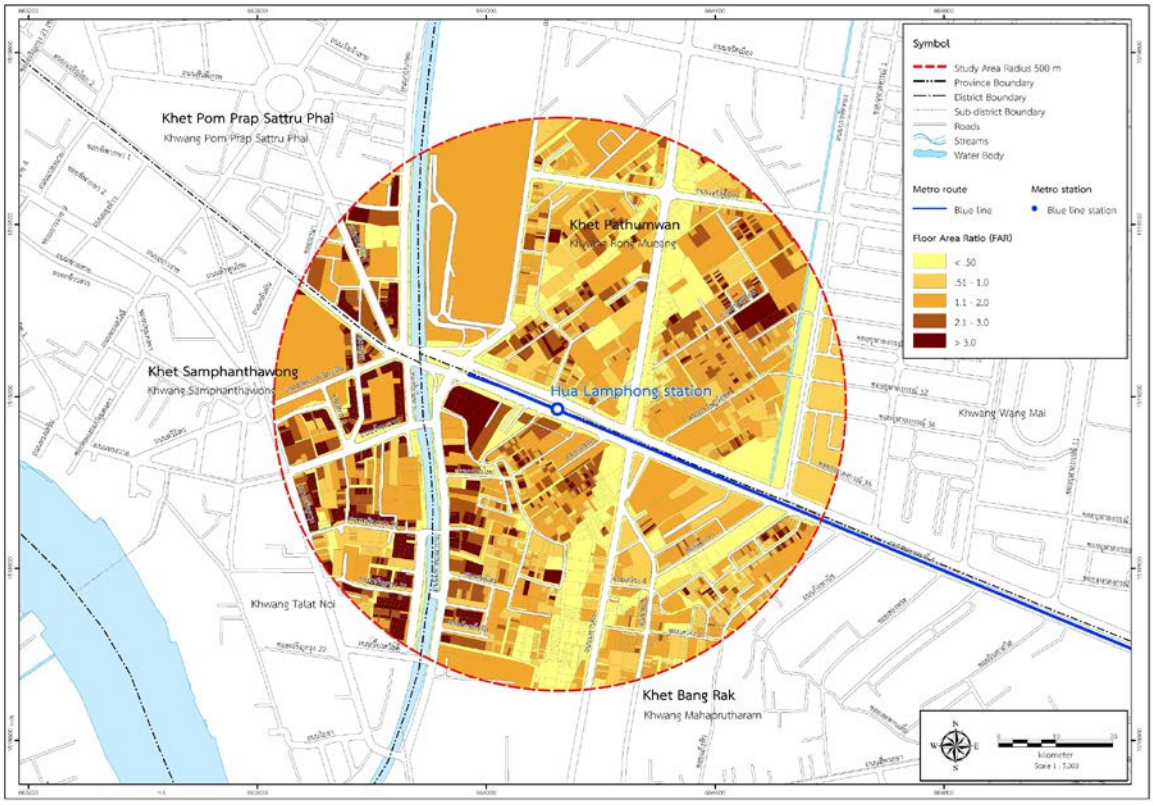

Figure 10. FAR Hua Lamphong station

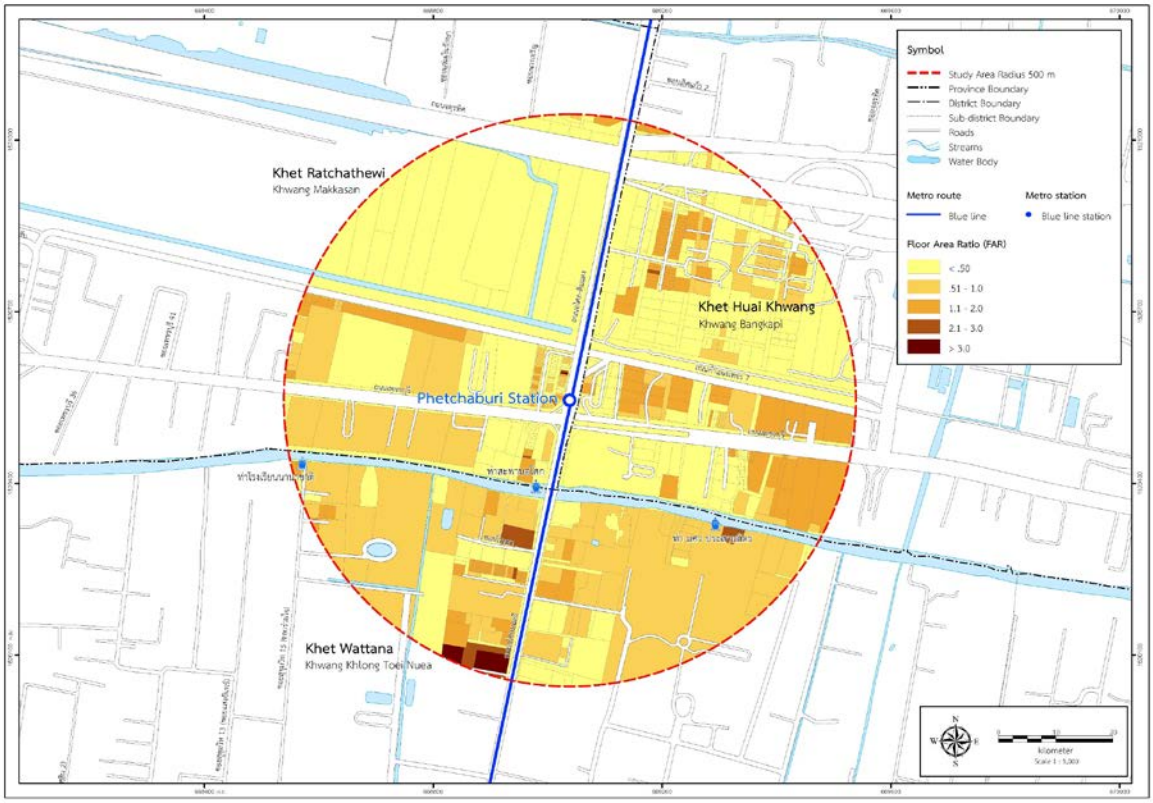

Figure 11. FAR Phetchaburi Station

5.1.4 Destination accessibility and destination diversity

Destination accessibility and destination diversity (Figure 12) are the numbers of public utility locations, including 10 major landmarks in 500 meters of each station area. Moreover, the analysis was performed by sum up the number of locations in each station to analyze the density and access to public utilities in the space.

