



Integrated TOD spatial model to guide transport planning in Jakarta Metropolitan Region

By

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Ph.D. in Urban and Regional Planning

A thesis submitted for the requirement of degree in Doctor of Philosophy

FACULTY OF ENVIRONMENTAL DESIGN

DEPARTMENT OF URBAN AND REGIONAL PLANNING

KING ABDULAZIZ UNIVERSITY

JEDDAH – SAUDI ARABIA

February 2019 G – Jumada al-thani 1440 H



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This thesis has been approved and accepted in partial fulfillment of the requirement for the degree of Doctor Philosophy in Urban and Regional Planning

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KING ABDULAZIZ UNIVERSITY

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Dedication

My Dear the Late Father and Mother

My Dear Daughter, Boy and Wife

My Dear Brothers and Sisters

My Advisor

My Staff Members of URP

and My Friends

Acknowledgement

First, I would like to say many thanks to Almighty Allah who blessed me a doctoral scholarship to do this research. The completion of this research was made possible due to the assistance, moral support, and encouragements of many worthy people. Therefore, I would like to thank them most sincerely.

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Abstract

Large growth of population impacts mostly to spatial dimension. One would argue that the negative effects of urbanization are population growth and density in cities of developing countries. In terms, it has a significant impact on urban transport problems, and it refers to a promising planning concept, which is needed to overcome such issues. One considered concept in urban planning is Transit Oriented Development (TOD). The TOD brings two major aspects together, embracing land use and transportation in one integrated system, in which the concept is to ensure a more sustainable development in Jakarta Metropolitan Region (JMR). The main objective of this thesis is to develop the Transit Oriented Development based on spatial model to guide the transport planning of JMR toward integrated public transit system. The method of this study started from building the concept, measurement and application of TOD from the literature review, evaluating actual TOD by index using AHP weighting and GIS technique, planning potential TOD using land suitability and spatial statistical analysis, and promoting integrated TOD to guide transport planning of JMR based on spatial model. This study provided an easy path from theory to practical with case studies of JMR. In addition, this study can be helpful for urban planning and local development agencies to planning areas in a compact form and eventually sustainable manner.

نموذج مكاني متكامل للتطوير الموجه للنقل العام لتوجيه تخطيط النقل والمرور بجاكرتا

اعداد

هريكا محمد تاكي

المستخلص

تعاني مدن العالم الثالث من ظاهرة التحضر وما يصاحبها من زيادة كبيرة في أعداد السكان والكثافة السكانية بتركز المدن وما يترتب عليها من زيادة مشاكل النقل والمرور مثل الاختناقات المرورية وتأخير زمن الرحلات وزيادة استهلاك الوقود وما ينتج عنه من زيادة تلوث الهواء. ويعتبر مفهوم التطوير الموجه للنقل العام (TOD) من المفاهيم الحديثة في التخطيط العمراني التي يمكنها التغلب أو التخفيف من حدة هذه المشكلات. ومفهوم التطوير الموجه للنقل العام يدمج كلا من استخدامات الأراضي والنقل والمرور في نظام واحد وذلك لضمان تحقيق تنمية أكثر استدامة بمنطقة الدراسة وهي مدينة جاكارتا بإندونيسيا. الهدف الرئيسي في هذا البحث هو تطوير نموذج مكاني متكامل للتطوير الموجه للنقل العام لتوجيه تخطيط النقل والمرور بجاكرتا، حيث تمت عمل مراجعة شاملة للعديد من الأدبيات التي تتناول المفهوم وطرق القياس والتطبيقات المختلفة للتطوير الموجه للنقل العام ثم تم عمل النموذج المكاني من خلال خطوتين أساسيتين الأولى عمل تقييم للوضع الراهن لمحطات المترو بجاكرتا من حيث ملائمتها للتطوير الموجه للنقل العام وذلك باستخدام تقنيات (AHP) ونظم المعلومات الجغرافية ثم تأتي الخطوة الثانية والتي من خلالها تم عمل تحليلات إحصائية مكانية لتحديد الملائمة المكانية وأفضل المواقع بجاكرتا للتطوير الموجه للنقل العام وذلك باستخدام نظم المعلومات الجغرافية ثم يعرض البحث بعد ذلك لكيفية تطبيق النموذج المكاني والاستفادة منه في توجيه تخطيط النقل والمرور بجاكرتا سواء على المستوى التخطيطي الاستراتيجي أو على المستوى التفصيلي حيث تم عمل ثلاثة تصنيفات لمحطات المترو بجاكرتا من حيث ملائمتها للتطوير الموجه للنقل العام واقتراح استعمالات الأراضي والضوابط العمرانية المناسبة. هذه الدراسة توفر مساراً جيداً من النظرية إلى التطبيق للمهتمين بمفهوم التطوير الموجه للنقل العام لعلاج أو تخفيف مشكلات المدن الكبرى من خلال تخطيط عمراني أكثر استدامة.

Table of Contents

DEDICATION	IV
ACKNOWLEDGEMENT	V
ABSTRACT	VI
المستخلص	VII
TABLE OF CONTENT	VIII
LIST OF ABBREVIATIONS	XII
CHAPTER I	1
INTRODUCTION.....	1
1.1. Background	1
1.2. Challenge.....	4
1.3. Choice of the topic	5
1.4. Problem statement.....	5
1.5. Research objectives.....	6
1.5.1. General objective.....	6
1.5.2. Specific objectives.....	6
1.6. Research questions	7
1.7. Significance of the thesis	7
1.8. Scope of the thesis.....	8
1.9. Description of the study area.....	8
1.10. Research method	12
1.11. Thesis in brief	16
CHAPTER II.....	18
THE CONCEPT, MEASUREMENTS AND APPLICATIONS OF TOD.....	18
2.1. Introduction	18
2.2. Urban planning and TOD.....	19
2.3. Integrating land use and transportation of TOD	20
2.4. Planning and assessment of TOD research	21
2.5. The policy and public transport plan of TOD	30
2.6. Cross-continent comparison of the transport and land use integration	36
2.7. Summary	43
CHAPTER III.....	45

EVALUATING ACTUAL TOD IN JAKARTA METROPOLITAN REGION.....	45
3.1. Introduction	45
3.1.1. Theory relevance	45
3.1.2. Evaluating actual TOD in JMR	47
3.2. Research method in Chapter 3	48
3.2.1. Research framework.....	48
3.2.2. Station area analysis	50
3.2.3. Data collection.....	51
3.2.4. Chosen criteria.....	51
3.2.5. Description of indicators	52
3.2.6. Weights calculation using Analytic Hierarchy Process (AHP)	55
3.3. Measuring actual TOD index	56
3.3.1. AHP weighting technique.....	56
3.3.2. Standardization of criteria using min-max methods.....	57
3.3.3. The composite of actual TOD index calculation	58
3.3.4. Actual TOD Index rankings	58
3.3.5. The composite TOD maps.....	60
3.4. Evaluating actual TOD in JMR.....	61
3.4.1. Statistical analysis	62
3.4.2. Improvement actual TOD based on corridor.....	62
3.4.2.1. Bekasi corridor.....	62
3.4.2.2. Bogor corridor.....	62
3.4.2.3. Serpong corridor	64
3.4.2.4. Tangerang corridor	64
3.4.3. Policy implication.....	65
3.5. Summary	66
CHAPTER IV	67
LAND SUITABILITY AND SPATIAL STATISTICAL ANALYSIS FOR POTENTIAL TOD.....	67
4.1. Introduction	67
4.2. Research method in Chapter 4	69
4.2.1. Data sources.....	69
4.2.2. Determination of selection criteria	70
4.2.3. Methodology overview.....	70
4.2.4. AHP pairwise comparison.....	71
4.2.5. Standardized criteria using Z-score	72

4.2.6. Land suitability assessment	73
4.2.7. Spatial statistical analysis	74
4.2.7.1. Spatial autocorrelation analysis for identifying existence of spatial clusters	74
4.2.7.2. Hot spot and outlier analysis for mapping spatial clusters	75
4.3. Calculating land suitability TOD	75
4.3.1. Classification of assessment criteria.....	75
4.3.2. Criteria maps for TOD suitability analysis.....	76
4.3.3. Calculation of criteria weight by AHP	77
4.3.4. Land suitability map of TOD	78
4.4. Assessment potential TOD using spatial statistical analysis.....	79
4.4.1. The distribution of potential TOD.....	79
4.4.2. Descriptive statistical analysis.....	81
4.4.3. Spatial statistical analysis	81
4.4.3.1. Spatial autocorrelation using Global Moran's I	81
4.4.3.2. High/low clustering using Getis-Ord General G	82
4.4.3.3. Cluster and Outlier using Anselin Local Moran's I	82
4.4.3.4. Hot spot and cold spot analysis using Getis-Ord Gi*	83
4.4.3.5. The statistically significant hot spots.....	84
4.5. Summary	86
CHAPTER V	88
IMPLEMENTATION OF THE INTEGRATED TOD SPATIAL MODEL FOR JAKARTA METROPOLITAN REGION	88
5.1. Introduction	88
5.1.1. Spatial planning of JMR	88
5.1.1.1. Urban structure	88
5.1.1.2. The spatial patterns.....	90
5.1.1.3. Transportation plan of JMR.....	91
5.1.2. Implementation of integrated TOD to guide transport planning in JMR	94
5.2. Research method in Chapter 5	95
5.2.1. Datasets.....	95
5.2.2. Methodology framework	95
5.4. Implementation of the integrated TOD spatial model in JMR.....	97
5.4.1. Spatial planning equipped by potential TOD	97
5.4.2. Planning concept appropriate to employ TOD	97
5.4.3. TOD typology.....	99
5.4.4. TOD characteristics.....	102

5.4.4.1. Building heights	102
5.4.4.2. Urban pattern	102
5.4.4.3. Development area	103
5.4.4.4. Transportation network.....	104
5.4.5. Producing TOD typology based on the spatial model for JMR	105
5.4.6. Policy implication of TOD typology in macro level	110
5.4.7. Planning regulations of TOD typology in micro level	110
5.4.8. Existing condition from sample station	112
5.4.8.1. Location of station	112
5.4.8.2. Station condition.....	112
5.4.8.3. Physical features of station	113
5.4.8.4. Land zone of station.....	114
5.4.9. Promoting TOD typology by urban design for future	115
5.4.9.1. Regional TOD.....	115
5.4.9.2. Urban TOD	117
5.4.9.3. Suburban TOD.....	117
5.5. Summary	120
CHAPTER VI	121
CONCLUSIONS AND RECOMMENDATIONS	121
6.1. Conclusion.....	121
6.2. Scientific contribution.....	122
6.3. Recommendations	123
6.4. Further research.....	124
APPENDIX	126
Appendix A	126
Appendix B	127
REFERENCES.....	134
Biography	141
Citations	142
Publications	143
SUMMARY IN ARABIC.....	145

List of Abbreviations

AHP	Analytical Hierarchy Process
BART	Bay Area Rapid Transit
BCR	Building Coverage Ratio
BORR	Bogor Outer Ring Road
BRT	Bus Rapid Transit
CBD	Central Business District
DEA	Data Envelopment Analysis
DSS	Decision Support System
EV	Electric Vehicle
FAO	Food and Agriculture Organization
GIS	Geographical Information System
ILWISS	Integrated Land and Water Information System
IoT	Internet-of-Things
JMR	Jakarta Metropolitan Region
LRT	Light Rail Transit
MRT	Mass Rapid Transit
SMCA	Spatial Multi-Criteria Analysis
TOD	Transit Oriented Development
VKT	Vehicle Kilometers Travelled

Chapter I

INTRODUCTION

Chapter I

INTRODUCTION

1.1. Background

Urbanization is one of the characteristics of developing countries where the rate of population in the big cities would increase rapidly caused by migrations from rural to urban areas. The United Nations projections indicate that 64% of the developing countries in 2050 will be urbanized (United Nation., 2011).

The density of the Central Business District (CBD) will increase due to urbanization. First, its population will be heavily concentrated. Then, it will spread from the city center into less-densely populated or the periphery. These cities will encounter urban sprawl issues such as environmental degradation, and intensified segregation of existing urban areas.

Today, Jakarta Metropolitan Region (JMR) is already a home to over 40 million people. Urbanization in JMR led to the increasing number of migrants (Winarso et al., 2015). To resolve this, in the beginning, the government developed several new satellite cities in the suburbs or peripheries to reduce urbanization. The satellite cities were expected to provide many job opportunities and comfortable residential. Nevertheless, most of the satellite cities did not provide a lot of job opportunities. The concept of creating independent communities does not match with its field implementation. By contrast, the satellite cities have become "bedroom suburbs for city-bound commuters" (Cybriwsky and Ford., 2001). The new satellite cities were still extremely dependent on

the major city. Furthermore, heavily congested traffic has an adverse impact on the daily interactions between suburbs and urban areas (Silver., 2007).

Most people living in JMR use motorcycles and cars for daily commutes to and from work, causing severe traffic jams in the capital city during rush hours. Based on study of Hadian (2018), it was stated that the forecast demand for total trips and modal share per day in 2020 becomes 36.578 million trips/day and in 2030 becomes 38.070 million trips/day (Table 1.1).

Table 1.1 Demand forecast for trips per day in JMR. Source: (Hadian, E., 2018)

Mode	Year	
	2020	2030
Private car	11.555.550	11.231.034
share	31,6 %	29,5%
Motorcycle	6.643.196	6.420.147
share	18,2%	16,9%
Bus	16.093.555	15.079.101
share	44,0%	39,6%
Rail	2.286.369	5.340.483
share	6,3%	14,0%
Total	36.578.671	38.070.766

The metro system of Jakarta Metropolitan Region services Jakarta, Bogor, Depok, Tangerang, and Bekasi. The metro uses rapid transit rolling stock standard and operates at high frequency with a minimum headway. The network route is recognized by Table 1.2 below.

Table 1.2 The existing conditions of JMR's railway

Lines	Services	No. of stations	Length
Bogor	Jakarta Kota to Bogor	26	54.8 km (34.1 mi)
Serpong	Tanah Abang to Serpong	7	55.6 km (34.5 mi)
Bekasi	Jakarta Kota to Bekasi via Pasar Senen	13	26.5 km (16.5 mi)
Tangerang	Duri to Tangerang	8	19.2 km (11.9 mi)

To accommodate many commuters needed development of transportation facilities with an emphasis on the development mass public transport system. The transportation modes in JMR will not be able to accommodate increased travel demand if without an increased mass transportation system for the public.

The main concern regarding public transportation in JMR is that majority people commute from the suburbs to Jakarta for working. The current public transportation system is incapable of significantly reducing the use of private automobile which -in turn- causing the available roads to become heavily congested. JMR needs to improvise the development of public transportation systems to reduce the number of motorcyclists and cars on the roads. The development of public transit system was expected to attract commuters to shift people from using privately owned vehicles to public transportation system. The concept of a public transit system can be done by integrating land use and transportation in one system by implementing Transit Oriented Development (TOD).

Transit-Oriented Development is the transit concept of moderate to higher-density development within the easy walking distance from major transit stops; mostly with a combination of employment, commercial and residential planned for pedestrians without

the car dependency (Parker., 2002). TOD development offers a pattern concerning pedestrians, improvement of integrated functions around a transit stop in higher density population, and the comfortable access to stations.

TOD application in JMR is expected to be part of integrated transportation system within the framework of the city plan and it can provide a solution for a sustainable development. Achieving sustainability as a common concern has been discussed by many researchers and specifically in the context of urban planning.

1.2. Challenge

Previous researches on TOD have been conducted mainly in developed countries such as in Europe and the United States of America. That includes some developed countries in Asia such as Japan and South Korea. However, TOD research in developing countries, especially Southeast Asia is still lacking. There is some research regarding TOD in developing country which was undertaken by Prasertsuppakij and Nitivattananon (2012) in Thailand case and HS Hasibuan (2014) in Indonesia case, but the primary indicator still refers to developed countries. There is no difference in weight for each indicator, the indicator is considered at the same level, even though each indicator has a different priority or level of weight. The TOD assessment is still not detailed, is the assessment of each indicator based on the opinions of various experts or only from the authors? in addition, the discussion of TOD has not yet integrated land use and transportation aspect, even though both are closely related to each other.

Therefore, our research filled the gap by presenting the case study of TOD research in JMR by taking many indicators and criteria according to the characteristic conditions

of developing countries such as land use, social, economy, and transportation behavior. This research discusses deeply about the difference between actual and potential TOD. TOD assessment using Analytical Hierarchy Process (AHP) techniques and involves expert opinions from scientific backgrounds and professions from various countries as well.

1.3. Choice of the topic

Transit Oriented Development is related to urban planning around transit nodes. TOD is expected to be able to integrate land use and transportation. Therefore, this thesis develops the integrated TOD based on spatial model to guide transport planning in Jakarta Metropolitan Region, Indonesia.

1.4. Problem statement

The public transportation network in JMR was less efficient because although the peripheries were integrated into the city, the mass public transportation was not fully integrated with the transit network. Moreover, urban traffic in JMR is seriously congested with high accident rates, resulting travel delays, long commutes, poor air quality, hikes on fuel prices, and the depletion of green open space (Handayani., 2008).

These problems were formed by numerous factors like the lack of authority officials, excessive number of motorcyclists and cars, the lack of an integrated planning system for public transportation, and no viable pedestrian facilities. If the stakeholders do not start to cooperate and take serious course of actions, the conditions will deteriorate even further (Susilo et al., 2007).

There is a need for sustainable daily mobility; reducing greenhouse emissions of urban transportation, decreasing transit pressure on the city, minimizing the necessity of traveling long distances, and giving preferences to sustainable trips as pedestrian by walking and use of bicycles (Mochtar and Hino., 2006).

Transit Oriented Development (TOD) is viewed as ways to cope or alleviate these problems. TOD refers to development activity located within walking distance to transit routes or stations that consists of residential, retailers, offices, and public uses in a walkable environment, making it convenient for residents and employees to travel by walking and riding bicycles (Jaiswal., 2008).

1.5. Research objectives

This thesis attempts to address transit problems faced by the Metropolitan Region of Jakarta, with particular emphasis on the determination of Transit Oriented Development. Several important objectives and questions are addressed in this dissertation:

1.5.1. General objective

To develop the integrated Transit Oriented Development based on spatial model of urban planning to guide transport planning in Jakarta Metropolitan Region.

1.5.2. Specific objectives

The specific objectives of the thesis are as follows:

1. To examine the concept, measurement and applications of TOD in various country.
2. To evaluate actual TOD by index at existing station in the metropolitan region.

3. To assess potential area for new TOD in the metropolitan region.
4. To integrate actual and potential TOD in spatial model to guide the sustainable development of the transport planning in JMR

1.6. Research questions

The research question of this thesis are:

1. What is the concept, measurement and application of TOD in various country?
2. How to evaluate actual TOD by index at existing station in the metropolitan region?
3. How to assess potential area for new TOD in the metropolitan region?
4. How to integrate actual and potential TOD in spatial model to guide the sustainable development of the transport planning in JMR?

In order to answer those questions, a spatial analysis covering the JMR will be generated. This spatial analysis contains various physical attributes, demographic data, socio-economic, and environmental considerations. These sets of data are analyzed using a combination of Geographic Information System (GIS) software, and Analytic Hierarchy Process (AHP)

1.7. Significance of the thesis

The significance of the thesis is to shift the auto-centric realm of urban living into transit-centric one. The main indicator of an urban's auto or transit orientation is the share mode. It means the proportion of daily trips made by private-own motorized vehicles in comparison to public and non-motorized transportation. TOD interventions aim to

significantly shift the share mode away from private-own motorized vehicles due to TOD is a solution to congestion and environmental degradation.

1.8. Scope of the thesis

The thesis scope is a spatial model of TOD guide to transport planning at metropolitan region scale. It includes spatial analysis of TOD using AHP, GIS, and integrating TOD into the transport planning by concerning to the land use and transportation conditions.

1.9. Description of the study area

Jakarta Metropolitan Region (hereafter: JMR) or Jabodetabek is the largest metropolitan region in Indonesia and second in the world after Tokyo metropolitan (Yamashita., 2017). JMR include Jakarta, the capital city makes this region as the center of social-cultural, economic and political activity (Rustiadi et al., 2015). This region plays a key factor in the Indonesian economy with a contribution to the National Gross Domestic Product of 19.93 percent (Bappenas., 2017). Meanwhile, population growth in this region reached 2.9 percent per year. In 2012, the population reached 22 million people, while in 2017, the population has reached 40 million inhabitants (Badan Pusat Statistik., 2017).

This thesis conducted in Jakarta Metropolitan Region (JMR), the largest metropolitan of Indonesia. It is located on the Northwest coast of the Java Island (Figure 1.1). Jakarta Metropolitan Region (JMR) or called Jabodetabek is divided into five municipalities, namely Jakarta, Bogor, Depok, Tangerang, and Bekasi. It covers 7.604

km² land area. JMR is an integrated area between Jakarta and its surrounding area, one of the top ten metropolitan areas in the world and the largest metropolitan area in Southeast Asia.

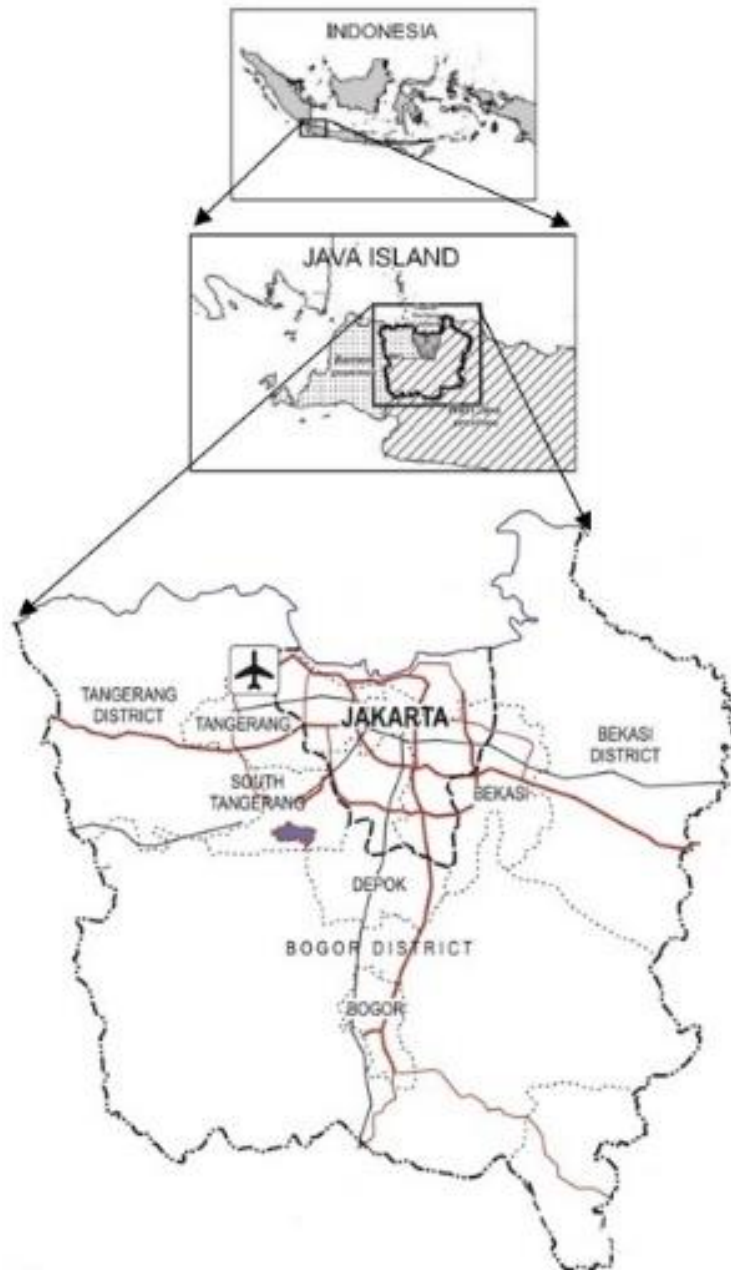


Figure 1.1 Location of study area

The total population of JMR is 40 million people and 29,2 million vehicles in 2017 (Wikipedia., 2017). Large numbers of trips from Botabek to Jakarta are based on the percentage of transportation modes used, namely: private vehicle, 62.2% (cars and motorcycles) and public transportation 12.9% (buses and trains). JMR is strained by transportation problems. The region suffers a lack of public transportation services due to prioritized development of road networks, which were mostly designed to accommodate private vehicles (Soehodho et al., 2005). The commuters from Botabek to Jakarta are highly dependent on the railway and highway network facilities.

The government of Indonesia has determined that the Botabek area as a buffer zone of Jakarta. This is due to the overcrowding of Jakarta serving its function in housing all government activities; including majority of trade, and industry activities. Based on the above, the government regulates the development and allocation of the region in Jabotabek as follows; the government activity is concentrated in the Jakarta's downtown. Industrial development is concentrated in Cibitung, Cikarang (Kab.Bekasi) and Cikupa (Kab.Tangerang). The development of large settlements in the form of satellite cities spread in Bekasi city, Tangerang city, Serpong, South Tangerang city and Depok city which is equipped with city supporting facilities such as schools, shopping centers, hospitals and entertainment venues.

The layout of Jakarta according to the study of Hasibuan and Soemardi (2014) is a strategic because of Jakarta is not only the capital city of Indonesia but also it covers urban and suburban area. It has a network of commuter rail serving residents to travel from the suburbs to the urban or city centre and vice versa.

The metro of transport modes being the most used daily by residents of Jakarta Metropolitan Region because of the economically effective and efficient in time. The metro from Jakarta capital city has four corridors, i.e. a Bekasi corridor (East), Bogor (South), Serpong (Southwest), and Tangerang (West) with the number of stations as much as 54 units (Figure 1.2 and 1.3).



Figure 1.2 The metro of JMR

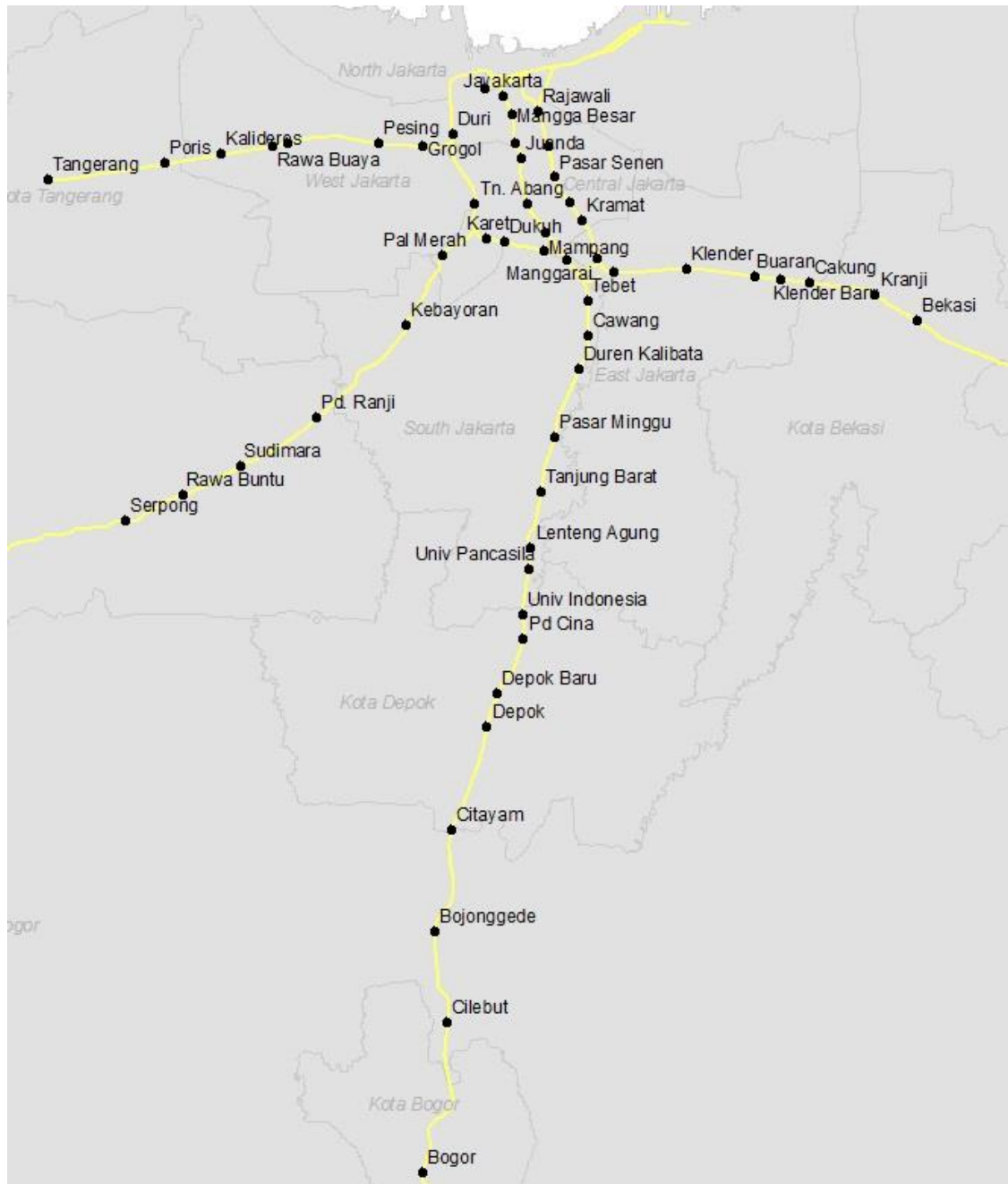


Figure 1.3 The metro route of JMR

1.10. Research method

The methodology used that was calculating several spatial indicator and criteria using AHP and combined it into actual and potential TOD using GIS technique. It has been depicted in the Figure 1.4 and Table 1.1 below.

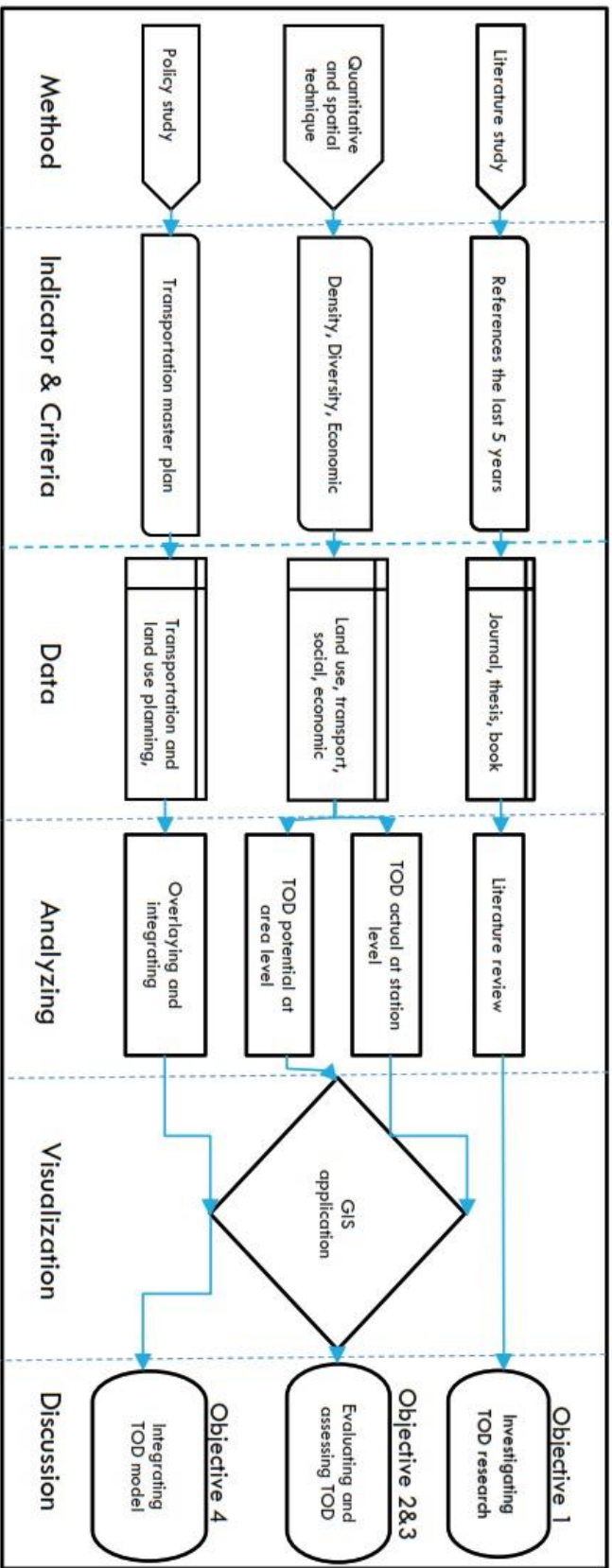


Figure 1.4 Illustrated cognitive map of theoretical framework in research

Table 1.3 The main references of researchresearch

No	Objective	Method	Level	Software	Indicator	Criteria	Main reference
1	Investigating TOD integration with land use and transport	Literature study	Worldwide	Mendeley	Integrated planning	Land use criteria Transport criteria	(Handayani 2014)
2	Evaluating TOD actual	Mathematical technique Weighted technique Spatial analysis Statistical analysis	Station level in metropolitan region scale	AHP calculation, ArcGIS Minitab 17	Density Diversity Economic	Commercial density Residential mix Parking area mix School density Open space mix Hospital density Population density Floor Area Ratio Building Coverage Ratio Land use diversity	(Singh 2015)
3	Assessing TOD potential	Quantitative technique Weighted technique Spatial statistical analysis	Area level in metropolitan region scale	Ilwiss ArcGIS Minitab 17	Transportation Facilities Environmen Economic	Airport, Seaport, Terminal, Busway shelter, Main road, Toll gate, Transportation, Education, Recreation, Hospital, School, BCR, Park, Housing, FAR, Population, CBD, Industrial, Commercial, Real estate	(Fard 2013)
4	Integrated TOD	Policy study by proposing integrated transit system for enhancing of the master plan	Metropolitan region scale	ArcGIS	Land use Transportation	TOD potential TOD actual	(Dorsey & Mulder 2013)

Thesis coherence

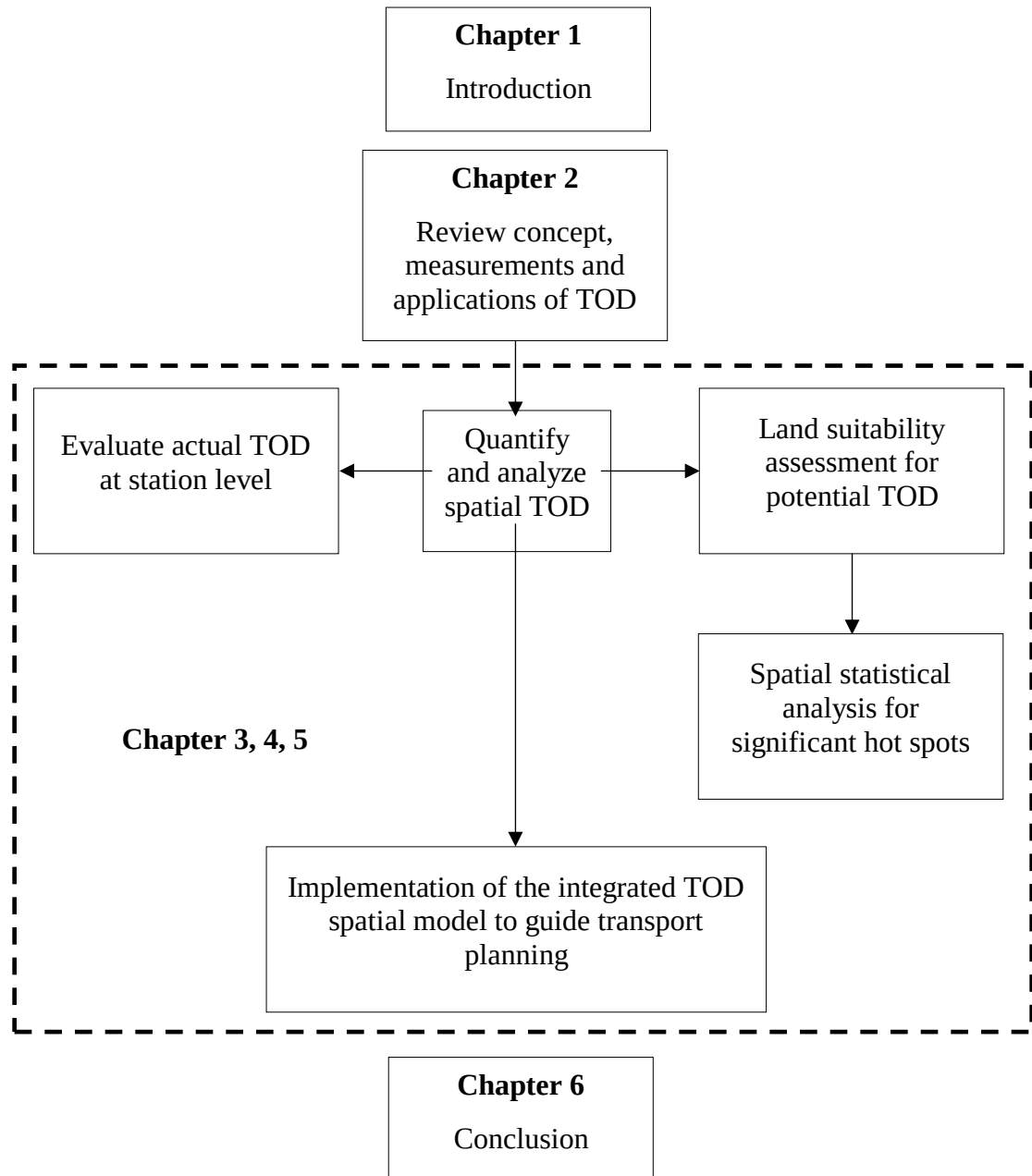


Figure 1.5 Thesis coherence and relationships

1.11. Thesis in brief

This thesis consists of 6 chapters in which Chapter 1 contains the introduction. Chapter 2 to 5 are a review of TOD concept, measurements, and applications, evaluating of actual TOD, assessment of potential TOD, and implementation of integrated TOD. Chapter 6 is the conclusion of the thesis containing the findings and recommendations. The following is the brief chapters in this thesis.

