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System Dynamics Modeling for Green Open Space Analysis A Case Study of Medan City, Indonesia

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Abstract

Objective of this research is to develop a model of green open space management aimed at development of green cities in Medan city. (1). The simulation results suggest that a decline occurs in the area of green open spaces throughout the simulation year period, i.e. from 10,830.06Ha (2003) to 4,411.28 Ha (2028); the total population during the simulation year period which formerly was equal to 1,993,602 inhabitants (2003) will have increased to 2,620,700 inhabitants (2028); while the temperature from 27.80ºC (2003) increases to 28.50ºC (2028); and finally, GDRP during the simulation year period which formerly was equal to IDR 28.670 billion (2003) increases to IDR 406.880 billion (2028). (2). There are two strategies for green city development in Medan City, namely: 1. The population policy strategy by means of controlling population growth in the downtown area as well as directing the population growth toward the area outside the downtown, namely towards the districts whose population density is relatively still very low. 2. The policy strategy in the form of green open spaces for the public, which is undertaken by improving The the quantity and quality of green open spaces for city parks and city forests.

Keywords: Green Open Spaces, Dynamic Systems, Medan City

INTRODUCTION

Presence of the *Green Open Space* (GOS) is very important in an urban areas, in addition to functioning as a social facility, also has ecological benefits, health and economic benefits [1, 2, 3]. Development of urban forest landscape for urban green spaces in Indonesia is ideal for comfort activity in urban form, especially with the percentage of 70-80% tree canopy cover [4]. Presence of GOS required by 30% of the total areas based on "Law of The Republic of Indonesia Number 26/2007 concerning Spatial Management" [5], the proportion can overcome the negative effects that will emerge in the region. Its effects on global warming [6], flooding [7], sinking islands and loss of germplasm that are susceptible to temperature [8]. Quantity GOS is less than ideal proportions, be a problem in the urban areas, because of the development undertaken is not offset by the allocation of GOS [9]

Development in Medan City is a series of sustainable development efforts which covers all the aspects of life. Medan City is a very attractive place for people to develop their social and economic life. The social and economic life affects population growth both naturally and by ways of migration, causing uncontrolled residential development and residential neighborhood in Medan City [10]. Whether it is realized or not, the population of Medan City has the very basic needs for the environment such as: healthy air, soil water availability, and space to facilitate social interactions [10, 11]. Therefore, it is necessary to have a space which is often called a green open space to facilitate such interactions which also serves as a public space. Rapid changes in land use in Medan City have evicted a green open space and developed it into built areas without any maximum control so as to marginalize the concept of a green city as a whole city ecological system [12].

The area of the built space in Medan City will continue to increase along with the development of the city. The analysis results of the landsat image map in 2009 reveal that the built area in Medan City increases to 14,096.46 Ha, which is quite large compared to that in 2005 with an area differential by approximately 347.16 Ha. If the annual increase is calculated starting from 2005, then it is estimated that the total built area increases by 86.79 Ha per year throughtout this period. This is due to the development of Medan City and therefore development of the region is done on a massive scale. Moreover, pressure in terms of land requirement for settlements of the hinterland population is also very high in this period and development of the Mebidang areas (which are comprised of Medan, Binjai and Deli Serdang) [10].

In general, the impacts resulting from urban management marginalization can be classified into two, namely the ecological impact and the socio-economic impact [13]. The rapid land conversion phenomenon by marginalization of the area of green open spaces has ecologically caused difficulties for Medan City to realize or maintain the protected area as an area designated for hydrological preservation, biodiversity development as well as the area to create microclimate and to reduce pollution [14].

A very important factor of the environmental issues in Medan City is the number of the human population. Population growth is a major factor which influences development of settlements and the needs for infrastructure and facilities. Inaccuracies in terms of the plan and space utilization may contribute to environmental degradation. Research findings [12] suggest that the temperature classification of Medan City consists of three classes, namely ranging from 26°C to 28°C, 28.1 to 30°C and 30.1°C to 32°C which scatter all over the districts of Medan City. The highest temperature level is

found in the asphalted land cover, airfields and highways with a temperature of 32°C. This is because their surrounding areas lack vegetation. As for the lowest temperature, it is found in the vegetation land cover, specifically campus parks and zoos, which is equal to 27°C due to the dense vegetation cover.