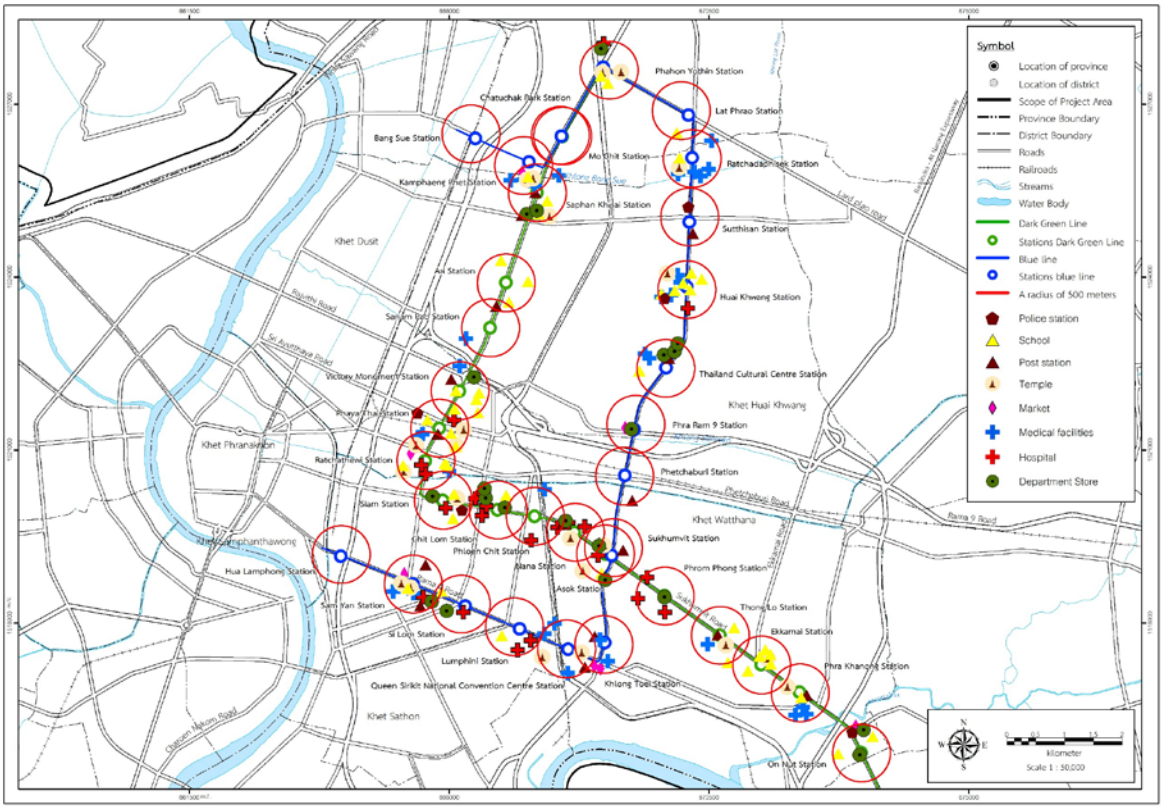

Figure 12. Destination accessibility and Destination diversity

5.2 Cluster Analysis

From the data analysis of the area development around the mass transit stations which were divided into 5 categories: Density, Diversity, Design, Destination Accessibility, Destination diversity within BTS station area (Green line and Blur line) which has been collected for a total of 35 stations. By using the statistical calculation to classify the characteristics, the cluster analysis technique with Hierarchical Cluster Analysis was employed for the calculation process. A method has potential, not necessary to divide as a group before. It will be classified according to the development indicators to differentiate the same characteristics to be in the same group by using a between-groups linkage. The calculation of the average distance between all pairs of the case was determined. The characteristics of two BTS stations from the Dendrogram graph can be divided into 6 groups as shown in Figure13 and Figure 14.

Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	3	5	.478	0	0	8
2	11	26	1.315	0	0	7
3	4	35	1.721	0	0	26
4	13	30	2.766	0	0	13
5	19	28	2.990	0	0	6
6	18	19	3.620	0	5	8
7	11	25	4.546	2	0	11
8	3	18	5.275	1	6	14
9	16	17	6.095	0	0	25
10	27	31	6.353	0	0	15
11	11	24	7.994	7	0	15
12	14	15	8.665	0	0	18
13	13	34	9.155	4	0	21
14	3	10	9.494	8	0	19
15	11	27	9.631	11	10	28
16	7	21	10.803	0	0	33
17	1	9	11.168	0	0	24
18	14	33	11.275	12	0	26
19	3	6	12.138	14	0	20
20	3	8	13.638	19	0	21
21	3	13	14.788	20	13	23
22	12	22	15.119	0	0	25
23	3	29	15.898	21	0	28
24	1	23	16.431	17	0	27
25	12	16	16.853	22	9	31
26	4	14	17.150	3	18	30
27	1	2	18.519	24	0	29
28	3	11	20.113	23	15	29
29	1	3	21.550	27	28	30
30	1	4	23.246	29	26	32
31	12	32	24.396	25	0	32
32	1	12	29.450	30	31	33
33	1	7	29.979	32	16	34
34	1	20	43.224	33	0	0