Chapter 1. Introduction.

This chapter provides general information on the research that has been conducted. The information consists of the topic choice, challenge, problem statement, research objective, research questions, research method, significance thesis, thesis scope, thesis outline, thesis coherence and thesis in brief.

Chapter 2. Concept, measurements and applications of TOD

This chapter review assorted studies related to planning TOD with land use and transport integration. The subject of the chapter described as follow: concept, measurement, and applications of TOD's research. Reviewing the strategic plan and the public transportation plan in the worldwide, and cross-continent comparison of integration planning.

Chapter 3. Evaluating actual TOD in Jakarta Metropolitan Region

This chapter evaluating the actual TOD of 54 railway stations in JMR using Analytical Hierarchy Process (AHP) and Geographical Information System (GIS). TOD

index was found that urban areas have high TOD index. On the other hand, the suburban areas have low TOD-index.

Chapter 4. Land suitability and spatial statistical analysis for potential TOD

This chapter identifying and prioritizing area for potential TOD using land suitability and spatial statistical analysis. This chapter employed two major indicators: main and sub-indicators depending on relevant references. The result shows that some of the metro areas of Jakarta were highly suitable for a new TOD, and it has characteristics of the development of urban areas.

Chapter 5. Implementation of the TOD spatial model to guide transport planning

This chapter presents the applications of integrated TOD as a spatial model, especially actual and potential TOD in JMR case. The result explains the different TOD typology into Suburban, Urban and Regional TOD. This analysis and modelling proposed to guide transport planning in JMR. Therefore, the planning, regulation, and policy for this region would greatly encourage reshaping the regional growth in a sustainable manner.

Chapter 6. Conclusions

This study overall concluded that TOD is a useful concept for overcoming urban transportation issues of JMR through the dual approaches; spatial and transportation integration.

Chapter II

THE CONCEPT, MEASUREMENTS AND APPLICATIONS OF TOD

Chapter II

THE CONCEPT, MEASUREMENTS AND APPLICATIONS OF TOD

2.1. Introduction

Transit-Oriented Development (TOD) is an urban planning concept to provide maximum access to passengers (Curtis and Scheurer., 2010; Hasibuan and Soemardi., 2014; Handayeni., 2014), especially public transport such as trains and bus with the purpose of the creation of comfortable atmosphere with friendly environment and are equipped with various facilities such as parking, parks, offices, and more. This requires a mix of residential and commercial areas as a basis for the development of area-based public transportation (Cervero and Dai., 2014).

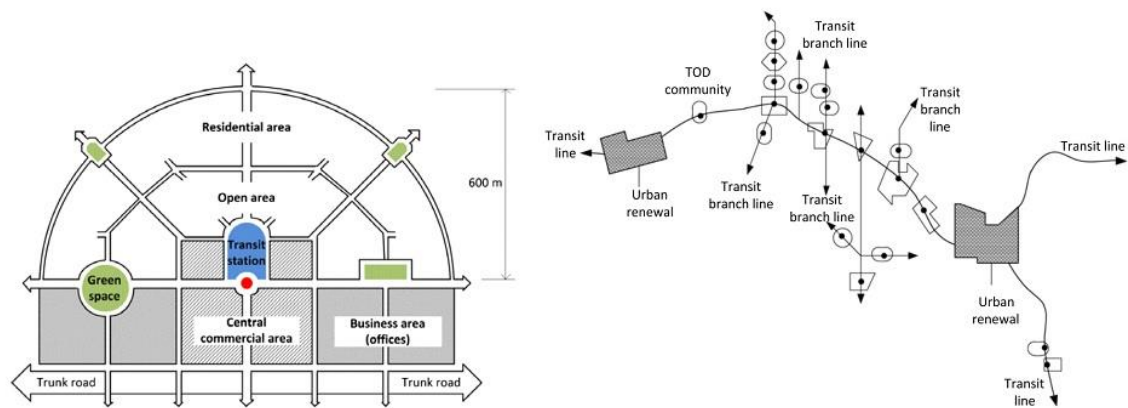


Figure 2.1. Transit Oriented Development

TOD in Figure 2.1, in general, is the part of the public transport system (Black et al., 2016). The positive results of TOD was obtained by a city include: creating a healthy environment due to the declining number of pollution (Dou et al., 2016), the city's

economic efficiency due to the increasingly large amounts of transportation costs and speed the travel time (Li et al., 2013), the creation of the city transportation system efficiency because of many passengers who switch from private cars to public vehicles and reduced congestion (Boschmann and Brady., 2013), and land use in surrounding area of the station has set up appropriate allocation through the compact and mixed manner (Ratner and Goetz., 2013).

2.2. Urban planning and TOD

The concept of TOD is very related to urban planning because it is a derivation from the movement of the garden city movement was popularized by Ebenezer Howard in the late 19th century (Black et al., 2016). Howard called on to decentralize the cities too dense. The concept now known as classic town plans are characterized by a pattern of radial road pattern grid which converges on a focal point or in town centers. The master plan includes the urban garden and put forward the use of the public (Arrington and Cervero., 2008). The road is designed to achieve a balance between pedestrian and vehicular, accommodate trees, sidewalks, and street furnishing while also providing visibility and ride comfort and on-street parking. The buildings directly facing made to roads with features that create the excitement of public spaces.

TOD generally has the commercial core with the distance reached by residents, a grid-shaped road network well connected, the width of the road that is not too large with parking on a side street, a buffer for the pedestrian, mixed-use, and residential, with diverse types of density (Dorsey and Mulder., 2013). The area resembles the traditional community form TOD with unique characteristics and different where the transit station and its surrounding areas became the focal point (Ulloa., 2011).

2.3. Integrating land use and transportation of TOD

Transit Oriented Development is a part of urban development with emphasis on a growth point to minimize the occurrence of sprawl (Zhang., 2008). Through the concept of TOD, a city developed at some points grow, which is the point of rest mass transportation. Consequently, there is the division point of growth based on the route to public transportation stops (Xie and Levinson., 2009). This concept is also an urban planning that makes up an accessibility network in regional scale and it becomes an integrated union. The unity was formed through an integrated transport network and land use that creates a territorial integration (Wieberneit., 2007).

The station area was developed by integrated TOD and pedestrian-oriented creates an environment with convenient, secure, fun and enough for the pedestrian walk-able environment (Wey and Chiu., 2013). The mixture of various function's activities generates a shorter trip and quickly. These functions are the land use includes commercial area center, offices, retail, services, and localities with a population density of medium to high density and public open space (Wey., 2015). In the transportation point of view, TOD involved the inhabitants in the everyday interaction and reduce auto-oriented activities. Inhabitants who have limitations in the use of private vehicles (due to economic reasons, the age of children or the elderly) still had access to many facilities and meet his needs (Vos et al., 2014).

Urban transportation activities have a significant effect on the increase of current environmental issues. There are solutions that have been implemented, but it still limited to practical approaches. Furthermore, the problems of urban transport need to be reviewed through a systemic approach, namely, the establishment of urban transport system in a

macro integrated aspects of land use and transportation. The current paradigm of the cities in the world in addressing the problems is by starting to implement innovative strategies through the application of the integrated system and concepts. One of them is the concept of Transit Oriented Development (TOD)

The aim of this Chapter is to encourage application of TOD as one of the alternative tools for solutions in addressing the problems of congestion and pollution of the city concerned through the integration between the transport nodes with land use in surrounding area of the station. This Chapter emphasizes the linkages characteristics-based TOD to encourage movement of ridership using mass transit.

This Chapter provides evidence of integration between transport and land use with TOD from literature by formulating a lengthy list indicator of the district-based TOD through study literature regarding TOD practices in cities in the world. The long lists meaning is done by a qualitative descriptive through the theoretical concept of TOD. It performed to confirm suitability indicator concepts for the TOD was adapted in the local context. The stakeholders are the key to understanding the characteristics of the land use and transportation. Formulation of criteria-based TOD is obtained using the descriptive method and comparative analysis between existing conditions of the space with TOD indicator that has been derived from the study of literature.

2.4. Planning and assessment of TOD research

Efforts to develop a TOD research has been discussed in some study and continue in discourse in accordance with developments of the public transport sector, this Chapter discussed several studies (Table 2.1).

Table 2.1 Measurement of TOD research

Study	Method	Criteria	Indicator	Measurement description
(Praser tsubpak ij and Nitivatt ananon, 2012)	Factor analysis and reliability test and assessment of metro accessibility	Psychosocial	Safety	Sufficient level of commitment of safety operation and strategies of managers/ staff.
			Social usefulness	The extent to which attitudes on positive feelings of users on metro services on perceived support (respect, recognition, approval)
			Trust	The extent to which attitudes of willingness to rely on metro services
			Comfort	Satisfaction level of people on cleanliness, lighting, weather, ventilation, shade, etc.
		Temporal	Activity period	Time period of target activities
			Trip purpose	The characteristics of trip purposes
			Duration	The comparison of duration preference of metro trip e.g., trips on daytime, on-peak, off-peak
		Affordability	Income	Personal income per month (THB/Thai Baht per month)
			Occupation	Occupation of respondents
		Basic needs and market-based	Basic needs	Attitude level on how metro services respond to their needs and desires.
			Market-based	Attitude level in response to “Do you get what you pay for?”
			Potential connectivity	The calculation of average connectivity and average integration by space syntax technique.
		Connectivity and mixed use	Mixed use	$1 - \left\{ \frac{ r-1 + c-1 + i-1 + o-1 }{3/2} \right\}$ Where: r=acres in residential use (single and multi-family housing), c=acres in commercial use, i=acres in industrial use, o=acres in other land uses, and T=r+c+i+o. A value of 1 indicates perfect mixing of the four land uses.
		Design attractiveness	Attractiveness of metro utilities	Percentage of weighted attractiveness summations of utility design (built-environment around stations) adopted to optimize metro the use of metro services
		Equity	Equality to access	The extent of attitude to which respondents think that they receive equal benefit from services.
			Opportunity to access	The extent of attitude to which respondents think that they have

				equal opportunity to access metro services and are taken into account in an equal manner
(Fard 2013)	Hot-spot analysis SMCA (spatial multi criteria analysis)	Time and activity obligation	Time obtaining Activity location	Total time (min). The distance of activity locations from stations (km).
			Compact	Percentage of residential, commercial, employment and other activities near the station within a 5 km radius.
		Urban environment/ compact	Reducing sprawl	Level of attitudes related to spatial knowledge and settlement, modal experiences, paths and behavior to reducing sprawl quantify.
		Level of density	Residential density and commercial density	Higher residential and commercial densities are required for more efficient public transport.
		Level of land use- diversity	Land use diversity	Higher diversity of land uses reduces vehicular trips and enhances the liveliness and safety of a place where people socialize.
		Level of mixed use	Mixed use	Higher mixed-ness of land uses (residential land use) encourages higher degree of walk and cycle for non-work trips.
		Level of economic-development	Number of business-establishments	The higher number of business establishments represents higher level of economic development and hence higher TOD levels.
		Urban rail transit	Average time from houses to stations (min)	Convenient path from home to transit station in TOD community.
			Average transfer time (min)	Efficient transfer between rail transit and buses.
			Utilization rate of the transit station capacity (%)	No waste of public transport resources and passengers should not exceed the capacity of transit station.
			Split ratio of bus trips (%)	Encourage public transit ridership.
			Vehicle kilometers travelled per capita (km per capita)	Reduce emissions from cars to protect the environment.
(Binglei and Chuan, 2013)	DEA (data envelopment analysis)		Trip distance per capita (km per capita)	Reduce unnecessary trips to control the total traffic demand.

(Kamru zzaman and Baker, 2014)	DEA projection	Land use	Population density (people per square kilometer)	Make full use of land resources to prevent low density spread.
			Employment- housing ratio (%)	Employment-Housing balance.
			FAR (floor area ratio)	High density development.
			Non-motor lane area ratio (%)	Comfortable environment for walking and using bicycle.
	cluster analysis, node place typology multinomial logistic regression analysis	Density	Non-residential land use area ratio (%)	Mixed land use incorporating different land use functions.
			Net employment density	The number of jobs located within a unit area of employment generating land uses (e.g. commercial, industrial) located within a CCD (Census Collection Districts; e.g. number of jobs/hectares).
		Diversity	Net residential density	The number of residential units located within a unit area of residential zoned land (e.g. unit/hectares) within the buffer of each CCD.
			Land use diversity	The following formula of Simpson's diversity index in which the higher value represents more diversity of land uses (value ranges from 0 to 1).
		Design	Intersection density	The number of 3 or more-way intersections located within a unit area of the buffer for each CCD (e.g. number/hectares).
			Cul-de-sac density	The number of dead ends located within a unit area of the buffer (e.g. number/hectares).
	Density	Accessibility	Public transport accessibility	Closeness to public transport Ease of walking to places Wanted to live close to shops Closeness to open space (e.g. parks) Near to green-space or bush land Closeness to schools Closeness to childcare Closeness to the city Closeness to work Access to freeways or main roads %
				Population density (persons / sqkm). Commercial density (number of commercial enterprises/sqkm).

(Singh 2015)	Weighted analysis	Land use diversity	Land use diversity	Land use diversity creates a vibrant/ lively place out of a node
			Mixedness of cyclability residential land use with other land uses.	Mixed-ness of residential land use with other land uses.
		Walkability and cyclability	Total length of walkable/cyclable paths.	Total length of walkable/cyclable paths (meters).
			Intersection density.	Number of intersections/sqkm.
			Impedance Pedestrian catchment area (IPCA)	Impedance Pedestrian catchment area (IPCA).
		Economic development	Density of business establishments	Number of business establishments/sqkm.
		Capacity utilization transit	Passenger load in peak hours. Passenger load in off-peak hours.	Passenger load at peak hours. Passenger load at off-peak hours.
		User-friendliness of transit system	Safety of commuters at the transit stop Information display systems	Safety of commuters at the transit stop. Basic Amenities at the station Presence of Information display systems (Yes/no).
		Access to and from the station	Frequency of transit service Interchange to different routes of same transit. Interchange to other transit modes. Access to opportunities within walkable distance from train station	Frequency of transit service (number of trains operating / hour) Interchange to different routes of same transit (number of routes). Interchange to other transit modes. Access to opportunities within walkable distance from train station (number of jobs).
		Parking supply at the station.	Parking supply-demand for cars/four wheelers. Parking supply-demand for cycles.	Parking supply-demand for cars/four wheelers. Parking supply-demand for cycles.

(Papa and Bertoli ni, 2015)	Bivariate and correlation	The place index	Structural land use	Study area (km ²) Inhabitants and jobs (inh. + jobs) Average population and jobs density ((inh. + jobs)/km ²)
	Node-place model	The node index	Structural transport system	Transport supply: Number of registered cars per 1000 inhabitants (n). Rail network: (Km/mln inh.) Rail network (n. stations/ mln inh.)
(Vale, 2015)	Cluster analysis node-place model, pedestrian shed ratio	Node-index: accessibility of the node	Number of directions served by train and/or ferry. Daily frequency of train and/or ferry services. Number of stations within 20 min of travel. Number of directions served by other public transport (bus, tram and underground). Daily frequency of services by other public transport. Distance from the closest motorway access. Car parking capacity	y1 = number of train and/or ferry services offered at station. y2 = number of trains and/or ferries departing from station on working day. y3 = number of stations reachable within 20 min by direct trains and/or ferries. y4 = number of public transport services offered at station. y5 = number of buses, trams and underground trains departing from station on working day. y6 = distance to next highway or freeway exit. y7 = number of car places at station (free or paid).
			Number of residents Number of workers in retail/hotel and catering. Number of workers in education/health /culture. Number of workers in administration and services. Number of workers in	x1 = number of residents within 700m. x2 = number of workers within 700m in retail/hotel and catering group. x3 = number of workers within 700m in education/health/culture x4 = number of workers within 700m in administration and services. x5 = number of workers within 700m in industry and distribution

(Higgins and Kanaroglou, 2016)	Latent class model-based clustering model-based latent class	TOD input measures for station typology analysis	industry and distribution. Degree of functional mix	$x_6 = 1 - \frac{((\frac{a-b}{d}) - (\frac{a-c}{d}))}{2} \text{ with } \begin{cases} a = \max\{x_1, x_2, x_3, x_4, x_5\} \\ b = \min\{x_1, x_2, x_3, x_4, x_5\} \\ c = (x_1 + x_2 + x_3 + x_4 + x_5) \\ d = (x_1 + x_2 + x_3 + x_4 + x_5) \end{cases}$
			Density	Reflects density and the intensity of land use development in a station area. Calculated as total Population+Employment / Hectare within each station's theoretical buffer area.
			Development mix	A statistic ranging between 0 and 1 that reflects the balance between population and employment in a station area. Calculated as the ratio of Employment to Population+Employment.
			Street connectivity	Measures overall street connectivity and the quality of pedestrian access to the transit station. Calculated as the ratio of a station's 10-minute walk buffer on the local road network to its 800-m circular buffer. In this case all station buffers were permitted to overlap to give a measure of overall street connectivity in the neighbourhood.
			Interaction potential	Regional station accessibility and interaction potential, or measure of gravity considering population, employment, and travel time.
			Land use mix	The proportion of residential, commercial, institutional, mixed, and industrial land in each station area. Commercial and institutional lands are combined into a single category.
		Output performance and additional descriptive measures	Transit commute mode share.	Commute to work mode share for transit among those 15 years and older from the 2011 National Household Survey.
			Walking commute mode share	Commute to work mode share for walking among those 15 years and older from the 2011 National Household Survey.
			Cycling commute mode share	Commute to work mode share for cycling among those 15 years and older from the 2011 National Household Survey.
			Household VKT	Total Vehicle Kilometers Travelled (VKT) divided by the number of households in the zones that make

Average median household income	up each station area from the 2011 Transportation Tomorrow Survey. Station area average of median household income values for each Dissemination Area (DA) from the 2011 National Household Survey, weighted by each DA's proportion inside the station area.
Bachelor's degree and above	Proportion of station area population aged 15 years and older with a bachelor's degree or above.
Population 20-35 years old	Proportion of the population that is between the ages of 20 to 25 in each DA from the 2011 Canadian Census.
Population 50-65 years old	Proportion of the population that is between the ages of 50 and 65 in each DA from the 2011 Canadian Census.

Table 2.1 shows the explanation of TOD research based on reviewing studies of many methods using measurement, criteria, and indicator. TOD is measured quantitatively or qualitatively of a spatial and a relationship among cities.

Prasertsubpakij and Nitivattananon (2012) measured metro station in Bangkok metropolis, Thailand by measuring TOD access, various values of some variable research made the comparison using the accessibility score, t-test, and t-significant. Data collection was obtained from questionnaire with approximately 600 respondents.

Binglei and Chuan (2013) measured the TOD mode analysis with Data Envelopment Analysis (DEA) mathematical formula using software. This study obtained the ranking by making evaluation of actual TOD with land use and urban rail transit as variables.

In his study, Fard (2013) found the TOD index using Spatial Multi-Criteria Analysis (SMCA) i.e. counting criteria and indicator of spatial data, the results obtained are TOD

level based on the potential area for construction of the new station. His study is equipped with hot-spot analysis techniques to observe potential differences between areas.

Ratner and Goetz (2013) divided type of TOD based on urban structure and land use, the study elaborated data of land use and urban form in the comparison of Denver area. The results are the typology and its impact on the development of Denver city, the study emphasize on descriptive variables and describing the relationships between variables.

TOD typologies were introduced by Kamruzzaman & Baker (2014) i.e. categorizing each TOD based on cluster analysis and node place typology. The multinomial logistic regression is applied as statistical analysis to obtain TOD cluster. TOD level is not very clearly presented in the final value yet elaborated based on the typology of each station, where the variable based on typology research is taken.

Study of Singh (2015) which discussed TOD composite study stated TOD index findings using weighted method from each of the criteria indicators followed by the assessment of each station based on the gained index, the study orientation is in Stenberg, Netherlands, using multi- criteria analysis using ArcGIS and ILWISS software to produce TOD score map.

Papa and Bertolini (2015) compared the TOD between 6 metropolitan areas in Europe, the study using node-place model with various indicator TOD and rail-based accessibility. The study observes existing area of the metropolitan with the result that accessibility is higher in urban areas.

Vale (2015) studied TOD classification to obtain the relationship between land use, transport, and pedestrian accessibility. The node-place model, pedestrian shed ratio with cluster analysis was implemented in the study. GIS application was complemented in the study. Based on the analysis of three values, the study concluded a balanced place-node is not necessarily.

Higgins and Kanaroglou (2016) discussed the performance of TOD based on inputs and outcomes. They applied latent class model-based clustering with multi-criteria research method. The study also outlined the type of station, based on the concept, and a significant level of the statistical indicators of each variable.

TOD research is done using many methods using multiple criteria and indicators. TOD in the many cities in the world is planned at different scales or level, such as station scale, corridor level or area-wide. It is needed a method which can assess holistically and covering all aspects, so that, planning for TOD attempt to integrate multi-criteria also concerns to the incorporation of multi-stakeholder viewpoints.

2.5. The policy and public transport plan of TOD

A TOD can also be an urban planning and design model around transit nodes with regional perspectives. It has compact mixed-use neighborhoods, and safe and active public spaces that favour social interaction. TOD happens on different scales and with different land uses, depending on the context.

Some of the policy and public transport plan of TOD is implemented in many cities of the world. It is valuable lesson taken in real life, such as policies and actual strategy that gives contributing to success TOD (Table 2.2).

Table 2.2 Guidelines of strategic plan and public transport plan in the worldwide

No	Study	City	Country	Geographic area	Strategic plan	Public transport plan
1	(Dorsey & Mulder 2013)	Ogden, Utah,	USA	America	Balance within the triad of privatism, government, and community	Developing better bike routes, signage, and other amenities to make the city more pedestrian oriented
2	(Feudo 2014)	North-Pas-de-Calais	French	Europe	Integration between land use and transportation, it matches strategic perspectives of regional planning	Helping concentrate urban development and activities near transit corridors, inducing higher transit use.
3	(Kamruzzaman & Baker 2014)	Brisbane, Queensland	Australia	Australia	A strong, green, smart, and healthy state by reducing congestion and by cutting one-third of its current carbon emissions	Facilitating development in a more "compact way" through locating self-contained activities in well-defined nodes along existing and planned transport corridors
4	(Kwon 2015)	Sejong	South Korea	Asia	A new urban paradigm of construction reflecting the Korean experience	Mass transit stops and stations are located along pedestrian pathways, bicycle roads, community retail facilities, and public facilities.

Different studies have implemented the planning of Transit-Oriented Development in distinct ways. They made guidelines of TOD in different cities in USA, Europe, Australia, and Asia. The strategic plan comes with experiences and applied to many projects.

Dorsey and Mulder (2013) describe a strategic plan and public transport in Ogden, Utah, USA (Figure 2.2). The strategic plan aim is to balance three things that are important in the development of the city, namely private aspects, society and government. All three components should work in harmony to achieve the goal of moving the city in the future. The public transportation applied in the routes which being developed is able to commute

the people and to connect the other modes of transportation. This is important to evoke the impression of a comfortable environment of the city as well as the awareness of the social interaction.



Figure 2.2 Proposed Ogden streetcar routes. Source: (Dorsey & Mulder 2013)

North-Pas-de-Calais region in French practices development using TOD for many years (Feudo., 2014). Application of TOD in this region is expected to be made as the model for other cities development in France that offer mixed land use, locations near the point of transit, reduce land consumption, punctuality of transportation, and promote an excellent quality of life in urban areas. Policy integration between transport and land use is based on the view of regional planning, namely, to assist the activities of the city are located near transit corridors to encourage the use of public transport (Figure 2.3).

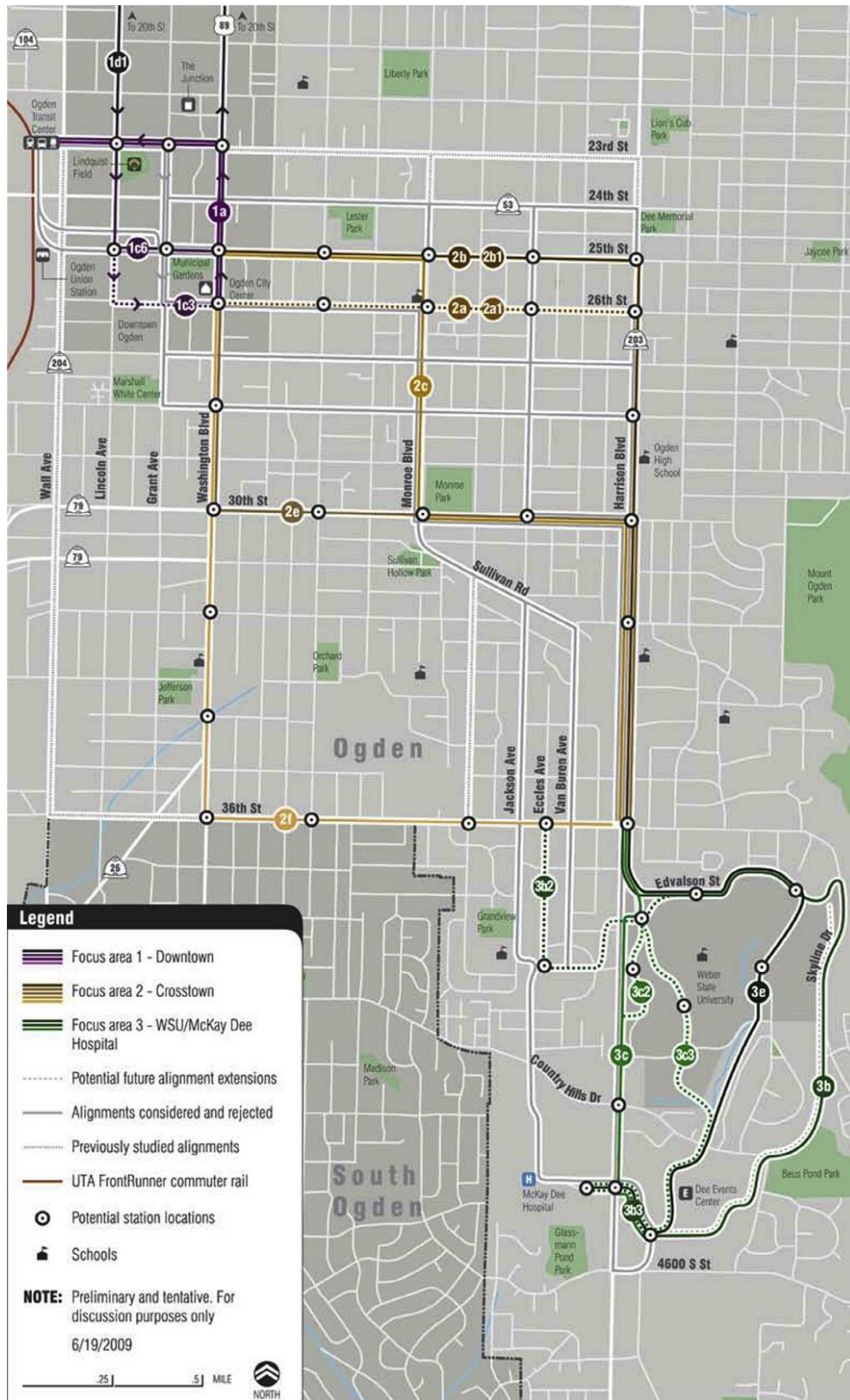


Figure 2.3 Application TOD in North-Pas-de-Calais French. Source (Feudo., 2014).

In Brisbane, Queensland, Australia (Figure 2.4). The objective of the strategy plan is to make Australia becomes a strong, intelligent, green, and healthy nation by reducing congestion and by cutting one-third of the current carbon emissions (Kamruzzaman and Baker., 2014).

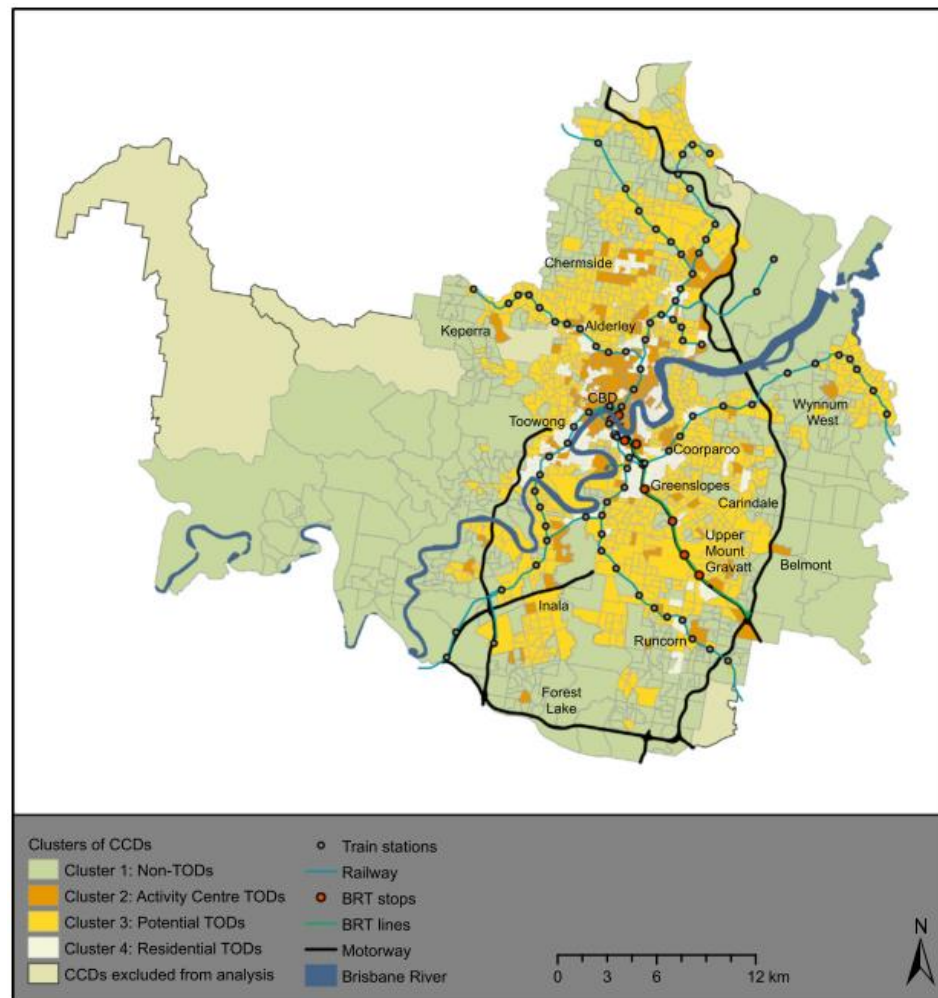


Figure 2.4 Spatial distribution of Census Collection Districts (CCDs) clusters in Brisbane.
Source: (Kamruzzaman & Baker., 2014).

The strategic plan and the public transport plan as above facilitate the development of better land use through transportation activities in the existing corridors. Therefore,

future planning of the corridors can be developed for long term anticipation of a growing urban area.

A new paradigm of master plan of Sejong City, South Korea (Figure 2.5), focus on the construction of the city that reflects the experience of Korea. The public transportation system was implemented to provide service which support the development by establishing stations located along the routes of pedestrian, bicycle paths, on-site retail community, and public facilities (Kwon., 2015).

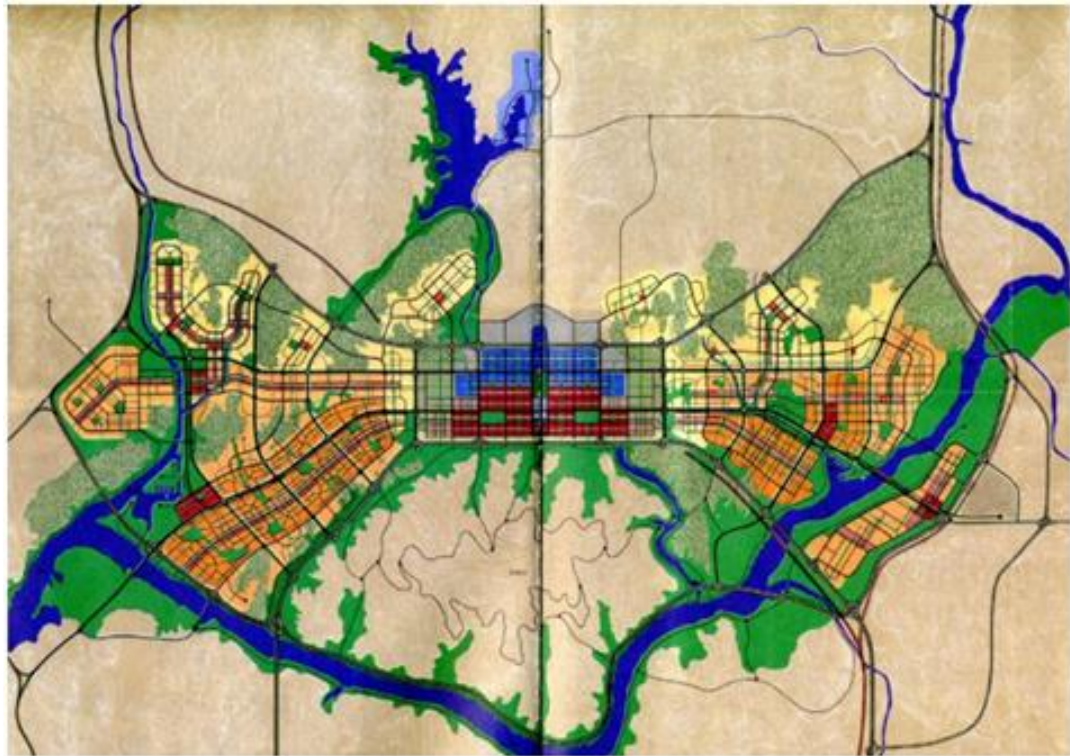


Figure 2.5 The construction of the master plan that reflects the experience of Korea. Source: (Kwon 2015).

TODs, as a form of land use, attempt to reduce the amount of travel by car by promoting the use of public transit and higher density mixed-use developments. Transit Oriented Developments, thus, are fundamental for a successful smart growth policy. They

are increasingly seen as a viable alternative to sprawl and suburban development. The study in this Chapter has shown that transit-oriented developments are effective in shifting the mode choice from personal vehicles to transit which would result in numerous benefits that range from congestion relief to improved air quality and land conversation.

2.6. Cross-continent comparison of the transport and land use integration

TOD has been applied in many parts of the world, it was originated in USA, further spread to Europe, Australia and Asia. Each country has distinctive characteristics in applying TOD. This Chapter explained the successful implementation of TOD with combines land use and transport (Table 2.3).