MATERIAL AND METHODE

Study Area and Methology

The research was conducted in Medan City, green open space North Sumatera Province. The city represents a high rate of population growth as well as other metropolitan cities. The population growth rate trigger a rapid change in land use to be urban residential / settlement, trade, services, and industry areas. A year of research period was started from January 2013 - January 2014, which consisted of three stages, those were stages of data collection and classification, analysis and synthesis, and the concept and planning.

The tools used in this research were a set of computer and its equipments which were useful in data processing and analysis. The tools used were as follows:

- Laboratory tools: computer hardware, with GIS (ArcGIS) and Image management (Er Mapper) Software, Arc View Software and its extension, SPSS Statistics 17.0 software, Powersim Constructor 2.5d software, and Criterium Decision Plus 3.0 software.
- *Global Positioning System* (GPS), compass, and other supporting tools to find the coordinate position of the ground control points which were useful in determining the training area of the vegetation covered areas.
- *Ikonos* satellite imaging of 2003 and 2013.
- Base map of Indonesia from the Geospatial Information Agency.

The data used were the secondary and primary data. The primary data was obtained through in-depth interviews with the stakeholders with regard to the direction of policy priority. The secondary data included the data of demographic, city utility facilities /developed space and vegetation covered area, temperature, humidity and local income and other processed data.

Concept of System Dynamics

The model is a form made to replicate a symptom /structure/system, or description (abstraction) of a system. The model consists of 3 types: (1) quantitative models: mathematical, statistical, and computer; (2) qualitative models: Delphi, causal diagrams, cross-impact matrices, and matrix morphology; and (3) model of the iconic [15]. Among the three types of models, one of the quantitative models are often used in environmental analysis is system dynamics. system dynamics method is widely used in environmental studies because some considerations like:

a. Following the change of time (dynamics)
b. Complexity problems both detail complexity and dynamic complexity
c. Non-linear (nonlinearity),
d. There is a feedback [16]

Sterman [17] explains that modeling with System Dynamics is a perspective and set of conceptual tools that enable to understand the structure and dynamics of complex systems. System Dynamics is also a rigorous modeling method that enables us to build a simulation of complex systems and use them to design more effective policies and organizations (www.Anylogic.com).

Darmono [18] in Rusiawan [16], states that the basic methodology of system dynamics is a system analysis. A system is defined as a set of elements which interact with one another [19.20.21.22.23.24.25]. A system can consist of several sub-systems, where the system definition is also applicable on it. Interactions that occur within it all the time will affect the state of the system components. The system structure is determined by the relationship between its elements. Meanwhile system boundary will separate the system from its environment (fig.1).

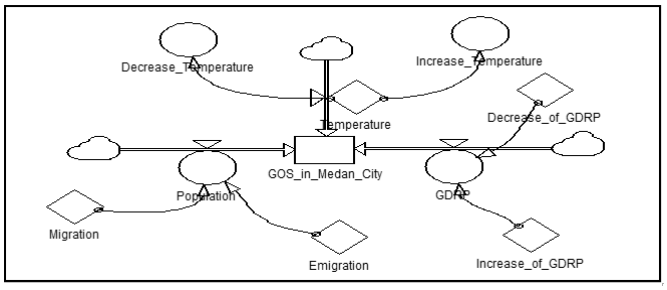

Figure 1. Causal Loop Diagram (CLD) of Green Open Space

Because system dynamics involves the study of the relationships between feedback structure and dynamic behaviour, there is a great impetus to try to infer dynamic behaviour from representations of structure. That impetus has apparently led to a set of definitions of the polarities of causal-loops that are phrased in terms of behaviour over time. As with definitions of causal links, so is with causal loops: the existence of rate-to-level links invalidates the traditional definitions of positive and negative loops in causal-loop diagrams. In this section the difficulties with the traditional definitions are noted, with the discussion focusing particularly on rate-to-level links, hidden loops, and net rates. The section ends with a brief analysis of a causal-loop which, together with the rest of the paper, cast grave doubt on the possibility of defining the polarity of causal loops in terms of dynamic behaviour [26]

Positive and negative feedback loops are the building blocks of system dynamics. While a complete specification of the feedback structure of a system requires specifying levels (states) and rates, the essential components and interactions in a system can be communicated quickly and concisely in a causal-loop diagram.[16]

RESULTS AND DISCUSSION

Establishing and Simulating Dynamic Models Relating to the Availability of a Green Open Space by Taking into Account the Physical, Social, and Economic Factors

The basic concept for the model developed in this research is a dynamic model which is comprised of three sub main systems, namely (1) Biophysical, (2) Social and (3) Economic. Simulation was undertaken for these three sub systems in accordance with a predetermined scenario.

