SUSTAINABLE DEVELOPMENT FOR THE CENTER OF SMALL CITIES

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Article History
Received : 29 January 2018
Accepted : 20 February 2018
Published: 01 April 2018

Abstract

As time goes by, cities have developed and grown to be crowded and densely populated area that lead to increasing energy consumption in cities. Thus, some guidelines need to be arranged to control the development of cities. Some of the guidelines are related to floor area ratio (FAR), operational energy, embodied energy, and mobility. Those aspects have strong influence on the consumption of energy in the cities in relation to the sustainability of the area future development. This is in line with the essence and objectives of sustainable cities. To calculate the guidelines, this research used experimental method by the means of computer simulation. The study utilized Rhinoceros with the plug in of Urban Modelling Interface (UMI), in which UMI is software that can simulate and calculate the four aspects correctly and accurately. The guidelines for city development are expected to provide comfortability of living to the community of cities during the development process.

This research investigated about the development sustainability in Boyolali City. Based on visual observation, the buildings in the five ways intersection of Boyolali are not too crowded and dense with low storey buildings. This research found that the value of FAR is 0.17, the operational energy is 71.48 kWh/m2/year, the embodied energy is 150 kWh/m2/year, and the mobility is 80. The score of FAR still can be improved up to ten times and the value of operational energy, embodied energy, and mobility were still below maximum threshold.

Keywords: *Sustainable City, Simulation, Urban Modelling Interface.*

Introduction

Cities are the symbol of human civilization, economic growth, source of innovation and creation, cultural centre, (Budihardjo, 1999). Along with the development of time, the cities also grow and develop. Some cities that were small town has grown to be big cities. If the development of the cities is not well-designed and regulated, cities may be not well regulated, uncomfortable for the people, and not environmentally friendly. Development of small town to big city is also happening in Boyolali. According to the data from Boyolali Regency in 2016, in the period of 2010-2015 the population increased up to 3.37%. In achieving the sustainable development of city, the environmental aspect has achieved more attention compared to social and economic aspect (Moughtin and Shirley, 2005). Environment is a key to the progress of several aspects that happen in cities such as economy, social, politic, and culture.

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The goal of this research is to get the formulation of FAR, operational energy, embodied energy, and mobility for small town. It is expected that in the future the small town will not sacrifice the life of the people in the city.

Literature Review

City

According to Irwan (1997), city is an area in which the people, the activities, and economy are concentrated. If we discuss further, city can be defined as an area where the economy, social, culture, and politics develop. Whereas, according to Oswald et al (2003), city is a pile of buildings that are covered by air pollution and ignorance related to the future. Followings are five criteria of city qualities:

- Identification
  The characteristics of the system in city can be communicated by various media. The characteristics can shape the orientation and regularity in space and time that are essentials for the existence of the city.
- Diversity
  Diversity explains various functions that can be done in the system of cities.
- Flexibility
  The ability of the system to handle internal and external changes with two ways, i.e. unchangeable system (homeostasis, supporting capacity) and renewable or improvable system (evaluation, potentials of innovation).
- Level of independence
  The relation between the available regional resources and available needed by certain area to fulfill local need
- Resources efficiency
  The relation between the quantity of resources that will be used and the resources that are available.

The cities are available into five parts i.e. centre of activity, transfer zone, housing zone for workers, better housing zone, and zone of commuters (Burgess in Yumus, 2000). Central Business Districts (CBD) is the centre of social, economics, culture, and politics in a city. In this zone, some prominent buildings are used for activities related to social, economy, culture, politics (Burgess in Yumus, 2000). The zone for centre of activities are divided into two parts namely Retail Business District (RBD) as the main part and Wholesale Business District (WBD) as the outer part of RBD. The RBD is indicated by dominant activities such as economic, banking, offices, shopping centres, hotels, movie theatres, and other social activities. Meanwhile, WBD is the location for big scale economic activities such as wholesale market and warehouse. Thus, downtown in the small town mostly become the central business district.