Table 2.3 Cross-continent comparison of TOD

No	Study	Case	Geographic area	TOD integration planning	
				Land use	Transport
1	(Loo et al. 2010)	New York City, US	America	✓ Mixed land use is conducive to railway patronage. ✓ Mixed land use help to generate bi-directional travel demand throughout the day	✓ Having well-established heavy rail systems, characterized by an extensive network structure and high transit ridership. ✓ The work trips were made by the subway system. Combined with the other public transportation modes, like buses and ferries
2	(Mathur & Ferrell 2013)	San Jose, US	America	✓ Emphasizing close land use-transportation integration. ✓ Joint development of station area public land (including sale or lease of air rights above the transit facilities such as the station or the rail line)	✓ TOD served by light rail line, commuter rail service and Rapid Transit District (BART), a heavy rail service. ✓ The station lies at the junction of two major freeways. ✓ 67 trains on the weekday and 62 on the weekend serve station at 15-min interval

3	(Qviström 2015)	Region Scania, Sweden	Europe	✓ Development of polynuclear structure, with special attention to cities acting as the growth engines for the region; which would be done with ✓ A call for “sustainable and efficient growth” of all settlements; and ✓ Which should be socially attractive	✓ Increased physical accessibility (primarily with public transportation), internally to “bind” the region together. and ✓ Externally to expand or strengthen the region;
4	(Vale 2015)	Lisbon, Portugal	Europe	✓ Developing significant suburban area. ✓ Urban development areas for both urban and transportation planning	✓ Reinforcing other places in the periphery of city as the main transportation interchanges. ✓ The development of a new suburban train line obliged to the construction of a new train station.
5	(Olaru et al. 2011)	Perth, Western Australia	Australia	✓ Emphasizing the creation of a mix of land use and residential density to attract trips, with	✓ Lying the station at the intersection of a primary distributor road and the main freeway.
				- access mainly by foot rather than car. ✓ Promoting mixed-use development.	✓ The station caters to car access (714 parking bays) and a feeder bus system along the distributor road that serves surrounding suburbs.
6	(Black et al. 2016)	Sydney, Australia	Australia	✓ Emphasizing for land-use developments along bus ways (transit lanes) in outer suburban.	✓ Applying suburban road-based “transit-way” (T-way) – or a bus rapid transit route.
7	(Li et al. 2013)	China’s pearl river delta, China	Asia	✓ Encouraging development around stations by prioritizing land quota for station areas. ✓ Applying a special zone policy to station proximity	✓ The construction of the line between two adjacent city to stimulate tourism industry and urban development ✓ Planning an inter-city rail transit network
8	(Sung & Oh 2011)	Seoul, Korea	Asia	✓ Applying compact land use pattern. ✓ Planning the quantity and quality of transit service, the density and diversity of land use and the features of the road network and urban design around the rail station.	✓ Managing rapid urban growth, were to be concentrated into a 1 km radius of rail stations in Seoul along the four railway lines under construction and four additional planned railway lines.

Integration between land use and transportation planning for TOD is part of the planners' expertise to ensure harmonic growth and a high quality of life for the residents of a city or county. It also addresses health, safety, and environmental concerns as well as convenience related to time and distance between home, work, school, shopping, and other human activities places. Effective integrated planning of TOD should consider the basic systems that influence urban spatial structure such as human activity, land development, and environmental concern.

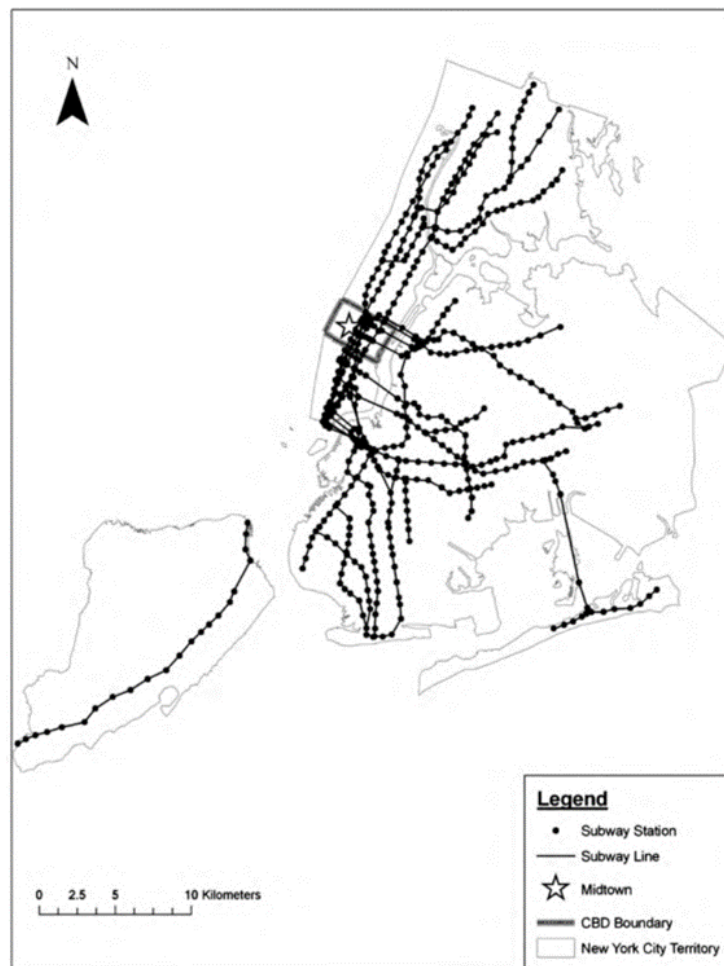


Figure 2.6 The railway network of New York City. Source (Loo et al., 2010)

USA is an excellent model of TOD application (Figure 2.6) by the case of New York City (Loo et al., 2010) and San Jose (Mathur and Ferrell., 2013). Integration of

transport and land use in TOD underscore the serious interest to the mixed land use because it is expected to maintain the traffic flow of passengers. Extensive network and high transit ridership of New York residents supported by the provision of heavy rail system. TOD is implemented within the transit are in which the interaction between modes of transportation is occurred, such as bus and ferries.

TOD in the San Jose is served by a complete transit system using light rail line, commuter rail service and Bay Area Rapid Transit (BART). Integration of land use and transport is done by exposing both into a cooperative development on the station. The transit system was built by having the 67 of train that operates on the working days and 62 of train on the weekend. The interval time each train is 15 minutes. The stations located at the intersection of two major highways.

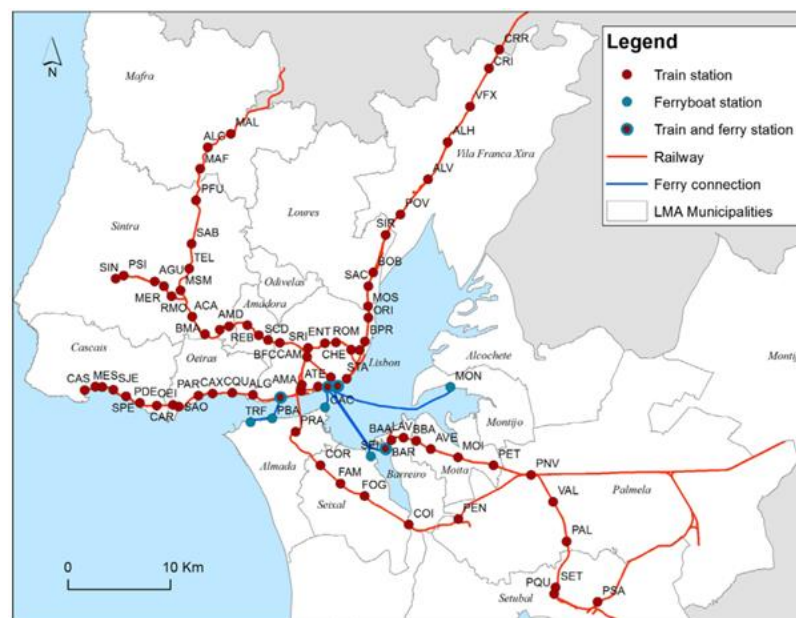


Figure 2.7 The train station locations in Lisbon. Source (Vale., 2015)

Lisbon, Portugal and the Region of Scania, Sweden are the examples of successful application of the TOD integration in the city and region scale (Figure 2.7). The

application of TOD integration in Scania region, Sweden is carried out by the regional strategy to move the accessibility based on sustainable social facilities and environment (Qviström., 2015). The point is the development of the city structure as the engine of growth towards sustainability and efficient, with no appeal of social and environmental.

In line with Scania, Lisbon, Portugal also apply TOD integration through planning suburban areas and strengthen the outskirts of the city as the main place of transportation interchanges. Transport and land use are the key features of urban development in Lisbon (Vale., 2015). Therefore, the application of urban planning in surrounding area of the station is important for the station sustainability.

Perth and Sydney experience of integration TOD is by applying a relation between form, use, transportation, density, urban development and the effect on the behaviour of human as the dominant factor. TOD in Perth started since the opening of the Mandurah railway station in 2007 (Figure 2.8). Integration of TOD in transportation planning revitalizes the quality of urban planning and social life of the community. The planning emphasizes on the creation of a mixed use and density of settlements, other plan emphasizes to attract pedestrian, i.e. putting the station on the intersection of the main distributor roads and freeways. The station also serves users of private car and service a bus feeder system along the distributor in suburban areas.

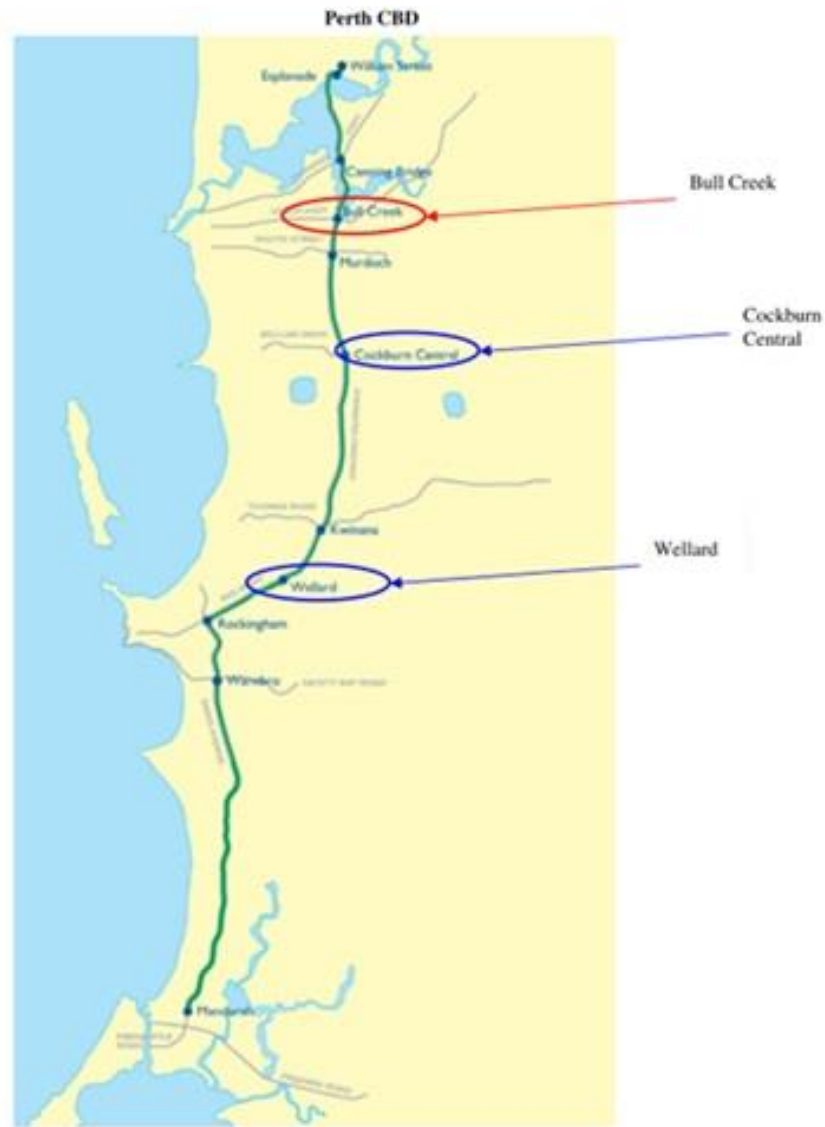


Figure 2.8 Integration planning of TOD in Sydney. Source (Olaru et al., 2011)

TOD and smart city were implemented in Sydney, Australia. TOD is in adjacent with the smart city movement where the concept of adaptation from beyond and performed by adjusting with the local conditions (Black et al., 2016). Integration planning of TOD in Sydney put on the land use development that located along the bus way or public transport lanes outside of the city. In addition, planning suburban road by implementing the transit way or a bus rapid route.

Cities in Asia have been an orientation to transit, such as Seoul, Korea and Shenzhen, China. In Seoul (Figure 2.9), TOD is integrated through the application of compact land use patterns (Sung and Oh., 2011). The planning of the quality and quantity of the TOD services is done through the creation of the features of the urban design and road network in the surrounding area of the train stop. The city government manage the rapid growth by emphasizing the concentration of areas within a radius of one km from the train station.

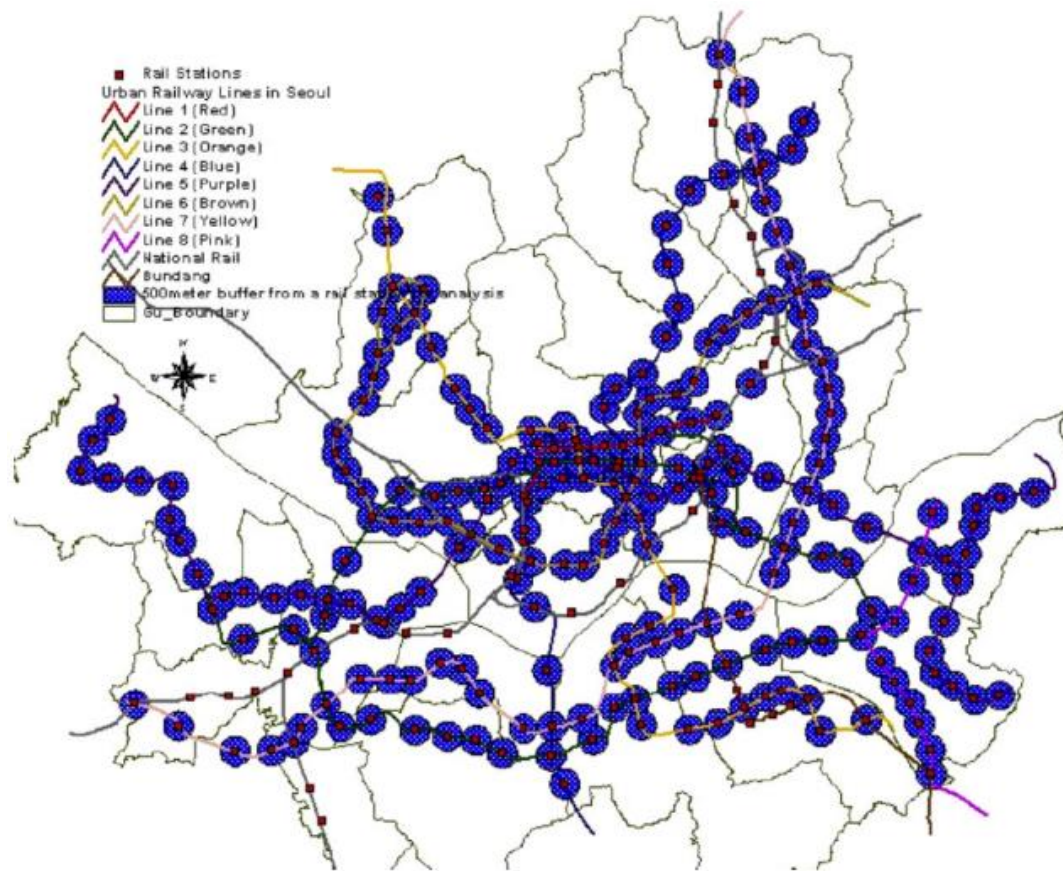


Figure 2.9 Railway system in Seoul, South Korea. Sources (Sung & Oh., 2011).

Integration of TOD in China (Figure 2.10) stressed on the development of the area around the station with prioritizing land quota and applying special zone (Li et al., 2013). It connects two adjacent cities to evoke the tourism industry and urban development.



Figure 2.10 Public transport plan in China. Source: (Li et al., 2013).

Planning TOD became more sophisticated with the advent of spatial and transportation integration. This planning may result in an optimal choice of sites and routes based on many environmental considerations. Integration of TOD is defined as a combination of one or more important infrastructure axes (road, rail, lines) link land use in the surrounding area of the station. This TOD making inhabitants hard to commute to other places, or in contrary, they will be so pleased because they can preserve their areas. Integrated planning of TOD tends to oversimplify the complexity of the land use and transportation system.

2.7. Summary

The concept of TOD ensures the existence of urban transport sustainability by integrating transportation networks to the growth of the city. The concentration of activities near transit area will encourage the use of TOD. Therefore, it can gradually reduce car dependence. Identification of the integration between transport and land use with TOD in various cities of the world shows the transit area has an affinity towards

many commuters. The transit area with a compact and diverse land use, which also completed with pedestrian path access, significantly able to attract larger numbers of commuters and it helps to decrease traffic congestion and environmental pollution. TOD is an alternative to encourage the attainment of sustainable urban development where the principles of planning and designing adjusted for the purposes of the development level of the strategic urban environment.

CHAPTER III

EVALUATING ACTUAL TOD IN JAKARTA METROPOLITAN REGION

CHAPTER III

EVALUATING ACTUAL TOD IN JAKARTA METROPOLITAN REGION

3.1. Introduction

3.1.1. Theory relevance

The relevance of the urban planning policy through evaluating actual TOD is conducted by looking at the whole and relating to various urban planning theories that can be described briefly as follows. Beginning of the 19th century about Garden City Movement is a theory that emphasizes the balance between residential areas, industrial and open spaces in urban areas bounded by the existence of green belts.

Concentric theory of the Central Business District (CBD) is the center of the city located right in the middle of the city and is the center of social, economic, cultural and political life, and is the zone with the highest accessibility in a city. The concept of sustainable development (1970) is the theory that encourages balance in the implementation of development, especially the economic, socio-cultural and environmental aspects.

The concept of integrated spatial and municipal space arrangement (early 1980s) encourages the provision of adequate open spaces and balance of space for occupancy and work activities, including the preservation of old towns and rebuilding of old warehousing areas. Transit-Oriented-Development (1990s) theory of mixed residential and commercial zones with ease of pedestrian accesses to freight (developed at locations along the railway or bus route), each TOD on the city has its own character in accordance with the environment. The 2000s emerges the concept of smart city with one of its policies

is the provision of guidelines for green public transport planning. This concept offers an enhancement the quality of life. Based on the theory above and associated with the development of the JMR, it can be seen the development that occurred in this area is as follows.

The rapid development of urban areas, especially in capital city of Jakarta led to the expansion of development areas to the suburban areas along with improved infrastructure. The city area renew with the emergence of various centers of integrated economic zones after the revitalization of urban renewal in addition to the economic center and business as a place of work is the main reason for commuters to commence travel activities.

Along with the time, it is occurred the formation of growth and maturation process of suburbs. Some new towns become independent cities that seek to meet the socio-economic needs of their inhabitants. For example, the cities i.e. Depok, Bekasi, Serpong, and Tangerang grow into satellite cities of Jakarta that seek to meet the socio-economic activities of its citizens.

The metro transport connection of all these satellite cities becomes vital. It means the connection is not only as a solution to the problem of urban and regional transportation but also has a mean of connecting between urban and suburban areas. Rapid developments are occurred on public transport routes linked to the existence of new cities on the peripheries of the city and along the existing corridors.

The phenomenon that occurs above encourages the emergence of the needs of residential areas that have the characteristics of TOD, namely: friendly to pedestrian (walkable), mixed-use between residential, business and commercial, and located near the metro station network. Therefore, the evaluation of the actual metro station in JMR is a

very important thing in determining the TOD characteristics through index. This method distinguishes between stations to facilitate the treatment increasing the area to the ideal TOD.

3.1.2. Evaluating actual TOD in JMR

Dynamics discourse of modern cities has occurred in many countries in the world where the dispute discusses the comparison which is better between the city of car-based and public-based (Blumenauer., 2002; Miller et al., 2016; United Nation., 2005). In the various paradigms, that gave rise to different periods in the pattern of the relationship between the city and transit activities (Olaru et al., 2011).

The problem of a metropolitan region in many countries like Jakarta Metropolitan Region (JMR) is the occurrence of a vigorous movement between urban and suburban areas where it is known by the phenomenon of urban sprawl (Sunarto., 2009). Transportation is sometimes not able to support this condition with an optimal service. One example is the station where its function becomes less able to accommodate the needs of the population movement as well as it has not been in accordance with the policy action (Marshall., 2013). Thus, it is needed an evaluation of station function to accommodate the mobility of a population between regions through the provision of the mass public transport services in transit nodes (Fard., 2013).

This effort can be done by applying the concept of Transit Oriented Development (TOD). According to Feudo (2014), TOD emerged not despite historical development patterns of the metropolitan region consists of urban, suburban and connection with public transportation such as trains or buses.

TOD was introduced in America in the late 19th century in which mode of transportation serving the growth pole (Cervero et al., 2002; Evans and Pratt., 2007; Jarboui., 2012). This phase marked the existence of a separate settlement zone patterns of work zones linked by mass transportation with the facilities such as stations, rail and modes made to cater to each zone (Arrington and Cervero., 2008; Olaru et al., 2011; Loo et al., 2010; Nasri and Zhang., 2014; Kwon., 2015). The zoning area between redevelopment site, development site, and new growth area where land use and transportation generate transit zonation thus motivating this study to reevaluating TOD uses the multi-criteria evaluation (Malczewski., 2006). Thus, Singh (2015) noted that assessing TOD becomes important because it is expected to improve the TOD success.

This Chapter provides an alternative solution to develop auto oriented by encouraging residents to use the facilities of public transport rather than private cars (Taki et al., 2017). Thus, it can solve problems sprawling (Renne and Wells., 2005). Previous TOD research for JMR has been conducted by H. S. Hasibuan (2014), it assessed the stations for TOD implementation using the analysis of land uses proportion around transit stations. Nevertheless, the assessment is still general. therefore, this Chapter enhanced previous research by evaluating TOD using index accompanied by more complete criteria and indicator generated from the experts.

3.2. Research method in Chapter 3

3.2.1. Research framework

The method of this Chapter is described in Figure 3.1. below as the analytical framework for evaluating actual TOD and analyzing the development of metropolitan region along railway network in urban and suburban areas.

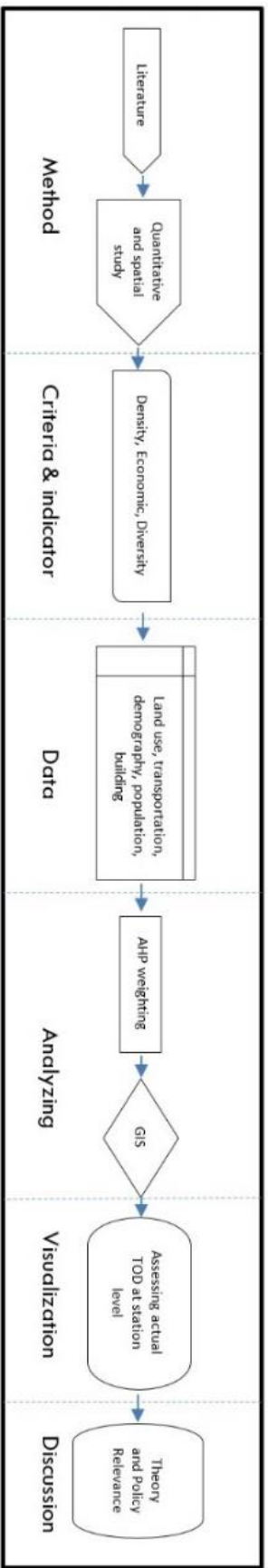


Figure 3.1 Illustrated cognitive of research in Chapter 3

3.2.2. Station area analysis

Transit Oriented Development is the area of influence of the railway station in its urban and suburban context, which is different on metropolitan and city scale. To include influences from a higher scale on the city scale station areas the railway route is examined on the regional or metropolitan scale, the scale of the whole railway, as an activity corridor, an activity center, and a transport corridor. Radius area of 800 meters around station of the railway is used to understand the structure of the line as a whole. Within this radius, important networks and issues can be known that are influencing the direct surroundings of the station in an 800-meter radius.



Figure 3.2 Area analysis of railway stations within an 800-meter radius (by author)

TOD is the walk-able area around transit stations, an area of 800-meter radius from the station, called the station area (Figure 3.2). Within this radius urban transformations

have a direct influence on the use of the train and the direct station areas as activity centers. Some of these station areas have better chances and more opportunities to develop, because of their well-accessible location and already existing attractions.

3.2.3. Data collection

Required data is a variety of spatial as well as non-spatial data (Table 3.1). The required data was collected from the ministry and agency. Administrative boundaries, railway network, station locations, land use data were all available as spatial data layers in vector format.

Table 3.1 Data types, year and sources

No	Type	Year	Source
1	Shapefile of administrative boundaries	2015	Geospatial Information Agency
2	Shapefile of land use type	2014	Geospatial Information Agency
3	Railway network GIS shapefile	2015	Ministry of Transport
4	Railway station location	2015	Ministry of Transport
5	Indonesian census of population	2015	Central Bureau of Statistics
6	Hospitals location	2014	Consultant project archive
7	Schools location	2014	Consultant project archive
8	Building Coverage Ratio (BCR)	2011	Corporation project document
9	Floor Area Ratio (FAR)	2011	Corporation project document

3.2.4. Chosen criteria

Chosen criteria of TOD based on the 3-D major concept of TOD consisting of Density (development), Diversity (mixing land uses) and Design (pedestrian-friendly) (Cervero and Kockelman., 1997). Economic development criteria are also an important part of the TOD concept as in the study (Fard., 2013). At that point, this Chapter makes this concept as a measurement and the basis for selection of criteria and indicators.

Density, Higgins and Kanaroglou (2016) noted density as describing how the interactions that occur within the station area which it has two meanings, namely the

ability to transact internally travel in stations such as walking, bicycles and the second is the ability to travel into a transit network system. The indicators used in this criterion are a mix of residential, open space, parking area, and a density for residential, commercial, school and hospital.

Diversity or a diversity index is a quantitative measure that informs the number of specific types (in terms of land use i.e. certain types of land use such as residential, commercial, etc.) and can also be useful to illustrate how evenly certain types of land use are distributed among the other types (Higgins and Kanaroglou., 2016). There are various kinds of diversity calculation, especially in calculating land use diversity. There are two popular indexes used: Simpson index and Shannon index. In this Chapter using the Simpson index to calculate the proportion of certain primary land use in each area around the station.

Economic referred to this Chapter that is the current degree of economic performance in the station area. The measurements of these criteria are calculated in diverse sizes, such as numbers of jobs (Atkinson et al., 2011), the percentage of employment (Prasertsubpakij and Nitivattananon., 2012), the number of business establishments (Fard., 2013). In the analysis of this Chapter, we use population density, Building Coverage Ratio (BCR) and Floor Area Ratio (FAR).

3.2.5. Description of indicators

The indicators of TOD are selected from previous research by looking at the trend of a growing research (Sung and Oh., 2011; Mu and De Jong., 2012; Binglei and Chuan., 2013; Singh., 2015; Higgins and Kanaroglou., 2016) hence generated the selected criteria as in Table 3.2 below.

Table 3.2 The selected criteria and indicators from previous studies.

No	Criteria	Indicators	Sung & Oh (2011)	Mu & Jong (2012)	Binglei & Chuan (2013)	Kamruzzaman & Baker (2014)	Singh (2015)	Higgins & Kanaroglou (2016)	This study (2017)
I	Density	Commercial density	x	x		x	x	x	x
		Residential mix	x	x	x	x	x	x	x
		Parking area mix		x	x		x		x
		School density		x		x			x
		Open space mix		x	x	x			x
		Hospital density		x					x
II	Economic	Population density			x	x	x	x	x
		Floor Area Ratio (FAR)			x				x
		Building Coverage Ratio (BCR)	x			x			x
III	Diversity	Land use diversity	x	x		x	x	x	x
		Case study	Seoul, Korea	Dalian, China	Pennsylvania United States	Brisbane, Australia	Arnhem and Nijmegen, Netherlands	Toronto, Canada	Jakarta, Indonesia

Residential mix, land use diversity, commercial and population density indicators are most commonly used in TOD research. Explanation of each indicator from the Table 3.2 above is as described in the following description.

(1). Population density

Data of population density (inhabitants/sqkm) derived from Statistics Indonesia in 2015 (<http://data.jakarta.go.id/>).

(2). Commercial, school and hospital density

It is calculated using GIS by adopting formula from Nasri and Zhang (2014).

$$\text{Density} = (\text{commercial}) \text{ area} / \text{the total area (sqkm)} \quad (1)$$

(3). Land use diversity.

The concept of diversity is derived from the Simpson index and Kamruzzaman & Baker (2014) used land use diversity in their research related to TOD with a formula:

$$\text{Land use diversity} = 1 - \sum (a/A)^2 \quad (2)$$

Where a is the total area of a specific land use category (e.g. commercial) within the buffer of a TOD, and A is the total area of all land use categories within the buffer.

(4). Residential, open space and parking area mix.

Measuring all indicators with the following formula, as adapted from Zhang & Guidon (2008):

$$MI = \frac{\sum Lc}{\sum (Lc + Lr)} \quad (3)$$

MI means the ‘Mixed-ness Index’, Lc shows the sum of total area under residential land use. Lr is the sum of the total area non-residential land uses.

(5). Building Coverage Ratio (BCR)

Land use zones restrict the use of buildings in each categorized zone; BCR controls the volume of buildings in each zone (Figure 3.3). The ratio of the building area divided by the land (site) area. Building area means the floor space of a building when looking down at it from the sky. In this Chapter, there are some categories of BCR such as < 20%, (20 - 40) %, (41 - 60) %, (61 - 80) %, and > 80%.

● Building Coverage Ratio (BCR)

$$BCR(\%) = \frac{\text{building area (B)}}{\text{site area (A)}} \times 100$$

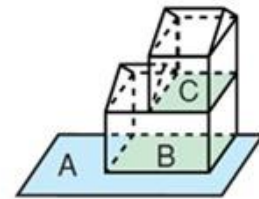


Figure 3.3 BCR

(6). Floor Area Ration (FAR).

FAR controls the height of buildings in each zone (Binglei & Chuan., 2013). The ratio of total floor area divided by land (site) area (Figure 3.4). Total floor area means the total of all the floor space in a building. The data of FAR in this Chapter are divided into four categories, those are the 1st, 2nd, 3rd and 4th floor.

● Floor-Area Ratio (FAR)

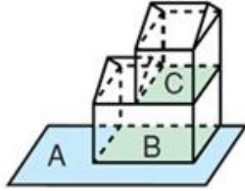
$$FAR(\%) = \frac{\text{total floor area (B+C)}}{\text{site area (A)}} \times 100$$


Figure 3.4 FAR

3.2.6. Weights calculation using Analytic Hierarchy Process (AHP)

The calculation of weights with techniques of analytic hierarchy process (AHP) is done by running the paired comparisons of some expert in their field, the expert provides expertise in accordance with the assessment against criteria and indicators are proposed on a Saaty scale (Bunruamkaew and Murayam., 2011).

This technique assesses the relative significance of the proposed criteria and indicator by assigning weight to those criteria and indicators according to the priority in the form of a hierarchical order.

To maintain the credibility of the relative significance, AHP provides a way to determine the inconsistency of judgments in the form of mathematical equations according to the Formula 4 below.

$$C_r = \frac{C_i}{r_i} \quad (4)$$

Where c_r is the consistency ratio, c_i shows the consistency index, r_i is random index.

The consistency index (c_i) is derived using the following Formula 5:

$$C_i = \frac{\lambda_{\max} - n}{n - 1} \quad (5)$$

$\lambda_{\max}$ means the maximum value of eigenvector and n is the criteria or indicator number.

Further information from Saaty (1990) with respect to the above formula is that the consistency level is quite acceptable if c_r is less than 10% (0.1), and vice versa, there is inconsistency in the evaluation process if c_r is greater than 10% (0.1), this means the results of AHP calculations do not produce meaning.

3.3. Measuring actual TOD index

3.3.1. AHP weighting technique

The calculation of weights with the analytic hierarchy process (AHP) is performed by running the paired comparisons of 12 experts in their field, such as professional, urban planners, policy-makers, researchers and work experience which they have worked on the project of TOD. Table 3.3 and 3.4 are the results of the weights calculation.

The result of weight calculation for criteria and indicator in Table 3.3 below shows the consistency ratio for all the pairwise comparison already proven consistent because of the value of $cr < 0.1$.

Table 3.3 The weight of criteria from 12 experts.

Criteria	Experts												SUM	Weighting	Ranking
	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12			
Land Use Density	0.49	0.33	0.49	0.62	0.60	0.59	0.59	0.59	0.60	0.60	0.60	0.06	6.17	0.51	1
Economic Performance	0.21	0.26	0.31	0.22	0.17	0.28	0.28	0.28	0.30	0.30	0.30	0.29	3.20	0.27	2
Land Use Diversity	0.30	0.41	0.20	0.16	0.23	0.13	0.13	0.13	0.10	0.10	0.10	0.65	2.63	0.22	3
<i>inconsistency</i>	0.03	0.05	0.05	0.09	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.07			
<i>Consistency Index (C_{ij}) =</i>	0.02	0.03	0.03	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.04			
<i>Random Index (r_{ij}) =</i>	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58			
<i>Consistency Ratio (C_{ij}) =</i>	0.03	0.05	0.05	0.09	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.07			

Table 3.4 Calculation of weight for the indicator

No	Criteria	Weight	Indicator	Experts												SUM	Weight	Ranking
				E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12			
I	Land Use Density	0.51	Commercial density	0.23	0.18	0.29	0.41	0.32	0.43	0.43	0.43	0.29	0.29	0.29	0.29	3.84	0.32	1
			Residential mix	0.39	0.46	0.14	0.30	0.19	0.22	0.22	0.22	0.32	0.32	0.32	0.14	3.24	0.27	2
			Parking area mix	0.10	0.09	0.22	0.11	0.18	0.09	0.09	0.09	0.07	0.07	0.07	0.32	1.51	0.13	3
			School density	0.09	0.10	0.12	0.05	0.11	0.14	0.14	0.14	0.14	0.14	0.14	0.10	1.41	0.12	4
			Open space mix	0.12	0.12	0.14	0.09	0.11	0.05	0.05	0.05	0.08	0.08	0.08	0.08	1.05	0.09	5
			Hospital density	0.06	0.05	0.09	0.05	0.09	0.08	0.08	0.08	0.10	0.10	0.10	0.07	0.95	0.08	6
			<i>inconsistency</i>	0.08	0.07	0.03	0.08	0.09	0.01	0.01	0.01	0.00	0.00	0.00	0.00			
II	Economic Performance	0.27	Population density	0.68	0.54	0.11	0.07	0.07	0.65	0.65	0.65	0.60	0.60	0.60	0.60	5.81	0.48	1
			Floor Area Ratio (FAR)	0.13	0.16	0.54	0.58	0.57	0.23	0.23	0.23	0.30	0.30	0.30	0.10	3.68	0.31	2
			Building Coverage Ratio (BCR)	0.19	0.30	0.35	0.35	0.36	0.12	0.12	0.12	0.10	0.10	0.10	0.30	2.51	0.21	3
			<i>inconsistency</i>	0.08	0.01	0.05	0.03	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
III	Land Use Diversity	0.22	Land use diversity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	12.00	1.00	1

3.3.2. Standardization of criteria using min-max methods

There is a difference in the unit of calculation for an indicator of population density, school density, and hospital density, therefore, the standardization of indicator unit is carried out using the Maximum - Minimum (Max – Min) method (BPS, 2010). This method means that linearly transforms real data values that the minimum and the maximum of the transformed data take certain values - frequently 0 and 1, the Formula 6 is:

$$I_{in} = \frac{X_{ni} - X_{min}}{X_{max} - X_{min}} \times 100 \quad (6)$$

Where: X_{min} = Value of minimum target, X_{msx} = Value of maximum target.

3.3.3. The composite of actual TOD index calculation

The composite TOD index calculation using the following Formula 7 (Anane et al., 2012).

$$R_i = \sum_k W_k r_{ik} \quad (7)$$

Where the composite TOD index (R_i) for each station area (i), W_k is the multiplication result of the weights of all indicator or criterion and r_{ik} the standardized value of station area in the map of the indicator or criterion k.

