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System Dynamics For Surabaya Sustainable Urban Planning

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Abstract: The purpose of this research is to analyze the influence of social aspects on the sustainability of the city, the analysis method used is model analysis using a dynamic system. The dynamic system model is used to answer the research objectives, namely how the influence of social aspects on the sustainability of Surabaya city as a metropolitan city in East Java, Indonesia. The research was conducted using secondary data with an observation period of 2023-2033. The results showed that the city of Surabaya as a metropolitan city tends to become an unsustainable metropolitan city in the next ten years until 2033, one of the most influential aspects in social aspects is such as the rapid increase in population which can be seen from the number of incoming migration and the number of births.

Index Terms - Population, Education, Health, Sustainable city, System dynamic.

I. INTRODUCTION

A metropolis or metropolitan area is defined as a major city, as well as the capital or city that is very important from a certain country or region (H. R. Adisasmita, 2005). It has its own attractiveness for most of its residents, both those in rural areas and to the surrounding small towns to come and settle in the city concerned. Economically, its general attractiveness is relatively due to higher employment and wage levels in urban areas than in rural areas. Meanwhile, from a social perspective, life in the city looks more advanced and enjoyable because there are more complete and more social and cultural life facilities (Sjafrizal, 2017). Adapting from the concept of a sustainable city, we need to pay attention to the balance of the three dimensions of a sustainable city, one of which is the social dimension. According to the United Nations, a sustainable city is a city that should be able to maintain the supply of natural resources while achieving economic, physical and social progress and remain safe from environmental risks that can hinder the achievement of development or growth (Hassan & Lee, 2015).

The phenomenon of metropolitan city problems such as population density, education problems, and health. It was explained in a previous study by (Afari, 2021) that the acceleration in uneven population growth in urban areas. It causes problems of urban population density, urban sprawl, urban poverty, unemployment, environmental degradation, and poor infrastructure. And in a study (Rana et al., 2019) the negative impact of urbanization in metropolitan cities adversely affects individuals so that they are poorly educated, citing the absence of enough good educational institutions in the city. This increases social crimes, economic growth is hampered, and unemployment problems. Meanwhile, in the study (Fang et al., 2015) population, urbanization rate, vehicle density and industrial proportion have a significant influence on urban air quality to health.

The concept of a metropolitan city based on (R. H. Adisasmita, 2005) a metropolitan city (kota raya) is a city that has a population of more than 1,000,000 people, for example such as big cities in Indonesia, such as Jakarta, Bandung, Surabaya, Medan, Makassar, and other big cities. The concept is clarified by (Pontoh & Kustiawan, 2018) further explaining the size of the population of cities in Indonesia which consists of: (1) Metropolitan City, > 1,000,000 people; (2) Big cities, 500,000-1,000,000 people; (3) Medium City, 100,000-500,0000 people; (4) Small cities < 100,000 inhabitants. And the city Surabaya ranks second with the largest population after DKI Jakarta, the city of Surabaya has a population of over two million people, while the highest data in 2023 has reached more than three million people.

The city of Surabaya itself ranks second with the largest population after DKI Jakarta, the city of Surabaya has a population of over two million people, while the highest data in 2023 has reached more than three million people. And the problems that generally occur in the metropolitan city also occur in the city of Surabaya, such as the problem of population density that continues to increase, which if left without sustainable urban planning, these problems become the main cause of the emergence of other internal urban problems in the city of Surabaya.

II. LITERATURE REVIEW

According to the socio-ecological system (SES) theory pioneered by Elinor Ostorm pioneered and developed in 1970, the city is an interrelated socio-ecological system. The city is a complex and complex system and humans dominate it so that the impacts caused by humans cause various changes both in population dynamics, water circulation and so on, the SES theory also states that the city is an interrelated node both economically, socially and ecologically so that it will affect each other on the three dimensions in a sustainable city (Spiliotopoulou & Roseland, 2020). Socio-ecological theories can also be called Socio-ecological systems (SES) theory, in this theory cities can be considered as a combination of human nature or interconnected socio-ecological systems, which highlight the dependence of human welfare on ecosystems and their activities that seek to guide urban development in a more environmentally friendly direction based on urban ecological knowledge and sustainable principles. And humans are one of the important aspects in it that need to understand themselves as part of the ecosystem in order to drive a good cycle or feedback loop that generates or improves ecosystem services and other positive social and ecological outcomes (Heymans et al., 2019).

