TOD Model through Low Carbon City Concept in Urban Design (case study: Palembang, Indonesia)

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Abstract. Nowadays, Indonesia confronts urbanization, which raises many problems in the urban area, one of them is carbon emissions. Many researches have been done to address the issue of carbon emissions, TOD (Transit-Oriented Development) is one of them. This paper focuses entirely on how to develop the Transit-Oriented Development (TOD) design through low carbon city concepts in Indonesia. The concept of low-carbon cities is potentially implemented for high-energy efficiency in the areas of transport and housing will be able to reduce carbon footprint by decreasing trip frequencies, greater public transportation use for residents, increasing of walking level and higher accessibility. The city has to stimulate compact development with the high mobility movement of space in which space, building and infrastructure will be incorporated into a complex to authorise for living varied, commercial and social space to merge in environmentally sustainability. The development of a design strategy for the stakeholders is needed to develop and promote design ideas to optimise the spatial structure of cities. This paper aims to improve low carbon city model by adding integration between the urban spatial structure and land use to promote urban mixed, mobility, walkability, urban connectivity, and accessibility. These strategies will be used in a new development city in Palembang. Palembang is selected as representative of the rising megapolitan city in Indonesia where it still has capabilities for new spatial development planning to be improved the quality of life, well-planned new connectivity and sustainable cities. In this issue the TOD approach will be harmonized with the low carbon city concept.

1. Introduction
Transit-Oriented Development is a vitality concept by generating a good connectivity, friendly environment for pedestrians, and mixed land use [1]. This concept is not only about transit, but also extends the core of transit, which will increase the liveability and walkability for pedestrian and bicycle priority in urban design. The TOD can help to restructure the quality and form of urban growth through refining pedestrian friendliness, mobility, accessibility, and increasing sustainability [2]. Then, the urbanization pattern plays an important role in decreasing the transport demand and enable an efficient organization urban transport in a compact city which organized public transport efficiently.

On the other hand, many cities have introduced a range of policies to deal with climate change. The ideas are fruitful to finally reduce the carbon emissions, urban heat island, and greenhouse gas emissions using the low carbon city concept [3]. The key to create low carbon cities is focus primarily on connectivity and urban morphology, especially building the pedestrian way and bicycle grids. Moreover, urban morphology shows an important role on the neighbourhood scale, as physical phenomena within
the climate elements: wind directions, wind velocity, and sun path (effect of radiation and sky view factor) [4].

Urbanization trends are a reason or a chance to implement low-carbon city concept. Road transport, the essential part of the transportation system in Indonesia, contributes more than 90% of the total oil usage and responsible for increasing the concentration of greenhouse gases that affect climate change globally [7]. Transit-Oriented Development (TOD) is potential mitigation in the transport sector to reduce the effects of climate change which is an evolving concept to integrate between land use and transportation. By creating and guiding the development area around transit points (terminal, station, buses stop) will improve the accessibility of areas and provide the ease mobility [8]. So, this strategy is an effort to reduce the consumption of fossil fuels by reducing the length of travelled and will lead the environment to become a low carbon area. It is a potential for increasing high energy efficiency in the transportation sector which contributes around 30% from the total energy consumption.

The idea of low carbon city is to systematically integrate adaptation and mitigation methods to make the city respond to the climate change through a well-planned and designed urban environment [9]. It can be improved through managing land use diversity, density, and pedestrian-friendly urban design [10]. These can lead an individual or people to decide to travel with public transport modes and shorter distances to trip destinations, where it can reduce the consumption of fossil fuels that can cause a rise of the urban heat island. The physical characteristics of the city have important relationships to be considered, such as size and amount of open space, density, and energy use in household and transport [11]. These physical characteristics of city are affected by the form of streets that measured from the height-to-width ratio of urban canyons, orientation from primary winds and sun, the area of green spaces, the location of public transport, public spaces and facilities.

