Planning TOD with land use and transport integration: a review

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Abstract
Transit Oriented Development (TOD) implementation in urban development is globally adopted by many countries in the world in a rapid manner. However, the city and regional acute problems is still propagating. An in-depth study to examine this problem is required. Thus, this paper review various study related to the integration of land use and transport with TOD. The subject of the paper will be described as follow: Method, criteria and indicators of TOD’S research, Reviewing the strategic plan and the public transport plan in the worldwide, and Cross-continent comparison of integration planning. In conclusion, practice and integration of TOD through land use and transportation is an alternative solution in acquiring the objective of the master plan and to solve urban issues such as urban congestion, reduce travel time, and car dependency.

Keywords: Planning, Transit Oriented Development (TOD), Transport, Land use, Integration

1. Introduction
Transit-oriented development (TOD) is a notion-oriented city-region development to provide maximum access to passengers (Curtis & Scheurer, 2010; Hasibuan & Soemardi, 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 of the compact and the mixture to facilitate become a base for the development of public transport transit area-based (Cervero & Dai 2014).

TOD, 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 the many passengers who switch from private cars to public vehicles and reduced congestion (Boschmann & Brady 2013), and land use had inflicted because of area around the station settings appropriate allocation that is compact and mixed (Ratner & Goetz 2013).

1.1 Urban Planning and TOD
The concept of TOD is very closely 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 & 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.

A TOD generally have an embodiment in the form of the commercial core with the distance reached by residents, a grid-shaped road network well connected, the width of the road that are not too large with parking on a side street as a buffer for the pedestrian, a back-lot alley, land use mixed-residential use, with different types of density (Dorsey & 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).
1.2 Integration land use and transport using TOD concept

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 & Levinson 2009). This concept is also a regional design 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 sufficient for the pedestrian walkable environment) (Wey & 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).

1.3 The research problem

Urban transportation activities have a significant effect on the increase of traffic congestion and air pollution. There are solutions that have been implemented, but still limited to practical approaches. Furthermore, the problems of urban transport need to be reviewed through a systemic approach, namely, the establishment of the urban transport system in a macro integrates 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 integration system concepts. One of them is the concept of Transit Oriented Development (TOD).

1.4 The objectives of research

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

2. The methods

This paper provides evidence of integration between transport and land use with TOD from literature by formulating a long list indicators of the district-based TOD through study literature regarding TOD practices in cities in the world. The formulation of the protracted lists is done by a qualitative descriptive analysis technique through the theoretic approach to the concept of TOD. The formulation of the protracted lists, which is 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 area and transportation. Formulation of criteria-based TOD area is obtained using descriptive method and comparative analysis between existed conditions of the area with TOD indicator that has been deduced from the study of literature.

3. Result and discussion

3.1 Planning and assessment of TOD research in the last 5 years cover methods, criteria and indicators.

Efforts to develop a TOD research has been discussed in some study and continue to grow in accordance with developments in the public transport sector. This section discuss some of the studies (See Table 1).

A study by Atkinson-Palombo & Kuby (2011) about TOD discusses TOD typologies, several stations classified based on the type of overlay zoning, the method used was factor analysis and cluster analysis with the result that is ranking from low to high advance TOD each station, although data based on multi-criteria but in separate discussions and after that created relationship between LRT and TOD.

Prasertsunpakij & Nitiwattanaporn (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 values. Data collection was obtained from questionnaire with approximately 600 respondents.

Binglei & Chuan (2013) measured the TOD mode analysis with DEA (data envelopment analysis) 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 SMCA (spatial multi-criteria analysis) 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 & 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 topology 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 multicriteria analysis using ArcGIS and ILWISS software to produce TOD score map.