3.3.4. Actual TOD Index rankings

The actual TOD index for 54 stations in the JMR as in Figure 3.5 and Table 3.5 contains the difference values of criteria and indicator. Based on this data, Indonesian University station has the lowest index 3.5 and Duri station has the highest index 0.58.

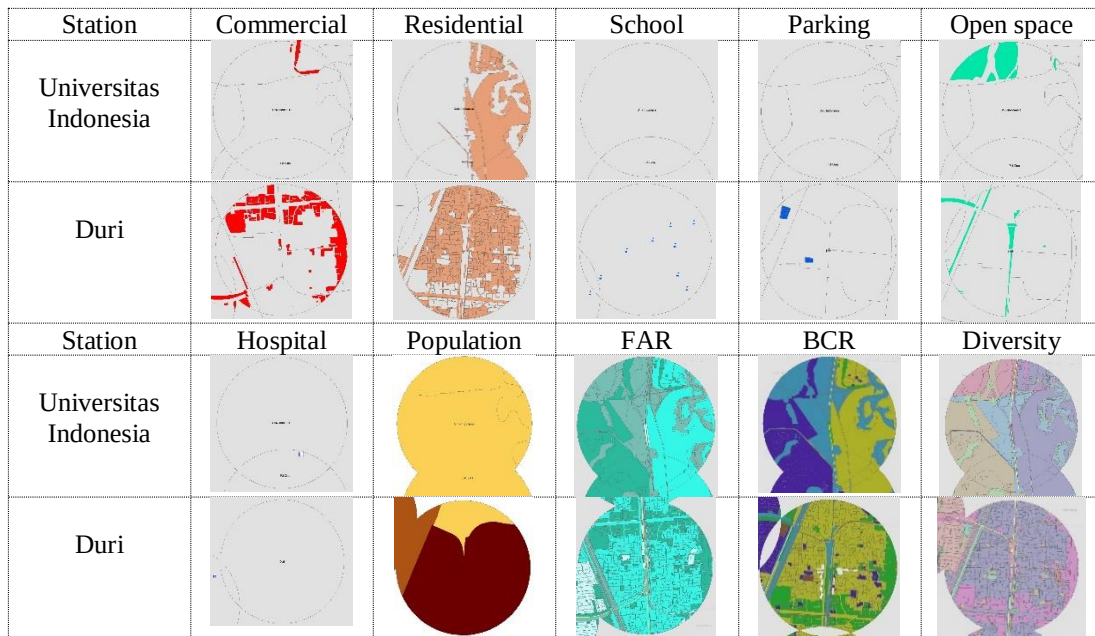


Figure 3.5 Comparing the indicators with highest and least.

Table 3.5 Actual TOD index for all 54 stations

Criteria		Density						Economic			Diversity		TOD Index
Weight		0.51						0.27			0.22		
Station		Commercial	Residential	School	Parking	Open space	Hospital	Density index	Population	FAR	BCR	Economic index	
Weight		0.32	0.27	0.13	0.12	0.09	0.08		0.48	0.31	0.21		1
Univ Indonesia	0.01	0.35	0.00	0.05	0.36	0.13	0.15	0.05	0.30	0.51	0.22	0.62	0.27
Pd Cina	0.13	0.37	0.00	0.08	0.09	0.13	0.17	0.05	0.55	0.54	0.31	0.46	0.27
Poris	0.01	0.46	0.00	0.04	0.34	0.00	0.16	0.24	0.31	0.52	0.32	0.46	0.27
Rawa Buntu	0.05	0.79	0.00	0.05	0.15	0.00	0.25	0.10	0.38	0.60	0.29	0.38	0.29
Sudimara	0.01	0.91	0.05	0.05	0.08	0.00	0.27	0.19	0.22	0.75	0.32	0.38	0.31
Cilebut	0.01	0.76	0.00	0.04	0.23	0.00	0.23	0.17	0.77	0.30	0.38	0.38	0.31
Depok	0.01	0.87	0.05	0.05	0.12	0.32	0.29	0.17	0.06	0.78	0.26	0.46	0.32
Pd. Ranji	0.05	0.77	0.11	0.05	0.18	0.00	0.26	0.30	0.41	0.58	0.39	0.38	0.32
Bekasi	0.04	0.76	0.14	0.05	0.18	0.00	0.26	0.10	0.60	0.40	0.32	0.54	0.33
Bojonggede	0.01	0.99	0.03	0.05	0.01	0.00	0.28	0.32	0.99	0.33	0.53	0.23	0.34
Kranji	0.05	0.85	0.00	0.05	0.08	0.00	0.26	0.39	0.17	0.75	0.39	0.46	0.34
Citayam	0.01	0.86	0.00	0.04	0.14	0.00	0.25	0.19	0.84	0.29	0.42	0.46	0.34
Serpong	0.01	0.87	0.21	0.04	0.12	0.16	0.29	0.22	0.88	0.31	0.44	0.38	0.35
Univ Pancasila	0.06	0.63	0.11	0.06	0.16	0.00	0.22	0.12	0.45	0.56	0.32	0.77	0.37
Pal Merah	0.19	0.33	0.03	0.09	0.30	0.12	0.20	0.00	0.49	0.42	0.24	0.92	0.37
Kalideres	0.01	0.62	0.03	0.06	0.08	0.08	0.20	0.18	0.54	0.59	0.38	0.77	0.37
Tanjung Barat	0.11	0.71	0.12	0.06	0.13	0.11	0.27	0.16	0.46	0.56	0.34	0.69	0.38
Cakung	0.04	0.78	0.10	0.06	0.10	0.00	0.25	0.21	0.20	0.72	0.31	0.77	0.38
Pasar Minggu	0.07	0.68	0.11	0.06	0.14	0.17	0.26	0.14	0.39	0.59	0.31	0.77	0.38
Juanda	0.33	0.13	0.26	0.11	0.19	0.23	0.22	0.11	0.72	0.32	0.34	0.85	0.39
Rawa Buaya	0.04	0.58	0.11	0.06	0.18	0.16	0.22	0.19	0.51	0.55	0.37	0.85	0.40
Klender Baru	0.05	0.78	0.08	0.06	0.06	0.00	0.25	0.36	0.44	0.65	0.45	0.69	0.40
Duren Kalibata	0.10	0.56	0.00	0.07	0.11	0.00	0.20	0.20	0.51	0.56	0.37	0.92	0.40
Bojong Indah	0.03	0.64	0.10	0.06	0.06	0.11	0.22	0.25	0.74	0.59	0.47	0.77	0.41
Depok Baru	0.13	0.66	0.05	0.06	0.18	0.32	0.27	0.17	0.37	0.52	0.31	0.85	0.41
Lenteng Agung	0.14	0.69	0.00	0.07	0.10	0.26	0.27	0.37	0.26	0.65	0.39	0.77	0.41
Kramat	0.15	0.59	0.15	0.08	0.06	0.33	0.27	0.30	0.41	0.61	0.40	0.77	0.41
Buaran	0.06	0.77	0.08	0.06	0.09	0.00	0.25	0.36	0.53	0.59	0.46	0.77	0.42
Jakarta Kota	0.55	0.20	0.20	0.12	0.07	0.00	0.28	0.19	0.73	0.24	0.37	0.85	0.43
Bogor	0.25	0.69	0.55	0.07	0.05	0.00	0.35	0.25	0.72	0.39	0.42	0.62	0.43
Jatinegara	0.19	0.60	0.11	0.08	0.08	0.00	0.25	0.41	0.34	0.60	0.43	0.85	0.43
Kebayoran	0.19	0.66	0.15	0.07	0.05	0.13	0.28	0.24	0.47	0.57	0.38	0.85	0.43
Karet	0.24	0.38	0.08	0.08	0.27	0.00	0.22	0.47	0.36	0.43	0.43	0.92	0.43
Sawah Besar	0.63	0.26	0.26	0.12	0.03	0.23	0.34	0.11	0.73	0.27	0.33	0.77	0.43
Tangerang	0.03	0.83	0.45	0.05	0.09	0.50	0.35	0.06	0.66	0.44	0.33	0.77	0.43
Pesing	0.26	0.51	0.19	0.08	0.13	0.00	0.27	0.30	0.75	0.38	0.46	0.85	0.45
Dukuh	0.38	0.37	0.35	0.08	0.21	0.88	0.36	0.17	0.63	0.30	0.34	0.77	0.45
Klender	0.15	0.65	0.19	0.07	0.05	0.29	0.28	0.39	0.35	0.64	0.43	0.85	0.45
Pasar Senen	0.32	0.46	0.34	0.09	0.06	1.00	0.37	0.14	0.58	0.46	0.35	0.77	0.45
Rajawali	0.31	0.49	0.20	0.08	0.09	0.22	0.29	0.21	0.62	0.42	0.38	0.92	0.46
Gondangdia	0.32	0.40	0.23	0.10	0.06	0.50	0.30	0.27	0.75	0.38	0.44	0.85	0.46
Mampang	0.12	0.70	0.35	0.07	0.09	0.88	0.36	0.17	0.75	0.47	0.41	0.77	0.46
Jayakarta	0.51	0.36	0.07	0.11	0.06	0.31	0.31	0.40	0.60	0.36	0.45	0.85	0.47
Pondok Jati	0.14	0.69	0.34	0.08	0.01	0.00	0.29	0.53	0.37	0.67	0.51	0.85	0.47
Tn. Abang	0.31	0.45	0.26	0.09	0.13	0.57	0.32	0.29	0.46	0.45	0.38	0.92	0.47
Manggarai	0.11	0.55	0.16	0.08	0.06	0.70	0.28	0.51	0.55	0.57	0.54	0.85	0.47
Cawang	0.14	0.63	0.08	0.07	0.12	0.00	0.25	0.48	0.52	0.53	0.50	1.00	0.48
Cikini	0.19	0.52	0.10	0.08	0.08	0.88	0.30	0.41	0.75	0.45	0.52	0.85	0.48
Grogol	0.21	0.53	0.19	0.07	0.13	0.28	0.28	0.36	0.86	0.35	0.51	0.92	0.48
Tebet	0.11	0.81	0.08	0.06	0.03	0.00	0.28	0.48	0.54	0.60	0.52	0.92	0.48
Kemayoran	0.33	0.47	0.05	0.09	0.06	0.00	0.25	0.70	0.50	0.49	0.60	0.92	0.49
Mangga Besar	0.50	0.37	0.00	0.10	0.03	0.00	0.27	1.00	0.60	0.39	0.75	0.77	0.51
Gang Sentiong	0.20	0.65	0.78	0.08	0.04	0.57	0.40	0.74	0.42	0.60	0.61	0.77	0.54
Duri	0.20	0.67	1.00	0.07	0.09	0.00	0.39	0.91	0.31	0.61	0.66	0.92	0.58

3.3.5. The composite TOD maps.

The result of the composite of actual TOD index is then visualized into the map using GIS application (ArcGIS software) (Figure 3.6). This map shows the distribution of index spread per station and divided into 3 categories; (category 0.26-0.35), category (0.36-0.43) and category (0.44-0.58).

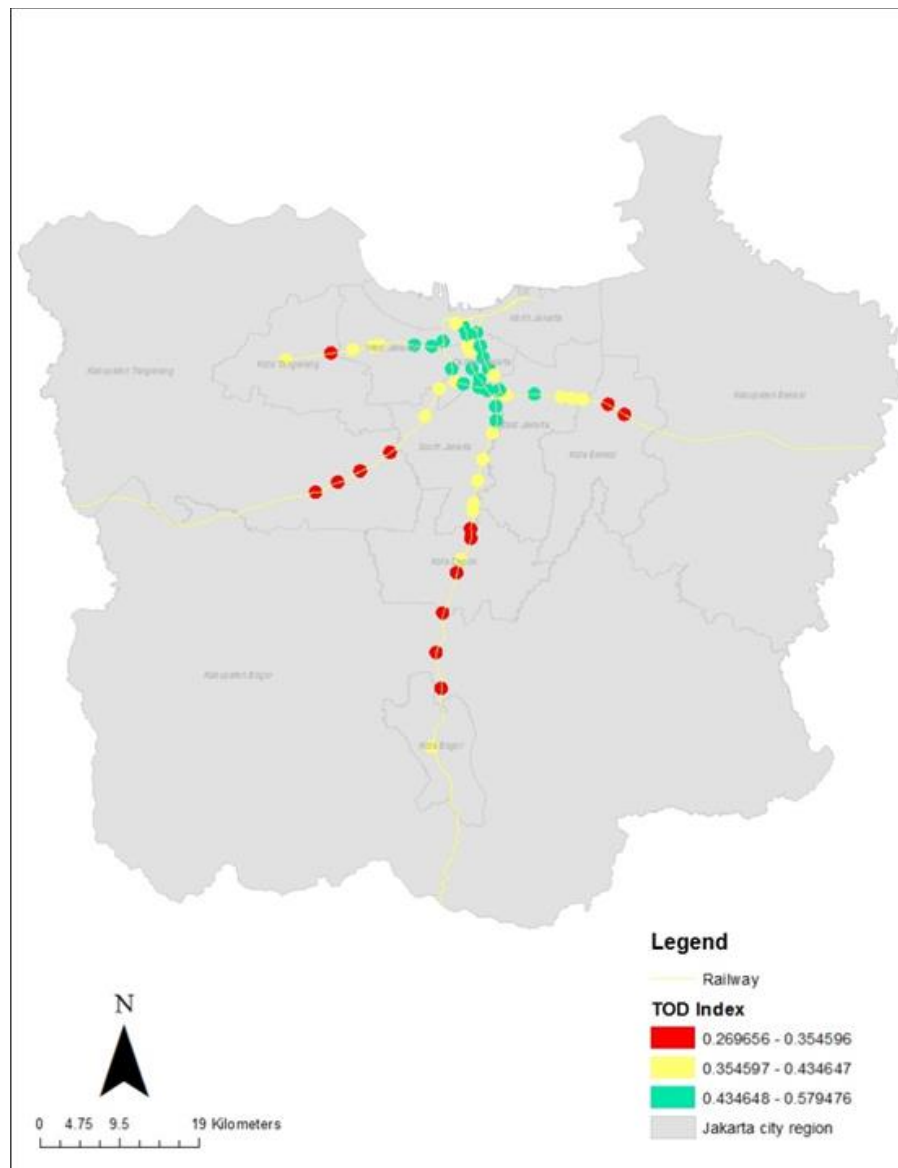


Figure 3.6 The actual TOD index map

3.4. Evaluating actual TOD in JMR

3.4.1. Statistical analysis

Statistical analysis was performed to describe the distribution of the data and to find correlations between variables and find out whether there are significant differences between variable and corridors. The analysis is performed using descriptive statistics.

Table 3.6 Calculation of weight for the indicator

Criteria	Number of station	Minimum	Maximum	Mean	Std. Deviation
Density	54	0.15	0.40	0.27	0.05
Economic	54	0.22	0.75	0.39	0.10
Diversity	54	0.23	1.00	0.77	0.19
TOD Index	54	0.27	0.58	0.42	0.07

Based on Table 3.6 above, the total number of stations is 54. The highest mean is found in the diversity 0.77 and the lowest mean of 0.27 in density indicator. The highest standard deviation is found in the criteria of diversity that is 0.19 and the lowest is found on the criteria of density 0.05.

Table 3.7 Descriptive statistics of TOD index in corridors

Corridor	Number of station	Min	Max	Mean	Std. Deviation
Bekasi	13	0.33	0.54	0.2822	0.0470
Bogor	26	0.27	0.51	0.2686	0.0535
Serpong	7	0.29	0.47	0.2686	0.0387
Tangerang	8	0.27	0.58	0.2598	0.0772

Based on Table 3.7 above that the minimum index is found in the corridors of the Bogor and Tangerang with a value of 0.27, while the maximum index found in the

Tangerang corridors is 0.58. The lowest standard deviation is found in the Serpong corridor which is 0.0387.

3.4.2. Improvement actual TOD based on corridor

3.4.2.1. Bekasi corridor

There are 13 stations in the Bekasi corridor, most of the stations have a good index (Table 3.8). However, there is potential for improvement in Bekasi and Kranji station (Figure 3.7).

Table 3.8 The ranking of TOD index in Bekasi corridor.

Number	Station	Corridor	Density	Economic	Diversity	TOD Index
1	Bekasi	Bekasi	0.26	0.32	0.54	0.33
2	Kranji	Bekasi	0.26	0.39	0.46	0.34
3	Cakung	Bekasi	0.25	0.31	0.77	0.38
4	Klender Baru	Bekasi	0.25	0.45	0.69	0.40
5	Kramat	Bekasi	0.27	0.40	0.77	0.41
6	Buaran	Bekasi	0.25	0.46	0.77	0.42
7	Jatinegara	Bekasi	0.25	0.43	0.85	0.43
8	Klender	Bekasi	0.28	0.43	0.85	0.45
9	Pasar Senen	Bekasi	0.37	0.35	0.77	0.45
10	Rajawali	Bekasi	0.29	0.38	0.92	0.46
11	Pondok Jati	Bekasi	0.29	0.51	0.85	0.47
12	Kemayoran	Bekasi	0.25	0.60	0.92	0.49
13	Gang Sentiong	Bekasi	0.40	0.61	0.77	0.54



Figure 3.7 The TOD index of Bekasi corridor

3.4.2.2. Bogor corridor

Bogor is a corridor with the greatest number of stations, namely 26 stations (Figure 3.8). Most of the stations are potential (red color) for improvements, mainly located in the suburban area (Table 3.9).

Table 3.9 The ranking of TOD index in Bogor corridor.

Number	Station	Corridor	Density	Economic	Diversity	TOD Index
1	Univ Indonesia	Bogor	0.15	0.22	0.62	0.27
2	Pd Cina	Bogor	0.17	0.31	0.46	0.27
3	Cilebut	Bogor	0.23	0.38	0.38	0.31
4	Depok	Bogor	0.29	0.26	0.46	0.32
5	Bojonggede	Bogor	0.28	0.53	0.23	0.34
6	Citayam	Bogor	0.25	0.42	0.46	0.34
7	Univ Pancasila	Bogor	0.22	0.32	0.77	0.37
8	Tanjung Barat	Bogor	0.27	0.34	0.69	0.38
9	Pasar Minggu	Bogor	0.26	0.31	0.77	0.38
10	Juanda	Bogor	0.22	0.34	0.85	0.39
11	Duren Kalibata	Bogor	0.20	0.37	0.92	0.40
12	Depok Baru	Bogor	0.27	0.31	0.85	0.41
13	Lenteng Agung	Bogor	0.27	0.39	0.77	0.41
14	Jakarta Kota	Bogor	0.28	0.37	0.85	0.43
15	Bogor	Bogor	0.35	0.42	0.62	0.43
16	Karet	Bogor	0.22	0.43	0.92	0.43
17	Sawah Besar	Bogor	0.34	0.33	0.77	0.43
18	Dukuh	Bogor	0.36	0.34	0.77	0.45
19	Gondangdia	Bogor	0.30	0.44	0.85	0.46
20	Mampang	Bogor	0.36	0.41	0.77	0.46
21	Jayakarta	Bogor	0.31	0.45	0.85	0.47
22	Manggarai	Bogor	0.28	0.54	0.85	0.47
23	Cawang	Bogor	0.25	0.50	1.00	0.48
24	Cikini	Bogor	0.30	0.52	0.85	0.48
25	Tebet	Bogor	0.28	0.52	0.92	0.48
26	Mangga Besar	Bogor	0.27	0.75	0.77	0.51

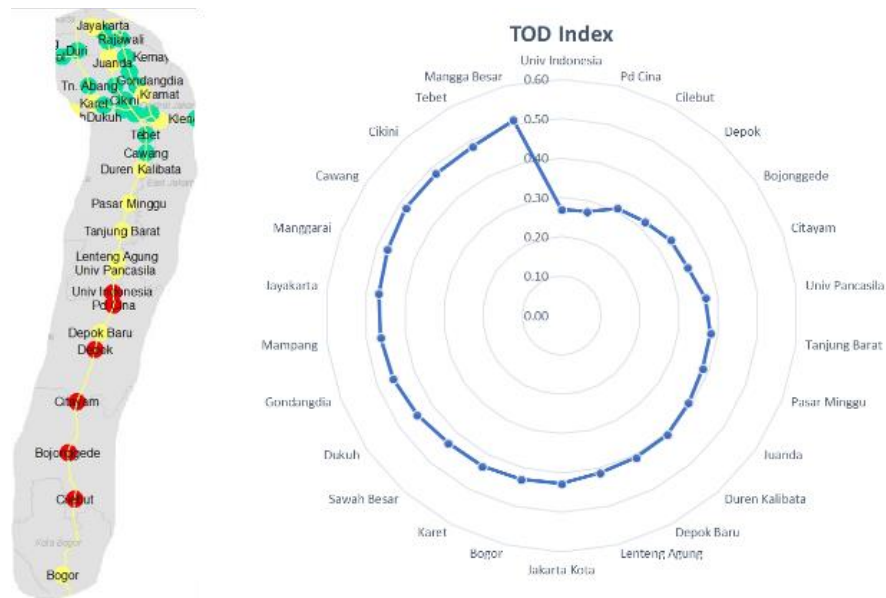


Figure 3.8 The TOD index of Bogor corridor

3.4.2.3. Serpong corridor

Serpong is the smallest corridor with the number of 7 stations (Figure 3.9). Same as to the other corridors, most of the stations which are potential (red color) for improvements are mainly located in the suburb (Table 3.10).

Table 3.10 The ranking of TOD index in Serpong corridor.

Number	Station	Corridor	Density	Economic	Diversity	TOD Index
1	Rawa Buntu	Serpong	0.25	0.29	0.38	0.29
2	Sudimara	Serpong	0.27	0.32	0.38	0.31
3	Pd. Ranji	Serpong	0.26	0.39	0.38	0.32
4	Serpong	Serpong	0.29	0.44	0.38	0.35
5	Pal Merah	Serpong	0.20	0.24	0.92	0.37
6	Kebayoran	Serpong	0.28	0.38	0.85	0.43
7	Tn. Abang	Serpong	0.32	0.38	0.92	0.47

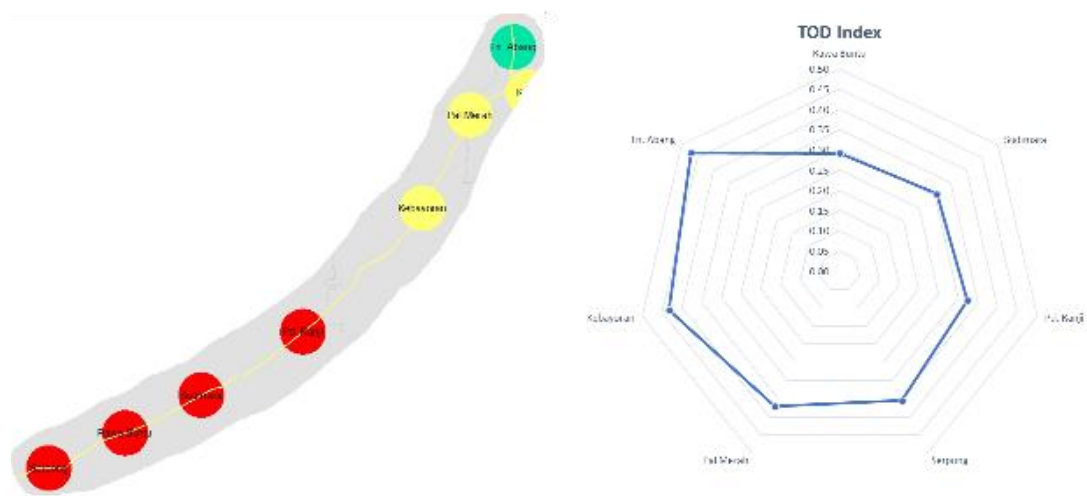


Figure 3.9 The TOD index of Serpong corridor

3.4.2.4. Tangerang corridor

The Tangerang Corridor is in the western area, which consists 8 stations (Figure 3.10). Poris station (red color) is potential for improvement because it has the lowest index value (Table 3.11).

Table 3.11 The ranking of TOD index in Tangerang corridor.

Number	Station	Corridor	Density	Economic	Diversity	TOD Index
1	Poris	Tangerang	0.16	0.32	0.46	0.27
2	Kalideres	Tangerang	0.20	0.38	0.77	0.37
3	Rawa Buaya	Tangerang	0.22	0.37	0.85	0.40
4	Bojong Indah	Tangerang	0.22	0.47	0.77	0.41
5	Tangerang	Tangerang	0.35	0.33	0.77	0.43
6	Pesing	Tangerang	0.27	0.46	0.85	0.45
7	Grogol	Tangerang	0.28	0.51	0.92	0.48
8	Duri	Tangerang	0.39	0.66	0.92	0.58



Figure 3.10 The TOD index of Tangerang corridor.

3.4.3. Policy implication

Based on the overall TOD evaluation, it is found that high TOD with index 0.44-0.58 is in urban area (Jakarta city) and low TOD with index of 0.26-0.35 located in suburban area (Tangerang, Serpong, Bekasi, Bogor) for that need an increase to TOD with low index by various policies as follows. Improvement of low TOD areas need to pay

attention to the main indicators of density, economy and diversity, but not limited to those indicators that can be expanded by considering the area that combines green, growth and job.

Density indicator is the main indicator based on expert judgment, the emphasis on special policy on demography and the strategy of developing new settlement centers. The quality of life of the population within the TOD area is enhanced by special arrangements in the utilization of locations for public interest such as residential, commercial, business, education, health. Making community-based on participatory planning considering the role of the private sector and the community are the main actors of urban development. The engagement process starts from planning, utilization and control. In the context of cooperation, effective coordination mechanisms are developed.

3.5. Summary

Transit Oriented Development is believed to be able to overcome the problems of urban transport. However, in practice, the current TOD in Jakarta Metropolitan Region is still a deficiency in accommodating the needs of transportation movement and not in facilitating services in terms of TOD function. The objective of this Chapter was to evaluate the service quality of actual TOD in 54 metro stations. The study of this Chapter performed criteria-indicators and measured a composite TOD index by using AHP-multicriteria model, statistics analysis, and GIS application. TOD index was found that urban areas have a high TOD index. On the other hand, the suburban areas have a low TOD-index. This Chapter concluded that most of the stations which were in the suburban area had a low index thus need improvement. Consequently, the station areas needed to have a policy relevance.

Chapter IV

LAND SUITABILITY AND SPATIAL STATISTICAL ANALYSIS FOR POTENTIAL TOD

CHAPTER IV

LAND SUITABILITY AND SPATIAL STATISTICAL ANALYSIS FOR POTENTIAL TOD

4.1. Introduction

Land use and transportation system, as well as socio-economic, demographic, and cultural characteristics in developing countries, are significantly different from their counterparts in developed countries. In developing countries, both urbanization and economic development are stacked not more than several decades. This is relatively a short duration for both urban and transportation infrastructure to develop in tandem and establish at workable proportions. A significant part of the energy consumption is consumed by the transportation sector. Relatively low-income countries display the highest potential for rapid increases in car ownership levels either nowadays or in the very near future. Developing countries require the provision of public transport facilities as a primary need. The use of public transportation in developing countries such as metro is one of the important characteristics of urban growth (Mohajeri and Amin., 2010; Taki and Lubis., 2017).

Many urban planning in the world relates to public service based transportation facilities that defined as compliance in the needs of present and future generations (Javadian et al., 2011). However, in some places, the transportation management of the railway is not well integrated resulting inconveniences of city life, especially the surrounding area of the station. For instance, traffic congestion, environmental pollution, unnecessary longer travel time, high fuel consumption. Consequently, it is very important

to plan a public transportation such as railway that move fast by carrying maximum number of passengers to reach the maximization of the potential area (Sunarto., 2009; Taki., 2017). This is the part of the urban planning in the transportation sector, especially the renewal of stations or rail networks in accordance with the Transit Oriented Development (Feudo., 2014; Binglei and Chuan., 2013; Galelo et al., 2014).

TOD is an urban planning concept where attempts are made to incorporate various functional activities (mixed-use) in the area around the transit station to the extent of a pedestrian reachable radius (i.e. $\pm$ 400-800 m or equal to mileage on foot for 10 minutes). TOD has the goal for creating a green environment that is comfortable, safe, pleasant and enough for pedestrians by mixing the various functions of the activities. These functions are central to commercial areas, offices, retail, service, high to medium density as well as public open space. Hasibuan & Soemardi (2014) consider TOD emphasizes the integration of area-based transits, renewing social community and living structures.

This Chapter has two objectives. First was to develop a method of spatial statistical analysis using Analytical Hierarchy Process (AHP) (Nguyen et al., 2015). This approach, integrating various assessment criteria from experts including the criteria of transport facilities, urban environment, and economic performance. This Chapter helped identify the most potential sites for TOD. Second objective was to apply this method in the context of GIS by conducting case studies in the metropolitan area of Jakarta. The spatial statistical analysis was employed to obtain a land hot spot grouping for specific uses. The hot spot classification in one area may differ with other areas depending on the land use under consideration. Spatial statistical analysis for TOD using GIS and AHP was a

planning process used to determine the feasibility of area (whether it was potential or not) for the use of TOD.

4.2. Research method in Chapter 4

4.2.1. Data sources

Collected data in this Chapter derived from The Ministry of Transportation, Ministry of Agrarian and Spatial Planning, Central Bureau of Statistics, Geospatial Information Agency (Table 4.1).

Table 4.1 Data list of the TOD suitability and their original sources

Number	Data name	Year	Source
1	Airport and Seaport	2010	Ministry of Transportation
2	Terminal	2010	Ministry of Transportation
3	Busway shelter	2010	Ministry of Transportation
4	Main road	2010	Ministry of Transportation
5	Tollgate	2010	Ministry of Transportation
6	Transportation facility	2014	Ministry of Agrarian and Spatial Planning
7	Education and public facility	2012	Ministry of Agrarian and Spatial Planning
8	Recreation facility	2012	Ministry of Agrarian and Spatial Planning
9	Hospital	2014	Geospatial Information Agency
10	School	2014	Geospatial Information Agency
11	BCR	2015	Consultant project archive
12	Park	2012	Ministry of Agrarian and Spatial Planning
13	Planned housing	2012	Ministry of Agrarian and Spatial Planning
14	Residential	2012	Ministry of Agrarian and Spatial Planning
15	FAR (floor area ratio)	2015	Consultant project archive
16	Population	2016	Central Bureau of Statistics
17	CBD	2014	Geospatial Information Agency
18	Industrial	2012	Ministry of Agrarian and Spatial Planning
19	Commercial and business	2012	Ministry of Agrarian and Spatial Planning
20	Real estate	2012	Ministry of Agrarian and Spatial Planning

The range of data in between 2010-2016 and the type of data was; First, AHP data were the primary data from interviews and questionnaires answered by experts of various

scientific fields related to this research for giving weight value of each indicator and sub-indicator. Secondary data in the form of GIS spatial data and attribute data, consisting of population statistic data, administrative boundary, land use, and transportation.

4.2.2. Determination of selection criteria

Determination of the criteria and sub criteria of the land suitability assessment for TOD was carried out by selecting and seeking for the appropriate criteria and sub criteria. It obtained from previous research and interviews by experts. These criteria and their references were; transport related (Taki, et al., 2017; Mohajeri and Amin., 2010; Atkinson and Kuby., 2011), facilities services (Ratner and Goetz., 2013; Vale., 2015; Olaru et al., 2011), urban environment (Binglei and Chuan., 2013; Black et al., 2016; Prasertsupakij and Nitivattananon., 2012), and economic performance (Taki et al., 2017; Fard., 2013; Singh et al., 2014). The explanations regarding these criteria and sub criteria were arranged in the hierarchy described in below (Figure 4.1).

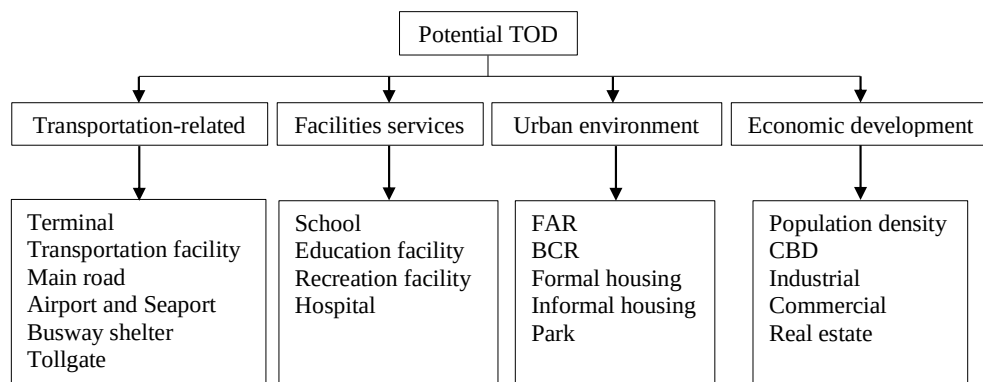


Figure 4.1 Criteria and sub criteria hierarchy.

4.2.3. Methodology overview

The applied methodology was a combination of AHP and GIS involving the following major steps (Figure 4.2):

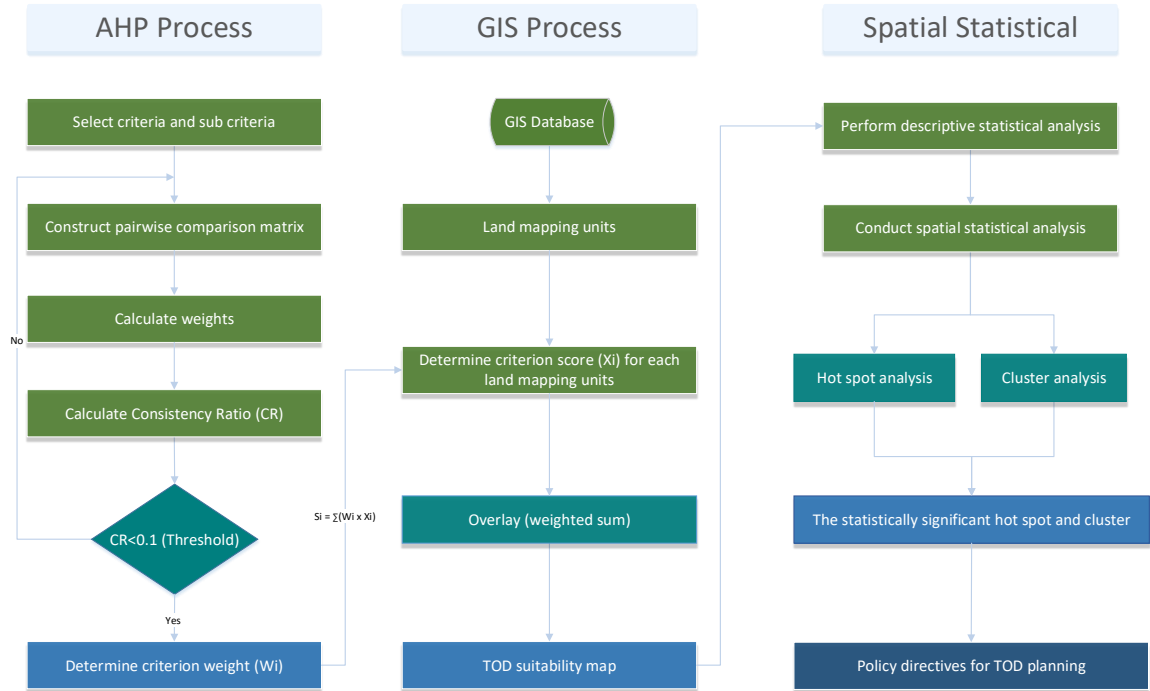


Figure 4.2 Methodological framework of potential TOD

This method begins with the selection of 20 criteria and sub criteria. Each criterion has a weight difference after the calculation is done by involving the opinions of 12 experts. The next stage is land suitability analysis using GIS to get a map of the suitability area of TOD using the overlay technique. Further analysis is spatial statistical analysis using hotspot and cluster techniques, maps of the results of these two methods are combined into one map to obtain potential TOD. The final stage is policy and planning analysis for the potential TOD.