Transit-Oriented Development (TOD) can lead low carbon cities, such as a reduction in carbon footprint by decreasing trip frequencies, greater public transportation use for residents, increasing walking level and higher accessibility, then there is a chance to the residents of high-density neighbourhoods have a tendency to choose fuel-efficient and more smaller vehicles. The city size can rise the transport emissions per capita because of the effect of urban land use characteristic on energy used in household transportation and travel. Most researchers believe that TOD, where mixed-use area and high urban density built in high-quality transit systems, provides a focused development to change the urban structure more environmental friendly [5]. This engagement in sustainable development can guide to climate change mitigation by considering a low carbon development approach as the principle of sustainable development which aim to merge ecological aspect, economic development, and social [6].

The case study is selected in the most challenging parts of Palembang and representative of Indonesia city, where the area has significant capacities for new development, such as new housing, sports facilities or commercial use, and capability to improve public transport access. This paper purpose is to improve a low carbon city model by adding integration between urban spatial structure and land use to promote urban mix, mobility, walkability, and accessibility. The objective of this paper is to measure a strategy of a new urban structural model in a new development area to promote low carbon city through the implementation of urban connectivity in Palembang. Thus, the study can be used as a design strategy for the urban designer or urban planner, local government, citizens, architect or property development to develop and promote design ideas to optimise the spatial structure of cities.

2. Urban Design Approach

Palembang is chosen as a city to be considered to develop TOD model through low carbon city concept, which was proposed by the National Planning Authority of Indonesia (BAPENAS) to be one of the megapolitan city in the future. We used two steps in term of urban design. Step one: collecting data, mapping, directing observations, literature and city master planning review on various issues from several aspects, such as city policy, stakeholder, urban spatial structure, socio-historical, environment, transport and connectivity issues. In step one, we will get all the parameters related to low-carbon city concept and TOD. Step two is implementation, and the possibility of a low-carbon concept and TOD used. At this step, all the data is analysed and concluded as a result of interpretation, at the end of approaching we used urban spatial analysis to examine low-carbon concept and TOD.
2.1. TOD model and Low Carbon City Concept Indicators
There are some influences of urban spatial structure using low carbon city concept. The urban spatial structure refers to the spatial configuration and pattern of the urban land use (including distribution of residential, office area, shopping/commercial area, recreational areas as well as leisure facilities). They can determine the activities of the city’s residents that affect travel needs both directly or indirectly. These substances examine the connection between travel behaviour pattern and urban spatial structure which describes the interactions between transport-related energy consumption and emissions with urban spatial structure. There are type of indicators that have to be implemented to integrate the urban spatial structure in low carbon city and transit-oriented development (TOD), as follow: intensity, distribution, proximity, connectivity, diversity and form (Table 1) [12]. These type of indicators are verified at three requirement level of issue; macro level, mid-level and micro-level (Figure 1) [13]. It is important to know the level of issue and how to analyse the integration of urban spatial structure through the network factors of transit.

Table 1. Type indicator concepts of the integration of urban spatial structure and network factors

| Indicator   | Description                                                                 |
|-------------|-----------------------------------------------------------------------------|
| Intensity   | Refers to the density of the concentration of people or a density of housing. It indicates an association of efficiency between the activities and energy |
| Distribution| Refers to the relativity and evaluate the equability on small concentration on a bigger scale, for instances the distribution of public space or parks or social housing with the whole city Homogenous is good |
| Proximity   | Refers to the distance two elements, for example, between homes and leisure events or between public transit stations and offices. |
| Connectivity| Refers to the relative accessibility or spatial interconnection of a network (streets) |
| Diversity   | Refers to the mix and variety of land use or the proportion of the size of an object |
| Form        | Refers to the volume, geometry of elements, and footprint in space |

Figure 1. The methodological framework

3. The Case Studies
The main objective of this study is to apply low carbon city model by adding integration between the urban spatial structure and land use to promote urban mix, mobility, walkability and accessibility. This case study is chosen to help understand how to implement low-carbon city concepts throughout network factors (accessibility and connectivity of land use).