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

| Table 1. Method, criteria and indicators of TOD research |
|-----------------------------------------------|
| study/paper | Method | criteria | indicator | measurement/description |
| (ATKINSON-PALOMBSO & KUTN 2016) | Factor analysis and cluster analysis | Social and demographic characteristics | Number of jobs | Population |
| | overlay zoning | | | Pet of people with Bachelor’s degree |
| | | | | Household income |
| | | | | Pet of having university occupied |
| | Percentage of land use in each station area (%) | Transportations-related characteristics | Park-and-Ride | Airport |
| | | | | Terminal |
| (Presernet & Hirokinnan 2002) | Factor analysis and reliability test. Indicator assessment of metro accessibility | Proximal (Y) | Safety | Social usefulness |
| | | | Trust | Comfort |
| | Temporal (Y2) | Activity period | Trip purpose | Function |
| | | | Time period of target activities | The characteristic of trip purposes |
| | | | | The composition of duration preference of metro trip e.g. trips on during, on-peak, off-peak |
| | | Affordability (Y3) | Income Occupancy | Personal income per month (THB per month) |
| | | | Occupation | Occupation of respondents |
| | Basic need and market-based (Y4) | Basic need | Market-based | The calculation of average connectivity and average integration by space syntax techniques |
| | | | | Mixed use |
| | | Comportivity and mixed use (Y3) | Potential connectivity | Accessibility of metro services |
| | | | Mixed use | Percentage of weighted attractiveness summation of ability design (built-environment around stations) adapted to optimize |
| | | | | attractive for metro services |
| | Design attractiveness (Y4) | Attractiveness of metro | Accessibility | The extent of attitude to which respondents think that they receive equal benefit from services |
| | | | Services | 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 |
| | Equity (Y5) | Equality to access opportunity to access | Total time (min) | The distance of activity locations from stations (km) |
| | Time and activity oblation (Y6) | Time obtaining | Accessibility | Percentage of residential, commercial, employment and other activities near the station within a 500 meter radius |
| | | | Activity location | Level of criteria related to spatial knowledge and settlement, travel experience, paths and behavior to reducing spread |
| | Ultra environment/ compact (Y6) | Compact | Rethinking spread | Percentage of residential, commercial, employment and other activities near the station within a 500 meter radius |
| Level of density | Residential density | 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 congregate. |
| Level of mixed use | Mixed use | Higher mixedness of land uses (e.g., residential and work) encourages higher degree of walk and cycle for work trips |
| Level of economic development | Number of business establishments | The higher number of business establishments represents a higher level of economic development and lower road levels |

**Urban rail transit**

- Conveniency path from home to transit station in TOD community
- Efficient transfer between rail and transit
- No waste of public transport resources and passengers should not exceed the capacity of transit station
- Encourage public transit ridership
- Reduce emissions from cars to protect the environment
- Reduce unnecessary trips to control the total traffic demand

- Average travel time (min)
- Utilization rate of the transit station capacity (%)
- Split ratio of bus trips (%)
- Vehicle kilometers travelled per capita (km per capita)
- Trip distance per capita (km per person)

**Land use**

- Make full use of land resources to prevent low density sprawl
- Employment-Housing balance
- High density development
- Comfortable environment for walking and using bicycle
- Mixed land use incorporating different land use functions

- Population density (people per square kilometer)
- Employment-housing ratio (%)
- FAR (Floor area ratio)
- Non-residential land use area ratio (%)

**Density**

- Employment density: the number of jobs located within a unit area of employment
- Residential density: the number of residential units located within a unit area of residential land use (e.g. units/hectare) within the buffer of each CBD

**Design**

- Intersection density: the number of sides or more ways of intersections located within a unit area of the buffer for each CBD (e.g., number/hectare)
- cul-de-sac density: the number of dead ends located within a unit area of the buffer (e.g., number/hectare)

**Regression analysis**

- Public transport connectivity
-必ず近い地域を公開
- Ease of walking to places
- Closest to public transport
- Closest to jobs
- Closest to schools
- Closest to work
- Access to freeway or main roads %

**Density**

- Population density (people / sqkm)
- Commercial density (number of commercial enterprises / sqkm)

**Land use diversity**

- Land use diversity is a vital tool to create a vibrant and lively place out of a node

**Walkability and Cyclability**

- Number of Cycling Residential land use with other land uses
- Total length of walking/cycling paths
- Intersections density
- Impedance Pedestrian catchment area (IPCA)

**Economic development**

- Number of business establishments / sqkm

**Capacity utilization transit**

- Passenger load at peak hours
- Passenger load at off-peak hours

**User-friendliness of transit system**

- Safety of passengers at the transit stop
- Basic amenities at the station Presence of Information display systems

**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 the station

**Packing supply at the station**

- Packing supply-demand for cars/four wheelers
- Packing supply-demand for cycles

**Nearest and correlation node-place model**

- The place index: Structural land use
- The node index: Structural transport system

**References**

- Singhal S. (2016)
- Gupta & Sartori (2014)
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 & 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.

3.2 The strategic plan and the public transport plan worldwide.

Some of the strategy plan and public transport plan that implement TOD in transit areas in the world is a lesson that is applicable taken in real life, in the form of policies and actual implementation of the strategy as well as the contributing factors, in the form of the circulation which also passing the urban area (See Table 2).