4.2.4. AHP pairwise comparison

AHP provides steps to ensure the credibility of relative significance used mathematically. The consistency ratio index (Cr) in Equation 2 can be calculated based on the nature of the reciprocal matrix. According to Saaty (1990) that if $cr < 0.10$, it indicates that the matrix of pair-wise comparison has acceptable consistency. Hence, the

weighting value is valid. However, if $Cr > 0.10$, this means that the pairwise ratio shows a lack of consistency or the matrix in which it should be modified.

$$Ci = \lambda_{max} - n/n - 1 \quad (1)$$

Where;

ci = consistency index

n = the number of items being compared in the matrix

λ_{max} = the largest Eigen values

$$Cr = Ci/ri \quad (2)$$

Where;

Cr = consistency ratio index

ri = random index means a constant which corresponds to the mean random consistency index value according to n .

4.2.5. Standardized criteria using Z-score

Z score is a standard score of the distance of a value of the sample or population in the standard deviation unit. It is generally used to change raw scores obtained from the different types of measurements. The Z-score also tells how much distance the score itself with mean. The Formula 3 is calculating the standard score is given below:

$$Z = (x - \mu) / \sigma \quad (3)$$

Where; x = score, μ = mean, σ = standard deviation

4.2.6. Land suitability assessment

Land suitability evaluation of the Food and Agriculture Organization (FAO, 1976) was adopted for land suitability assessment of potential TOD in which the FAO's classifications proposed 'appropriate' (S) and 'unsuitable' (N) classes (Table 4.2).

Table 4.2 Land suitability classes of FAO.

Class	Name	Definition
S1	Highly Suitable	Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.
S2	Moderately Suitable	Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land.
S3	Marginally Suitable	Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.
N1	Currently Not Suitable	Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner.
N2	Permanently Not Suitable	Land having limitations which appear so severe as to preclude any possibilities of successful sustained use of the land in the given manner.

The Equation 4 was used to combine evaluation criteria (factor) according to weighted linear combination method (Figure 4.3).

$$Si = \sum_{i=1}^n (Wi \times Ri) \quad (4)$$

Where;

Wi = the result of multiplication of all related weights in the factor hierarchy level

Ri = the standard assessment of each pixel assigned to the class on the criteria map

n = the number of criteria under element

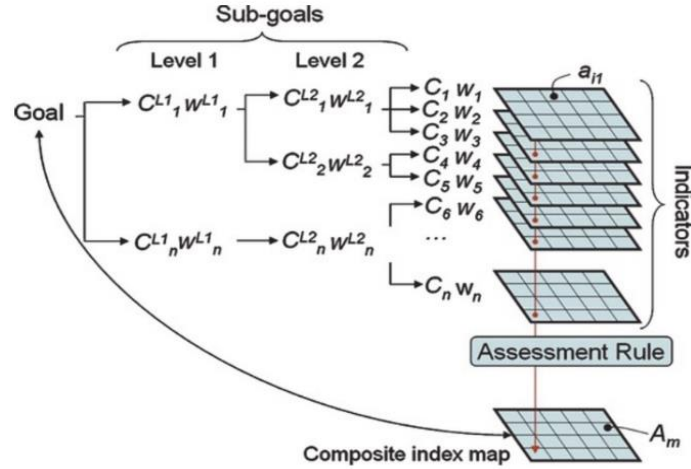


Figure 4.3 Composite TOD map

4.2.7. Spatial statistical analysis

Spatial data used in this analysis are coordinated grids on the map or pixels form from the satellite image. Thus, the spatial statistical analysis is presented in the form of a thematic map. Spatial distribution patterns are generally divided into three groups (random, uniformed, and clustered).

4.2.7.1. Spatial autocorrelation analysis for identifying existence of spatial clusters

The Moran's Index (I) is a spatial autocorrelation measurement that can be applied at intervals related to a point or area. For area data, the coefficient equation of Moran (Equation 5) is as follows:

$$I = \frac{n \sum_{i=1}^n \sum_{j=1}^n w_{ij} (x_i - \bar{x}) (x_j - \bar{x})}{\sum_{i=1}^n (x_i - \bar{x})^2} \quad (5)$$

Where, n is the number of cases. $\bar{x}$ is the mean of the variable. x_i is the variable value at a particular location. x_j is the variable value at another location. W_{ij} is a weight indexing location of i relative to j .

4.2.7.2. Hot spot and outlier analysis for mapping spatial clusters

Hot Spot Analysis (*Getis-Ord G_i^**) is contained in the mapping cluster set to identify statistically and formulated as Equation 6 follows:

$$G_i^* = \frac{\sum_{j=1}^n w_{ij}(d)x_j}{\sum_{j=1}^n x_j} \quad (6)$$

Where, W_{ij} is a spatial weight matrix element and (d) is the spatial object spacing element, while x_j is the attribute value for feature j in distance d .

4.3. Calculating land suitability TOD

4.3.1. Classification of assessment criteria

This Chapter identifies the following criteria (Table 4.3) as an indicator of suitability assessment in the selection of potential sites for the development of TOD. The assessment for this location is based on four main-criteria and 20 sub-criteria selected. All Criteria are obtained from data that describes the circumstance that occurs in the field. These data include land use, social, economic, transportation, education, environment, and facilities. All these data are expected to provide maximum result in an effort to obtain potential TOD in the study area.

Table 4.3 Classification of assessment criteria

Main criteria	Sub-criteria	Unit	Suitable rating				
			Suitable			Not suitable	
			High S1	Moderate S2	Marginal S3	Current N1	Permanent N2
Transportation-related	Airport and Seaport	distance	<250m	250-500m	500-800m	800-1000m	>1000m
	Terminal	distance	<250m	250-500m	500-800m	800-1000m	>1000m
	Busway shelter	distance	<250m	250-500m	500-800m	800-1000m	>1000m
	Main road	distance	<250m	250-500m	500-800m	800-1000m	>1000m
	Tollgate	distance	<250m	250-500m	500-800m	800-1000m	>1000m
Facilities services	Transportation facility	distance	<250m	250-500m	500-800m	800-1000m	>1000m
	Education and public facility	ratio	0.37-0.81	0.009-0.36	0.004-0.008	0.01-0.003	0.00
	Recreation facility	ratio	0.50-0.86	0.23-0.49	0.05-0.22	0.01-0.04	0.00
	Hospital	distance	<250m	250-500m	500-800m	800-1000m	>1000m
	School	distance	<250m	250-500m	500-800m	800-1000m	>1000m
Urban environment	BCR (building coverage ratio)	percentage	>80%	61-80%	41-60%	20-40%	<20%
	Park	percentage	2.55-9.08%	1.26-2.54%	0.48-1.25%	0.12-0.47%	0.00-0.11%
	Planned housing	ratio	1.23-2.32	0.72-1.22	0.32-0.71	0.08-0.31	0.00-0.07
	Residential	ratio	1.98-4.62	0.92-1.97	0.44-0.91	0.14-0.43	0.00-0.13
	FAR (floor area ratio)	FAR	4	3	2	1	0
Economic development	Population	density	28607-49345	14808-28606	6967-14807	2003-6966	0-2002
	CBD	density	0.000001	0.000001-0.000000	0.000001-0.000000	0.000001-0.000000	0.000000
	Industrial	ratio	4.77-8.78	2.32-4.76	1.05-2.31	0.31-1.04	0.00-0.30
	Commercial and business	ratio	0.33-0.54	0.03-0.08	0.09-0.18	0.19-0.32	0.33-0.54
	Real estate	ratio	6.90-12.91	3.24-6.89	1.62-3.23	0.48-1.61	0.00-0.47

4.3.2. Criteria maps for TOD suitability analysis

The map of potential TOD is compiled based on a GIS database of 20 sub-criteria (Figure 4.4 to 4.7). The process of map analysis conducted using overlay technique is to unite all layers of the map into a joined and comprehensive layer. Hence, it presents a result map that shows a potential suitability of TOD in the final stage.

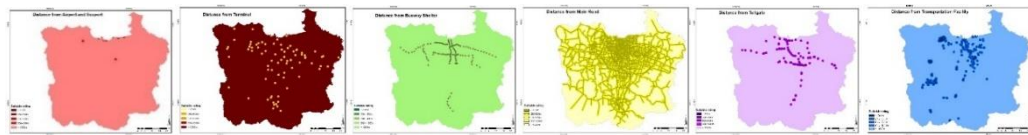


Figure 4.4 Transportation-related

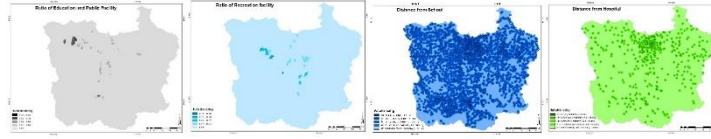


Figure 4.5 Facilities services

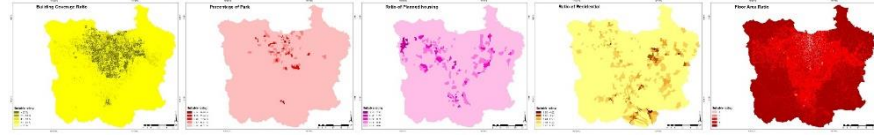


Figure 4.6 Urban environment

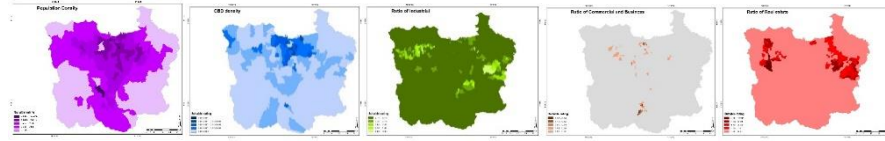


Figure 4.7 Economic performance

4.3.3. Calculation of criteria weight by AHP

This Chapter uses the opinion of experts in their fields to assess the relative importance of the selected criteria. There were 12 experts and they were required to answer and submit their opinions through a set of questionnaires, which consist of contained pairwise comparisons of the 4 main criteria and 20 sub criteria (Table 4.4 and Table 4.5).

Table 4.4 The weight of criteria from 12 experts

Criteria	Experts												SUM	Weighting	Ranking
	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12			
Transportation-related	0.53	0.45	0.50	0.41	0.41	0.52	0.52	0.52	0.26	0.26	0.26	0.12	4.75	0.40	1
Economic development	0.08	0.08	0.07	0.38	0.38	0.26	0.26	0.26	0.48	0.48	0.48	0.49	3.68	0.31	2
Facilities services	0.25	0.27	0.26	0.12	0.13	0.14	0.14	0.14	0.14	0.14	0.14	0.18	2.05	0.17	3
Urban environment	0.14	0.20	0.17	0.09	0.08	0.08	0.08	0.08	0.13	0.13	0.13	0.20	1.51	0.13	4
<i>inconsistency</i>	0.08	0.06	0.06	0.09	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.08			
Consistency Index (C_i) =	0.07	0.06	0.06	0.08	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.07			
Random Index (I_0) =	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90			
Consistency Ratio (C_R) =	0.08	0.06	0.06	0.09	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.08			

Table 4.5 Calculation of weight

No	Main-criteria	Weight	Sub-criteria	Experts												SUM	Weight	Ranking
				E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12			
I	Transportation-related	0.40	Terminal	0.22	0.21	0.29	0.22	0.19	0.41	0.41	0.41	0.13	0.13	0.13	0.40	3.16	0.26	1
			Transportation facility	0.09	0.08	0.14	0.33	0.32	0.16	0.16	0.16	0.41	0.41	0.41	0.25	2.89	0.24	2
			Main road	0.12	0.13	0.14	0.09	0.10	0.21	0.21	0.21	0.11	0.11	0.11	0.10	1.65	0.14	3
			Airport and Seaport	0.28	0.33	0.09	0.08	0.10	0.10	0.10	0.10	0.15	0.15	0.15	0.12	1.74	0.14	4
			Busway shelter	0.18	0.15	0.24	0.17	0.16	0.07	0.07	0.07	0.13	0.13	0.13	0.07	1.58	0.13	5
			Tollgate	0.11	0.11	0.11	0.12	0.14	0.05	0.05	0.05	0.07	0.07	0.07	0.06	0.98	0.08	6
			Inconsistency	0.09	0.09	0.08	0.08	0.09	0.03	0.03	0.03	0.06	0.06	0.06	0.09			
II	Economic development	0.31	Population density	0.45	0.41	0.34	0.40	0.29	0.46	0.46	0.46	0.44	0.44	0.44	0.23	4.82	0.40	1
			CBD	0.35	0.24	0.25	0.27	0.18	0.25	0.25	0.25	0.21	0.21	0.21	0.19	2.85	0.23	2
			Industrial	0.14	0.11	0.14	0.20	0.33	0.15	0.15	0.15	0.18	0.18	0.18	0.23	2.15	0.17	3
			Commercial and business	0.23	0.19	0.18	0.05	0.08	0.07	0.07	0.07	0.06	0.06	0.06	0.13	1.25	0.10	4
			Real estate	0.08	0.06	0.09	0.07	0.11	0.07	0.07	0.07	0.11	0.11	0.11	0.23	1.18	0.10	5
			Inconsistency	0.09	0.08	0.06	0.05	0.08	0.04	0.04	0.04	0.01	0.01	0.01	0.09			
III	Facilities services	0.17	School	0.08	0.05	0.08	0.09	0.23	0.59	0.59	0.59	0.50	0.50	0.50	0.24	4.06	0.34	1
			Education and public facility	0.48	0.53	0.42	0.41	0.52	0.20	0.20	0.20	0.23	0.23	0.23	0.14	3.78	0.32	2
			Recreation facility	0.25	0.28	0.33	0.38	0.16	0.08	0.08	0.08	0.08	0.08	0.08	0.36	2.26	0.19	3
			Hospital	0.20	0.14	0.16	0.12	0.09	0.13	0.13	0.13	0.19	0.19	0.19	0.26	1.90	0.16	4
			Inconsistency	0.05	0.06	0.08	0.09	0.06	0.02	0.02	0.02	0.01	0.01	0.01	0.08			
II	Urban environment	0.13	FAR	0.07	0.11	0.09	0.49	0.48	0.48	0.48	0.48	0.28	0.28	0.28	0.48	4.03	0.34	1
			BCR	0.36	0.33	0.21	0.31	0.31	0.10	0.10	0.10	0.11	0.11	0.11	0.13	2.28	0.19	2
			Formal housing	0.18	0.18	0.22	0.06	0.06	0.17	0.17	0.17	0.21	0.21	0.21	0.16	2.00	0.17	3
			Informal housing	0.13	0.14	0.17	0.09	0.09	0.12	0.12	0.12	0.26	0.26	0.26	0.13	1.90	0.16	4
			Park	0.26	0.24	0.31	0.05	0.05	0.13	0.13	0.13	0.13	0.13	0.13	0.11	1.78	0.15	5
			Inconsistency	0.09	0.09	0.06	0.09	0.09	0.07	0.07	0.07	0.05	0.05	0.05	0.01			

4.3.4. Land suitability map of TOD

All criteria values were standardized by the Z-score method using ArcGIS software (Figure 4.8). Each main-criteria had a different land suitability pattern. The highest index was found in the urban environment (4.0) and the lowest index was found in transportation related (0.0033). Variations pattern of land suitability map consisted of the spread points (facilities services and urban environment), area-polygon (economic development) and line buffer (transportation related).

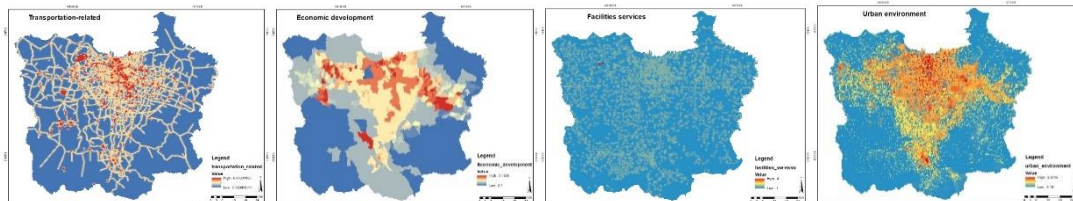


Figure 4.8 Criteria map

The red color in Figure 4.9 showed the altitude value of the suitability, whereas the blue colour indicated the lowness of land suitability value.

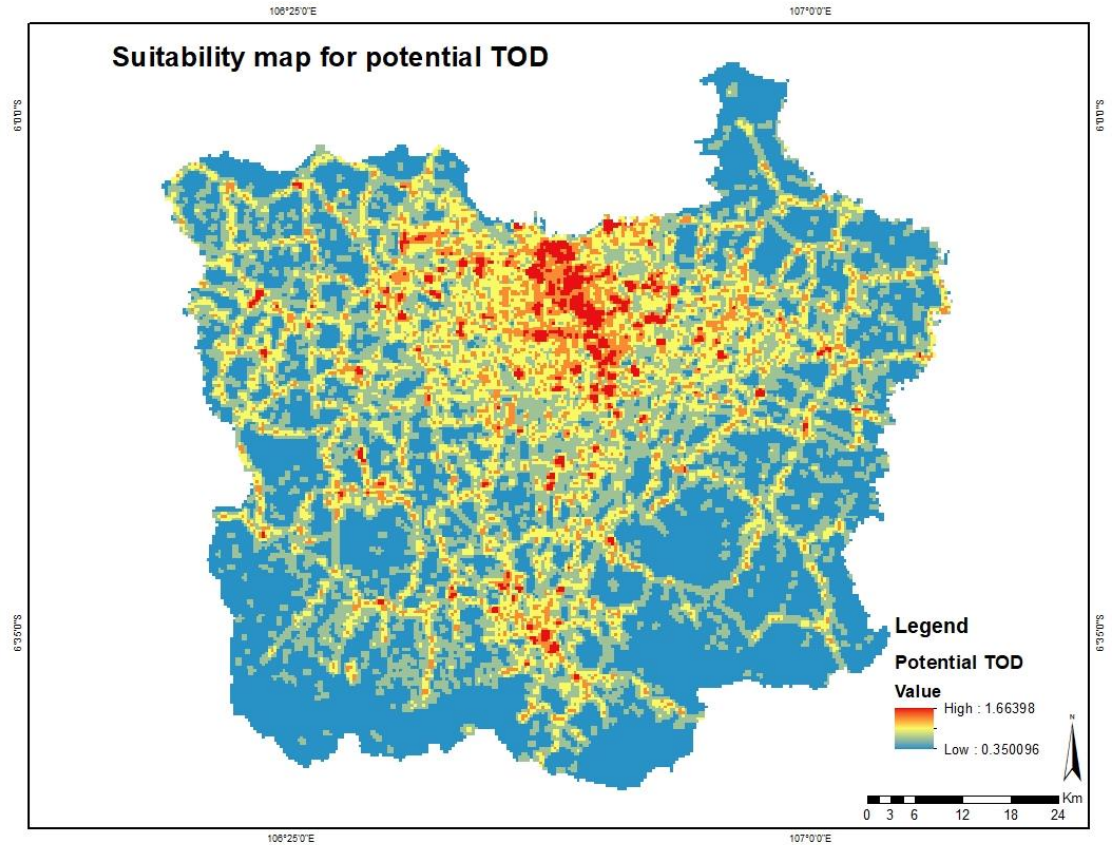


Figure 4.9 Suitability map of TOD

The figure of suitability TOD has a different color; each color gives values meaning to high or low of potential TOD. The detailed explanation of this map analysis is presented in the following discussion below.

4.4. Assessment potential TOD using spatial statistical analysis

4.4.1. The distribution of potential TOD

Based on the suitability map of potential TOD, suitability analysis conducted a comparative class analysis based on percentage and proportion of the study area (Table 4.6 and Figure 4.10).

Table 4.6 The distribution of potential TOD based on percentage and area

Suitable rating	Class	Percentage (%)	Area (Ha)
Highly suitable	S1	2.3	174.69302
Moderately suitable	S2	9.0	682.65415
Marginally suitable	S3	28.1	2135.25561
Currently not suitable	N1	24.3	1847.69085
Permanently not suitable	N2	36.4	2769.68325
Total		100	7609.97688

The distribution of potential TOD is permanently not suitable class (N2) has the biggest percentage (36,4%) with wide area about 7609.97 ha. The highly suitable class (S1) only has 2.3% of the study area with wide area about 74.69 ha. Thus, TOD planning is focused in areas with highly suitable categories.

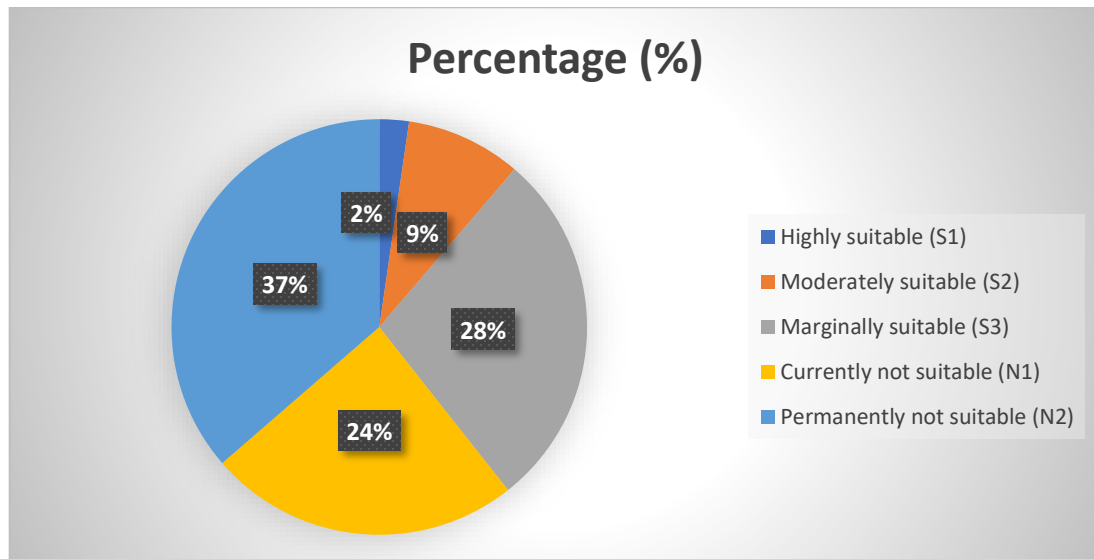


Figure 4.10 Pie chart of distribution land.

4.4.2. Descriptive statistical analysis

Table 4.7 below is descriptive statistical analysis indicated mean and standard deviation for each main criteria and potential TOD index. The highest of mean (2.17) and standard deviation (1.04) was facilities services, while the lowest of mean (0.00) and standard deviation (0.00) was transportation related. All the indexes were positive, indicating high index value and there was no low negative index.

Table 4.7 The descriptive statistics of main criteria.

Statistics	Transportation related	Economic development	Facilities services	Urban environment	Potential TOD
Minimum	0.000989011	0.50	1.00	0.19	0.35
Maximum	0.00331986	3.05	4.00	2.87	1.66
Mean	0.00	0.90	2.17	0.55	0.71
Std. Deviation	0.00	0.43	1.04	0.49	0.27

4.4.3. Spatial statistical analysis

4.4.3.1. Spatial autocorrelation using Global Moran's I

The calculation results of Global Moran's I statistic can be seen that the value of Z-score = 4,838 > $Z_{0.99} = 2.58$. Therefore, H_0 is rejected or the conclusion that there is spatial autocorrelation. The Moran Index is 0.247 in the range $0 < I \leq 1$ and indicates a positive spatial autocorrelation. It concluded that inter area each other have similarity values or indicate that data in the clustered (Figure 4.11).

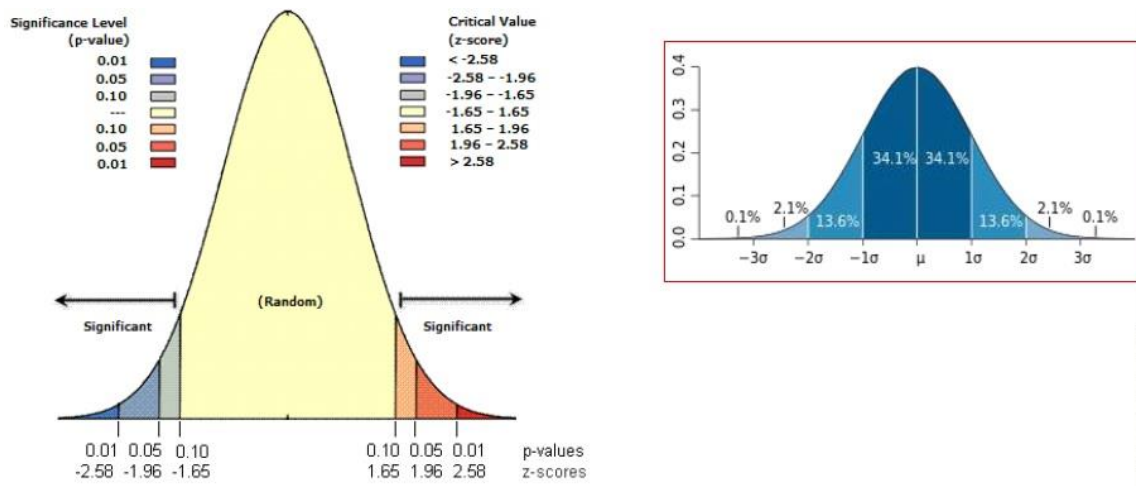


Figure 4.11 The critical value (Z score)

4.4.3.2. High/low clustering using Getis-Ord General G

Analysis result of High/Low Clustering using Getis-Ord General G shows that the Z-score value of 19.6713 with P-value 0. Based on the result can be stated that the spatial TOD index in the region has a global pattern or a clustering trend or highs cluster because there are no spatial clustering feature values. This happens because the p-value is small and statistically significant, thereby the value of the Z-score becomes important. If the Z-score is positive, it shows high value clustered in the research area (high cluster). Conversely, if the Z-score is negative, it shows low values clustered in the study area (low cluster).

4.4.3.3. Cluster and Outlier using Anselin Local Moran's I

Cluster area based on a difference Global Moran's TOD index is a measure that has not been able to show in the area where cluster occurs. Therefore, the results in Figure 4.12 show that most areas are in the LH (Low-High) and HL (High-Low), which has a high index and is surrounded by low neighboring areas and vice versa.

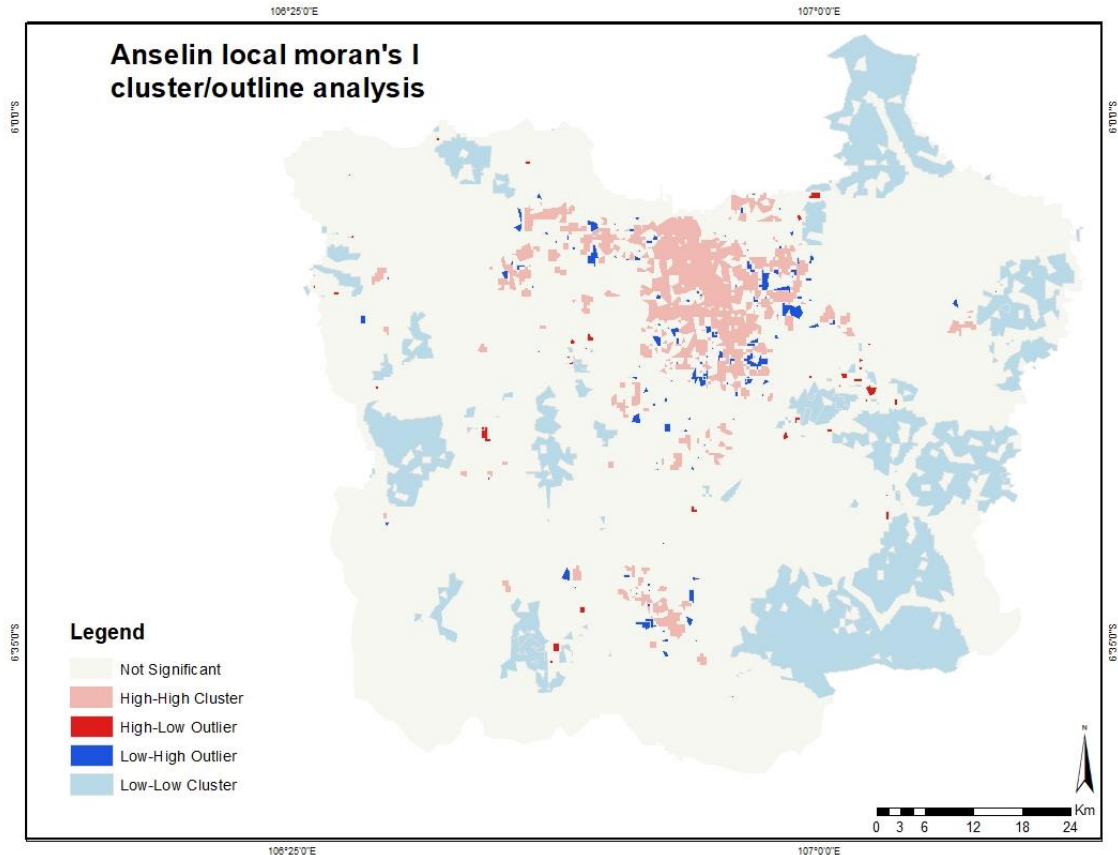


Figure 4.12 Cluster map

4.4.3.4. Hot spot and cold spot analysis using Getis-Ord G_i^*

Based on hot spot results map using Getis-Ord G_i^* statistic in Figure 4.13, there are 7 groups of interval classes in each class distribution describing distinct colour intensity levels in each color. The higher intensity of color indicates that the area has a high spatial concentration, also with the surrounding area (for areas with hot spot status), in contrast with areas that have cold spot status (blue color).

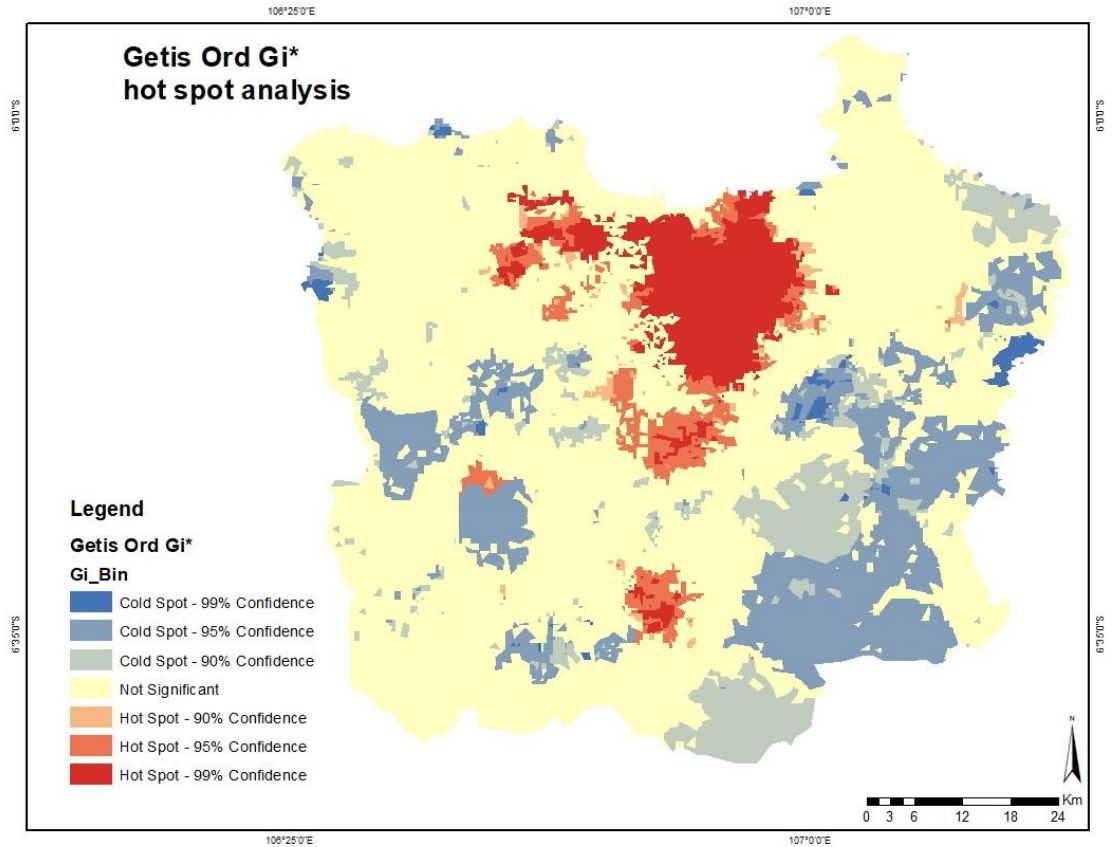


Figure 4.13 Mapping hot spot

4.4.3.5. The statistically significant hot spots

Figure 4.14 and 4.15 below show some areas in JMR in red color. It means that the area being the center of the hot spot of the potential TOD index. Statistically significant hot spots have been identified at a 99% confidence.