The biophysical components are comprised of swamp forests, mixed forests, paddy fields, dry land, and open land significantly determine increases in the area of green open spaces in Medan City. Results of the simulation for the sub-model of green open space areas in Medan City, the beginning of the simulation year (in 2003) was equal to 10,830.06 Ha, a decline at the end of the simulation year (in 2028) into 4,411.28 Ha. Likewise, the same trend also applies for the temperature in Medan City, the beginning of the simulation year (in 2003) reached 27.8°C, at the end of the simulation year (in 2028) the temperature will have increased to 28.50°C. Results of the simulation in terms of the social sub-model (population) indicate an increasing trend of the population number in Medan City, which at the beginning of the simulation year (in 2003) was equal to 1,993,602 inhabitants while at the end of the simulation year (in 2028) the population number increases into 2,620,700 inhabitants.

Based on the results of the simulation of the GDRP sub-model, indicate an increasing trend in the amoun in which at the beginning of the simulation year (in 2003) amounted to IDR 28.670 billion and at the end of 2028 until the end of the simulation year, it increasing to IDR 406.880 billion. The details are presented in table 1.

Table 1. The Existing Simulation Results for the Dynamic System Model of Green Open Space, Total Population and Total GDRP Years 2003 –2028

Year	Green Open Space (Ha)	Temperature (°C)	Population (People)	GDRP (billion)
2003	10,830.06	27.80°C	1,993,602	28.670
2004	10,820.95	27.83°C	2,015,531	35.706
2005	10,797.30	27.86°C	2,037,702	43.397
2006	10,758.54	27.88°C	2,060,117	51.585
2007	10,704.05	27.91°C	2,082,778	60.254
2008	10,633.17	27.94°C	2,105,689	69.420
2009	10,545.23	27.97°C	2,128,851	79.105
2010	10,439.50	28.00°C	2,152,269	89.335
2011	10,439.50	28.02°C	2,175,943	100.140
2012	10,171.64	28.05°C	2,199,879	111.548
2013	10,007.88	28.08°C	2,224,078	123.591
2014	9,823.08	28.11°C	2,248,542	136.300
2015	9,616.30	28.14°C	2,273,276	149.710
2016	9,386.59	28.16°C	2,298,282	163.857
2017	9,132.92	28.19°C	2,323,564	178.778
2018	8,854.21	28.22°C	2,349,123	194.514
2019	8,549.34	28.25°C	2,374,963	211.104
2020	8,217.13	28.28°C	2,401,088	228.594
2021	7,856.33	28.30°C	2.,427,500	247.028
2022	7,465.62	28.33°C	2,454,202	266.455
2023	7,043.64	28.36°C	2,481,198	286.926
2024	6,588.93	28.39°C	2,508,492	308.493
2025	6,099.98	28.42°C	2,536,085	331.212
2026	5,575.18	28.45°C	2,563,982	355.141
2027	5,012.87	28.47°C	2,592,186	380.342
2028	4,411.28	28.50°C	2,620,700	406.880

Source: Data Processing by Powersim in 2003-2028

Directions in terms of the allocation of green open space areas directed towards establishment of a green city in Medan City have already required improvement with fundamental management related to the biophysical sub-model, the social sub-model and the economic sub-model. Based on the test results and the verification in terms of the simulation and historical proximity, then strategic policy can be used in the next step as one of the standards for the model of green open space management towards the establishment of a green city in Medan City.

Formulation of the Directions for the Strategy of Green City Development Policies in Medan City

Green cities are defined as an eco-friendly city which effectively and efficiently utilizes water resources and energy, reduces waste, implements an integrated transportation system, ensures environmental health, synergizes between the natural environment and the artificial environment, based on the urban planning and design consistent with the principles of sustainable development.[29]

Green city development in Medan City requires joint efforts from all the stakeholders. It also requires both fundamental (from practices until values) and massive changes/ innovations/ initiatives. The Law No. 26 of 2007 concerning spatial planning expressly specifies that 30% of the total area of a city shall be designated for a green open space, which is comprised of a public green open space by 20% and a private green open space by 10%. This green open space allocation by 30% is set forth in the Regional Regulation concerning the Regional Spatial Planning at the City and Regency Levels.[11].