The site is located in Palembang city, South Sumatera. This area has a unique characteristic that can be a representative of low carbon city models in Indonesia. This area is approximately 4.036 Ha and
bordered by Musi River, also known as Sport and Heritage City which explained in National Medium-Term Development Plan 2015-2019. Palembang is included in the Nawacita development agenda, the National guidelines for a strategic plan, as 11 cities to be developed as the new urban area and new town in Indonesia. This development is focused on the liveable city, green city, and smart city, where several aspects have written in the grand design of Minister of National Development Planning Indonesia to campaign Sustainable Development Goals (SDGs).

3.1. The Case Study area in Palembang City
Palembang has the basic potential area such as sports centre, mixed-use, commercial and services, office, residential, tourism and education. But in this area there are some issues, such as flooding from Ogan River and Musi River, illegal housing growth, ecosystem pollution from household’s waste, unhealthy building environment, lack of infrastructure capacities, inadequate accessibility growth, high density and irregular housing, and the most significant problem is the area is mostly in the wetland (Figure 3a).

This city also has some potencies (Figure 3b) as a generator to apply an improved urban spatial structure and land use to promote low carbon city concept through urban connectivity, which can lead an individual or people to travel shorter distances to trip destinations activities, where it can reduce the energy consumption and emissions in Palembang.

Before analysing the implementation low carbon city concepts throughout network factors (accessibility and connectivity of land use), there are seven types of indicators; intensity, distribution, proximity, connectivity, complexity, diversity and form that should be considered [12]. Process sequences are categorised into macro-level (contains sectorial documents, city’s goal and mission, policy review), mid-level (contains existing spatial planning and structure planning), and micro-level (Figure 4). These sequences are used to describe where the low carbon city concept can be implemented through connectivity.
Based on these conditions and sequences, the analysis of urban connectivity is used to define spatial activities to other spatial activities, including socio-historical aspects, local economy and home industry, residential typology, green area, other variables (Figure 5). Then, it will define the location by urban spatial structure through transport mobility, including the existing Light Rapid Transportation (LRT), bus station and train station as Transit-Oriented Development (TOD). These elements will be integrated to make ease mobility to decrease the carbon footprint of transport cost and gas emissions usage. This result will be implemented in purposed of urban planning (Figure 6).
According to urban analyses and the potentiality of Palembang, some transit-oriented points (station, buses stop, etc.) (Figure 6) and land use pattern which impact the transport mode choices and behaviour of travellers are used as the basis of spatial connectivity structure. Despite all the parameters mentioned above we have to consider direct and indirect consequences parameters, i.e. climate, air quality, use of (renewable) energy; that can improve the accessibility of urban spatial structure to reduce energy consumption and emissions, and increase the economic development and quality of life.

**Figure 6.** The purposes of transit-oriented points’ connectivity

### 4. Result and Discussion

Figure 7 shows the implementation and recommendation of urban spatial structure, transit-oriented points, and the integration physical characteristics of the city, including culture, complexity, context and community-oriented. Those are collected into (sup)port city goal’s concept, through history, culture, connectivity, economy, nature, and community development that merged into low carbon city concepts. Besides that we still have to pay attention to the infrastructure aspects, namely connectivity, building guidelines, and drainage systems. All the parameters are distributed into detail action that lead to reducing the energy consumption and emissions, such as reducing the length of travelled and the environment carbon footprint, integrating the complexity of land-use form more accessible.

**Figure 7.** (a) Activity integration and connectivity recommendation, (b) spatial structure recommendation

There are some guidelines to integrate the spatial distribution of culture, complexity, context and community-oriented in Palembang, not only from land-use patterns but also urban spatial structures aspect. Land use patterns aspects can improve the spatial existing development to link easily, for example, people will have a shorter trip to move in some activities in history area, culture area, nature or green space, community. Meanwhile, urban spatial structures that managed by local authority consist
of connectivity networks, building guidelines (for land housing or river housing), drainage systems, waste systems, water systems, energy systems, and evacuation systems in green and public space. These elements are deeply rooted in urban morphology and merged into spatial indicators by Bourdic [12], including integration between diversity activities and urban spatial structures.