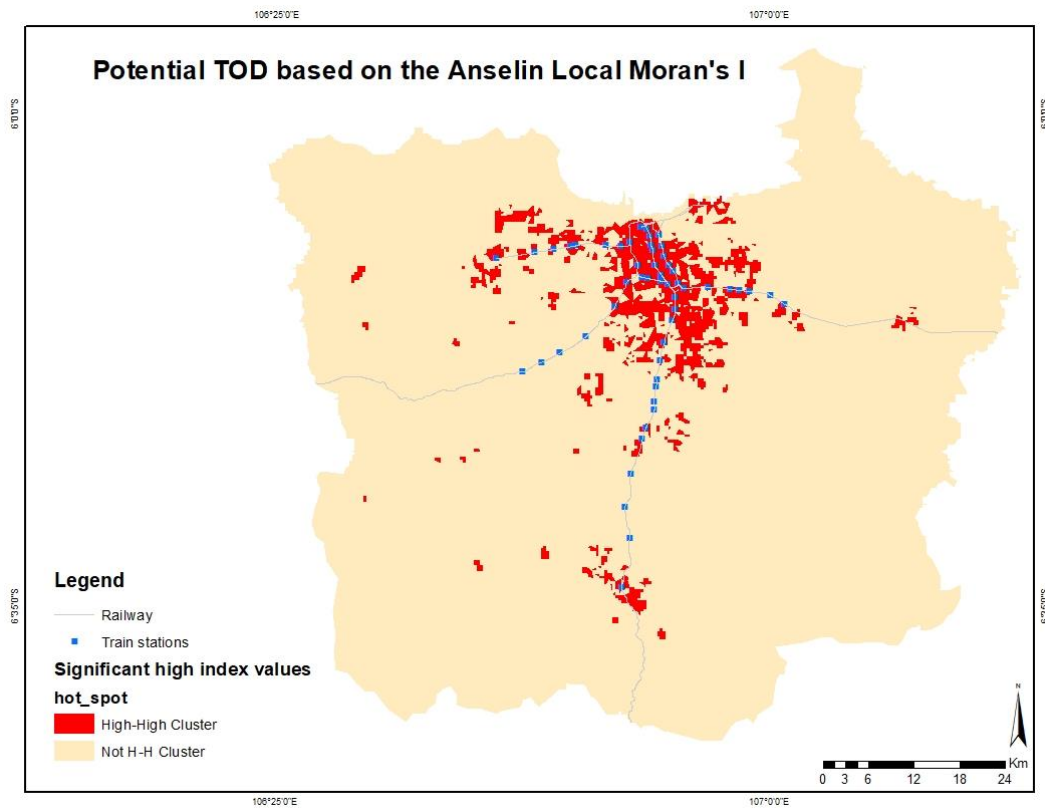


Figure 4.14 Potential TOD based on the Anselin Moran's I

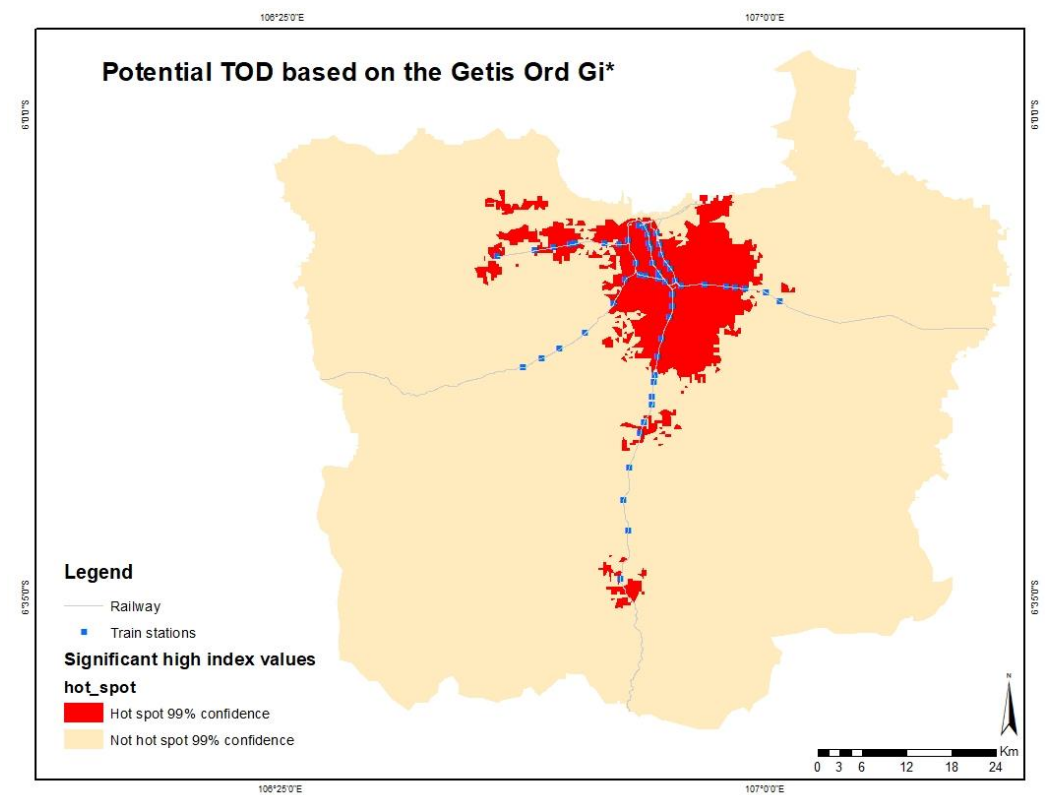


Figure 0.15 Potential TOD based on the Getis Ord Gi*

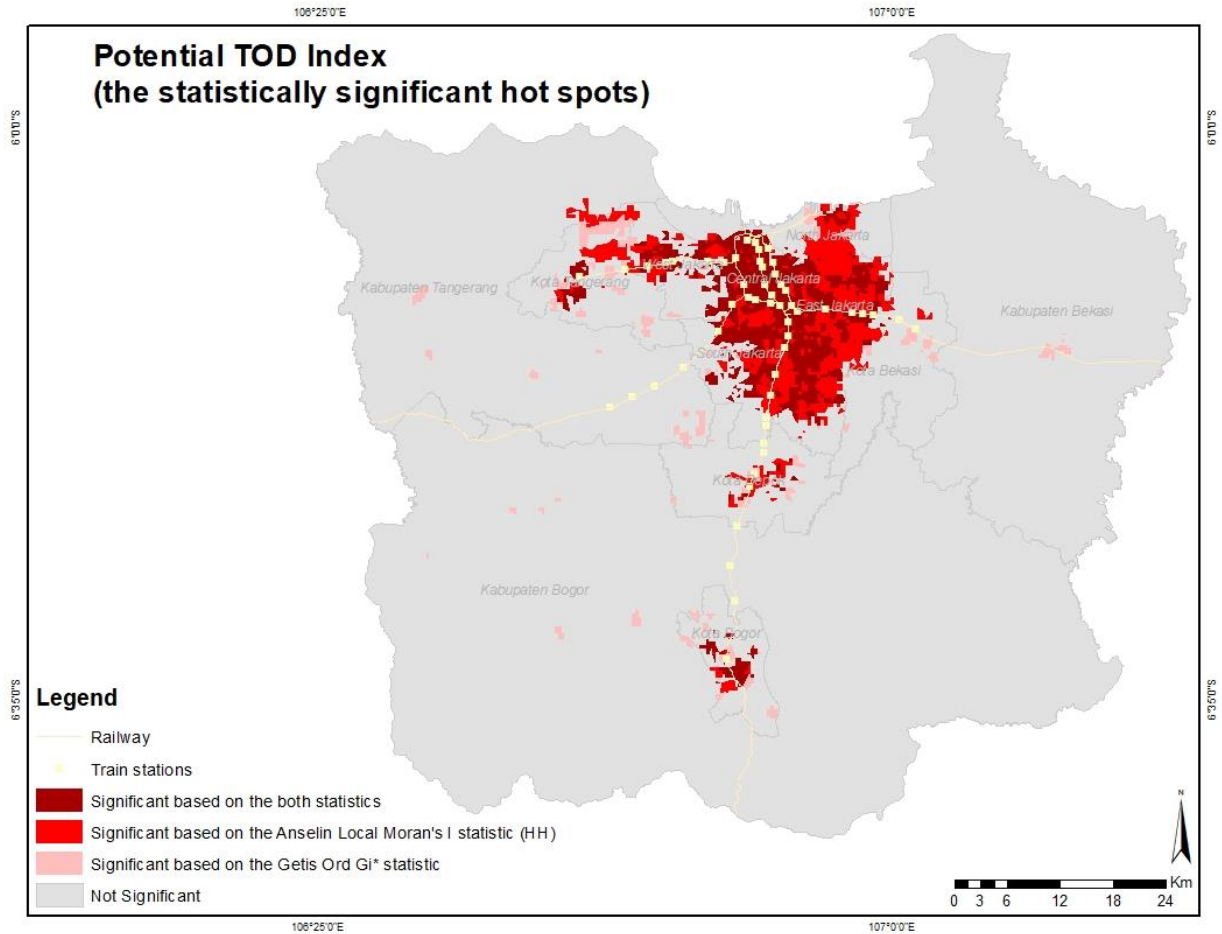


Figure 4.16 Potential TOD Index based on the statistically significant hot spots

The significant hot spots cluster in Figure 4.16 indicates that the area has a high value and is surrounded by high-value areas. Those areas in this cluster are the capital of Jakarta, Tangerang city, Depok city, and the city of Bogor.

4.5. Summary

Spatial planning on Transit Oriented Development concerns with the integration between land use and transportation aspect. However, in some places, public transport management based on transit nodes such as train services which are not well- integrated, and causing spatial chaos, especially surrounding station areas. It is essential to prepare a

public transportation plan by maximizing regional potential capacity with TOD model. The purpose of this Chapter is to identify and prioritize potential areas for TOD using spatial statistical analysis with combined models of Geographic Information System (GIS) and Analytical Hierarchy Process (AHP) in Jakarta Metropolitan Regional, Indonesia. This Chapter employed two major indicators: main- and sub-indicators depending on relevant references. The weight of each indicator was determined by chosen experts. The finding of this Chapter showed that some of the areas of JMR were statistically significant hot spots for potential TOD and indicated the characteristics of the development of urban areas. This Chapter's result was useful to determine the potential location of TOD and was applicable to other areas within the same geographical conditions.

CHAPTER V

IMPLEMENTATION OF THE INTEGRATED

TOD SPATIAL MODEL FOR JAKARTA

METROPOLITAN REGION

CHAPTER V

IMPLEMENTATION OF THE INTEGRATED TOD SPATIAL MODEL FOR JAKARTA METROPOLITAN REGION

5.1. Introduction

The population of JMR continues to increase, and this region experiencing growth with the distribution of development in suburban settlements. While the city of Jakarta acts as a trade, business center, and social communication. Suburban areas continue to grow, the number of commuters from suburban to Jakarta will increase. For this reason, at the beginning of this Chapter, it is important to shed light on the spatial and transportation planning of JMR before introducing the implementation of the integrated TOD based on the spatial model.

5.1.1. Spatial planning of JMR

5.1.1.1. Urban structure

The spatial planning covering the whole JMR includes human settlement, environment, transportation, economic infrastructure, health and social facilities. The urban structure of JMR consists of core city is the Jakarta and the satellite cities are Bogor, Depok, Tangerang, Bekasi (Figure 5.1). The space utilization of Jakarta as a downtown is directed to the residential housing with high density, trade, and services on a national and international scale, non-pollutant and market-oriented light industry.

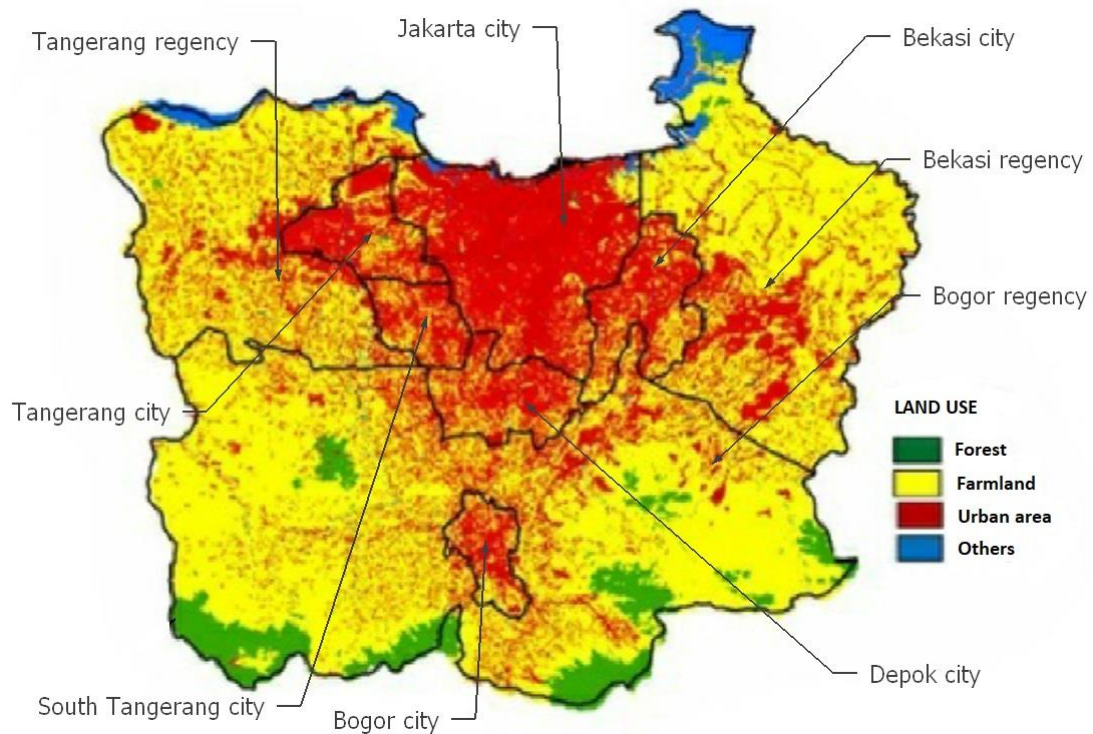


Figure 5.1 Land cover of JMR, Source: (Rustiadi, et al., 2012)

The space utilization of Tangerang and Bekasi city as a satellite city are directed primarily for residential with high and low density, trade and services on a national scale, non-pollutant light industry oriented to the market and labor, a small proportion of agriculture or fields, fisheries, agroindustry. The space utilization of Bogor and Depok city as a satellite city are directed to a high and low density of residential, trade centers and services with national scale, non-pollutant and market oriented light industry, agriculture, limited plantations, fisheries, livestock, agroindustry, and the national park.

The space utilization of Tangerang and Bekasi regency as urban and rural areas is directed primarily to dense and low occupancy housing, local trade and services, labor-oriented industries, agriculture or fields, wetland agriculture and dryland farming with the appropriate technology use, plantation, fishery, livestock, agroindustry, production forest,

protected area and nature reserve. Space utilization of Bogor regency as urban and rural areas is directed to medium or low occupancy housing, local trade and services, agriculture or fields, dry farming with appropriate technology, plantation, fishery, livestock, agroindustry, production forest, protected areas, and nature reserves.

5.1.1.2. The spatial patterns

The spatial patterns of JMR includes land zone planning, control, supervision, community role, and guidance. Upstream (Figure 5.2), this area is directed to a protected area, as a water catchment area, river borders, areas around reservoirs, springs, swamps, geological hazard areas, national parks, forest parks, nature parks, cultural heritage areas, and low or medium occupancy housing

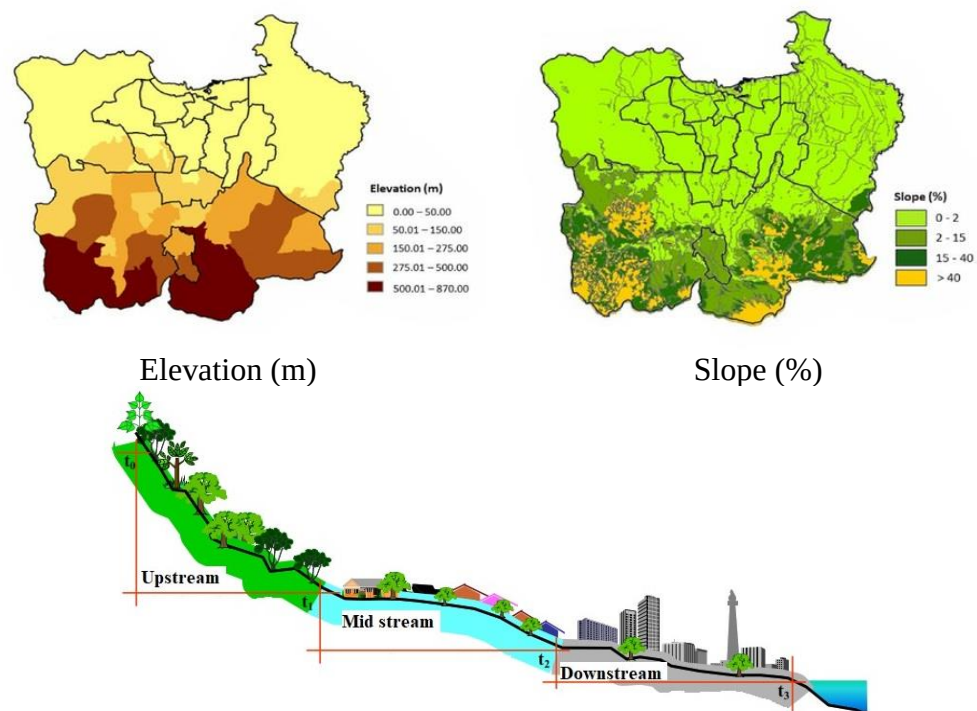


Figure 5.2 Elevation and slope of JMR

Mid-stream, this buffer zone directed to medium or low occupancy housing, trade and services, light and non-pollutant light industry oriented and market-oriented. Low

residential housing using technical engineering, agriculture, wet or dry farming, plantations, fisheries, agroindustry farms, production forests.

Downstream, the mainstay of Jakarta is directed as a densely populated residential, trade and service area, light and non-polluted and market-oriented light industry while maintaining. In the western and eastern parts for labor-intensive industries, wet or dry farming, plantations, fisheries, livestock, agroindustry, production forests, agricultural irrigated wetland agriculture.

5.1.1.3. Transportation plan of JMR

A railway system of Jakarta Metropolitan Region services Jakarta, Bogor, Depok, Tangerang, and Bekasi. The rail system uses rapid transit rolling stock standard and operates at high frequency with a minimum headway.

To accommodate many commuters needed development of transportation facilities with an emphasis on the development mass public transport system. The transportation modes in JMR will not be able to accommodate increased travel demand if without an increased mass transportation system for the public. The network route is recognized by Figure 5.3 below.

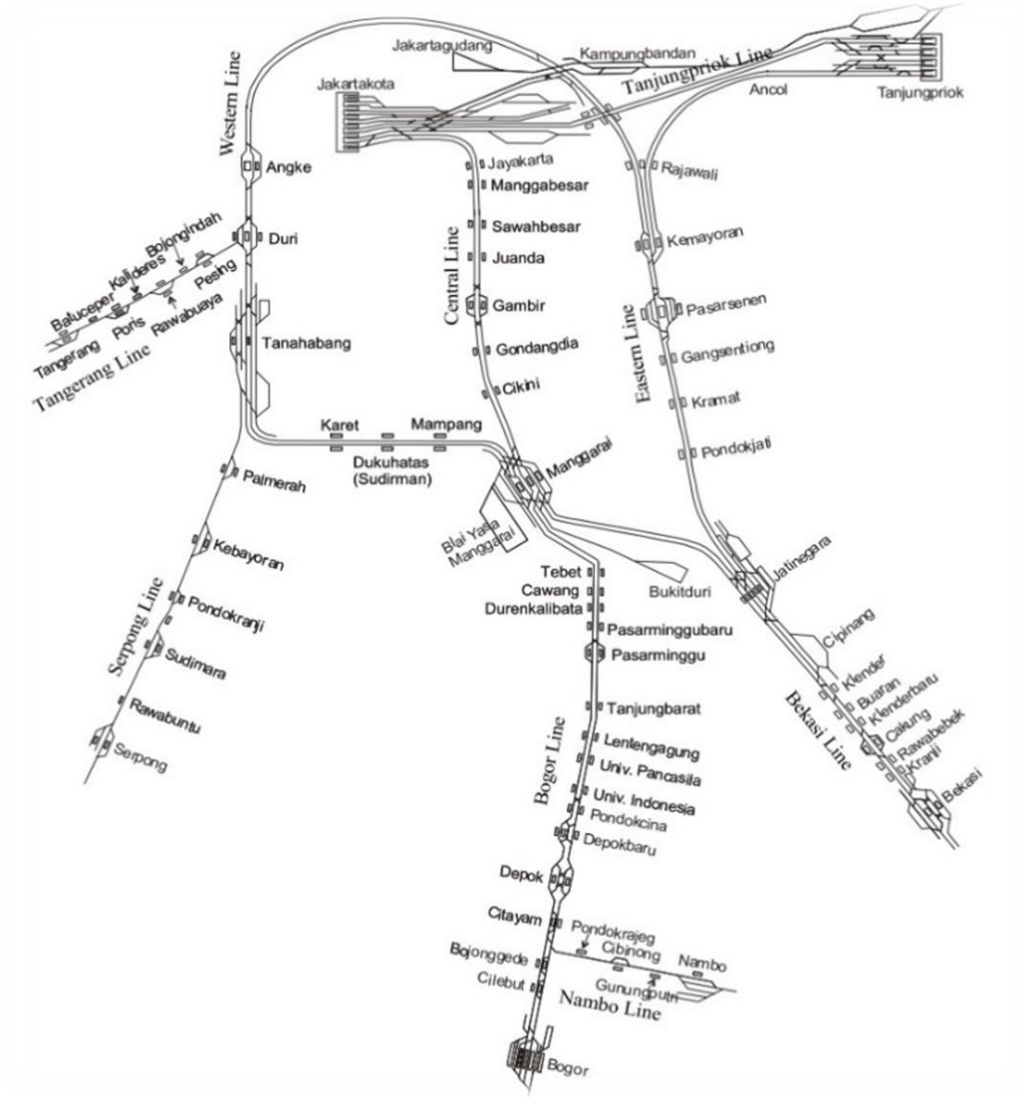
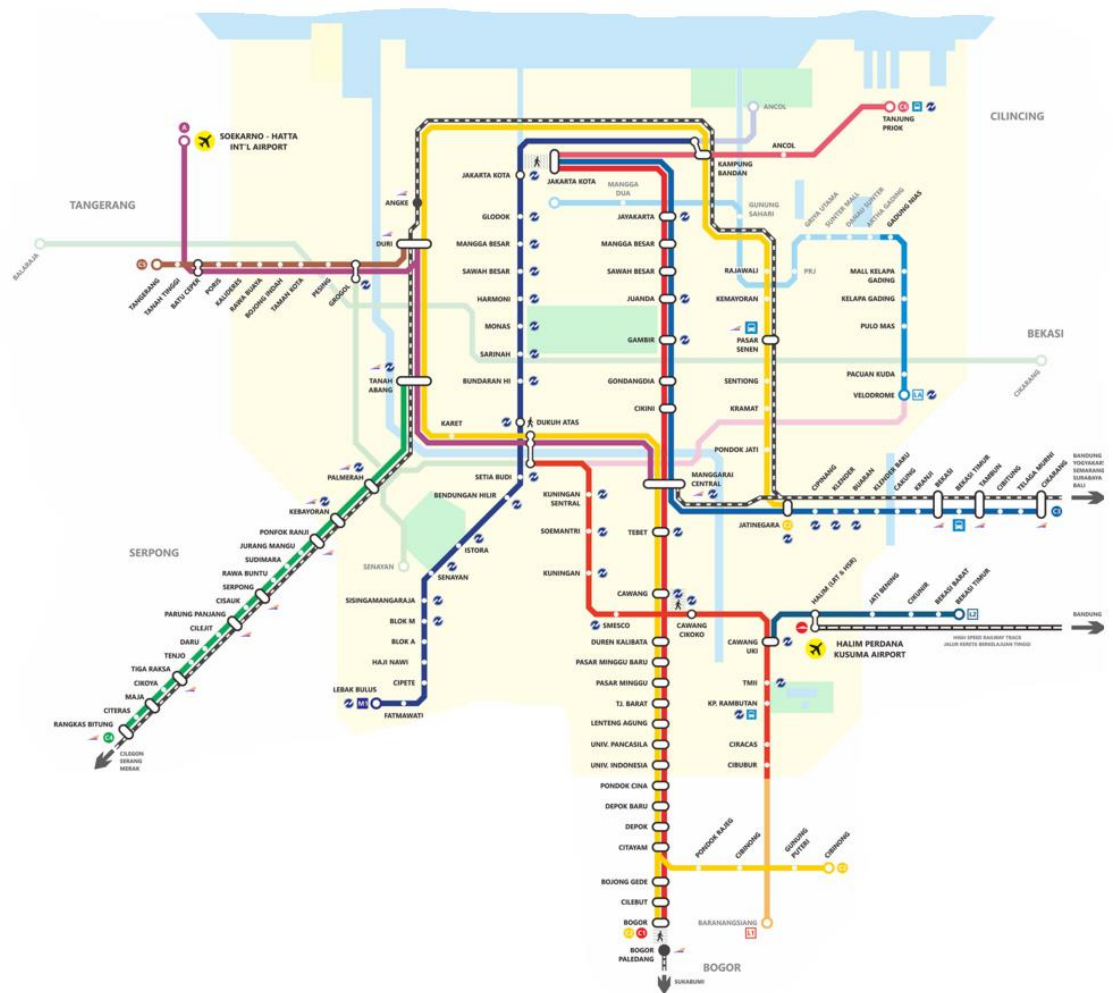


Figure 5.3 Railway route of JMR

The transportation master plan of JMR in Figure 5.4 below is directed to the development of a rapid mass transportation systems until 2030, including LRT (Light Rapid Transit) and MRT (Mass Rapid Transit), the development of a cross-regional road and toll road network system. In addition, revitalization of commuter line, providing park and ride facilities and implementation of TOD in areas with high density.



COMMUTER LINE	LRT	MRT
C1 Red Line Jakarta Kota - Bogor	LA Kelapa Gading Jakarta Kota - Kelapa Gading	M1 Blue Line Lebak Bulus - Ancol
C2 Yellow Line Jatinegara - Bogor	L1 Cibubur Cibubur - Dukuh Atas	AIRPORT SERVICES
C3 Blue Line Jakarta Kota - Bekasi	L2 Bekasi Bekasi - Cawang	A Rail link Manggarai - SHIA
C4 Green Line Tanah Abang - Rangkas Bitung		
C5 Brown Line Duri - Tangerang		
C6 Pink Line Jakarta Kota - Tj. Priok		

Figure 5.4 Transport Master Plan of JMR

Improving public transport services will encourage a decrease in the usage of private vehicles and contribute to reducing traffic congestion, decreasing air pollution and noise and increasing transport safety. The main policy of developing a transportation system of JMR is to support inter-regional transportation needs, the development of urban corridors, strengthening access, and developing the road system.

5.1.2. Implementation of integrated TOD to guide transport planning in JMR

Land use and transportation are the key factors to urban and regional planning. The well-regulated city is characterized by the conditions of land use and transportation systems and it indicates economic prosperity. However, there is a tendency that the city development is followed by the various issues of transportation and land use (Putman., 2013). These issues include traffic congestion, energy wastage, delayed travel time, air and sound pollution. This is a complex problem that involves many aspects and interrelated. Thereby, many researches were conducted to pursue the solution of these issues. Most previous studies examine the application of TOD in Indonesian cities. Nevertheless, lack of study determined the typology of TOD at the regional and urban levels as well as improving transport and spatial planning in an integrated manner. Therefore, this Chapter introduces an integrated TOD as spatial model to guide transport planning of JMR.

5.2. Research method in Chapter 5

5.2.1. Datasets

The data in this Chapter is spatial and attributes data (Table 5.3). Data collection obtained from agencies, ministry, and previous researches. It can expect to support the process in this Chapter.

Table 5.3 List of datasets

Datasets	Source	Year
Administrative of study area	Geospatial Information Agency	2015
Spatial plan	Geospatial Information Agency	2014
Mass transportation plan	Ministry of Transportation	2015
Actual TOD map	Previous research (Chapter 3)	2017
Potential TOD map	Previous research (Chapter 4)	2017

5.2.2. Methodology framework

The methodology framework is done by studying the literature about the concept of TOD, land use, and transportation, collecting and analyzing spatial and non-spatial data. The finding of this chapter is obtained by creating an integrated TOD by combining actual and potential TOD, differentiating TOD based on typology, afterward implementing the integrated TOD spatial model to guide transport planning. The conceptual framework of this Chapter is presented in Figure 5.5 below.

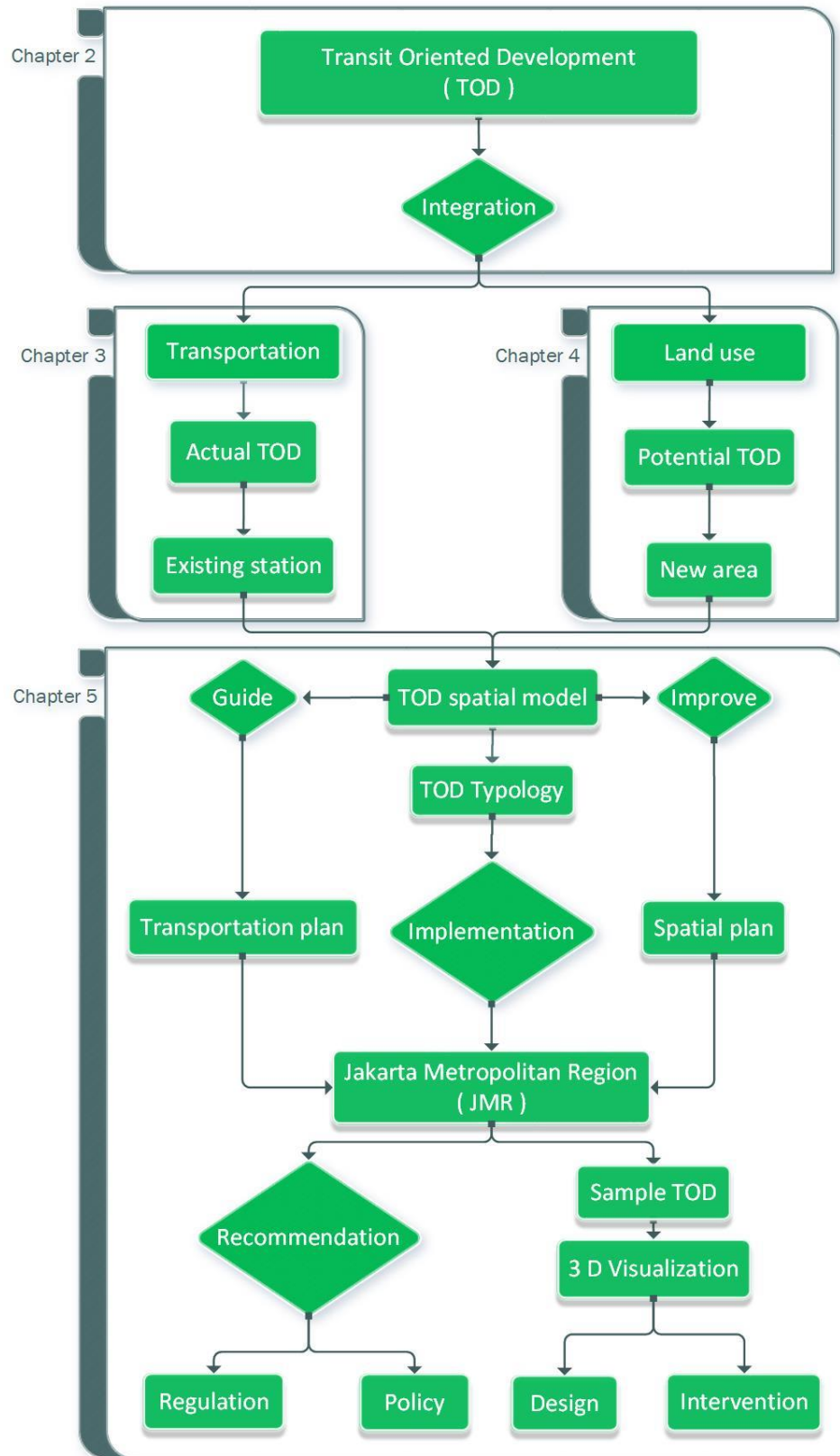


Figure 5.5 Conceptual framework of Chapter 5

5.4. Implementation of the integrated TOD spatial model in JMR

5.4.1. Spatial planning equipped by potential TOD

Referring to the spatial pattern of JMR previously mentioned in Sec. 5.1.1.2, in the upstream area with strong conservation function, space allocation should be dominated by a kind of protection.

In mid-stream can be proportioned the allocation of space that may function for economic, social, and environmental activities. Space allocation of economic activity in this section can be wet or dry agriculture, plantation, shops, and trade, as well as limited and non-pollutant industries.

The dominance in the downstream is for settlement activity and the dominant economic activity, but still, pay attention to green open space in macro area. Economic activities in the downstream area can function as dense residential on the scale of economic activity in residential, shops, large and small industries, malls, services and trade both on a regional, national and international scale.

Referring to the above exposure, the suitable location for TOD is in the mid and downstream areas. Placement of TOD at this location not only support transport and spatial dynamic by time but also consider the environmental balance.

5.4.2. Planning concept appropriate to employ TOD

The transport network pattern of JMR is the radial system and spatial form is the multinucleated urban structure with corridors and nodes. It means that the intense land uses in this structure are extended out from the CBD along major transportation routes. Tanuwidjaja and Chang (2017) promote to the placement of TOD on that location with

the proposal like the Figure 5.6 below. Placement of stations and railways right on the hub and passing the entire main cities of this region.

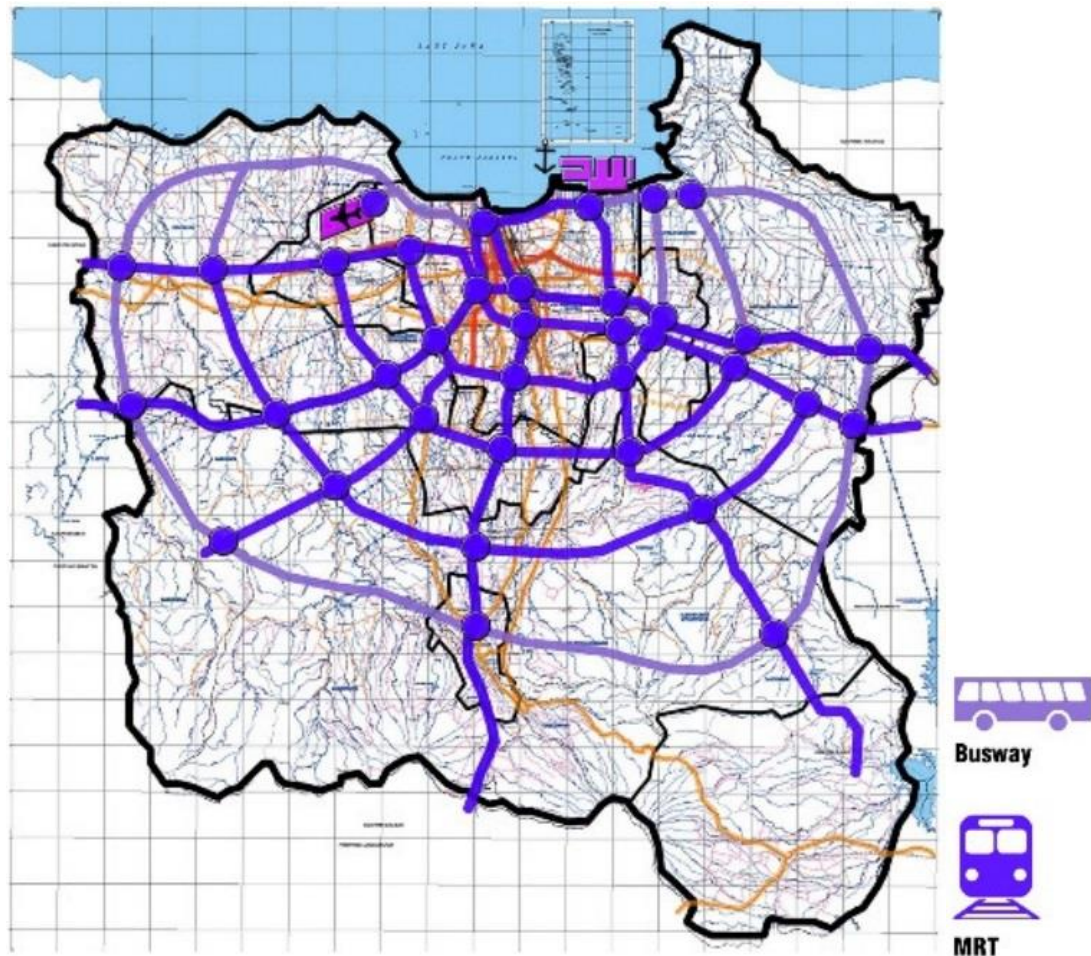


Figure 5.6 Public transport network plan (Tanuwidjaja and Chang., 2017)

The development proposal of BRT, LRT, and MRT with TOD is designed to cover the entire JMR area by looking at physical conditions of land use and available road network. Improvisation of this public transport connecting sub-urban and urban areas between Jakarta and surrounding area, with good ties is expected to create solutions from various issues that occur such as congestion and environmental pollution.

This TOD proposal is only a general design without measuring in detail and determining the type of TOD at the station. Therefore, further in-depth research is needed to find out what type of TOD is suitable to be placed at each existing station in the transportation network system, as well as determine which potential areas for new TOD placement in the urban structure.

5.4.3. TOD typology

TOD typology is done by grouping transit areas according to existing conditions so that it is useful to identify potential TOD. Peter Calthrope (1993) introduced the TOD typology into Urban and Neighbourhood TOD, then the typology was developed by various subsequent studies such as (Bertolini., 1999; Kamruzzaman et, al., 2014; Lyu., 2016). Widyahari & Indradjati (2013) proposed the TOD typology called TOD Regional Center, Urban Center TOD, TOD Suburban Center and Transit-Town TOD. In this Chapter, TOD typology is limited to Regional, Urban and Suburban TOD with the following explanation:

1. Regional TOD

TOD with regional service centers, namely the development of the region as a center of economic activity and regional community. This TOD creates synergy between the community and the region, between work and settlement, between the level of density and service, between individuals and society. Dittmar and Ohland (2004) identified the TOD Regional with the presence of thematic land-use mix, with the dominance of the building environment served by various modes of transportation in a network. Figures 5.7 illustrate 3D visualization of the Regional TOD.

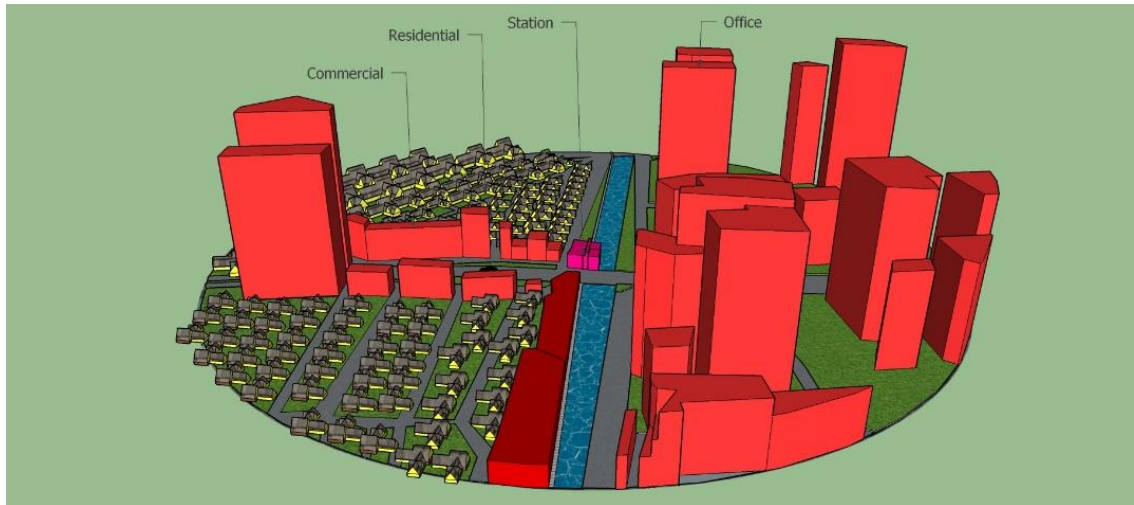


Figure 5.7 3D visualization of Regional TOD

2. Urban TOD

TOD with the city service scale, which is the character of urban development as the primary functioning economic center in the main circulation path of the city such as intercity bus stops and train stations both light rail and heavy rail (Figure 5.8). Urban TOD was developed in conjunction with commercial functions that have high intensity, office blocks, and high-density dwellings. Planning of TOD patterns have a high density because it allows direct access to transit points without having to change other modes.