The approach in urban systems theory to urban sustainability focuses on dimensions and attributes that explain the long-term impact of a city on its resource base, ecosystem function, and population well-being. In urban system theory, it can also be understood as a set of various ecosystems that are interconnected in urban areas. Cities are complex and complex systems, and the human factor that dominates them, their impact has caused various changes in the concept of ecosystems in terms of climate, soil, water circulation, species composition, population dynamics, energy and material flows, and shaped other ecosystem phenomena (Cepeliauskaite & Stasiskiene, 2020). The concept of the SES theory states that an urban area is a node of transformation that is interrelated economically, socially, ecologically and politically. Because previous researchers have also analyzed that cities are dynamic, integrated, and multi-scale systems, which have a broader understanding of urban areas as human-driven ecosystems or socio-ecological systems in general.

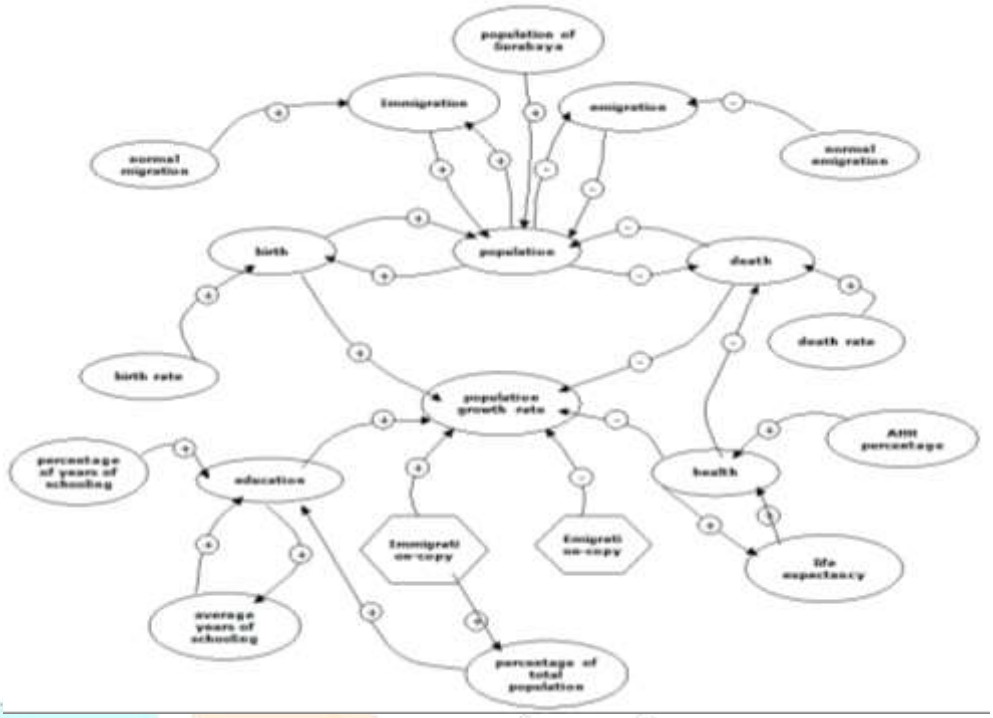
III. METHODOLOGY

The dynamic system model is used to answer the purpose of this study, namely. To analyze the influence of social aspects on the sustainability of the city of Surabaya with a dynamic system approach. The use of dynamic system models is a continuous simulation that focuses on the structure and behavior of the system consisting of interactions between variables and feedback loops. The advantage of dynamic systems in sustainable urban development is the simulation of cause and effect from human and environmental actions. In general, in formulating the steps of this system, namely by causal loop diagrams, stock and flow diagrams, building model confidence, the basis for running simulations, and analyzing scenarios (Suryani et al., 2020).

