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Developing a Dynamic Model for Sustainable Development in Yogyakarta City

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Abstract

Developments in Yogyakarta City have driven residents of the city and its outskirts to access available social facilities, such as education, healthcare, and employment. If this continues, various social and urban problems may emerge, including increased population density and traffic congestion. Another implication of this process is decreased environmental carrying capacity as a result of continued use of non-sustainable approaches to development. This study aims to model the complexity of the relationships between aspects i.e., social, economic, and environmental of the area studied. The system dynamics method is used, as it is a disciplinary approach that is able to fully explore problems that occur in interconnected systems rather than examining incidents partially. As the basis for this model, the causal loop diagram (CLD) model has been applied based on literature studies and field observations. The result shows that developments in the tourism and education sectors are the main factors affecting the intersections of social, economic, and environmental considerations.

Keywords: education; sustainable development; system dynamics; tourism

1. Introduction

The interrelations between society and economy at the regional, national, and even global level are very complex (Arrow et al., 1995; Beckerman, 1992; Boulding, 1966; Grossman & Krueger, 1995, 1996; Markandya, 1998; Selden & Song, 1994; Shafik & Bandyopadhyay, 1992). Such issues as environmental degradation, which were initially faced primarily by developed countries and emerged as a side effect of industrial development, are now being faced prominently by developing countries. Many poor countries are now attempting to balance ecological needs and economic development (World Commission on Environment and Development, 1987), but have faced problems of wasted opportunities in utilizing resources. What is needed now is an era of new economic development, which emphasizes the similarities between social and environmental sustainability (World Commission on Environment and Development, 1987).

Increased competition in urban society has sparked global discussion regarding the urban environment and living space, particularly within the framework of sustainable development (UN Habitat, 2010). Sustainable development involves a balance or harmony between economic sustainability, social sustainability, and environmental sustainability; in other words, it integrates economic, environmental, and social aspects (Elkington & Rowlands, 1999; Manzi, Lucas, Lloyd-Jones, & Allen, 2010). Sustainable development promotes economic growth, environmental conservation, and social development, both in developed and in developing countries. As a dominant paradigm, the principles of sustainable

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development have been adopted around the world, and have had a significant impact on international agreements and policies as well as national strategies. Sustainable development emphasizes the need to achieve economic growth in a manner that is environmentally friendly, recognizing that previous patterns of economic development have had serious implications for the global environment.

Yogyakarta City, with its high population density and relatively good infrastructure, has developed much more rapidly than the surrounding regions. However, the economic growth of this city has yet to significantly reduce real poverty rates. Furthermore, looking at its human development index (HDI), Yogyakarta City is an area of above-average economic growth but below-average human development; in other words, it is high-growth, less-pro human development. This indicates that economic growth in Yogyakarta City has only been enjoyed by certain elements of society, and has not been balanced with improved public services such as education and healthcare (Bappeda DI Yogyakarta, 2016).

The increasingly rapid and intensive development of Yogyakarta City, particularly its tourism infrastructure, has reduced available land for housing. As such, Yogyakarta City has been forced to expand. Among the most severely affected is Umbulharjo District (Rahayu, 2009), which has transformed from a primarily agrarian area into a non-agrarian area filled with houses, offices, factories, and shops. As of 2014, a total of 107 ha of land in Yogyakarta City has been converted into housing and other socio-economic facilities; Umbulharjo District in particular has expanded an average of 6.1 ha per annum (Dinas Lingkungan Hidup Kota Yogyakarta, 2015).

As a city's population increases, the environment is negatively affected (Todaro & Smith, 2009), as population will exceed the carrying capacity of the environment. In 2014, Yogyakarta City was home to 400,467 people, while its area was 3,250 km2, meaning that its population density was 123.22 persons/km2 (BPS Kota Yogyakarta, 2015). This high population, which has continued to grow over time, has resulted in increased demand for urban land and reduced the amount of available (open space), both green open space and non-green open space. Urban open spaces are increasingly being used for housing and cultivation, even though the Law on Spatial Planning (Law No. 26 of 2007) stipulates that green open space and non-green open space must represent 20% and 10%, respectively, of available land. As of 2014, the city has 584.45 ha (17.78%) of green open space, 329.63 ha being public and 254.82 ha being private. Given its total area, Yogyakarta City requires another 390.55 ha of green open space; meanwhile, given its total population, Yogyakarta requires another 220.91 ha of green open space (Ratnasari, Sitorus, & Tjahjono., 2015).

