Using GIS to integrate the analysis of land-use, transportation, and the environment for managing urban growth based on transit oriented development in the metropolitan of Jabodetabek, Indonesia

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Abstract. There is an interaction between land use, transportation, and environment in improving and managing urban quality. One of the concepts to integrate those three aspects is Transit Oriented Development (TOD). It is a concept for managing urban growth in transit corridors which have characteristics of mixed land use, compact, walkability, and development focused around public transit area. This research aims at utilizing GIS to organize, sort, and analyze spatial data including aspects of land use, transportation, and environment. Jabodetabek is a strategic metropolitan area in Indonesia, and consists of DKI Jakarta and the neighboring Bodetabek cities, with more than 27 million population in 2010. Approximately 1,105,000 people are entering Jakarta every workday from the neighboring Bodetabek region. The surge in the number of passenger cars and motorcycles is astonishing. In contrast, the usage of public transport has declined deeply. Public transport infrastructure development without the integration of TOD may not attain the objective of reducing car dependency. This paper discusses the study which was carried out to identify the applicability of TOD principles in Jabodetabek using GIS as a tool to analysis and create model.

1. Introduction
An urban sustainability demands a balance among economic, social, and environmental concerns. The development of urban sustainability involves several aspects, including population (socio-ecology), land use and urban structure, and mobility behaviour (transportation) [1]. The dynamics of urban is reflected the interaction between human and environment in spatial and temporal context. Urban structure strategies alone or sectoral strategies, such as transportation infrastructure policies, cannot be relied upon for achieving sustainability. Instead, the integrated land use, transportation, and environmental strategies are required.

The urbanization is a dynamic system with the all changes in human, habitats, land uses, resources, infrastructure, and sociocultural linked each other. This urban management cannot be managed solely with the fragmented perspective. This fragmented and unigated planning has led the sprawl in the metropolitan structures in which the spread of development across the landscape far beyond the city area and causing congestion problems and reducing urban environmental quality. This paper examines alternative sustainable concept for green and sustainable development in Jabodetabek, a greatest metropolitan area in Indonesia. The alternative concept of TOD is examined in this paper. Transit oriented development (TOD) incorporates land use and transportation management, including the environmental impact solution, since TOD is an approach of mixed land

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use designing with providing proper accessibility to transit and non-motorized transportation and encouraging transit ridership [2]. This paper focuses on the applying of TOD concept with the connections between transit and urbanization at the regional scale, urban scale, rather than the local scale.

2. Data and Method

2.1. Profile of the study area

Metropolitan Jakarta, the capital of the Republic of Indonesia, expanded from 180 km\(^2\) in 1960 to a fully urbanized metropolis in the 1970s. Today, as a mega city, Jakarta’s nucleus area has spatially and economically expanded beyond its original fringes. Jakarta has increasingly been integrated with eight other proximate cities: Kota Depok, Kota Bogor, Kota Bekasi, Kota Tangerang, Kota Tangerang Selatan, Kabupaten Bogor, Kabupaten Bekasi, and Kabupaten Tangerang. Now, Jabodetabek encompasses a total land of 6,580 km\(^2\), with Jakarta area is 656 km\(^2\) and 9.6 million habitats.

A dramatic increase in the growth of private vehicles has been observed during 2000-2010 in Jabodetabek. The number of registered passenger cars in Jakarta was roughly 2.0 million in 2010 (double the 2000 number) and motorcycles were 6.8 million (four times of 2000). The usage of public transport has declined deeply from 38.3% in 2002 to 12.9% in 2010. Mode share of train has a similar figure with the buses, has declined during this period, with the passenger only 3% of total mode share in Jabodetabek. The capacities of railway in 2010 are such followings: (1) west line, Tangerang corridor has 20,000 daily passengers, (2) west line, Serpong corridor has 55,000 daily passengers, (3) south line, Bogor corridor has 119,000 daily passengers, and (4) east line, Bekasi corridor, has 64,000 daily passengers. Totally for three lines has capacity of 258,000 daily passengers.