Figure 5.8 3D visualization of Urban TOD

3. Suburban TOD

TOD as a sub-city center, it services local residence and helps the development of housing for the low- and middle-income class. Suburban TOD is equipped with public facilities and green open spaces, so it provides easy access using various modes (Figure 5.9).



Figure 5.9 3D visualization for Suburban TOD

5.4.4. TOD characteristics

5.4.4.1. Building heights

The building heights of the Regional TOD have many high-rise buildings because it located the downtown or urban center, besides that, there are various buildings from medium to high (Figure 5.10).

Building heights on Urban TOD is almost the same as Regional TOD, there are buildings from low to high, but the percentage of the number of high-rise buildings is less, on the contrary, there are many middle buildings, while the number of housing is more than the Regional TOD

Building heights in the Suburbs TOD is seen to be dominated by low building, this is because most of the area is occupied by housing, the commercial and office functions are less than the number of residential areas.

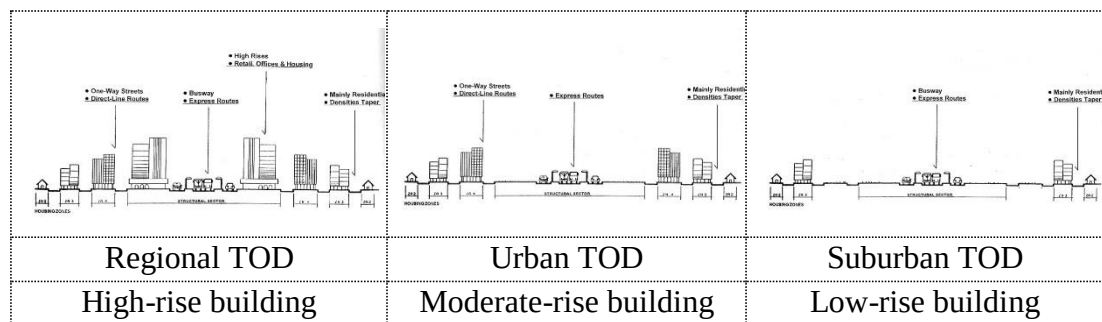


Figure 5.10 Building heights

5.4.4.2. Urban pattern

Urban pattern of the TOD by type is shown in Figure 5.11 where the TOD type representing the Regional TOD is in the urban center or downtown with the appearance of a compact and effective condensed, the location is very limited, while the TOD type representing Urban TOD is looked still has enough space for the movement of vehicles

and passengers out from the station. The Suburban TOD type appears once the availability of wide space around the station coupled with the movement of vehicles and passengers are well ordered. Passengers in large numbers using this station because they live in the suburbs and work in the urban center or downtown.

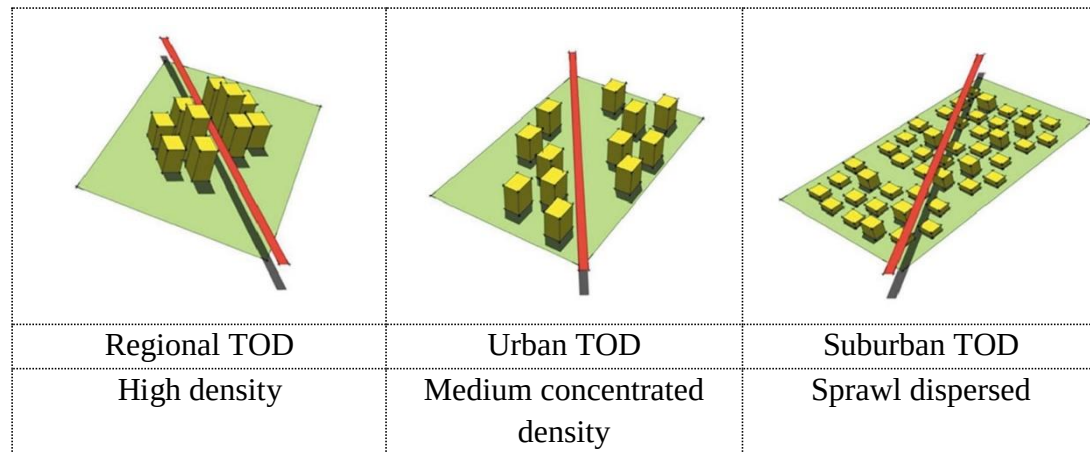


Figure 5.11 Urban pattern of station

5.4.4.3. Development area

Regional TOD facilitates passenger mobility from the exchange station, bus terminal, and airport. A layout of the station has a mixture of buildings with a dominance commercial area until 80 percent. There is limited open space to optimize green area with trees to shade and beautify this area. Thus, the station is not only equipped with modern facilities but also seen greener to maximize area as the largest service center in the region (Figure 5.12).

Urban TOD connected to many transit nodes. In addition, there is 40 percent of the commercial area for servicing inhabitant who comes from 60 percent of the residential area. This station is well known for its crowds, where every morning in office hours, the

worker from suburbs come to the station for going to work in an office, mostly located in the urban center area.

Suburban TOD station as a transit node has a proportion, 80 percent of the area is residential. Development of urban planning directed to improve this area by considering sustainable environment. The pedestrian path in this station is critical due to connecting inhabitant to another transit node. The plan of the station should adopt a mixed spatial with maximization of transit access

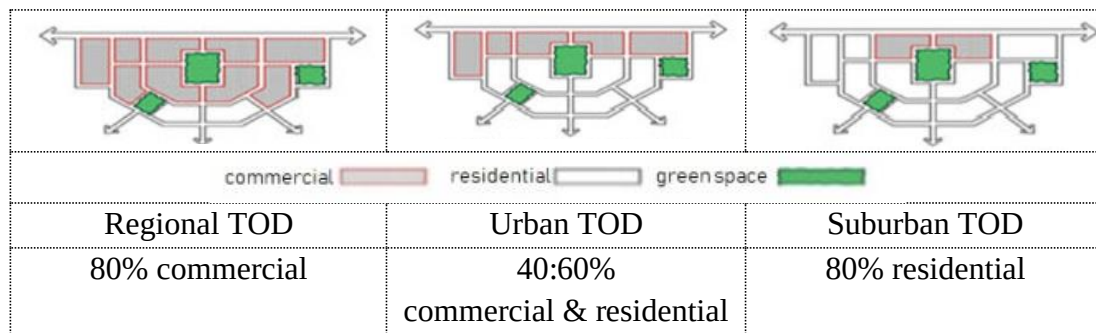


Figure 5.12 Development area of station

5.4.4.4. Transportation network

Regional TOD becomes a central transit and connected to intermodal stations for all types of transportation modes in the urban center or downtown. This is a manifestation of the fulfillment of public transport interconnected for the community (Figure 5.13).

Urban TOD serves departure and arrival of the passenger from anywhere inside an urban area. In addition, it is also a station for some public transport modes which connect each other. There is the main road and several streets to serve public transport by bus or microbus. The station connected to the bus terminal and it has the car park.

Suburban TOD has the main road access and less street to connect whole suburbs. The intensity of modes in Suburban TOD is lower than another TOD type but many modes

appear in there such as taxi car, taxi motorcycle, microbus, medium bus. All modes make inhabitant easier to access various destination from different parts of the area.

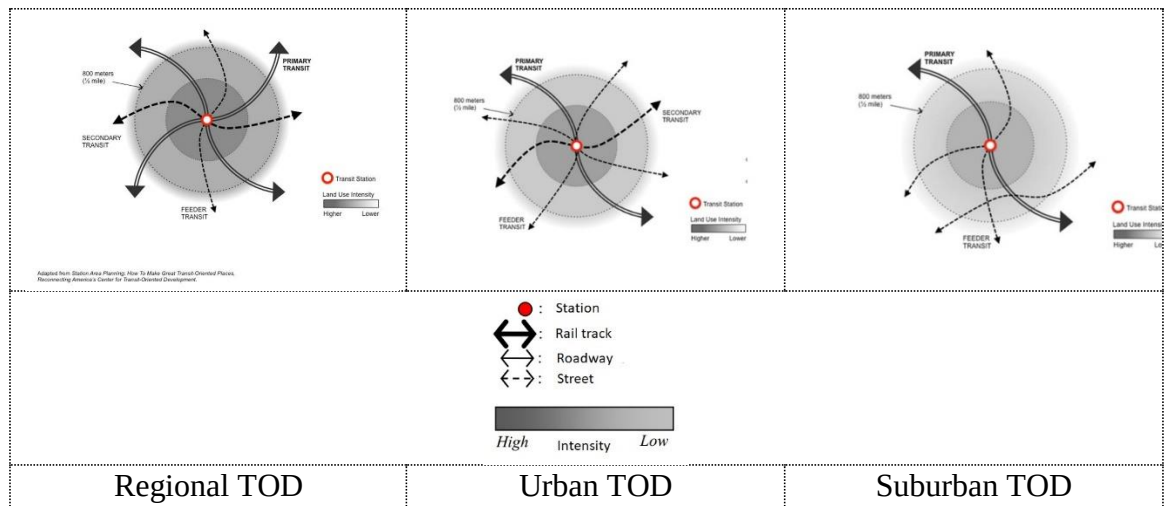


Figure 5.13 Transportation network

5.4.5. Producing TOD typology based on the spatial model for JMR

JMR is a metropolitan region of several surrounding cities with its centre in Jakarta capital city. Railways in study area crossed several cities including Tangerang city, Depok city, Bekasi city and Bogor city. The primary road is the main access in this region besides railway access. The primary road network connects between centres or regional activities. Therefore, the role of TOD in this case as transit and service centres in residential areas is equipped with good service infrastructure facilities. TOD of JMR is very helpful in the city and region development because it becomes a spatial model to overcome urban sprawl that is the expansion of urban activities in the suburbs with irregular patterns, the impact of the migration of some residents of high density from urban areas to suburban.

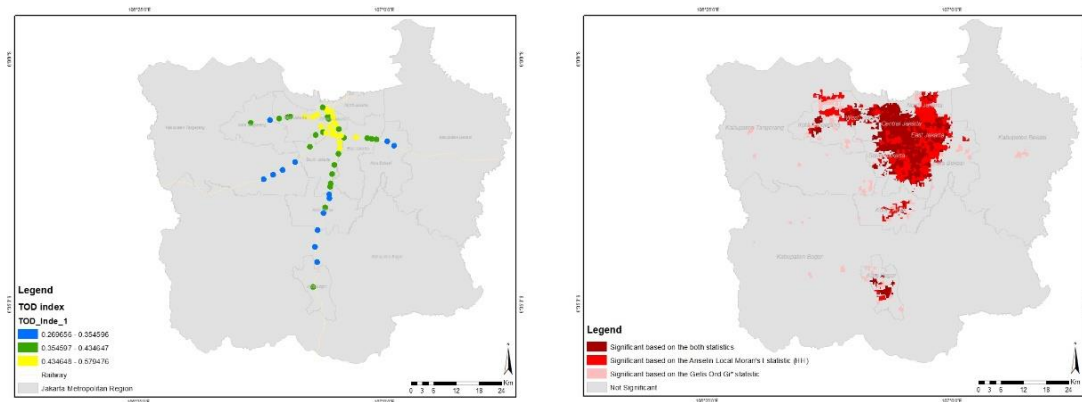
The method used in this Chapter is a data analysis introduced in Chapters 3 and 4 and it has resulted in a basic spatial model for urban planning. Data derived from actual and potential TOD which are combined to produce an integrated map of TOD in JMR.

The method used for the analysis is multicriteria analysis to get actual TOD and the land suitability evaluation method to get potential TOD. Both methods are supported by AHP techniques to gain priority criteria values and GIS applications to explain spatial in the Table 5.4 below.

Table 5.4 TOD typology by index

Criteria		Density							Economic				Diversity		TOD Index	TOD Typology
Weight		0.51							0.27				0.22			
Station	Commercial	Residential	School	Parking	Open space	Hospital	Density index	Population	FAR	BCR	Economic index	Diversity index				
Weight	0.32	0.27	0.13	0.12	0.09	0.08		0.48	0.31	0.21		1				
Univ Indonesia	0.01	0.35	0.00	0.05	0.36	0.13	0.15	0.05	0.30	0.51	0.22	0.62	0.27	Suburban		
Pd Cina	0.13	0.37	0.00	0.08	0.09	0.13	0.17	0.05	0.55	0.54	0.31	0.46	0.27	Suburban		
Poris	0.01	0.46	0.00	0.04	0.34	0.00	0.16	0.24	0.31	0.52	0.32	0.46	0.27	Suburban		
Rawa Buntu	0.05	0.79	0.00	0.05	0.15	0.00	0.25	0.10	0.38	0.60	0.29	0.38	0.29	Suburban		
Sudimara	0.01	0.91	0.05	0.05	0.08	0.00	0.27	0.19	0.22	0.75	0.32	0.38	0.31	Suburban		
Cilebut	0.01	0.76	0.00	0.04	0.23	0.00	0.23	0.17	0.77	0.30	0.38	0.38	0.31	Suburban		
Depok	0.01	0.87	0.05	0.05	0.12	0.32	0.29	0.17	0.06	0.78	0.26	0.46	0.32	Suburban		
Pd. Ranji	0.05	0.77	0.11	0.05	0.18	0.00	0.26	0.30	0.41	0.58	0.39	0.38	0.32	Suburban		
Bekasi	0.04	0.76	0.14	0.05	0.18	0.00	0.26	0.10	0.60	0.40	0.32	0.54	0.33	Suburban		
Bojonggede	0.01	0.99	0.03	0.05	0.01	0.00	0.28	0.32	0.99	0.33	0.53	0.23	0.34	Suburban		
Kranji	0.05	0.85	0.00	0.05	0.08	0.00	0.26	0.39	0.17	0.75	0.39	0.46	0.34	Suburban		
Citayam	0.01	0.86	0.00	0.04	0.14	0.00	0.25	0.19	0.84	0.29	0.42	0.46	0.34	Suburban		
Serpong	0.01	0.87	0.21	0.04	0.12	0.16	0.29	0.22	0.88	0.31	0.44	0.38	0.35	Suburban		
Univ Pancasila	0.06	0.63	0.11	0.06	0.16	0.00	0.22	0.12	0.45	0.56	0.32	0.77	0.37	Urban		
Pal Merah	0.19	0.33	0.03	0.09	0.30	0.12	0.20	0.00	0.49	0.42	0.24	0.92	0.37	Urban		
Kalideres	0.01	0.62	0.03	0.06	0.08	0.08	0.20	0.18	0.54	0.59	0.38	0.77	0.37	Urban		
Tanjung Barat	0.11	0.71	0.12	0.06	0.13	0.11	0.27	0.16	0.46	0.56	0.34	0.69	0.38	Urban		
Cakung	0.04	0.78	0.10	0.06	0.10	0.00	0.25	0.21	0.20	0.72	0.31	0.77	0.38	Urban		
Pasar Minggu	0.07	0.68	0.11	0.06	0.14	0.17	0.26	0.14	0.39	0.59	0.31	0.77	0.38	Urban		
Juanda	0.33	0.13	0.26	0.11	0.19	0.23	0.22	0.11	0.72	0.32	0.34	0.85	0.39	Urban		
Rawa Buaya	0.04	0.58	0.11	0.06	0.18	0.16	0.22	0.19	0.51	0.55	0.37	0.85	0.40	Urban		
Klender Baru	0.05	0.78	0.08	0.06	0.06	0.00	0.25	0.36	0.44	0.65	0.45	0.69	0.40	Urban		
Duren Kalibata	0.10	0.56	0.00	0.07	0.11	0.00	0.20	0.20	0.51	0.56	0.37	0.92	0.40	Urban		
Bojong Indah	0.03	0.64	0.10	0.06	0.06	0.11	0.22	0.25	0.74	0.59	0.47	0.77	0.41	Urban		
Depok Baru	0.13	0.66	0.05	0.06	0.18	0.32	0.27	0.17	0.37	0.52	0.31	0.85	0.41	Urban		
Lenteng Agung	0.14	0.69	0.00	0.07	0.10	0.26	0.27	0.37	0.26	0.65	0.39	0.77	0.41	Urban		
Kramat	0.15	0.59	0.15	0.08	0.06	0.33	0.27	0.30	0.41	0.61	0.40	0.77	0.41	Urban		
Buaran	0.06	0.77	0.08	0.06	0.09	0.00	0.25	0.36	0.53	0.59	0.46	0.77	0.42	Urban		
Jakarta Kota	0.55	0.20	0.20	0.12	0.07	0.00	0.28	0.19	0.73	0.24	0.37	0.85	0.43	Urban		
Bogor	0.25	0.69	0.55	0.07	0.05	0.00	0.35	0.25	0.72	0.39	0.42	0.62	0.43	Urban		
Jatinegara	0.19	0.60	0.11	0.08	0.08	0.00	0.25	0.41	0.34	0.60	0.43	0.85	0.43	Urban		
Kebayoran	0.19	0.66	0.15	0.07	0.05	0.13	0.28	0.24	0.47	0.57	0.38	0.85	0.43	Urban		
Karet	0.24	0.38	0.08	0.08	0.27	0.00	0.22	0.47	0.36	0.43	0.43	0.92	0.43	Urban		
Sawah Besar	0.63	0.26	0.26	0.12	0.03	0.23	0.34	0.11	0.73	0.27	0.33	0.77	0.43	Urban		
Tangerang	0.03	0.83	0.45	0.05	0.09	0.50	0.35	0.06	0.66	0.44	0.33	0.77	0.43	Urban		
Pesing	0.26	0.51	0.19	0.08	0.13	0.00	0.27	0.30	0.75	0.38	0.46	0.85	0.45	Regional		
Dukuh	0.38	0.37	0.35	0.08	0.21	0.88	0.36	0.17	0.63	0.30	0.34	0.77	0.45	Regional		
Klender	0.15	0.65	0.19	0.07	0.05	0.29	0.28	0.39	0.35	0.64	0.43	0.85	0.45	Regional		
Pasar Senen	0.32	0.46	0.34	0.09	0.06	1.00	0.37	0.14	0.58	0.46	0.35	0.77	0.45	Regional		
Rajawali	0.31	0.49	0.20	0.08	0.09	0.22	0.29	0.21	0.62	0.42	0.38	0.92	0.46	Regional		
Gondangdia	0.32	0.40	0.23	0.10	0.06	0.50	0.30	0.27	0.75	0.38	0.44	0.85	0.46	Regional		
Mampang	0.12	0.70	0.35	0.07	0.09	0.88	0.36	0.17	0.75	0.47	0.41	0.77	0.46	Regional		
Jayakarta	0.51	0.36	0.07	0.11	0.06	0.31	0.31	0.40	0.60	0.36	0.45	0.85	0.47	Regional		
Pondok Jati	0.14	0.69	0.34	0.08	0.01	0.00	0.29	0.53	0.37	0.67	0.51	0.85	0.47	Regional		
Tn. Abang	0.31	0.45	0.26	0.09	0.13	0.57	0.32	0.29	0.46	0.45	0.38	0.92	0.47	Regional		
Manggarai	0.11	0.55	0.16	0.08	0.06	0.70	0.28	0.51	0.55	0.57	0.54	0.85	0.47	Regional		
Cawang	0.14	0.63	0.08	0.07	0.12	0.00	0.25	0.48	0.52	0.53	0.50	1.00	0.48	Regional		
Cikini	0.19	0.52	0.10	0.08	0.08	0.88	0.30	0.41	0.75	0.45	0.52	0.85	0.48	Regional		
Grogol	0.21	0.53	0.19	0.07	0.13	0.28	0.28	0.36	0.86	0.35	0.51	0.92	0.48	Regional		
Tebet	0.11	0.81	0.08	0.06	0.03	0.00	0.28	0.48	0.54	0.60	0.52	0.92	0.48	Regional		
Kemayoran	0.33	0.47	0.05	0.09	0.06	0.00	0.25	0.70	0.50	0.49	0.60	0.92	0.49	Regional		
Mangga Besar	0.50	0.37	0.00	0.10	0.03	0.00	0.27	1.00	0.60	0.39	0.75	0.77	0.51	Regional		
Gang Sentiong	0.20	0.65	0.78	0.08	0.04	0.57	0.40	0.74	0.42	0.60	0.61	0.77	0.54	Regional		
Duri	0.20	0.67	1.00	0.07	0.09	0.00	0.39	0.91	0.31	0.61	0.66	0.92	0.58	Regional		

Actual TOD index means an assessment of the existing station and related to transportation aspect. The unit of analysis carried out based on the node of the train station location, which is explained by the index. The method is used in this Chapter is a combination of AHP and multicriteria analysis technique. The tools used are GIS application to display the resulting map obtained (Figure 5.14).



Actual TOD means an actual or existing condition of station (transportation)

Potential TOD means a potential location for the new station (spatial)

Figure 5.14 Actual and Potential TOD

The planning of potential TOD in Figure 5.14 means a potential location for the new station and it relates to the spatial aspect. The method used is the land suitability evaluation method involving 20 criteria to obtain a very potential area for developing a new station. The study in this Chapter is done in more detail by using spatial statistical analysis technique for getting the hotspot area which is very significant for a new TOD station. The results obtained are many clusters of hotspots in the urban center (Jakarta downtown) and few in surrounding areas (Tangerang, Depok, and Bogor).

Figure 5.15 below show a station typology of TOD based on actual and potential. This typology is found in the administrative area of JMR. The figure describes TOD

implementation in JMR based on its typology. Each type is taken one example of a station that represents other stations of the same type, this scenario can be used as a model by the government and related parties. Each type is represented by samples such as Sudirman station for Regional TOD, Depok station for Urban TOD and Bojonggede station for Suburban TOD, all these examples represent the whole type of TOD and stations spread throughout the JMR.

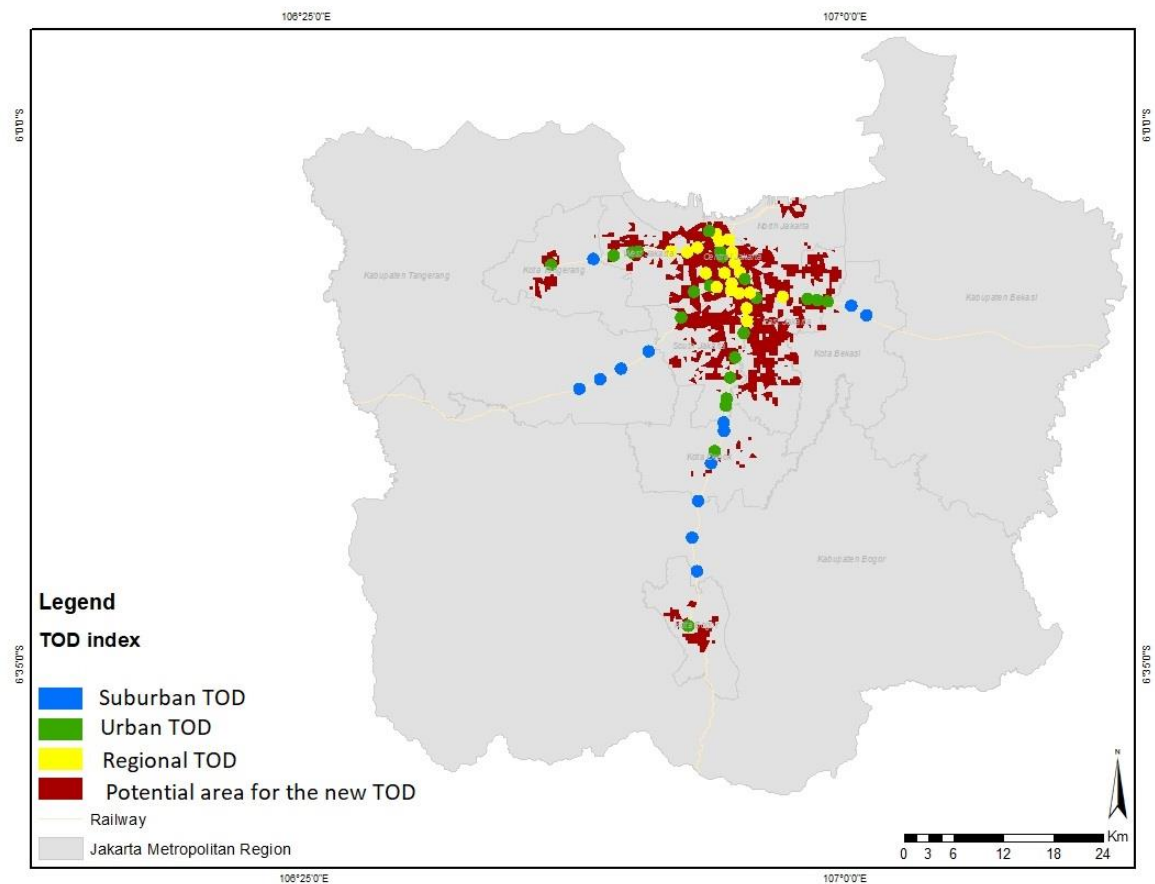


Figure 5.15 The typology of integrated TOD spatial model

The implementation of TOD typology into the transport planning in JMR depicted in Figure 5.16 below. The figure shows the difference in each station based on TOD typology where the green color indicates the Urban TOD type, the blue indicates

Suburban TOD and the yellow color indicates Regional TOD. The application of TOD typology is the finding that conducted in this Chapter.

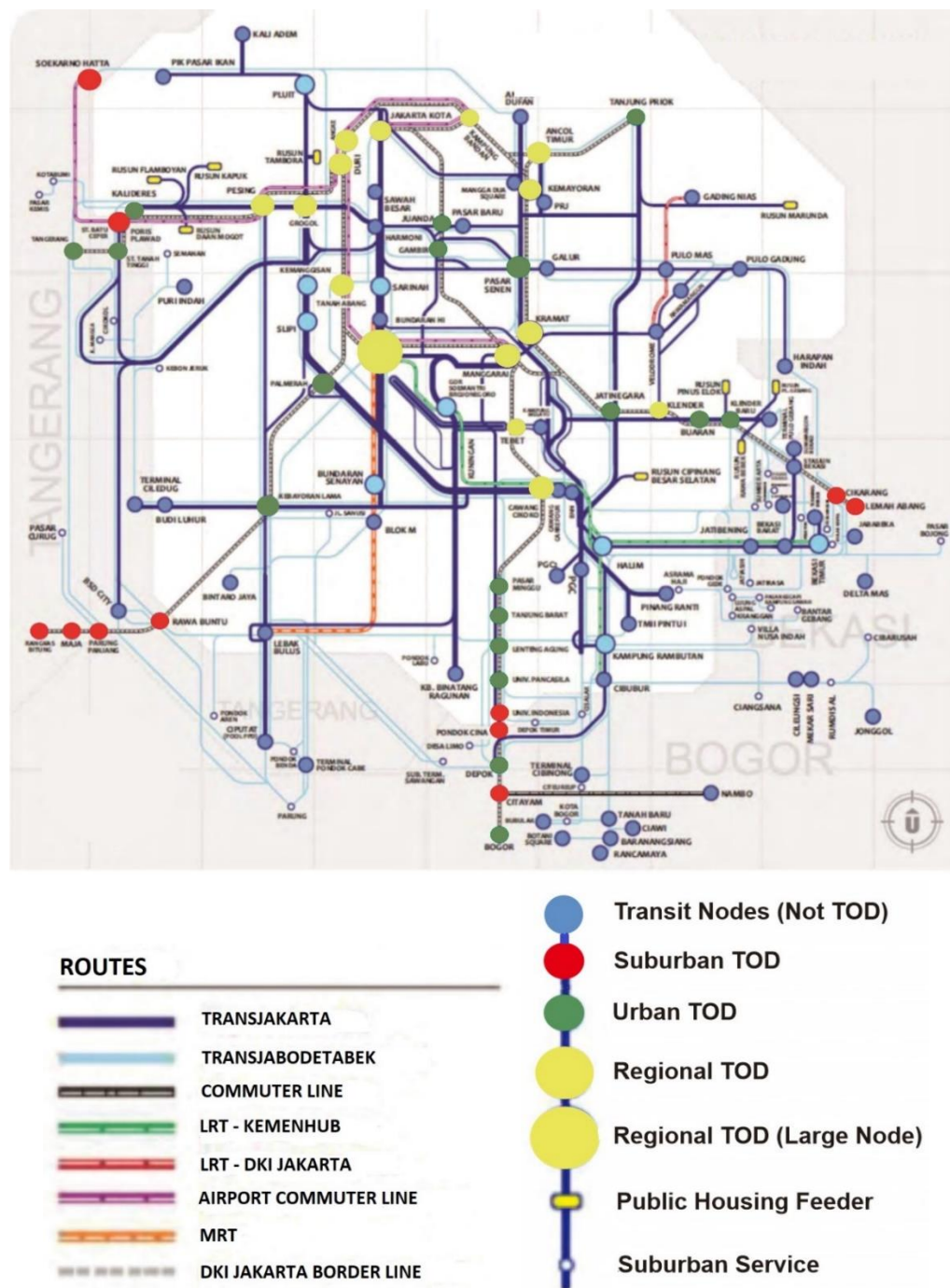


Figure 5.16 Transport planning of JMR equipped by TOD typology

5.4.6. Policy implication of TOD typology in macro level

Determination of TOD area is based on consideration of the transportation system and land use. TOD development can be done with the following policies: 1. Redevelopment site, which is revitalized with the provision of new facilities and functions equipped with an arrangement and utilization area around TOD station. 2. The development site, i.e. development on vacant land on the radius of TOD area. 3. New growth area, i.e. opening of new areas wide and generally located in the periphery border area. All TOD development policies can be used in combination, complementary to the situation and conditions in the field (Table 5.5).

Table 5.5 Policy implication

		TOD typology		
		Regional	Urban	Suburban
Policy implication	Land use	a. Domination of office area b. Development of strategic areas of economic interest c. Provision of bridges to residential areas	a. Mixing residential and office areas b. Construction of primary activity centres c. Development of high-density vertical office area	a. Domination of residential area b. Development of a secondary activity centre c. Construction of flats and green open spaces
	Transportation	a. Optimization of mass transportation services between modes b. Operation of the airport train	a. Provision of pedestrian paths between stations or bus stops b. Organizing park and ride c. Improving commuter rail service	a. Changes to local rail service b. Extension of rail service c. Improving service quality of pedestrian and bike paths integrated with public transport

5.4.7. Planning regulations of TOD typology in micro level

Planning TOD is proposed for mixed housing and commercial lands. It planned to maximize access to public transport for encouraging the use of public transport modes.

Allocation of land around station is developed with difference of density. The following Figure 5.17 shows the TOD zonation in detail based on the distance from the station as the center point.

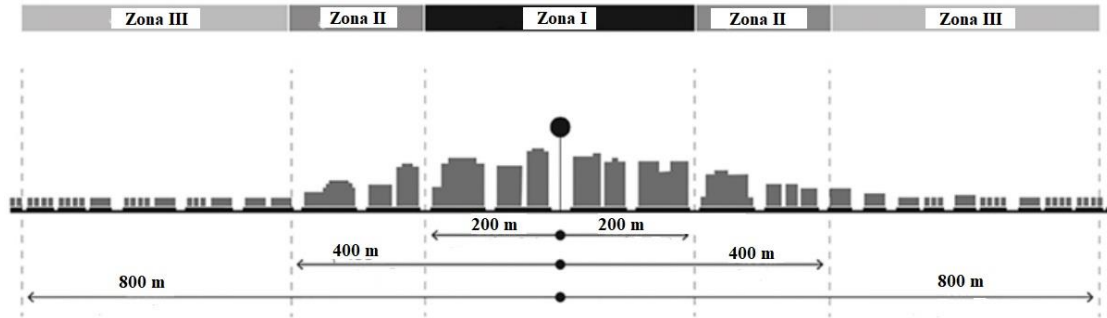


Figure 5.17 TOD zonation

The following Table 5.6 is a proposal of the general regulations in micro level

Table 5.6 General regulations of TOD typology

	TOD typology								
	Regional			Urban			Suburban		
	200m	400m	800m	200m	400m	800m	200m	400m	800m
Sustainability requirement									
Targeted rank of LEED	Platinum	Gold	Silver	Gold	Gold	Silver	Gold	Silver	Bronze
Connectivity requirement									
Maximum length of land (m)	75-120	75-150	120-150	75-120	120-150	150-180	120-150	150-180	120-240
Open space requirement									
Width of pedestrian paths (m)	9-+14	7.5-+10	6-+8	8-+12	6-+10	6-+8	6-+10	6-+8	5-+8
Ratio of public open spaces	10-15%	10-15%	10-15%	10-20%	10-20%	5-15%	10-20%	10-20%	10-20%
Building regulation									
FAR	5-10	3.5-6	1.2-1.8	3-5	2-4	1.2-1.8	2-4	1.5-2	1.2-1.8
Maximum BCR	50%	50%	50%	50%	50%	50%	50%	50%	50%
Maximum number of floors	No control	No control	No control	10	8	3	8	4	3
Active facades*	70-100%	65-90%	50-80%	60-100%	50-80%	<50%	60-90%	60-90%	<40%
Land use									
Ratio of residential	20%	30%	40%	45%	50%	70%	60%	75%	85%
Parking									
Nature of parking	Underground/multi floor	Underground/multi floor	Underground/multi floor	Underground/multi floor	Underground/multi floor	Overground	Underground	Multi floor	Superficial
For every 100 m ² out of the total built up area	1.18-1.66	1.56-1.79	1.44-1.65	1.15-1.51	1.43-1.59	1.23-1.37	1.30-1.46	1.14-1.27	0.94-1.06

Active Façade: a building exterior equipped with Smart Glass, shading systems, or other technologies that can dynamically change the optical and thermal transmission characteristics of the windows.

5.4.8. Existing condition from sample station

An in-depth exploration of TOD typology was carried out from three sample station (Station of Sudirman, Depok, and Bojonggede) which representative of the different type of TOD in JMR. Explanation of the existing condition consists of the location map, physical feature, and land zone.

5.4.8.1. Location of station

Sudirman station is a railway station located at east side of main road in central of Jakarta. Depok station located in Depok city and Bojonggede station located in Bogor regency. All station is the crowded station in the morning and afternoon due to the big number of commuters (Figure 5.18).

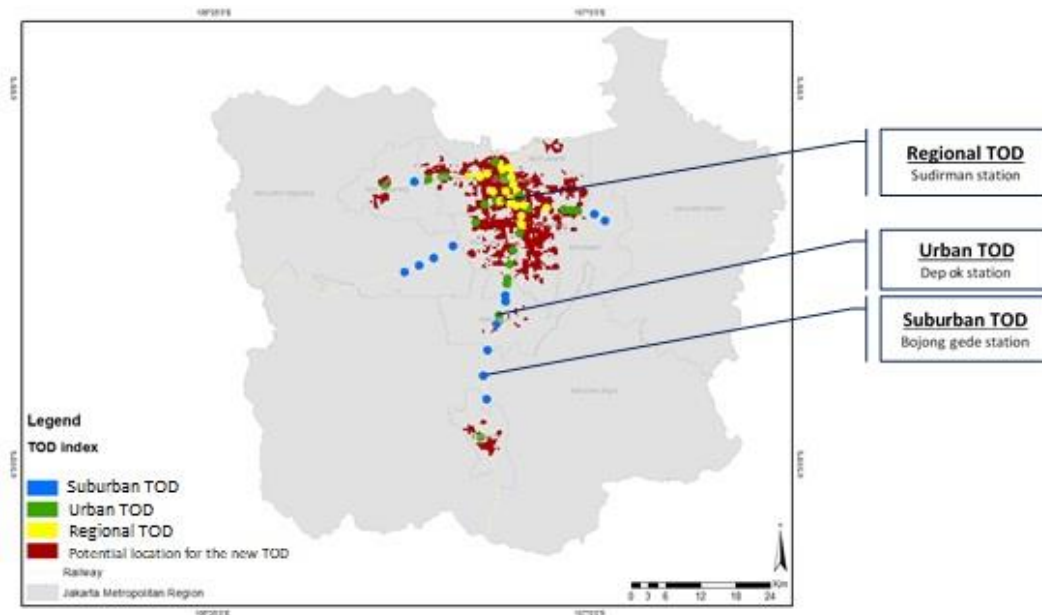


Figure 5.18 Location of station

5.4.8.2. Station condition

Facilities owned by Sudirman station include ticketing counter, tapping gate, escalator, commercial area, toilet, and mosque (Figure 5.19). On the left and right, large

glasses adorn the body of the station, aluminum-based chairs, four escalators, and two lifts on both sides. The platforms are long and wide, with a thickness that has been adjusted to the height of the train door. So no longer make it difficult for female passengers to get in and off the train. Depok station is very strategic because it is more precisely behind the mayor's office, terminal and in opposition to the police office and directly adjacent to main road in the east, north and south. Bojonggede station has various buildings and supporting facilities such as platform extension, mosque, toilets, mini market, parking lots and so on.