Figure 13 Agglomeration Schedule

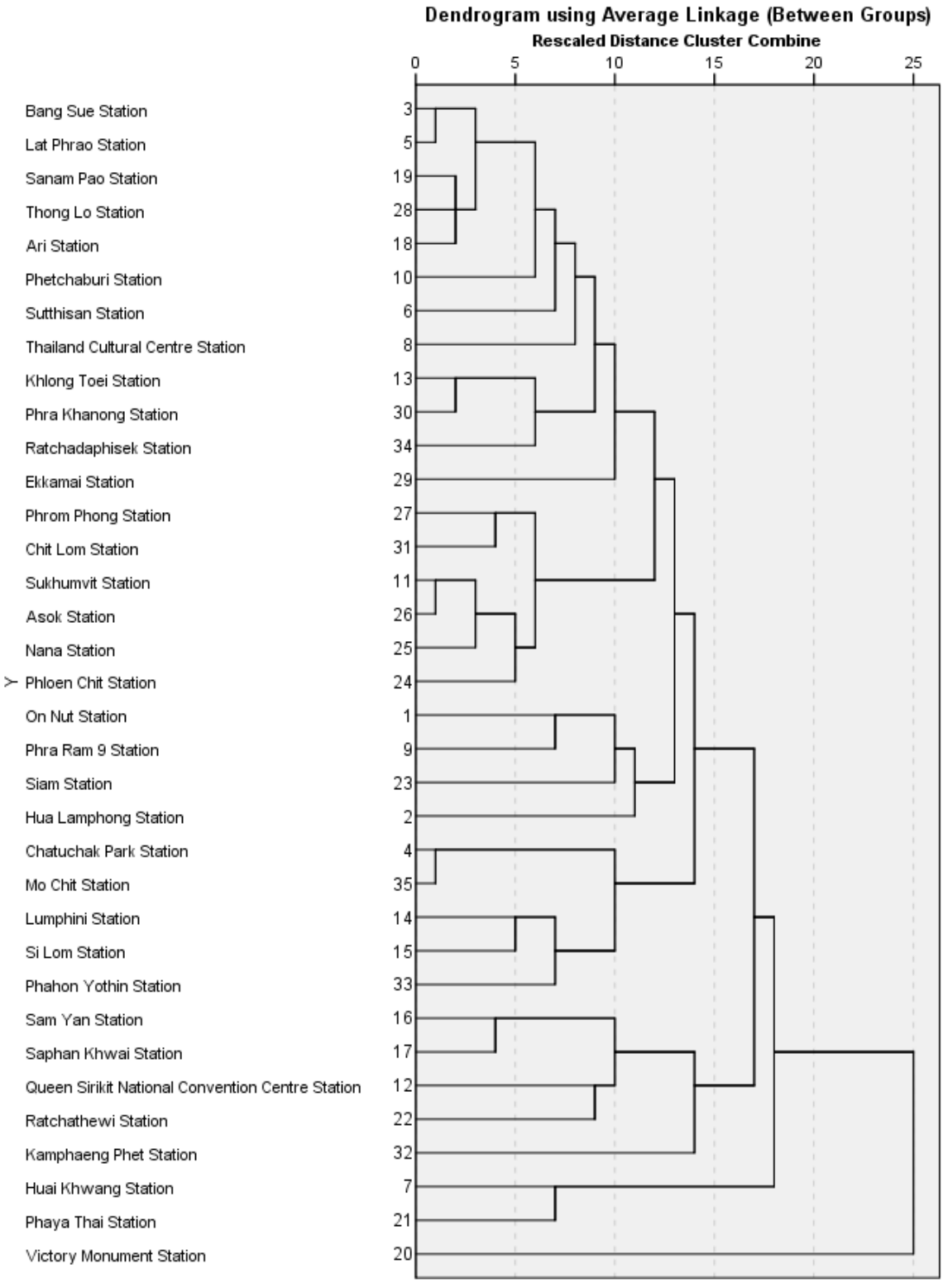

Figure 14. Graph Classification of station

The Dendrogram graph shows the characteristics of stations which are classified based on BTS (Green Line) from On Nut Station to Mo Chit Station and MRT (Blue Line) were divided into 5 groups of classification as demonstrated by the following (shown in Figure 15).

Group 1: represents the residential areas consisted of 8 stations: Bang Sue station, Lat Phrao station, Sutthisan station Cultural Center station, Phetchaburi Station, Ari station, Sanam Pao station and Thonglor station.

Group 2: shows the Mix used areas consisted of 4 stations: Khlong Toei station, Ekamai station, Phra Khanong station and Ratchadaphisek station.

Group 3: demonstrates the commercial areas consisted of 6 stations: Sukhumvit station, Ploenchit station, Nana station, Asoke station, Phrom Phong station and Chidlom station.

Group 4: represents the transportation areas consisted of 4 stations: Onnut station, Hua Lamphong station, Rama 9 station and Siam station.

Group 5: is the recreation area consisted of 5 stations: Chatuchak Park station, Lumpini station, Silom station, Phahonyothin station and Mo Chit station.

Group 6: illustrates the government centre office area consisted 8 stations: Huay Kwang station, Queen Sirikit National Convention Center station, Sam Yan station, Saphan Khwai station, Victory Monument station, Phaya Thai station, Ratchathewi station and Kamphaeng Phet station.