2.2. Data

The scope of primary data collection began by identifying several transit precincts for analysis. Those transit locations were referred to the railway network in Jabodetabek, including those inside Jakarta and in sub-urban areas. There are three Jabodetabek railways: south line, east line, and west line, with a total length of 166 kms approximately. The transits observed for analysis are selected from several transits in Jakarta and suburbs. The land use observed is the area within a radius of 1 km from the

![Figure 1. The study area of Jabodetabek Metropolitan area, Indonesia.](image1)

![Figure 2. The Distribution of population number in Jabodetabek Metropolitan area.](image2)
2.3. Method
This study classified lands based on its suitability to support TODs within the Jabodetabek Metropolitan area. GIS was used to integrate three layers of land use, transportation, and environment data. GIS was also used to investigate the pattern of urban structure growth, the conversion of land use, and the density changes in some areas focused around transit area using the historic data of land uses, from 2000 to 2010.

The final model came from the findings from the results of GIS analysis into the separate sub-model then creating the one-integrated model. In this study, the concept of TOD has been analyzed and measured in Jabodetabek area, based on following factors: (1) the mixed land use factor between home, jobs, and services and residential density, (2) the accessibility of the transportation network, and (3) the proportion of green open space.

3. Result and Analysis

3.1. Land use analysis of TOD
An ideal TOD includes compact development and mixed land uses while still provided green and natural space. The study finds the difference characteristics between transits inside Jakarta with the transit in sub-urban areas. An analysis of land use by GIS with the scale of 1:15,000 depicts the amount and variety for different type of land uses (see figure 3-6). Table 1 and table 2 show the proportion of land uses in the transit precincts in Jakarta and in sub-urban areas.

![Figure 3](image1.png)  ![Figure 4](image2.png)

**Figure 3.** Land uses within a radius 1 km of Dukuh Atas rail station in Jakarta, with domination of work places.

**Figure 4.** Land uses within a radius of 1 km of Harmoni rail station in Jakarta, with domination of work places.

There are 10 selected transits observed by GIS tool to get the land uses data. The study finds the characteristic of land uses in transit precincts in Jakarta were dominated by work places and commercial facilities. Land use of Dukuh Atas transit rail precinct is 60% work places (see figure 3) and Harmoni Transit Rail precinct also has 66% of land use as work places (see figure 4). Several transit precincts in Jakarta have characteristics of low mixed land uses, since the land uses were dominated by either workplaces (4 transit areas) or residential area (4 transit areas). Only 2 of 10 that have a good ratio of mixed land uses, and potential become a TOD. The proportion of land uses around transits in Jakarta is shown by table1.
Meanwhile, the characteristics of transit precincts in suburbs were mostly dominated by residential. There are eight transit precincts that are studied in suburbs, distributed in southern, western, and eastern line of Bodetabek railway corridor. Almost all of the transit precincts have more than 50% residential land use (see figure 5-6).

| Land Use         | Minimum (%) | Maximum (%) |
|------------------|-------------|-------------|
| Residential      | 18.66       | 68.72       |
| Work places      | 10.59       | 66.05       |
| Social Facilities| 5.09        | 14.80       |
| Green open space | 6.22        | 21.95       |

**Table 1.** Proportion of land uses around Transit station in Jakarta.

The residential areas within transit are usually the high density residential, some of residential are the developer residential. Only in one transit observed that the land use of work places reached 30%. For the green open space availability in the transit of suburbs, the analysis finds the share of this land use is low, the maximum share is only less than 20% (see table 2).
3.2. Interlinkage of transportation services of TODs

Master Plan of Jabodetabek railway infrastructure described some of the important planning of railway infrastructure and services development and improvement, such as followings: planning of mass rapid transit (MRT) development, and improvement the existing Jabodetabek commuter line, and development of two line monorel.

The transit areas included in the Master Plan of Jabodetabek infrastructure are: (1) Manggarai transit area planned as the centre of business activities, (2) Dukuh Atas transit area planned as interface of Jabodetabek Commuter rail west line and green line MRT, (3) Kampung Bandan transit area planned as residential and commercial area integrated with MRT and Jabodetabek Commuter line, (4) Senen planned as interface of Jabodetabek Commuter Line and east-west MRT, (5) Duri Pulo transit area planned as interface of Jabodetabek Commuter west line and east-west MRT, (6) Blok M planned as interface south-north MRT and east-west MRT and connected with existing bus terminal.