The contributions of the transportation sector to sustainable development, in particular, are linked to traffic density and contributions to gross domestic product. A high level of traffic density will place increased pressure on the environment, particularly through energy consumption and air pollution. Air pollution has created numerous serious problems in urban areas. Hadi & Sa'duddin (2015) find that motor vehicles on Yogyakarta's main roads are the main contributors to air pollution in the region. Motor vehicles contribute 97.55% of NOx emissions, 99.86% of SO emissions, 99.96% of CO emissions, and 88.43% of CO2 emissions.

Another major issue being faced in Yogyakarta is water pollution. The rivers that flow through Yogyakarta City have become polluted by domestic and industrial waste. According to data from BLH (2014), the rivers of Yogyakarta have passed acceptable DO and BOD parameters. As such, there is a lack of clean water. Asriningtyas & Putra (2006) found that only 28,968 m3/28,968 liters of groundwater was collected per day, far below the city's estimated need of 1,182,036–1,576,048 liters/day. Similarly, Atmasari (2014) finds that the groundwater level in Yogyakarta City has decreased by 20–30 cm per annum.

The rapid development of Yogyakarta City, in various aspects, has led to persons from outside the city accessing such social facilities as education and healthcare, as well as job openings and business opportunities. If this phenomenon continues, numerous social and urban problems may potentially emerge, including increased population, traffic, and housing density. Another implication of this phenomenon is decreased environmental carrying capacity as a result of continuous development without consideration of sustainability principles. Various environmental problems such as a lack of clean water (owing to limited availability of groundwater) and water pollution may significantly affect the economy.

Chen, Ho, & Jan (2006) suggested that the essence of sustainability is the balance of social, economic, and environmental sustainability aspects. Environmental issues that are present in the city of Yogyakarta are always socially based and are triggered by economic sector activities, especially trade and tourism. Environmental protection is not possible before carrying out economic development (Basiago, 1998; Economides & Philippopoulos, 2008). The potential increase in income will encourage an increase in the proportion of tax revenue to GDP so that local governments should be able to increase government spending to protect the environment. However, in the context of sustainable development planning, the benefits of economic activities cannot yet be fully utilized to reduce the potential for social and environmental problems to emerge.

In 1987, the Bruntland Commission published a report, "Our Common Future", in an effort to link issues of development and environmental stability. This report defined sustainable development as "development that meets current needs without sacrificing future generations' abilities to meet their own needs" (Commission,W 1987). Albeit implicitly, it can be seen that sustainable development is intended to sustain economic growth and progress while simultaneously ensuring the long-term survival of the environment by preparing "a framework for integrating environmental policy and development strategies" (United Nations General Assembly, 1987). Although there are various definitions of sustainable

development, the most widely used is that of the Brundtland Commission (Cerin, 2006; Dernbach, 1998, 2003; Stoddart, 1992). The conservation of resources for future generations is one key aspect that distinguishes sustainable development from traditional policy, as it recognizes the need to avoid environmental degradation.

The main goal of sustainable development is to ensure economic and environmental stability over the long term, which can only be realized by integrating and recognizing economic, environmental, and social considerations over the course of the policymaking process. Sustainable development is broader than environmental conservation, as it emphasizes the creation of balance between economic, social, and environmental factors (Chen et al., 2006). Following this concept, global development has focused on sustainability as an explicit goal. However, it must also be translated practically into operational concepts by recognizing the presence (or lack thereof) of sustainability, as well as threats to sustainability in development (Bossel, 1999).

For this article, definition of three aspects of development is necessary. First, economy; a sustainable economic system must be capable of producing basic goods and providing basic services to ensure that the government can pay its foreign debts and avoid sectoral imbalances that may be detrimental to the agricultural and industrial sectors. Second, environment: a sustainable environmental system must be capable of ensuring the continued availability of natural resources, avoid excessive exploitation of non-renewable natural resources, and avoid the depletion of non-renewable natural resources except in the context of ensuring a sustainable substitute. This includes, for example, maintaining biodiversity, atmospheric stability, and the function of the environmental system, as well as other elements that are not considered economic resources. Social: a sustainable social system must be capable of ensuring just distribution and meeting social needs (healthcare, education, gender equality, and representative participation in politics) (Harris, 2009; Holmberg, 1992).