3.1 Causal Loop Diagram

Causal loop diagrams are an important tool in the representation of the feedback structure of the system. Causal loop diagrams are good when used for (Sterman, 2000):
Quickly capture the dynamic causal hypothesis
Capture or get a mental model from individuals or teams
Communicate feedback that is important and believed to be responsible for an issue.

A causal loop diagram usually consists of variables connected by arrows that indicate the influence of cause and effect between these variables.



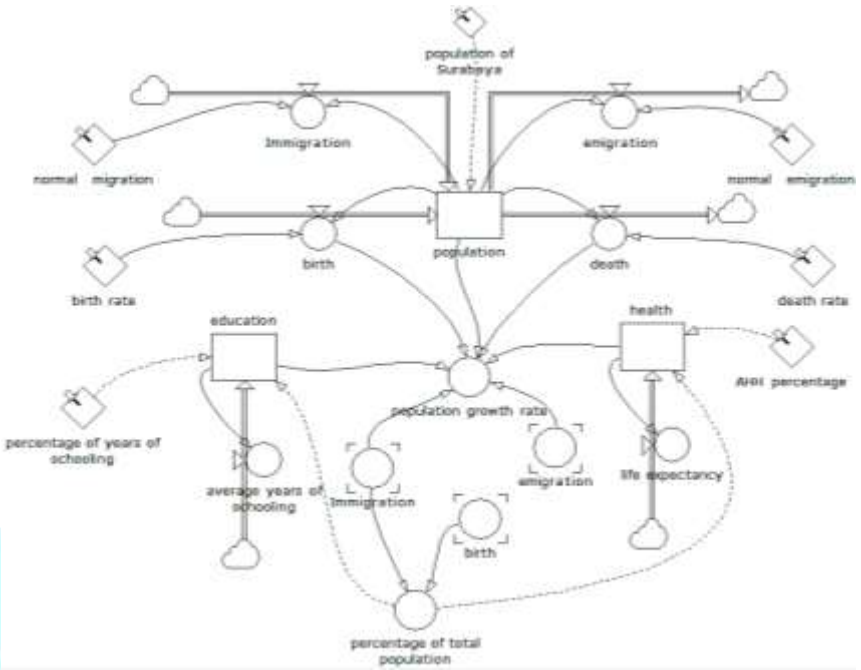
Causal Loop Diagram

The selected indicators are population variables that can be measured by the number of population or population density, then the education variable is measured by the average length of schooling (new method), and the health variable is measured by the life expectancy number. The indicator is in accordance with the size of the sustainable city indicator in Indonesia's Sustainable City Index (IKB).

The indicators in the causal loop of the social chart are related to each other and the population variable has a negative loop and a positive loop with auxiliary variables such as birth and death, migration and emigration. It can be explained that the population of the city of Surabaya increases due to the number of births and will decrease due to death, and vice versa, births will increase the population of the city of Surabaya and death will decrease the population of the city of Surabaya. Migration also increases the number of people in the city of Surabaya and the population of the city of Surabaya increases because of the people who migrate to the city of Surabaya, as well as emigration which reduces the number of residents of the city of Surabaya and the population of the city of Surabaya decreases due to the number of people who emigrate. The educational variable will increase the number of people in the city of Surabaya because it attracts people to migrate because the educational facilities in the city of Surabaya as a metropolitan city are better than the surrounding small towns so that the immigration rate also affects the population of the city of Surabaya. And the number of people in the city is getting denser, where the population density in the city of Surabaya will affect the health of its residents. Meanwhile, the health variable will affect the life expectancy of the residents of Surabaya City and vice versa.

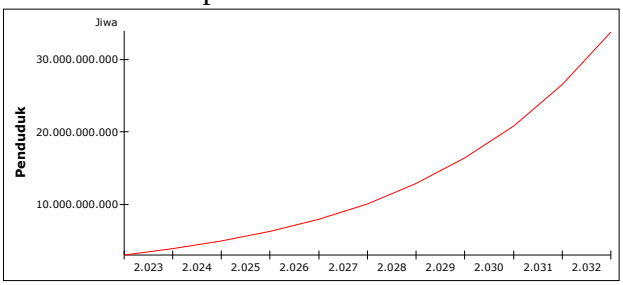
3.2 Stock and Flow Diagram

Based on dynamic system modeling to measure the influence of social aspects on the sustainability of the city of Surabaya using the powesim studio application, the model structure that has been created based on the Causal Loop Diagram is obtained as follows.