Dorsey & Mulder (2013) describe a strategic plan and public transport in Ogden, Utah, USA. The strategic plan aim is to balance three things that are important in the development of the city, namely private aspects, society and Government.
Policy integration between land use and transport on the view of regional planning implementation emphasize in supporting the activities near transit corridors to encourage the use of urban transport.

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

**Fig. 2. Scales of TOD. Source (Feudo, 2014).**

**Fig. 3. Spatial distribution of CCD clusters in Brisbane. Source: (Kamruzzaman & Baker 2014).**

**Table 2. The strategic plan and the public transport plan 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 private, government, and community | Developing better bike routes, signage, and other amenities to make the city more pedestrians oriented |
| 2  | (Feudo 2014) | North-Pas-de-Calais, France | 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. |
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 urban strategy plan of Sejong City, South Korea, focuses 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).

3.3 Cross-continent comparison of the transport and land use integration with TOD

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 different characteristics in applying TOD. This section explained the successful implementation of TOD with combines land use and transport (See Table 3).

USA is an excellent model of TOD application by the case of New York City (Loo et al. 2010) and San Jose (Mathur & Ferrell 2013). Integration of transport and land use in TOD underscores the serious interest to the mixed land use because it is expected to maintain the traffic flow of passanger. 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 Rapid Transit District (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.

Lisbon, Portugal and the Region of Scania, Sweden are the examples of successful application of the TOD integration in the city and region scale. 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.
## Table 3.
Cross-continent comparison of integration planning of transport and land use with TOD practice

| 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. | ✓ Having well-established heavy rail systems, characterized by an extensive network structure and high transit ridership. |
|    |       |      |                 | ✓ Mixed land use help to generate bi-directional travel demand throughout the day | ✓ 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. | ✓ TOD served by light rail line, commuter rail service and Rapid Transit District (BART), a heavy rail service. |
|    |       |      |                 | ✓ 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) | ✓ 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 | ✓ Increased physical accessibility (primarily with public transportation), internally to “bind” the region together, and |
|    |       |      |                 | ✓ A call for “sustainable and efficient growth” of all settlements; and | ✓ Externally to expand or strengthen the region; |
|    |       |      |                 | ✓ Which should be socially attractive | |
| 4  | (Vale 2015) | Lisbon, Portugal | Europe | ✓ Developing significant suburban area. | ✓ Reinforcing other places in the periphery of city as the main transportation interchanges. |
|    |       |      |                 | ✓ Urban development areas for both urban and transportation planning | ✓ 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. |
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. Integration of TOD in transportation planning rejuvenates the quality of urban planning and social life of the community. The planning emphasize on the creation of a mixed use and density of settlements, other plan emphasize to attract pedestrian, i.e. putting the station on the intersection of the main distributor roads and freeways. The station also serve users of private car and service a bus feeder system along the distributor in suburban areas.

TOD and smart city was 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).

|   | 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. |
|---|------------------|-------------------|-----------|---------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| 6 | (Li et al. 2013) | China’s pearl river delta, China | Asia      | Encouraging development around stations by prioritizing land quota for station areas. | The construction of the line between two adjacent city to stimulate tourism industry and urban development |
| 7 | (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.

Fig. 7. Integration planning of TOD in Sydney. Source (Olaru et al. 2011).

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,
TOD is integrated through the application of compact land use patterns (Sung & 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 manages the rapid growth by emphasizing the concentration of areas within a radius of 1 km from the train station.

Integration of TOD in China 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.

3.4 Finding

The concept of TOD ensure the existence of urban transport sustainability by integrating transportation networks to the growth of the city. This objective is manifested through the centralization of activities and developments around transit area. 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.

4. Conclusion

Efforts to address problems of congestion and air pollution have been performed by the City Governments globally by implementing transport strategy. One of the above mentioned strategy is transport system plan-based mass transit in the city or regional scale. This planning is supported by structuring space and providing a connecting mode of transportation to facilitate passenger accessibility from the passanger's origin to their destination. However, the provision of mass public transport alone is not enough to cope with the urban problems such as congestion and pollution. A solution is required, in which the solution mustable to integrate land use and transport. One of the best solution is Transit Oriented Development (TOD).

Based on a review of the previous studies incorporated in this paper, practice and integration of TOD through land use and transportation showed that TOD can be the alternative solution in addressing the problems of developing urban area. The implementation of TOD is able to reduce congestion by facilitating the population preference of public transport compare to private modes of transportation and improved environmental quality. However, of course, it takes a strong commitment and consistency of the stakeholders to be involved in the implementation of TOD in a persistent manner.

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