The rise of sustainability as a concept in development studies has led to development planning increasingly applying the principles of sustainability, including in debates about how cities and other regions must be revitalized and redeveloped. Sustainability has become perceived as an appropriate final solution for urban development. Presently, the search for "urban sustainability" has been translated into efforts to overcome such problems as urban sprawl, congestion, and urban decline. The sustainability and vitality of a city, as a complex system, involves not only the quality of life therein, but also the environment's capacity to support residents' activities. More narrowly, the sustainability of a city can be defined as the sustainability of a city's economy. In this context, all potentials can be used to achieve a certain socio-economic situation, demography, and new technology, all of which can provide a long-term and solid foundation for the urban system (Ewers & Nijkamp, 1990). Another definition links city sustainability with the principles of community, equality, and social participation, particularly social involvement in development (Friends of the Earth, 1994). For environmental planning, city sustainability means ensuring the combination of regional development and environmental conservation.

In the context of practical planning, Agenda 21 presented a number of concrete steps for achieving socio-economic sustainability, including justice, entrepreneurship, and the transfer of technology. Agenda 21 links land access, land ownership, renters' rights, credit policies, and low-cost construction materials to sustainable urban living and addressing the issues of homelessness and poverty. It also urges developing countries to promote small businesses and the informal economy, while holding that developed countries should provide monetary and technical support to developing countries so they can better educate environmental managers. Regional governments in developing countries must provide clean water, sanitation, and waste disposal services to the poor (Keating, 1993).

Agenda 21 also recommended a number of strategies for ensuring environmental sustainability, including targeted technologies, transportation reform, and urban renewal. Governments have been asked to help rural areas and revitalize urban ghettos, to build mid-sized cities by promoting the creation of jobs and housing, and developing cities while considering potential disasters. Technology-based construction policies must promote the use of local materials that are environmentally friendly and saved energy, as well as the conservation of energy and use of renewable energy sources such as wind, solar, hydro-electric, and biomass. Governments have also been urged to pass transportation policies that benefit users of public transportation, bicyclists, and pedestrians. Furthermore, Agenda twenty one holds that urban development must be planned to reduce the flow of traffic, promote efficient use of land, reduce the potential for urban sprawl, and protect agricultural and other lands (Keating, 1993).

Economic growth, development, and productivity was central to conventional development paradigm. This paradigm assume that, through the allocation of resources, economic growth would "drip down" to the poor. Sustainable development has expanded this scope, looking not only at financial considerations but at environmental, social, and human resources. Social sustainability includes within it understandings of equality, empowerment, accessibility, participation, cultural identity, and institutional identity, all of which is oriented towards environmental protection through economic growth and poverty eradication. Environmental sustainability, meanwhile, includes within it the integrity of the ecosystem, biosystem, and carrying capacity. It requires that natural resources be maintained as economic resources as well as means of assimilating waste. Resources must not be consumed at a faster pace than they are regenerated; similarly, waste must not be produced at a faster pace than the environment can assimilate it (Khan, 1995).

The complex connections between various aspects of society in sustainable development demand a systematic and holistic approach (Duran-Encalada & Paucar-Caceres, 2009; Ehrenfeld, 2005;

Schellnhuber & Wenzel, 2012). A multi-methodology systems approach is capable of combining and linking various techniques, methods, and methodologies, be they from the same system of thinking or from different systems (Michael C Jackson, 1999; Mike C Jackson, 1997; J Mingers & Brocklesby, 1996; John Mingers, 1997a, 1997b). The connections between these various aspects of development include different individuals and social preferences, which change over time. As such, it is difficult to manage, control, and transform complex systems (Dorner, 2003; Forrester, 1971; Meadows, 1999; Sterman, 1994; Sterman & Sweeney, 2002). A systems approach is often used in the quantitative model, although there are significant differences in goals and practical realities (Robinson, 2004; Rotmans, 1998). According to van der Sluijs (1997), the quantitative model seeks to model the complexities of cause and effect, with causal factors (socio-economic ones) leading to economic activities and other practices that may result in environmental degradation, emissions, socio-economic effects, and physical changes to communities and the ecosystem.

Wiranatha & Smith (2000) developed a dynamic system model by adopting a holistic view of the bio-physical and socio-demographic conditions on the island of Bali. The main issues identified include increasing the impact of development (tourism) on socio-cultural conditions, land conservation that is difficult to control, conflicts of interest (mainly coastal areas) between cultural-religious and social-tourism activities, limited resources especially land and clean water, and the occupation of migrants. The dynamic system model consists of 3 (three) subsystems, specifically the social-population subsystem, economy, and natural resources with development activities. The results of the study show that there are 2 (two) main sectors, i.e., tourism and agriculture, which compete with each other in resource use, exceptionally clean water and land. Increased water and land consumption by people also have an impact on the agricultural sector, particularly in maintaining adequate rice production. The migrants in Bali also impacts socio-cultural cohesiveness. Population and socio-cultural cohesiveness are closely related to socio-cultural problems, which in itself will affect the development process and the welfare of the community.