Stock and Flow Diagram Models

The dynamics or behavior of parameter interactions in the social dimension component is depicted in the Stock and Flow Diagram (SFD) on the variables of population, education, and health in the city of Surabaya. The population variable is explained by the number of residents of the city of Surabaya which is influenced by a positive loop such as births measured by the birth rate, and immigration measured by inbound migration, where each of the variables in the positive loop will increase the number of people every year in the city of Surabaya. Then in the negative loop there are death variables which are measured by the death rate and death rate which is also influenced by the health of the residents of Surabaya City, then the second is emigration which is measured by emigration out or the number of residents of Surabaya City who move outside the city of Surabaya. From the positive loop and the negative loop, both will affect the number of people in the city of Surabaya in the dynamics of the system, and will also affect the population growth rate of the city of Surabaya in measuring the sustainability of the city of Surabaya in the next ten years. And the modeling results of the dynamics of the system on the social aspect are obtained as follows:

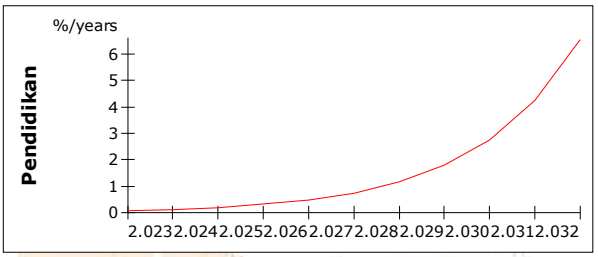


Sumber: processed data 2023-2033, population increase.

It can be seen from the results of the simulation from the population variable of the city of Surabaya, that the population of the city of Surabaya continues to experience a significant increase from 2023 to 2033. Which in 2023 the population is 3,009,286,000.00 people with a population density of 79 people per Ha and in 2024 with a population of 3,834,010,921.16 people with a density of 101.2 people per Ha. Then from 2025 with a population of 4,884,759,954,213 people and a density of 129.0 people per Ha, in 2026 there will be 6,223,477,267,265 people with a density of 164.3 per Ha, and in 2027 there will be 7,929,083,447,131 people

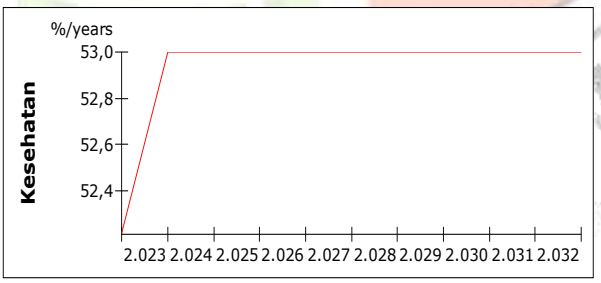
with a population density of 209.3 people per Ha in the medium population density category. And in 2028 it will be 10,102,128,056.65 with a density level of 266.6 people per Ha, and in 2029 it will increase to 12,870,717,271.86 people with a density level of 339.8 people per Ha, and in 2030 it will be 16,398,066,047.38 with a population density level of 432.9 per Ha with a very dense category. Until 2031 there are 20,892,120,028.33 people with a population density of 551.4 people per Ha and have reached the category above the maximum, and in 2032 it will reach 26,617,814,443.29 people with a population density of 702.7 people per Ha. And it will reach 33,912,692,669.62 people in 2033 with a population density of 895.7 people per Ha. Thus, significantly, the population of Surabaya City from 2023 to 2033 will continue to increase. This means that if there is no policy from the social aspect, the population of Surabaya City will continue to increase, and in the long term from 2030 according to Indonesia's sustainable city standardization, the city of Surabaya will become an unsustainable city.