Figure 5.19 Station condition

5.4.8.3. Physical features of station

Sudirman station is a train station serving the commuter line route and serves the stop of the international airport. Depok station has four lanes to accelerate the commuter line trip from Bogor and to the final stop of the train in Depok. The station is located on the main railway line of the Southern part of Java island that connects Jakarta-Bogor which is crowded because of many trains passing by. Bojonggede station is the third commuter line station from the direction of Bogor. Some areas in Bogor will be more easily reached from this station than via Bogor station.



Figure 5.20 Physical feature of station

5.4.8.4. Land zone of station

Sudirman station is very crowded on monday to friday especially at starting for working hours at 9 am and going home at 5 pm. This is because the land use surrounding the main road is many office areas so there are a lot of train passengers working there.

Depok station is located just behind the terminal and market, besides this station is flanked by artery road in the east. Land use around the station is a mix between commercial and residential with almost equal proportions. In the rush hour of the morning the number of train passengers from both directions is full of vehicles and people. The situation in left and right of the road there is many homes used for business of motorcycles parking even uses the part of road for motorcycle parking.

Bojonggede station plays a key role in the life of the Bogor-Jakarta commuters every day because tens of thousands of people every day hustle back and forth through this station. It almost no space of land for housing in the city of Bogor, border areas are increasingly filled with settlements. As a result, commuter line become one of the main transportations for Bogor residents who live in the area to go to Bogor, Depok or Jakarta.

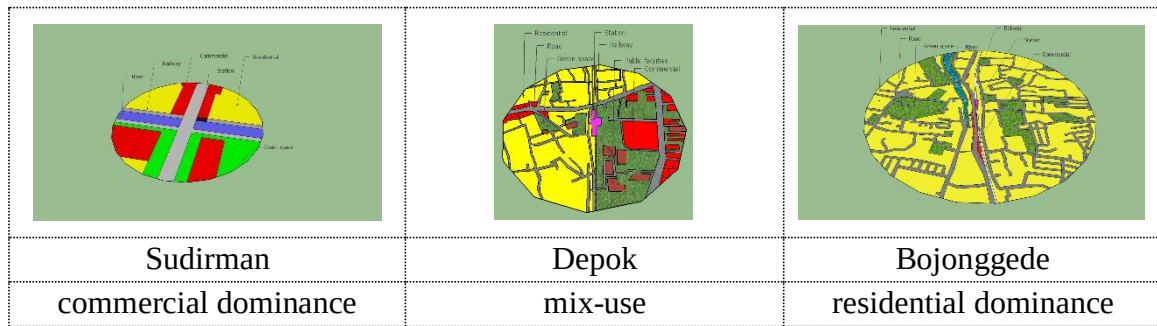


Figure 5.21 Land zone of station

5.4.9. Promoting TOD typology by urban design for future

The aim of promoting TOD typology by urban design for future is to eliminate urban sprawl in the future by changing it into compact city. Urban design should pay attention to some zoning such as residential, business, office, public and social facilities so that people can do activities and meet their needs in the area without having to go to the city center. For this design, the TOD is divided based on the following typology.

5.4.9.1. Regional TOD

Sudirman station as Regional TOD is a station where the area around the station is the center of government, business and other urban activities so that the existence of the station is not just as a stopover place from the commuter but as a mass movement of citizens. This Regional TOD creates synergies between communities in the JMR and the surrounding environment also synergies between commuters and local people. The aim of Sudirman station planning is to create a world-class integrated transport system with integrated land use, transportation modes and transit nodes. Sudirman station as Regional TOD links the transit function of urban areas and the development of surrounding areas based on land use and facility functions (Figure 5.22).

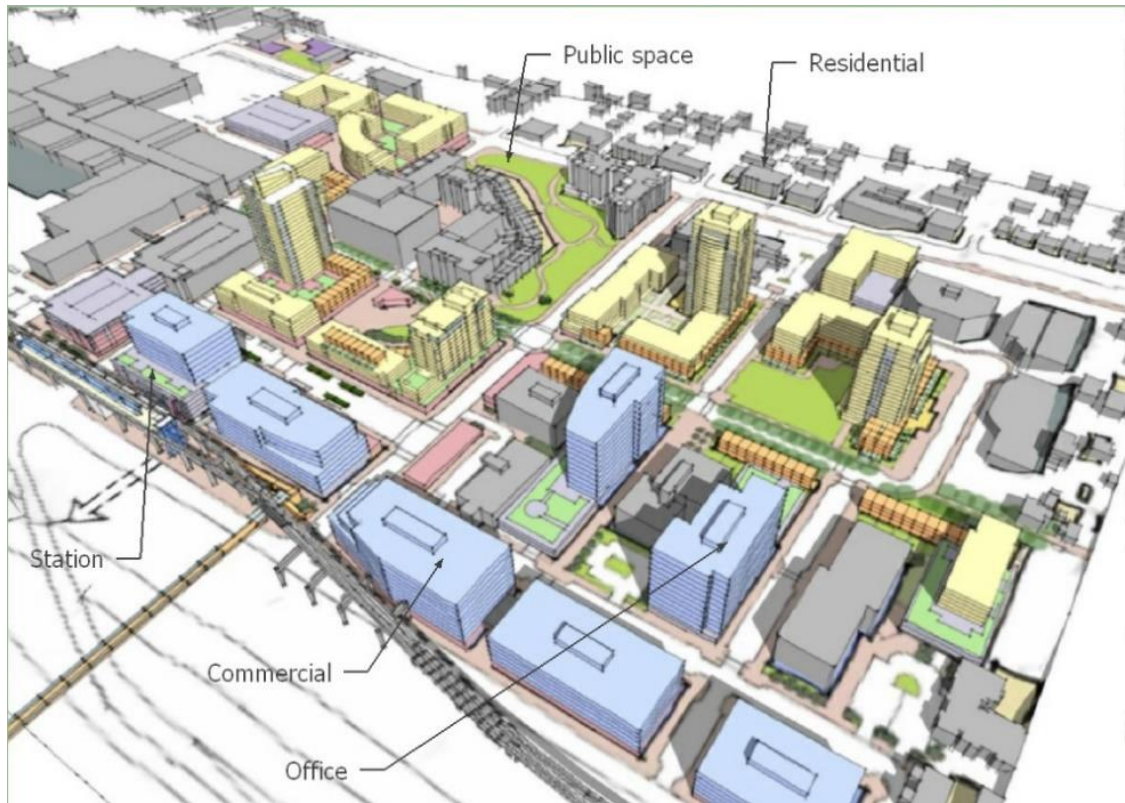


Figure 5.22 Urban design of reality dream look like Regional TOD in Sudirman

The intervention in this area is not only planned as a transit point, but also a center filled with mixed-use buildings with comfortable surroundings. That way will attract more passenger train enthusiasts. conversely, this causes the use of private vehicles to be reduced (Table 5.7).

Table 5.7 Intervention for Regional TOD

	Maximum FAR	Cover area	Number of floors	Land use
Existing	3-6	70%	10 st floor	commercial, office, residential
Intervention	10	80%	open	commercial, office, residential

Regional TOD has a mixture of land use with a high-rise building and it is serviced with a variety of modes of transportation within a network. In addition, the Regional TOD has a thematic land use, mixed with having a tendency towards distinct functions. The maximization of Regional TOD design as a transit center can change the dynamics of public transport in JMR.

5.4.9.2. Urban TOD

Depok station is a type of urban TOD with service scale of all areas of Depok city which are on the main circulation path of the city like bus stop, market and train station. Urban TOD of Depok station at a medium-intensity mixed-use location and integrate between trains with buses and microbuses serving city dwellers. Design of Urban TOD not only on its function as a transit point, but also consider the convenience of its users (Figure 5.23).

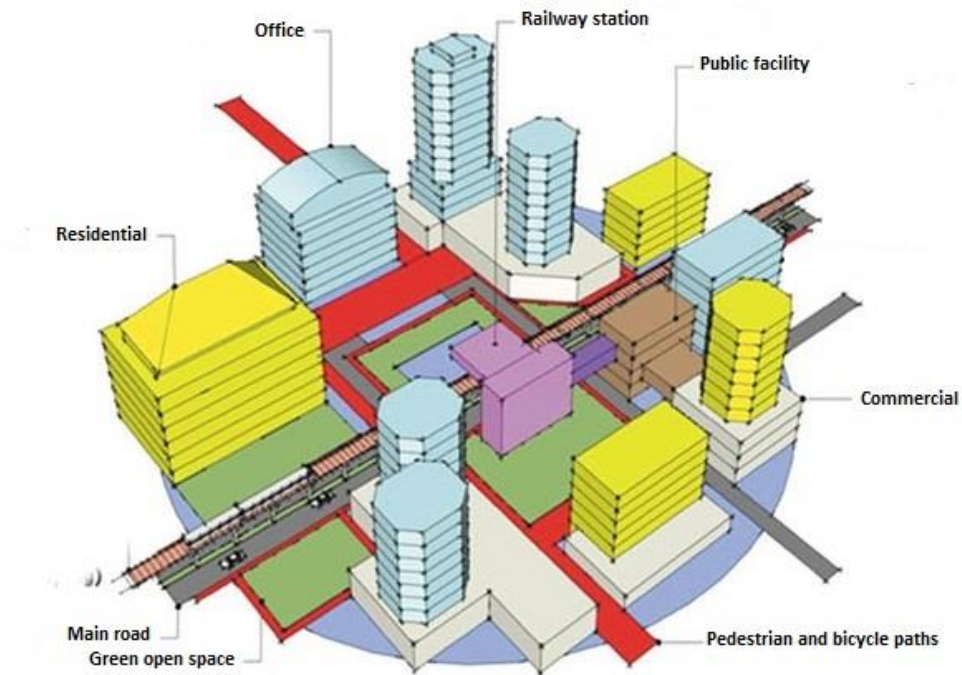


Figure 5.23 Urban design of reality dream look like Urban TOD in Depok

Urban TOD Depok station was developed along with commercial functions that have medium intensity, blind block, and medium-intensity residence in accordance with the character of the environment.

Table 5.8 Intervention for Urban TOD

	Maximum FAR	Cover area	Number of floors	Land use
Existing	1	50%	5 nd floor	commercial, residential
Intervention	4	60%	15 st floor	commercial, industry, residential

5.4.9.3. Suburban TOD

Bojonggede station is Suburban TOD located in the middle of a residential area and has public transportation trails with affordable distance by walking. Suburban TOD has a high-intensity residential environment with public facilities and green open spaces, providing easy access to passengers (Figure 5.24).

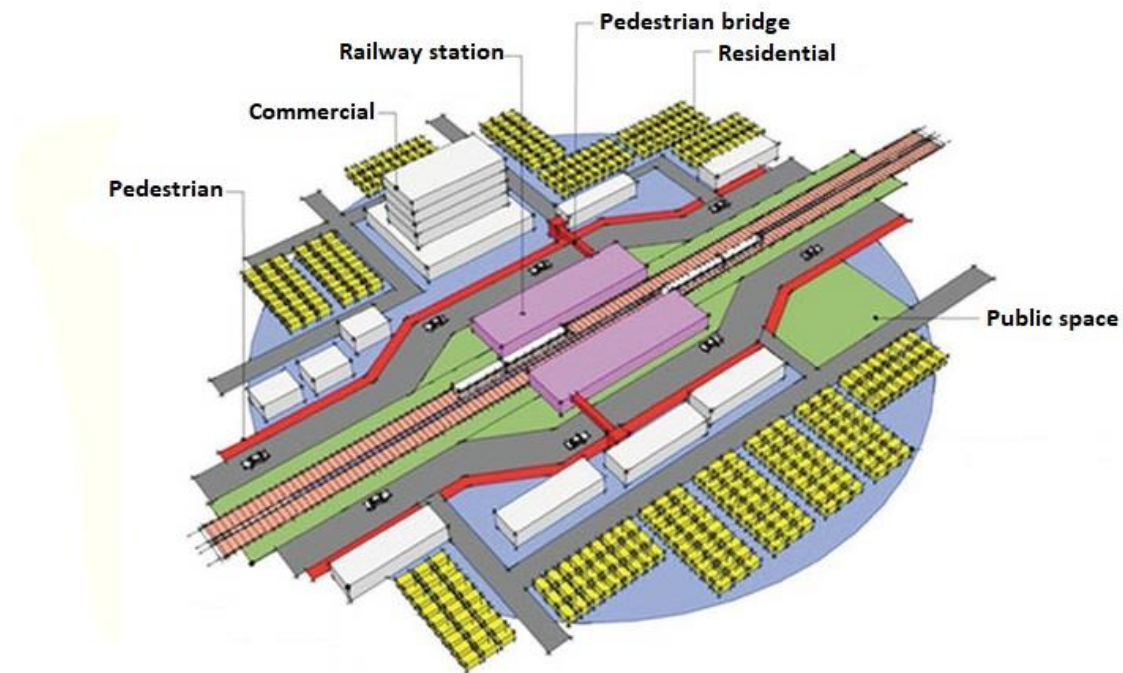


Figure 5.24 Urban design of reality dream look like Suburban TOD in Bojonggede

Bojonggede station design seeks to awaken the building's existence for economic revitalization and environmental improvement through the density of commuter traffic that uses it. The design of this TOD focuses on incorporating the principles of environmental justice into planning. The area has special characteristics due to its occupants are dominated by commuter settlers who working in downtown and away from

their settlements. But slowly the area around the station is built also a commercial area to serve the population but by creating a pedestrian-friendly environment.

Table 5.9 Intervention for Suburban TOD

	Maximum FAR	Cover area	Number of floors	Land use
Existing	1.2-2	40%	2 nd floor	residential
Intervention	4	50%	10 st floor	commercial, residential

5.5. Summary

Jakarta Metropolitan Region is the busiest region as the economic and government center of Indonesia. Various problems of urban transportation and sustainable development occurred in this region, especially congestion and urban sprawl. To overcome those problems, this Chapter carried out the development of TOD based on typology applied to the railway network. The method used is actual and potential TOD based spatial analysis to produce an integrated TOD system. The results showed that there were differences in typology from each TOD in urban, suburban and regional TOD, Therefore, it needed the different policy for each typology from stakeholders to guide the transport planning in a sustainable manner.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusion

The first review of TOD in this thesis cover of the method, criteria, and indicator showing that the method was widely used in the form of both quantitative and qualitative while the criterion and indicators derived from land use, transportation, and social economy. The second review of the strategic plan found that public transportation planning could be successful if it is supported by good spatial planning and provision of transportation facilities. It would facilitate passenger access from a place of origin to destination. The third review found that centralizing activities through integrated land use and transportation around the station could encourage the use of TOD and attract more passengers.

The determination of 10 indicators and 3 criteria for the evaluating of actual TOD. It found that urban areas have high TOD index. On the other hand, TOD-index in suburban areas was found to be low, it shows the need of improvement. The range of TOD index values of 54 stations in JMR can be concluded that a high index value of stations tends to be in the urban areas, and, vice-versa, the station with low index value located in the suburb.

There is spatial regularity of potential TOD in the study area. where area with high TOD index tend to concentrate in the middle of city, while area class with low TOD index tend to show spatial spread patterns. Central JMR has the pattern of potential TOD that belongs to highs cluster. The pattern of distribution in the territory of the region has a

strong relationship with the level of development in accordance with the selected research criteria.

Integrated TOD in JMR provide services for passengers as well as being a node of integration for public transportation. Thus, TOD planning can be developed based on its typology. The integration emphasizes the land use around the station with transport-based. Integrated TOD provides achieving travel destinations of passengers by eliminating waste of time, distance, pollution, energy, cost, and volume. Planning of integrated TOD in JMR requires several regulations and policies for implementation.

6.2. Scientific contribution

This section reflects in the findings and results of the study. It includes a summary of the main contributions.

First, this study provides rich literature reviews related to TOD from various cities in the world. As a result, this study contributed to an in-depth insight of practice as well as integration of TOD through land use and transportation as an alternative solution to solve urban transport issues.

The second major contribution of this study is the development of criteria-indicators, measured a composite TOD index (actual and potential) by using Analytical Hierarchy Process (AHP) and Geographical Information System (GIS). This study helps stakeholders to assessing TOD by quantifying and visualized the maps, in which useful for determining policies.

The third major contribution is related to land suitability assessment for the potential location of TOD, in conjunction with AHP and GIS to make an in-depth study

of the spatial planning. It designated this transitional area as a service center with varied functions and modal transfer shelters. It is expected to lead to multi-purpose of integrated urban development.

The fourth major contribution is related to the use of spatial statistical analysis to potential TOD model. This study developed statistically significant hot spots with the spatial autocorrelation analysis for identifying existence of spatial clusters and determined hot spot and outlier analysis for mapping spatial clusters. The use of the spatial autocorrelation method combined with AHP in the planning of potential areas of TOD has advantages because it would describe the high significance level and spatial clustering of hot spots among criteria to provide more accurate spatial analysis.

The fifth major contribution is related to developing the integrated model of TOD planning based on the urban planning. TOD (in the form of a model scenario) focusing on solving the integration problem of both land use and transportation for Jakarta Metropolitan Region (JMR). Therefore, the policy from stakeholders would greatly encourage reshaping transportation master plan in a more sustainable development.

6.3. Recommendations

Recommendation would follow the line of variation of further study for TOD models. Thus, one would forecast variety of TOD models in developing countries toward green TOD.

First, the policy of making land zoning of each sub-district on a more detailed scale, thus there should be comprehensive regulation on the land allocation to the developed area.

Second, conducive transport regulation needed for further development. For example, settlement and housing areas are located within walking distance, if they are in slightly distance, one would make sure and range of 500 meters to TOD bringing about efficient distance.

Third, the building permit regulation or policy in areas classified as hot spots to keep the TOD area around the station from disordered land use.

Fourth, when settlement is located farther distance, supporting public transport vehicles needed to fulfill the limitation of distance, elderly people need some help for farther location.

Fifth, surrounding TOD, the local government needs to implement green open space and park. Such as areas would attract activities for outdoor recreation for dweller around TOD.

6.4. Further research

This study has strived to elaborate and analyze the TOD relationship, between land use and transportation in order to support urban and transportation planning in metropolitan region. The following recommendations are suggested for future research:

First, considering the literature review of integrated land use and transport with TOD, further review on TOD research of comparing among developing countries due to cultural differences among further study cases would learning and richer perfective.

Second, further investigation of assessing actual TOD using accessibility approach with different variable and underlines to the movement of pedestrian or cycling from point of origin to destination.

Third, given the complexity of the land suitability assessment for potential TOD, further research extending the future scenario assessment with an innovative approach, concerning to spatial temporal growth. It needed comparison from last, recent and future conditions of land use and transportation for an in-depth-analysis.

Fourth, further inclusion of economical benefit indicator-criteria for potential TOD with spatial statistical analysis such as tax, land value, land rent, and more investigation for its effect to surrounding areas of stations regarding population groups, in accordance to income, gender, age, tribes, religion, and education.

Fifth, further research to determine policies for supporting the integrated land use and transportation with TOD in urban planning. The policies from government to manage new building and renovation, network systems services, access stations, and trade services sector.

Six, there is an endeavor to ‘retrofit’ with a decision-support system (DSS) modeling with a ‘what-if’ capability, which relates to the GIS-based MCE Analytics above, and the carrying capacity raster calculation feature in GIS layers (economic exploitation vs environmental protection) of the surrounding locations of the TODs.

Seven, the next study proposes TOD as the foundation to work with the Smart-City Movement and Urbanism, where smart-mobility will use Internet-of-Things (IoT), transportation sensors, automations, robotics, early warning systems for safety, security and disaster management. This will almost make sure to erase fossil-based fuel vehicles for the advent of full Electric Vehicle (EV) environment.

APPENDIX

Appendix A

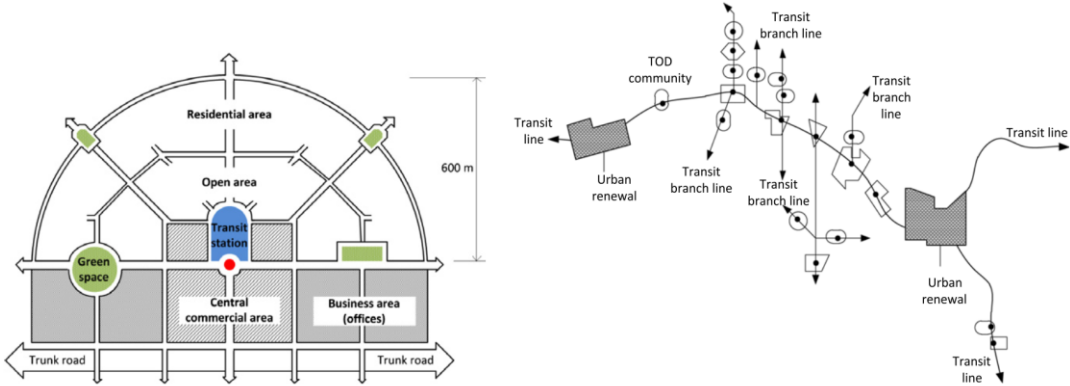
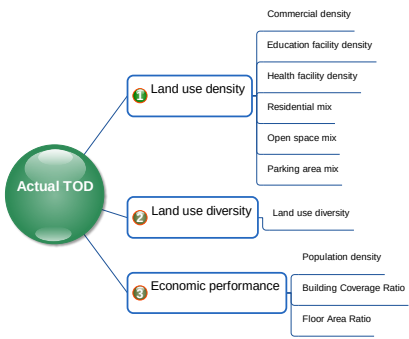
Experts List Name

No	Name	Nationality	Institution
1	Professor Raldi Hendro Koestoer	Indonesia	University of Indonesia
2	Professor Emirhadi Suganda	Indonesia	University of Indonesia
3	DR. Hayati Sari Hasibuan	Indonesia	University of Indonesia
4	DR. Bambang Mahendra	Indonesia	University of Indonesia
5	DR. Adi Wibowo	Indonesia	University of Indonesia
6	DR. Ammar A. Naji	KSA	King Abdulaziz University
7	DR. Emad Qurnfulah	KSA	King Abdulaziz University
8	DR. Mansour Rifaat M. Helmi	KSA	King Abdulaziz University
9	DR. Mohamed Mahmud H. Maatouk	Egypt	King Abdulaziz University
10	Professor Abdalnasser A.A. Mohamed	Egypt	King Abdulaziz University
11	Professor Wahid Zakaria I. Salem	Egypt	King Abdulaziz University
12	DR. Abdulhafeez Awad Hafazalla	Sudan	King Abdulaziz University

Appendix B

Panel survey from expert

Pairwise comparison AHP priorities for evaluating criteria weight of actual TOD

Herika Muhamad Taki	PhD Candidate in Urban and Regional Planning Department, King Abdulaziz University KSA
Research title:	
Evaluating actual TOD index at station level using GIS and AHP-multicriteria analysis in Jakarta Metropolitan Region	
Transit-Oriented Development (TOD) is the transit concept for walkable located within the main transit stations, high-density development, mostly with a combination of employment, commercial and residential planned for pedestrians without the car dependency (Parker 2002).	
 Fig. 3. A sketch map of a TOD community and a TOD city. Source: Jiang and Han (2009).	
Description of criteria	
	
The criteria based on major concept of TOD consisting of land use Density (development), Diversity (mixing land uses) and Design of Economic Performance (pedestrian-friendly) (Cervero et al. 2002; Singh et al. 2014).	

Weights calculation using analytic hierarchy process (AHP)

AHP is done by running the paired comparisons of some expert in their field, the expert provides expertise in accordance with the assessment against criteria and indicators are proposed.

Table 2
Saaty's importance scale

Intensity of importance	Definition	Explanation
1	Parameters are of equal importance	Two parameters contribute equally to the objective
3	Parameter <i>I</i> is of more importance compared to parameter <i>J</i>	Experience and judgement strongly favour <i>I</i> over <i>J</i>
5	Essential or strong importance of <i>I</i> compared to <i>J</i>	Experience and judgement strongly favour <i>I</i> over <i>J</i>
7	Very strong or demonstrated importance	Criteria <i>I</i> is very strongly favoured over <i>J</i> and its dominance is demonstrated in practice
9	Absolute importance	The evidence favouring <i>I</i> over <i>J</i> to the highest possible order of affirmation
2,4,6,8	Intermediate values between two adjacent judgement	Judgement is not precise enough to assign values of 1,3,5,7 and 9 (compromise is needed)

For example

Pairwise comparison matrix of agricultural land use suitability map.

Criteria	GSG	LUCC	LUCS	Depth	Slope	Aspect	Elevation	Erosion	OSP	Weights
GSG	1	2	2	3	4	6	8	9	9	0.278
LUCC	1/2	1	2	3	4	6	7	9	9	0.233
LUCS	1/2	1/2	1	2	3	4	5	7	8	0.162
Depth	1/3	1/3	1/2	1	2	3	5	6	7	0.116
Slope	1/4	1/4	1/3	1/2	1	3	5	6	7	0.096
Aspect	1/6	1/6	1/4	1/3	1/3	1	1	2	3	0.040
Elevation	1/8	1/7	1/5	1/5	1/5	1	1	1	3	0.032
Erosion	1/9	1/9	1/7	1/6	1/6	1/2	1	1	2	0.025
OSP	1/9	1/9	1/8	1/7	1/7	1/3	1/3	1/2	1	0.018

GSG = great soil group, LUCC = land use capability class, LUCS = land use capability sub-class, OSP = other soil properties

reciprocal area

ranking area

equal area

from a figure above, the value of GSG is twice more importance than LUCC and twice higher than LUCS, 3 times compare than Depth and so on. Conversely, LUCC is 1/2 less importance than GSG, LUCS is 1/2 lower than GSG, Depth is 1/3 lower than GSG and so on.

Expert Name:
Title:
Major Specialization:
Institution Name:

Please give the ranking (1-9) between criteria/indicator *I* (columns) compared to criteria/indicator *J* (rows) for actual TOD based on Saaty's importance scale

Criteria

Criteria	Land use density	Land use diversity	Economic performance
Land use density	1		
Land use diversity		1	
Economic performance			1

Indicator of Land use density

Indicator	Commercial ^a	School ^a	Hospital ^a	Residential ^b	Open space ^b	Parking area ^b
Commercial ^a	1					
School ^a		1				
Hospital ^a			1			
Residential ^b				1		
Open space ^b					1	
Parking area ^b						1

^a density, ^b mixed-ness

Indicator of Economic performance

Indicator	Population ^a	Building Coverage Ratio (BCR) ^d	Floor Area Ratio (FAR) ^d
Population ^a	1		
Building Coverage Ratio (BCR) ^d		1	
Floor Area Ratio (FAR) ^d			1

^a density, ^d ratio

Appendix C

Panel survey from expert

Pairwise comparison AHP priorities for criteria of planning potential TOD

Herika Muhamad Taki

PhD Candidate in Urban and Regional Planning Department, King Abdulaziz University KSA

Research title:

Spatial planning for potential TOD using suitability analysis at metropolitan-region scale

Main criteria and sub criteria used in the potential TOD suitability analysis

The measurement of the TOD index using GIS techniques can be done by main criteria and sub criteria as figure and table below.

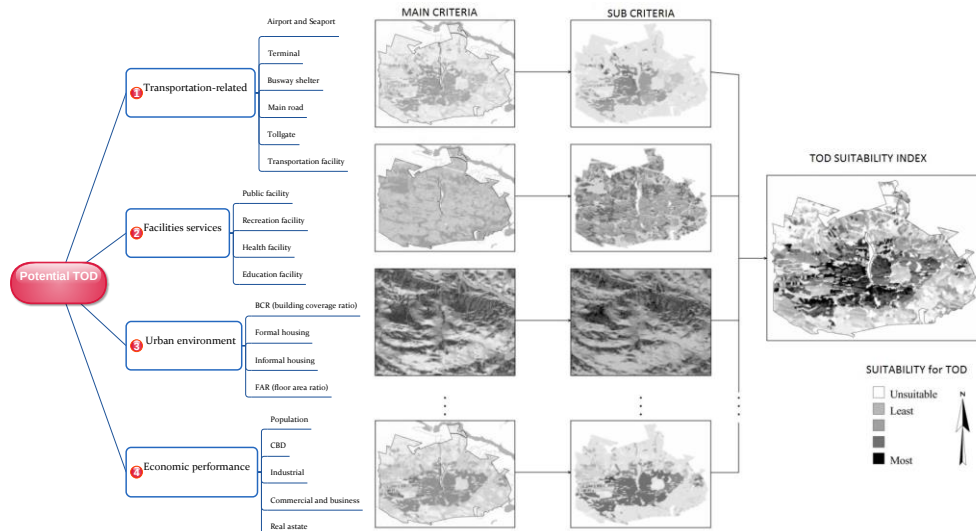


Figure 1. Hierarchy and the process of combining potential TOD criteria to suitability index

Expert Name:
Title:
Major Specialization:
Institution Name:

Main Criteria

<i>Main criteria</i>	Transportation-related	Facilities services	Urban environment	Economic performance
Transportation-related	1			
Facilities services		1		
Urban environment			1	
Economic performance				1

Sub criteria 1

Transportation-related

Sub criteria	Airport and Seaport ^a	Terminal ^a	Busway shelter ^a	Main road ^a	Tollgate ^a	Transportation facility ^a
Airport and Seaport ^a	1					
Terminal ^a		1				
Busway shelter ^a			1			
Main road ^a				1		
Tollgate ^a					1	
Transportation facility ^a						1

^a distance from

Sub criteria 2

Facilities services

Sub criteria	Education and public facility ^b	Recreation facility ^b	Hospital ^c	School ^c
Education and public facility ^b	1			
Recreation facility ^b		1		
Hospital ^c			1	
School ^c				1

^b ratio, ^c density

Sub criteria 3

Urban environment

Sub criteria	BCR ^d	Formal housing ^b	Informal housing ^b	FAR ^e
BCR (building coverage ratio) ^d	1			
Formal housing ^b		1		
Informal housing ^b			1	
FAR (floor area ratio) ^e				1

^d percentage, ^b ratio, ^e FAR

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Biography



Herika Muhamad Taki was born on 06 May 1982 in Jakarta, Indonesia. In 2001, He joined Department of Geography, Indonesia University, Depok, Indonesia, where he received his bachelor's degree in Geography Science. In 2012, He earned his MSc degree with specialization in Transportation and Telecommunication Geography, in Department of Geography, Faculty of Mathematic and Natural Science, Indonesia University, Depok, Indonesia. In 2015 He was awarded PhD scholarship from King Abdulaziz University, Saudi Arabia. He joined Department of Urban and Regional Planning, Faculty of Environmental Design, King Abdulaziz University, Saudi Arabia. At the beginning of January 2015, He started his PhD at the Department of Urban and Regional Planning, King Abdulaziz University, Saudi Arabia. His research interests include Geographical Information Systems, Land Use Modelling, and Public Transport Planning. During his PhD, He published 10 publications from his thesis, it contains journal papers, book chapter, and conference proceedings. This thesis is the output of his PhD research.

Citations



Herika Muhamad Taki

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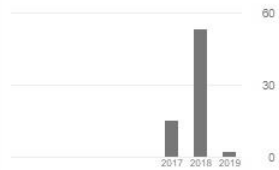
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SUMMARY IN ARABIC

نموذج مكاني متكامل للتطوير الموجه للنقل العام لتوجيه تخطيط النقل والمرور بجاكرتا

اعداد

هريكا محمد تاكي

الملخص

تعاني مدن العالم الثالث من ظاهرة التحضر وما يصاحبها من زيادة كبيرة في أعداد السكان والكثافة السكانية بتلك المدن وما يترتب عليها من زيادة مشاكل النقل والمرور مثل الاختناقات المرورية وتأخير زمن الرحلات وزيادة استهلاك الوقود وما ينتج من المفاهيم الحديثة في التخطيط العمراني التي (TOD) عنه من زيادة تلوث الهواء. ويعتبر مفهوم التطوير الموجه للنقل العام يمكنها التغلب أو التخفيف من حدة هذه المشكلات. ومفهوم التطوير الموجه للنقل العام يدمج كلا من استخدامات الأراضي والنقل والمرور في نظام واحد وذلك لضمان تحقيق تنمية أكثر استدامة، حيث يعمل على تركيز استخدامات الأراضي المختلفة (تجاري- مكتبي- حكومي- ترفيهي- ... الخ) في نطاق حضري حول محطة المترو مع توفير المناطق الخضراء وممرات المشاة لتشجيع السكان على المشي واستخدام النقل العام والتقليل من استخدام السيارة الخاصة وبالتالي التخفيف من الاختناقات المرورية وتلوث الهواء بالمدن الكبرى.

ومنطقة الدراسة بهذا البحث هي مدينة جاكارتا بإندونيسيا والتي تعتبر المركز الاقتصادي والإداري بإندونيسيا ويدخل في إطار منطقة الدراسة إقليم مدينة جاكارتا. وتعاني المدينة من العديد من مشاكل النقل والمرور والنمو السكاني والعمراني المتسارع. وهناك قصور كبير في منظومة محطات المترو الحالية عن تلبية احتياجات سكان المدينة مما يجعل من الضروري العمل على تطوير هذه المنظومة بحيث تعتمد على نموذج مكاني يعتمد بدوره على مفهوم التطوير الموجه للنقل العام.

الهدف الرئيسي في هذا البحث هو تطوير نموذج مكاني متكامل للتطوير الموجه للنقل العام لتوجيه تخطيط النقل والمرور بجاكرتا، حيث تمت عمل مراجعة شاملة للعديد من الأدبيات التي تتناول المفهوم وطرق القياس والتطبيقات المختلفة للتطوير الموجه للنقل العام ثم تم عمل النموذج المكاني من خلال خطوتين أساسيتين الأولى عمل تقييم للوضع الراهن لمحطات المترو ونظم (AHP) بجاكرتا وعددها 54 محطة وذلك من حيث كفاءتها وملائمتها للتطوير الموجه للنقل العام وذلك باستخدام تقنيات المعلومات الجغرافية.

ثم تأتي الخطوة الثانية والتي من خلالها تم عمل تحليلات إحصائية مكانية لتحديد الملائمة المكانية وأفضل المواقع بجاكرتا للتطوير الموجه للنقل العام وذلك باستخدام نظم المعلومات الجغرافية وقد أظهرت النتائج العديد من نقاط القوة داخل الحيز

الحضري لمدينة جاكرتا نفسها وأيضاً بعض نقاط الضعف في ضواحي المدينة، وقد أمكن عمل ثلاثة تصنيفات لمحطات المترو بجاكرتا من حيث ملائمتها للتطوير الموجه للنقل العام واقتراح استعمالات الأراضي والضوابط العمرانية المناسبة والذي يعتبر توضيحاً لكيفية تطبيق النموذج المكاني والاستفادة منه في توجيه تخطيط النقل والمرور بجاكرتا سواء على المستوى التخطيطي الاستراتيجي أو على المستوى التفصيلي. ولذلك توفر هذه الدراسة مساراً جيداً من النظرية الى التطبيق للمهتمين بمفهوم التطوير الموجه للنقل العام لعلاج أو تخفيف مشكلات المدن الكبرى من خلال تخطيط عمراني أكثر استدامة.





نموذج مكاني متكامل للتطوير الموجه للنقل العام لتوجيه تخطيط النقل والمرور بجاكرتا

إعداد الطالب

هريكا محمد تاكي

بحث مقدم لنيل درجة دكتوراه الفلسفة في التخطيط الحضري والإقليمي

إشراف

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جامعة الملك عبدالعزيز

جده-المملكة العربية السعودية

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