Sustainable Cities Development

To maintain the sustainability of the city, both for the present and the future, the public needs to pay attention to the environment. To maintain the urban environment, every action in building the city and the impact that will be generated should be considered based on sustainable urban development.
According to Yigitcanlar et al (2014), sustainable means maintaining the existence of ecosystems as well as providing human needs, while urban development means improving the quality of life without exploiting resources and destroying nature. This is in line with Brundtland's statement (in Budiharjo and Sujanto, 1999), sustainable development is a development capable of meeting the needs of the present without ignoring the ability of future generations to meet their needs. Thus, it can be concluded that sustainable development is a development that minimizes the use non-renewable resources, achievement of sustainable use of renewable resources and the absorption of local and global waste (Kusumawanto and Astuti, 2014). Sustainable urban characteristics should be determined in a measurable way to provide understanding of complex interactions, between economic, social and environmental, which is in line with the three sustainability pillars. FAR is the comparison between the floor area of the building and the area of land where the building is located. The magnitude of the FAR value will affect the sunlight that can illuminate the building and the FAR value will affect the level of density in a region. The building of areas by human will certainly increase the use of energy that aims to provide a sense of comfort and security to humans. Based on the results of a study conducted by Dawodu and Chezmehzangi (2017), the best FAR values and efficient energy consumption are between 2.5 and 3.

Furthermore, operational energy is the energy used to operate a building, such as energy for carriage, lighting, and for other electronic equipment. The standard energy usage of one building is regulated by ASEAN-USAID in 1992 which sets the intensity of energy consumption (IKE) that is grouped into four categories. The first is the office building with 240 kWh / m2 / year, then the shopping centre, hotel and apartment with 300 kWh / m2 / year, and the last is a hospital building with 380 kWh / m2 / year (Nugrahaini, 2016).

The energy used during the construction and renovation of a building is called embodied energy (Ramesh et al, 2010). Embodied energy can also be interpreted as the amount of energy consumed in the entire process of material or production system (Wuryanti, 2012). Based on the two terms, Haynes (in Adi, 2017) concluded that embodied energy is the cumulative energy values for resource extraction, raw material transportation, fabrication process, transportation of finished materials, assembly, maintenance, and energy for demobilization or recycling. To determine embodied energy value of a building, many versions of the research have been done with various results depending on the type of building and the location of the study. A research on embodied energy conducted by Adi (2017) in Boyolali district office complex found the embodied energy value of 4,955 kWh/2 for 60 years. The embodied energy value for house building in Indonesia is 818 mj/m2 or 227 kWh / m2 (Main and Gheewala, 2008) and for high buildings is 883 mj/m2 or 245 kWh/m2 (Utama and Gheewala, 2009).

Table 1. Classification of walking score (https://www.walkscore.com/methodology, accessed on 11 November 2017)

Score	Remarks
0-24	*Car dependent* Almost all activities require a car
24-49	*Car dependent* Most of activities require a car
50-69	*Somewhat walkable* Some activities can be done by walking
70-89	*Very walkable* Most of activities can be done by walking
90-100	*Walker's paradise* All daily activities do not need a car

According to Reknoningtyas (2016), mobility in urban space should be easy, safe, and fun, and the use of space should have affordability of parking areas and public transportation. It should be supported by clear and safe markers and circulation between beauty and function, which is safe for all people and easy to maintain. Ease of access can affect mobility that may increase or decrease (Miro, 2005). In UMI, the mobility in question is a mobility that does not use motor vehicles, i.e. pedestrians and cyclists. The measurement for the level of walkability can be seen in the following table.1.