To formulate the master plan of a green open space in Medan City, it is necessary to have a priority scale to indicate the program of green open space provision in Medan City. This should be based on the condition of public green open space requirements which are still insufficient and by predicting the very high developmental pressure, then it is necessary to carry out anticipatory management in order that the need for a green open space can be met and utilized properly. There are 2 (two) strategies to establish Medan City into a green city, namely:

The Population Policy Strategy :

The current population in Medan City are not evenly-distributed and generally concentrated in downtown areas such as Medan Kota District, Medan Perjuangan District, Medan Maimun District, Medan Area District and Medan Tembung District. In line with the trend of physical development of the city, currently the development of thesettlement begins to move to the South. Such a phenomenon where the settlement begins to move to the South should be controlled given the region is a conservation area. Therefore, in the near future it should be directed to the North, such as in Medan Marelan District and Medan Labuhan District.

Some considerations to determine the directions of the population distribution are:

a. The population growth in several periods indicates an increasing trend. In 1980 to 1990, the population growth increased by 1.5% per year on average while in 1990 to 2000, the population growth increased by 1.8% per year, and in 2003 to 2013, the population growth reached 2% per year. Population growth control is carried out by restricting the number of births (birth control) and migration. Birth control is undertaken by intensifying the family planning program while restrictions on migration are implemented by controllling the economic activity and making a plan for the allocation of facilities.

b. The availability of land for developmental purposes for the population in each district varies, in districts located in the downtown area, it is estimated that the number of the population will not increase as this area has been quite densely populated and there is no vacant land for development and even there is a tendency that the residential areas change their function into commercial areas.

c. The existence of growth centers such as secondary centers to be developed is among the factors causing the development of residential areas to move the region. Medan Marelan District and Medan Amplas District are areas with the highest level of population growth. In there areas, many new housing complexes are built.

d. The plan to build new development centers for economic and commercial activities will lead to the development of such residential areas, such as the primary center in the North (Medan Labuhan District and Medan Marelan District).

Based on the above considerations and the conditions of each district, then the directions for the development and the strategies for the distribution of the population in Medan City are elaborated as follows:

1. To control population growth in the downtown area (Medan Polonia District; Medan Maimun District; Medan Baru District; Medan Petisah District; Medan Barat District; Medan Timur District; Medan Kota District), undertaken by restricting establishment of new houses in certain areas or increasing taxes for land and buildings; and

2. To direct population distribution to areas outside the downtown areas, namely areas whose levels of population density and land use are still relatively low such as:

    - Southern areas: Medan Johor District, Medan Tuntungan District, Deli Tua District and Pancur Batu District (Deli Serdang Regency);
    - Western areas: Medan Sunggal District and Sunggal District (Deli Serdang)
    - Medan Tembung District, Percut Sei Tuan District and Tembung District (Deli Serdang).

The appropriate strategies to cope with the population growth rate in Medan City are:

1. to create an adequate economic balance between the outskirts and the downtown area;
2. to reduce the rate of population growth through poverty alleviation programs in the outskirts; and
3. to provide basic infrastructure/ facilities (streets, utility networks and social facilities as well as public facilities) in each district in Deli Serdang Regency.

The Strategy in the Form of the Public Green Open Space Policy

Strategies to meet the needs of public green open spaces by 5,217.7 Ha (19.68%) are undertaken by increasing the quantity and quality of the following green open spaces to be developed in Medan City:

1. Green Open Spaces in the Form of City Parks

Green open spaces in the form of city parks are parksintended to serve the inhabitants of a city or an area of the city. These parks serve a minimum of 480,000 inhabitants with a minimum standard of 0.3 m^2 per city inhabitant, with an area of a park by at least 144,000 m^2. These parks may be in the form of a green open space (a green field), equipped with recreational and sports facilities, and a sports area with a green open space by at least 80 to 90%.