The second variable from the social aspect is education with an indicator of the average size of school length (new method) in the standardization of sustainable city indicators, with the results obtained from the dynamic system dynamics model as follows:



Sumber: processed data 2023-2033, education variables.

From the graph above, it is known that in the education variable in the city of Surabaya, the results depicted in the graph above can explain that the education variable in the city of Surabaya from 2023 to 2033 has experienced a slowing increase and the value ranges from 0.09 – 6.55 per year until 2033. And this value is in the sustainable category from 2031 with a value of 2.76 to 6.55 in 2033. And the third variable is health measured by the life expectancy of the residents of Surabaya City, and the results are illustrated in the graph below:



Sumber: processed data 2023-2033, health variables.

From the results depicted with the graph above, it can be seen that the health variable of the city of Surabaya has experienced a slight increase from 2024 with an initial value of 52.22 in 2023, increasing to 53.00 from 2024 to 2033. The result is the minimum value of the size of the sustainable city indicator in Indonesia, namely a minimum value of 53.00 and a maximum value of 73.40, thus from the results of the analysis of the dynamics of the dynamic model system, it can be explained that the sustainability value of the social dimension with health indicators has a minimum value of 53.00.

IV. Results And Discussion

Based on the Sustainable City Development (SCD) framework, social aspects are one of the important indicators in seeing its impact on city sustainability. The results of this study show that there is a significant increase in the population in the city of Surabaya from 2023 to 2033. Education in the city of Surabaya tends to be unsustainable in the short term from 2023 to 2030, and from 2031 to 2033 education in the city of Surabaya is sustainable according to the measure of the sustainable city indicator. Meanwhile, the results of

the Surabaya city health indicators fluctuate from 2023 to 2024, and from 2024 to 2033 obtained stagnant and unsustainable results with a minimum value according to the size of the sustainable city indicator.

The number of residents of the city of Surabaya can explain that more and more people from outside the city of Surabaya are migrating to the city of Surabaya with the aim of getting higher wages or to enjoy more complete facilities in the city of Surabaya that are not owned by other areas of the small cities around the city of Surabaya, so that the interests of the population who migrate in the city of Surabaya are different such as for work, education, enjoying more adequate health facilities, and just to enjoy entertainment facilities and other more complete facilities that are not available in other areas around the city of Surabaya. This attraction will then increasingly make the city of Surabaya the main destination for residents in small cities around the city of Surabaya, the city of Surabaya which is a metropolitan city in the province of East Java is increasingly attracting residents from other regions to migrate to the city of Surabaya and settle in the city, so that it will increase the number of births in the city of Surabaya which will further increase the number of people in the city of Surabaya.

However, the increasing population is not balanced with employment or with the decrease in the population in the city of Surabaya, which is seen from the large number of residents of Surabaya who emigrate out of the city of Surabaya with the number of deaths of the residents of the city of Surabaya. So that it will cause problems or impacts in the city of Surabaya itself, both positive and negative impacts. The positive impact is that the increasing number of people in the city of Surabaya will further increase the level of consumption and have a positive impact on the economic growth of the city of Surabaya, while the negative impact is that the higher the population of the city of Surabaya can cause a high unemployment rate because job opportunities are not balanced with the number of new labor force. From this high unemployment, it has the potential to increase poverty, social inequality and social instability. This can reduce the quality of life, exacerbate mental health problems, and increase vulnerability to criminal acts due to social jealousy. In addition, the population density that occurs will also affect the environment such as air quality and water quality that deteriorates in the city of Surabaya.

The results of the scenario show that there is a need for a new policy from 2025, because considering the results that have been explained, the population of Surabaya City will continue to increase until the threshold of population density per hectare which is included in the medium category in 2025. And if left without a new policy until 2033, the population density per hectare will change to be very dense and above the maximum value of Indonesia's sustainable city standardization, and the city of Surabaya will become an unsustainable metropolitan city. Thus, one of the appropriate policies seen from the scenario in the dynamic system model, the policy that must be taken is from 2025 by reducing the inbound migration rate from 30.31% to 7% and reducing the birth rate from 9.3% to 5%. So that if the implementation of policies from the social aspect is implemented in the city of Surabaya, the increase in population will tend to be stable and controllable, and the population density per hectare will be stable with a low level of density.