The walkable characteristics according to NZ Transport Agency are as follows:

- Connected
  A direct access network for pedestrians and connected to public transport.
- Legible
  The road network is easy to understand and searchable on the map.
- Comfortable
  Not distracted by excessive air pollution and sound, wide tracks with a flat surface, and the presence of places to rest.
- Convenient
  The route efficiency is unhindered and pleasing to pedestrians.
- Safe
  Safe for pedestrians, both at the intersection and pedestrian routes.
- Secure
  A safe and crime-free environment.
- Universal
  Suitable for all circles, including people with special needs (such as people with disability).
- Accessible
  Has the orientation to ease walking.

Whereas, the measurement for the level of bikeability can be seen in the following table.2.

Method

The method of this research is experiment through computer software simulation with empirical measurement and computer simulation. Research by simulation method is used when the research relates to scale and complexity (Groat and Wang, 2013).

Table 2. Classification of bikeability (https://www.walkscore.com/methodology, accessed on 11 November 2017)

Score	Remarks
0-49	*Somewhat bikeable* Minimum infrastructure for bike
50-69	*Bikeable* Limited for bike
70-89	*Very bikeable* It is comfortable to use bike for most of the activities
90-100	*Biker's paradise* All daily activities can be done by using bicycle

The software used in this study is Rhinoceros version 5.12 with the plug in of Urban Modelling Interface (UMI) version 2.1. UMI is used to analyse FAR, operational energy, embodied energy, and mobility. To get the results of these four aspects, it is necessary to rebuild the three dimensions in Rhinoceros in accordance with the conditions of the field.

Discussion and Result

The location of this research is at Boyolali intersection area which is the centre of Boyolali. The boundary of this research area refers to the criteria of a small urban centre and the central area of activity or CBD.

Figure 1. Research Area (Source: Researcher's Documentations, 2017)

The research area is adjacent to Jalan Merbabu, Jalan Boncis, and river on the northside. The eastern part is bordered by Jalan Pemuda, and the south is bordered by Jalan Pisang and Jalan Teratai. While on the west side is bordered by Jalan Widuri, SD Negeri 7 Boyolali, Boyolali State Detention House, and community road. In this research area, there are 244 buildings, consisting of 159 units of public houses, 34 commercial buildings and 51 office buildings.

Based on the UMI simulation results, the FAR value in this area is 0.17. This is because the majority of buildings located in this research area are non-storied buildings and urban forest included in the research area resulted on low FAR value. Compared with the studies from Dawodu and Chesmehzangi (2017) that stated optimal FAR values between 2.5 to 3, the current conditions can still be increased.

For energy operational values, it is necessary to enter the data of building materials and window to wall ratio. As for the type of material entered UMI there are three types, namely wall filler material, concrete, and glass. The types of materials used in existing buildings, both for home, commercial and office buildings are red bricks that have conductivity values of 1.02 W / mK, density of 2,000 kg/m3, and specific heat 790 J/kgK (Selparia et al, 2015). For concrete material, the conductivity is 2,836 W/mK, density of 2,305,42 kg / m3, and specific heat of 1,040 J/kgK. While plastering has conductivity value of 0.72 W/mK, density of 1.860 kg/m3, and the specific heat of 840 J/kgK (Gandage et al, 2013). Glass material is 3mm clear glass with conductivity of 0.9 W/mK, IR transmittance 0, back-side solar reflectance 0.075, 0.075 front-side solar reflectance, 0.081, 0.01, front-side visible reflectance of 0.081, and visible transmittance of 0.898. Based on the UMI simulation, the average value of existing operational energy is 71.48 kWh/m2/year. Considering the type of building, the operational energy value of house building is 32.11 kWh/m2/year, commercial building is 108.19 kWh / m2/year and the office building is 74.14 kWh/m2/year. Existing operational energy is still far below the maximum IKE value, so this area can still be improved.