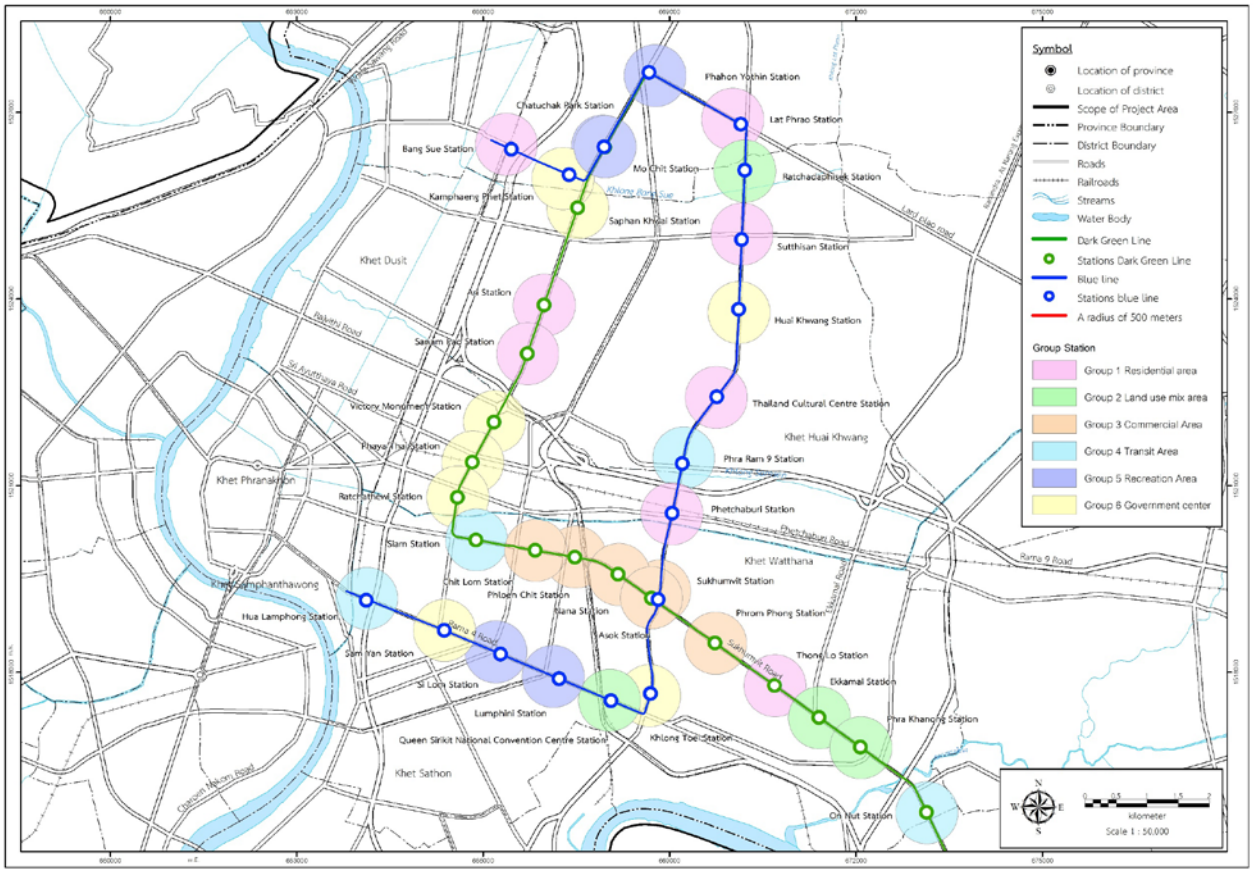

Figure 15. Feature classification of BTS and MRT stations.

Group 1: residential area

It was a residential area with has 8 stations of Bang Sue station, Lad Phrao station, Sutthisan station, Cultural Center station, Phetchaburi station, Ari station, Sanam Pao station and Thong Lor station. These areas are located on large and expensive real estate zone. Especially, Lad Phrao station is in a dense residential area and nearby many educational institutions. Moreover, it is also close to government offices, especially the department of the court of justice as well. Apart from that, Lad Phrao is located adjacent Lad Phrao Road which is an important station for connecting from Lad Phrao road to other places, such as Chok Chai Si, Wang Thonglang and Bang Kapi. The area around Sutthisan Station is residential zones with a variety of accommodation in the heart of the city. The Sutthisan Winitchai Road is the main route that connects Vibhavadi Rangsit Road in Din Daeng area and connects to Soi Lat Phrao 64 (Soi Ketunuti) to various communities that are scattered along of Soi Lat Phrao Road. Huai Khwang, Wang Thonglang, and Thailand Cultural Center station located in the business property, shopping centre, and residential area and near significant arts and cultural sites such as the Thailand Cultural Center. Additionally, it can connect from Huay Kwang station at ground level and allow to enter the Huai Khwang BTS Maintenance Center by connecting for both the airport link to Suvarnabhumi Airport at Makkasan Station and Asoke Pier. The surrounding area is a mixed activity, both job sites the important educational institutions and large department stores. Besides that, it also connects as a centre of the station in the direction from Huay Kwang station to the ground level to Huai Khwang Electric Railway Maintenance Center. Phetchaburi station is connecting Suvarnabhumi Airport, Makkasan station and Asoke Pier. The surrounded areas are mix used space, workplace, educational institutions and department stores. This is same as Ari Station, Sanam Pao and Thong Lo represent a mixed-use land area surrounded by government offices, companies, stores, workplaces, the restaurant of famous street food, community Malls, etc.