The next indicator of sustainable urban development in the social aspect is education. Education is an important role to achieve a sustainable city, because education can build public awareness about environmentally friendly practices, health, and sustainable economic development. With education, people can better understand the importance of resource management, and renewable energy, and can better maintain the cleanliness and sustainability of the environment. In addition, good education will improve job skills and can open up more inclusive economic opportunities, reduce poverty, and social inequality. Therefore, through education we can gain the foundation to create a more resilient and innovative society in facing the challenges of a sustainable metropolis.

The next indicator is health, which is one of the important indicators in sustainable city development from a social aspect, life expectancy serves as the main indicator of the quality of health services in the city of Surabaya, such as the availability of medical facilities and access to a healthy environment. Theoretically, a city with a high life expectancy indicates its success in disease prevention, access to adequate health care, and increased awareness of the healthy lifestyle of the people in the city. Because, with the increasing population if balanced with the high life expectancy of its people, the city will be able to reduce health costs in the long term, and can reduce the death rate, increase productivity, and strengthen the local economy. All of these things are important aspects of sustainable city development. Meanwhile, the sustainability of health indicators in the social aspect in the city of Surabaya from 2023 to 2033 tends to be unsustainable, because in

addition to the increasingly high rate of population growth in the city of Surabaya, it also causes population density which will increasingly produce piles of garbage which eventually if not managed properly will affect air quality and water quality which affects the life expectancy or health of the population in the city of Surabaya. and increasing the death rate of the population in the city of Surabaya. The results of the scenario show that the health indicators of the city of Surabaya have a minimum value of Indonesia's sustainable city standardization.

The influence that dominates the linkage of the sustainability of the city of Surabaya is the increasing growth of the population, which will have an impact on other dimensions such as the economic and environmental dimensions. The high number of population, if not balanced with new policies in reducing the high increase in the number of people every year in the city of Surabaya, will cause overurbanization in the city of Surabaya, so that it can have a bad impact on the quality of education and health in the city of Surabaya. Thus, the influence of social aspects on the sustainability of the city of Surabaya tends to be unsustainable. And there needs to be a policy in limiting the increase in population, and one of them by limiting the number of migrations to the city of Surabaya and reducing the birth rate in the city of Surabaya is the answer to the problems that exist in the city of Surabaya.

This result is in accordance with the socio-ecological system (SES) theory by Elinor Ostorm stating that the city is an interrelated socio-ecological system. The city is a complex and complex system and humans dominate it so that the impacts caused by humans cause various changes both in population dynamics, water circulation and so on, the SES theory also states that the city is an interrelated node both economically, socially and ecologically so that it will affect each other on the three dimensions in a sustainable city. And this result is also in accordance with previous research from (Zeng et al., 2022) in his research entitled "Urban Resilience for Urban Sustainability: Concepts, Dimensions, and Perspectives" that social aspects such as the high rate of urbanization in big cities have a negative effect on their economic, social, and environmental aspects, making the city tend to be unsustainable.

V. CONCLUSIONS

Based on the results of the analysis in the previous chapter, this study resulted in the following conclusions.

Based on the results of the research with a dynamic system model of the influence of social aspects on the sustainability of the city of Surabaya, it can be concluded that the population of the city of Surabaya from 2023 to 2033 will significantly increase, and this will cause a high population density to exceed the maximum standardization of Indonesia's sustainable city parameters and is not sustainable, then education tends to be unsustainable in the short term until 2030 because the value is below the Indonesian sustainable city standardization, and from 2031 to 2033 in the long term sustainable because the value is above the Indonesian sustainable city standardization value. Furthermore, health with an initial value is below the minimum value of sustainable city standardization, but from 2024 to 2033 there will be an increase of 1% so that the health of the city of Surabaya is within the minimum value according to Indonesia's sustainable city standardization. It can be concluded that the influence of social aspects on the sustainability of the city of Surabaya tends to be unsustainable.

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