While the average embodied energy value of the existing building is 150 kWh/m2/year, which is the average amount of embodied energy from 244 existing buildings. It can be explained that the embodied energy value of house building is 130 kWh/ m2/year, commercial building 153 kWh/m2/ year and the office building is 167 kWh/m2/year. For mobility value in existing condition, walkability value obtained is 80. Based on the walking score, it is included into very walkable classification. As for the bikeability of the existing condition is 81, which belongs to a very bikeable classification. Basically, the existing mobility conditions in the intersection area Boyolali already have good access, such as roads that are interconnected with each other and various types of buildings located in this region. However, there are some shortcomings that need to be improved in this mobility aspect, that is the existence of the alley that is not connected with road or other alley. This of course can hamper mobility in this area. The other shortcomings are the lack of adequate standard facilities for pedestrians and cyclists. Then, the arrangement of existing building functions need to be reviewed in the future, so that the mobility value in this area becomes better.

Based on the simulation results on the existing condition and after the analysis, then this research obtained the recommended values for the intersection of Boyolali. The recommended FAR value in this region is 2.57. This value is recommended because the most optimal and operational energy, embodied energy, and mobility value are still low. The value is in accordance with Dawodu and Chezmehzangi (2017) research results that is 2.5-3.0.

The recommended operational energy value for Boyolali intersection area is 76.75 kWh/m2. In relation with building function, the operational energy for house building is 33,36 kWh/m2, commercial building is 116,69 kWh / m2 and office building is 80,22 kWh / m2. To obtain the value, the type of material used especially for wall and glass filler should be replaced with material that produces low operational energy value. Three simulations were performed with different materials to obtain suitable materials and this can lower the operational value of energy. The experiment used the current condition to have a benchmark value, which is a value in the current state.

Here are the results of three experiments on energy operational values. (Table 3.)

The first simulation experiments of wall filler materials used the bricks with conductivity values of 0.339 W/mK, density 1.000 kg/m3, and specific heat of 920 J/kgK (Selparia et al, 2015). The glass material used 6 mm thick grey glass with conductivity of 0,9 W/mK, IR transmittance of 0, back-side solar reflectance of 0.05, 0.05

Table 3. experiments on energy operational values (Researcher's analysis, 2017)

Condition	Type of Buildings		
	House	Commer-cial	Office
	kWh/m²/year		
Existing	32,11	108,19	74,14
Experiment 1	30,91	102,12	68,07
Experiment 2	30,90	102,10	68,12
Experiment 3	30,54	100,64	68,44
Score decrease	**1,57**	**7,55**	**6,07**
	4,89%	**6,99%**	**8,19%**

for front-side solar reflectance, diesel transmittance of 0.48, back -side visible reflectance of 0.006, front-side visible reflectance of 0.006, and visible transmittance of 0.57. In the second experiment, the replaced material is a wall filler material replaced with a lightweight brick and a fixed glass material using 6mm grey glass. Wall filler material used lightweight brick with conductivity value of 0,195 W/mK, density of 595 kg/m3, and the specific heat of 920 J/kgK (Selparia et al, 2015). The third experiment uses lightweight brick filler material and double glass with a grey glass formulation with airspace.

Based on the material recommendation above, the average embodied energy value is 70 kWh / m2 / year. If the value of embodied energy is based on the type of building, the house building has an embodied energy value of 72 kWh/m2/year, commercial building of 66 kWh/m2/year and office building of 72 kWh/m2/year. When compared with research conducted by Adi (2017), the value of embodied energy recommendation in this research is much lower than the Boyolali district office.

The value of the mobility recommendation in this area for walkable and bikeable is 92, which is included in the walker's paradise and biker's paradise classifications. To get the value, some improvements on the aspect of mobility should be done, such as fixing broken access connectors, such as the alley that is not connected to the road or other alley. Then, variations of building types should be done in a more organized way and it should be easier to access existing facilities.