For Jabodetabek circular line would be improved with vertical elevating to avoid mixed with road base transportation. Also planned to improve the existing stations and add some new stations. The total length of Jabodetabek railway will be increased into 239 kms in 2020, and 354 kms in 2030. Public transportation services coverage is planned to cover 36.5% population or about 12.2 million people in 2030. The ratio of total railway length (km) to the Jabodetabek area (km square), called as the rate of railway accessibility, is very small, less than 0.02 km/km square. The railway mobility, the ratio of total length of railway per 1000 people, is around 0.005 km/1000 people.

All of the transits in Jabodetabek have a poor walkways accessibility into the work places or commercial areas or to residential areas. The existing design of residential and work places are not concentrating and radiating from the transit station. Therefore, the circulation of the walkways to the transit station from the origins and to the destinations are disorders. The primary survey to the commuters who live within a radius of 1 km from transit station figured that they took more than 10 minutes walking to the transit station; even they should take other modes such as motor-cycle.

4. Discussions and Conclusion

Rapid population and economic growth and increase in personal income have led to a sharp growth in the demand for transportation. The urban growth in Jabodetabek has triggered the increasing number of commuters from suburbs to city centre of Jakarta. Therefore, there is a need to manage the growth of land use and transportation for the better environment and urban sustainability.

The purpose of this study was to create models to identify areas within Jabodetabek Metropolitan area suitable for TODs for managing the urban growth. The final model was a compilation of the analysis of three sub-models that each has its own characteristics but in spatial context were interlinked each other. Using GIS in analysis those sub-systems this research found the areas suitable for future development with the TOD concept. This GIS can present relevant environmental and planning considerations in a geographic and visual form and convey information in a more efficient manner. This spatial approach also useful in monitoring and evaluating the results, benefits and constraints of managing the urban growth in Jabodetabek area with TOD principles.

The transits located in metropolitan city centre, Jakarta, would be an ideal for infill TOD because the transits are major civic centre with the several government offices, institutions, and work places. The TODs in the city centre should be designed with the good accessibility to the work places and

| Table 2. Proportion of Land Use around Transit station in Bodetabek suburbs. |
|---------------------------------------------------------------|
| Residential | Minimum (%) | Maximum (%) |
| Work places | 50.76 | 78.50 |
| Social Facilities | 2.68 | 31.14 |
| Green open space | 0.77 | 11.41 |
| Residential | 5.15 | 19.51 |

8th International Symposium of the Digital Earth (ISDE8)  IOP Publishing
IOP Conf. Series: Earth and Environmental Science 18 (2014) 012177 doi:10.1088/1755-1315/18/1/012177
commercial centers with the proper green open space area for sequestering the carbon and pollutants from transportation activities.

With TOD concept, an integrated plan can be prepared with incorporating urban growth management, landscape, traffic and transportation schemes, safe pedestrian walkways, and the functional green open space for better urban environment quality. TOD provide some benefits such as: congestion reduction, with shifting from the auto-dependent transportation and auto-oriented cities into the increasing transit ridership and transit-oriented cities, road cost savings, improved safety, improved mobility options for non-motorized including walking and cycling, improved public health with more walking and cycling, energy conservation and emission reductions.

Smart growth is an efficient and sustainable way of development to provide people with proper housing, congestion free roads, and employment choices by focusing future growth closer to existing transits. This could be achieve only by Transit Oriented Development throughout the main city of metropolitan and applying it in other suburbs within the Metropolitan, the aim of sustainable development can be achieved. TOD is one of the most sustainable solutions and thus there must be more emphasizing on controlling growth of the urban by TOD rather than investing money in expressways. This is defined as transit oriented metropolises that invested in rail systems to guide urban growth for purposes of achieving larger societal objectives, such as preserving open space and producing affordable housing in rail-served communities [3]. By promoting mixed land-use, proper public transport services and achieving TOD, the urban can be developed sustainably as well as can easily cater the needs of the present and provide direction for the future of Jabodetabek Metropolitan.

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