The spatial indicator concepts are to implement the integration between the urban spatial structure in low carbon city and transit-oriented development (TOD)-points that are transformed by type of indicators. All the detail indicators have to be adapted with the local context, namely Palembang city (Table 2).

Table 2. Evaluation of the integration between the dimension of urban spatial structures (local authority) and spatial indicator’s value (Bourdic)

| Spatial indicators (Bourdic) | The dimension of urban spatial structures | Descriptions |
|-----------------------------|------------------------------------------|--------------|
| Connectivity                | Connectivity networks                     | Enhance the network street quality to clarify the urban spatial structure |
|                             |                                          | Enhance the green corridor and green belt to reduce air pollution by vehicles |
|                             |                                          | Enhance the connectivity as a walkable area |
|                             |                                          | Enhance the integration of mode transportation |
| Intensity                   | Building guidelines                       | Develop four types of settlement; conservation settlement, revitalization settlement, upgrading settlement, new development settlement |
| Diversity                   |                                          | Revitalise heritage and traditional building |
| Proximity                   |                                          | Create visual active interaction and permeability between building to other buildings |
| Form                        |                                          | Create a private green area in every settlement to enhance a green area |
| Connectivity                | Water systems                             | Enhance the primary and secondary networks in the water system to distribute and service to people |
| Form                        |                                          | Use water harvesting as alternative sources |
| Connectivity                | Drainage systems                          | Rehabilitate drainage systems based on the capacity of standardization and characteristic of street |
| Form                        |                                          | Enhance the drainage quality systems |
|                             |                                          | Construct other retention ponds |
| Connectivity                | Waste systems                             | Provide the central waste treatment plan |
| Form                        |                                          | Provide trash boxes to support 3R (reduce, recycle, reuse) program |
|                             |                                          | Separate organic and nonorganic waste to be solved by zero waste concepts |
| Distribution                | Green and public space                    | Enhance active green public area as activity facilities |
|                             |                                          | Categorise green public area according to the level of street |
|                             |                                          | Create a green public area in the edge of the river |
| Connectivity                | Evacuation systems                        | Provide assembly point and fire extinguisher to all area |
| Proximity                   |                                          | Provide evacuation networks as the safety and accessibility of people and firefighters |
| Connectivity                | Energy systems                            | Provide the alternative energy system, such as sun as a renewable energy source |
| Form                        |                                          | Provide water capture and treatment as other sources of electricity |
The table above describe both urban spatial structure that related to low carbon city concept managed by each local community and spatial indicator’s value of connectivity have same characters to enhance the integration network systems; diversity activities and urban spatial structures, that flexibly adapted in Palembang (Table 2). Reducing distances and make places more easily accessible are created by connect structural systems and mixed land use activities. Also, purposing in numerous intersections points in a street network will increase the number of possible ways and reduce the distances to go from one point to another (Figure 7). Therefore, the city will optimise the land use and integration strategy to promote low carbon city model.

5. Conclusion
The aim of this paper is intend to design a model of low carbon city with regard to integration between the urban spatial structure and land use, connectivity and accessibility are the parameters that have to be considered. This concept can be employed as a design strategy for urban designer or urban planner to develop the design directly from the important aspects of low carbon city. Through connectivity and accessibility planning strategies, we can make places more easily accessible and reduce distances. Despite that, Palembang is selected as a most challenging city and still has significant capacity improved to be the sustainable and liveable city. This concept is possible, not only for developing the city but also for new development city. This concept could be proposed for a new spatial planning approach which will improve the quality life of people and well-planned new connectivity to lead on low carbon city model. Then, it will reduce the energy usage and emissions gas to facing climate change. Through this paper, we realize that low carbon city concept is more comprehensive than TOD but they are supporting each other. TOD is part of a low carbon city concept.

6. References
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