Conclusion

Based on the simulation results using UMI on the current condition, it can be concluded that at the intersection of Boyolali 5 can still be classified as green area. This area can still be developed further considering the FAR is only 0.17. The average operational energy value in this area is 71.48 kWh / m2/year. Compared to the operational energy set by ASEAN USAID, operational envy in this region is still very low. In addition, the average embodied energy value in this area is 150 kWh/m2/year. Whereas, for the mobility value, the walkability score is 80 and bikeability score is 81. The mobility value is quite good considering the classification of walk score and bike score.

To further develop the area and not to sacrifice sustainability values during the development, it is necessary to limit the value of FAR, operational energy, embodied energy, and mobility. For the recommended FAR value is 2.57 and the average operational energy in this area is 76.75 kWh /m2/year and embodied energy of 70 kW/m2 /year. To get the value of operational energy and embodied energy, it is necessary to pay attention to the type of material used, especially material filling the walls and glass. For wall fillers, it is recommended to use lightweight bricks and glass material with grey double glass. The recommended mobility value, both for the value of walkability and bikeability is 92. The high value of mobility in a region will certainly reduce the use of motor vehicles for the citizens in moving from one place to another.

It is expected that the implementation of sustainability principles in developing a region will preserved the environment and make life in the future better. Thus, the need for natural resources in the future can be maintained and controlled.

Reference

Adi, Alifiano Rezka. 2017. Kajian penerapan arsitektur hijau pada kantor pemerintahan kabupaten Boyolali: Fokus pada nilai embodied energy bangunan. Jurnal Arsitektur Komposisi 11 (6). pp: 243-251.

Badan Pusat Statistik kabupaten Boyolali. 2016. Kabupaten Boyolali dalam Angka 2016. BPS kabupaten Boyolali: Boyolali

Budihardjo, Eko dan Sujanto Djoko. 1999. Kota berkelanjutan. Alumni: Bandung.

Dawodu, Ayotunde dan Ali Cheshmehzangi. 2017. Impact of floor area ratio (far) on energy consumption at meso scale in China: case study of Ningbo. Energy Procedia 105. pp: 3449-3455.

Irwan, Zoer'aini Djamal. 1997. Tantangan lingkungan dan lansekap hutan kota. Cides: Jakarta.

Kusumawanto, Arif dan Astuti Zulaikha Budi. Arsitektur hijau dalam inovasi kota. Gadjah Mada University Press: Yogyakarta.

Miro, F. 2005. Perencanaan Transportasi: Untuk Mahasiswa, Perencana, dan Praktisi. Erlangga: Jakarta.

Nugrahaini, Fadhilla Tri. 2016. Titik nol kilometer Yogyakarta menuju pusat kota yang berkelanjutan melalui simulasi Urban Modelling Interface (UMI). Tesis. Universitas Gadjah Mada, Indonesia.

Oswald, Frans dan Peter Baccini. 2003. Netzstadt: Designing the Urban. Birkhäuser: Basel.

Ramesh T, et al. 2010 Life cycle energy analysis of building: An overview. Energy and Buildings 42. pp: 1592-1600.

Reknoningtyas, RR Tri. 2016. Aksesibilitas di Kawasan Wisata Heritage Kotagede. Tesis. Universitas Gadjah Mada, Indonesia.

Utama, Agya dan Shabbir H. Gheewala. 2008. Life cycle energy of single landed houses in Indonesia. Energy and Buildings 40. pp: 1911-1916.

Utama, Agya dan Shabbir H. Gheewala. 2009. Indonesian residential high rise buildings: A life cycle energy assessment. Energy and Buildings 41. pp: 1263-1268.

Wuryanti, Wahyu. 2012. Keputusan multikriteria dalam menilai konstruksi rumah tinggal terhadap lingkungan. Jurnal Permukiman 7 (2). pp: 66-75.

Yigitcanlar, Tan, et al. 2015. Towards prosperous sustainable cities: A multiscalar urban sustainability assessment approach. Habitat International 45. pp: 36-46.

Yumus, Hadi Sabari. 2000. Struktur Tata Ruang Kota. Pustaka Pelajar Offset: Yogyakarta.