Group 2: land use mix

The Mix used areas: Khlong Toei station, Ekamai station, Phra Khanong station and Ratchadaphisek station. The areas have varieties of activities and choices of the market, retail stores, bus stations, schools or educational institutions. With more option of activities, it is worthwhile to enjoy commuting to the area. It is a must to promote the community to be a part of the economic district. Thus, it can be more self-reliant in times of crisis and manage the land to provide more jobs and activities.

Group 3: Commercial Area

The area of this station used for the city's infrastructures such as hospitals, universities, with mixed land use. There is a variety of land use which includes the residential type and building density as well. Being in the centre of the city, there are many high buildings and offices in this area. Commercial land use in the initial stages of establishing the city is usually located in the centre. Along with important roads while small shops are often mixed with the residence. An essential factor in selecting a shopping location is the convenience of travelling by customers. Therefore, shopping often locates at the road intersection as in the past, there was a large settlement along the canal or river. In the commercial area, not only shops that sell goods or products but also includes various service centres such as the barber, the beauty zone, hospital, movies, etc.

Group 4: Transit Area

The result discovered of 4 stations that are Onnut station, Hua Lamphong station, Rama 9 station and Siam station. All these places are station convince people to travel by public transport and by car because of the potential of connection point to change a way for the sky train station or a freeway in the same area. Rama 9 and Siam Station in rush our face with traffic jam sometimes. Transport part which is roads, parking and transportation stations disperse differently in both cities and urban areas. The current network functions as veins of body nourish to the parts of the city. Managing land in a different type of building users with a good plan can be effective continuously if traffic is not jam. Nevertheless, if the transportation system has failed, activities in the city such as trading operations will be disrupted.

Group 5: Recreation Area

There are 5 stations in this group which are; Chatuchak Station, Lumpini Station, Silom Station, Phahon Yothin Station and Mo Chit Station which is the majority of land consisting of the main public parks of the city. It is found that Chatuchak Station and Mo Chit Station within a radius of 500 cover the Chatuchak Park, Wachirabenchat Park and the Queen Sirikit's Garden. The Lumpini Station consists of Lumpini Park. Therefore, it is an area that is suitable for recreation activities. If this area is developed, the investment will not be higher in creative. Only promoting policy guidelines is needed to encourage people to use this type of land or activity. Most of them are belong to the government, including parks, playgrounds, youth centres, sports stadiums, and some of them occupy or own by privately, such as amusement parks, swimming pools, etc. Using this type of land, every city should well manage for all users and should be on economy service or free, as it helps to reduce the stress of daily life in people.

Group 6 Government center

The central government office area consists of 8 stations, namely Huay Kwang Station, Queen Sirikit National Convention Center Station, Sam Yan Station, Saphan Khwai Station, Victory Monument Station, Phaya Thai Station, Ratchathewi Station and Kamphaeng Phet Station. Mentioning about the area that the Government agencies and government offices are located, some agencies require large lands such as hospitals, educational institutions. Some agencies require small areas such as police stations, fire stations, etc. Government offices that have to provide services related to the daily life of people are usually located near residential or downtown areas. Currently, some government buildings are expanding to the suburbs and many cities including government offices.

6. Conclusions

From the analysis and classification of 22 Bangkok Transit System Skytrain (BTS) and 18 Metropolitan Rapid Transit stations (MRT). The total of 35 stations from the classification of the different group by considering all 5 factors or 5D of the TOD consisting of Design, Diversity, Density, Destination accessibility, and Destination diversity. This study applied statistical calculations to classify the characteristics by using Hierarchical Cluster Analysis technique of the cluster analysis. This method is not necessary to know how many groups are divided in the first place. Classifying groups according to the development indicators around the mass transit station by focusing on the same characteristics to be in the same group by using the between-groups linkage method. It will calculate the average distance of all pairs of cases. The characteristics of the two train lines from the Dendrogram graph can be divided into 6 groups of stations

All these groups of stations can be estimated and find ways to develop plans and policies that help reducing traffic congestion and air pollution from congestion. To guide on entering the station area on foot may be proposed for measures or any design recommendation for TOD.

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