City parks in Medan City are built in areas with a green open space of less than 30 percent, such as Medan Amplas District, Medan Area District, Medan Barat District, Medan Baru District, Medan Deli District, Medan Denai District, Medan Helvetia District, Medan Johor District, Medan Kota District, Medan Maiumun District, Medan Perjuangan District, Medan Petisah District, Medan Polonia District, Medan Sunggal District, Medan Tembung District, and Medan Timur District.

2. Green Open Spaces in the Form of City Forests

Currently, Medan has 7 (seven) green open spaces inthe form of city forests, namely in Medan Baru District, Medan Johor District, Medan Polonia District, Medan Tuntungan District and Medan Labuhan District. The details are presented in table 2.

Table 2. Distribution of City Forests in Medan City

No.	Name of the City Forest	Location District
1.	Banyan Forest	Medan Baru
2.	The Scout Campground Cadika	Medan Johor
3.	City Forest CBD Polonia	Medan Polonia
4.	Zoo	Medan Tuntungan
5.	Deli River Channel	Medan Johor
6.	City Forest	Medan Labuhan
7.	City Forest	Medan Tuntungan

Source: Badan Perencanaan Pembangunan Daerah Kota Medan 2008

The low proportion of city forests in Medan City compared with its total area implies the need to increase the areas of city forests in order to improve the microclimate and the aesthetic value of the city. City forests in Medan City should be built in areas with green open spaces which fall into the high category (greater than 30 percent), such as in Medan Belawan District, Medan Marelan District, Medan Selayang District, Medan Tuntungan District, and Medan Labuhan District.

Green open spaces are among the fundamental building blocks of an urban space or an urban area which play an important role in supporting (*biofiltering*), controlling (*biocontrolling*) and repairing (*bioengineering*) quality of the environment of an urban area [28]. The existence of the urban conditions with all the challenges has to be able to remain ensuring that both the protected area and the cultivated area are in a balanced proportion. Therefore, green open urban spaces are deemed as part of the functional space which can improve the physical and non-physical quality of the city face.

In an attempt to establish a comfortable, productive and sustainable urban space, then it is the time to give enough attention to the existence of public open spaces, especially green open spaces in urban areas. Green cities are defined as an eco-friendly city which effectively and efficiently utilizes water resources and energy, reduces waste, implements an integrated transportation system, ensures environmental health, synergizes between the natural environment and the artificial environment, based on the urban planning and design consistent with the principles of sustainable development.

Sustainable green city is a city built by continuously fostering all the assets including the people, the built environment, the natural resources, the environment and the quality of urban infrastructure. Such a city also adapts to and mitigates the climate change. Green City Development also refers to the development of urban people which have the initiative and cooperate to strive for changes and joint movement. Green City Development in Indonesia requires joint efforts from all the stakeholders. It also requires both fundamental (from practices until values) and massive changes/ innovations/ initiatives. As part of the efforts to establish a green city, it is necessary to plan and design an environmentally friendly city intended for the general public, with an emphasis on the quality, the social and cultural activities as well as the green space therein.

The green city development program which has been initiated by the Ministry of Public Works c.q. the Directorate General of Spatial Planning is one of the concrete step of the central government along with the provincial government and the city/municipality government to meet the provisions specified in the Act on spatial planning, particularly related to the fulfillment of green open space in urban areas as well as to address the challenges arising from the climate changes in Indonesia. The green city development program is an innovation of the program to establish urban green open spaces [27].

CONCLUSIONS

In the dynamic analysis model, there is a relationship among the biophysical, social, and economic components. The simulation results suggest that a decline occurs in the area of green open spaces throughout the simulation year period, i.e. from 10,830.06 Ha (2003) to 4,411.28 Ha (2028); the total population during the simulation year period which formerly was equal to 1,993,602 inhabitants (2003) will have increased to 2,620,700 inhabitants (2028); while the temperature from 27.80ºC (2003) increases to 28.50ºC (2028); and finally, GDRP during the simulation year period which formerly was equal to IDR 28.670 billion (2003) increases to IDR 406.880 billion (2028). There are two strategies for green city development in Medan City, namely: 1. The population policy strategy by means of controlling population growth in the downtown area as well as directing the population growth toward the area outside the downtown, namely towards the districts whose population density is relatively still very low. 2. The policy strategy in the form of green open spaces for the public, which is undertaken by improving the quantity and quality of green open spaces for city parks and city forests.

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