Cavana & Ford (2004) studied the application of system dynamics and sustainable growth for various environmental and resource systems over the past four decades. In the context of system dynamics and sustainable development, the theory of limits to growth has influenced and contributed to an awareness of environmental and resource issues. This has driven increased use of the system dynamics method to examine issues of sustainability, such as by (Saeed, 1998) and (Sterman, 2002; Sweeney & Sterman, 2000). (Springael, Kunsch, & Brans (2002) note that system dynamics may be considered the ideal methodology for analyzing the complexity of sustainability issues and for promoting social participation in discussions on environmental topics (Dietz & Stern, 1998; Gregory, 2000; Hale, 1993; Stave, 2002). Stave (2002) used a system dynamics approach to examine the issue of traffic and its environmental impact in Las Vegas. The model used represents various urban sectors and detects behavioral variables to determine effective and efficient policy, particularly given the high rate of vehicle ownership in society.

Ho & Wang (2005), meanwhile, examined how rapid economic growth has social and environmental effects, including increased traffic density, environmental pollution, and social disparity. Since its founding in 1980, Hsinchu Science Park (HSP) has experienced rapid development and provided extraordinary economic benefits. Between 1998 and 2000, it contributed 8% of Taiwan's GNP, with the output of the industrial sector twice that of other countries. In the case of Hsinchu City (HC), there has been significant concern for urban issues such as quality of life, population/settlement density, traffic congestion, and limited open space, as well as other socio, economic, and environmental problems. The system dynamics method can be used to help strategically evaluate and understand changes in policy implementation (Sweeney & Sterman, 2000). The sustainable urban development model formulated included HSP as well as the city of Hsinchu, with historical data (from 1986–2000) used as the basis for simulating and predicting the future development of HSC. The model included five sub-systems: industry (productivity, industrial output, research and development expenditures), demography (population, density, age structure, education), housing/land use (area of city, floor space per capita, uninhabited homes, average house price, land space per resident), environmental degradation (waster per capita, garbage per capita, legal cases of environmental degradation), and economy (income per capita, savings per capita, unemployment rate, industrial value).

Bassi (2010) attempted to model energy consumption policy in the United States following the T21 Model. Bassi used a model to analyze the implications of policies, such as fuel efficiency standards and enactment of renewable energy policies in the urban transportation sector. The simulation used scenarios of rapid recovery and of slow recovery from economic crisis, finding that, without environmentally friendly policies (i.e. green policies), positive economic growth would be achieved in 2010. However, the gross domestic product would remain below the gross domestic product before the crisis, and economic growth would be lower than in the other scenario.

Another study, by Kamath, Kamath, & Rodrigues (2014), used the system dynamics approach to illustrate the complexity of the relationship between ecological, social, and environmental sustainability. Using the causal loop diagram (CLD) model, they showed that human population (including birth and death rates) influences the number of people migrating to urban areas to find work, income, and a better future. As the urban population increases rapidly, so too does the demand for fuel. Total fuel consumed depends on the average amount of fuel consumed. Increased demand for fuel will lead to increased fuel prices, which will in turn result in social unrest (particularly among economic actors) and thereby influence the gross domestic product and economic activities. Economic activities, in turn, will increase the

consumption of resources and affect environmental conservation. Increased gross domestic product, meanwhile, will improve quality of life, which will in turn affect population levels.

Another study, by Lektauers (2015), attempted to explain the conceptual framework of system dynamics modelling within the context of sustainable development by regional governments. The system dynamics approach was used to formulate, simulate, calibrate, and validate the sustainable development program in Kuldīga City, Latvia. The greatest challenge for developing such a model of sustainable development was determining a scope for study and prioritizing certain issues. In this study, 33 key indicators were chosen and grouped into three subsystems (human systems, supporting systems, natural systems), before being categorized into 7 (seven) composite indicators (Bossel, 1998). These seven composite indicators covered three dimensions: social cohesion, economic cohesion, and environmental balance (Zgurovsky, 2009). Human systems consisted of three components: the individual development sector, the social system sector, and the government sector. Supporting systems, meanwhile, consisted of two components: the infrastructure sector and the economic system sector. The natural system, finally, included the environmental aspects of sustainable development, particularly the natural resources sector and environmental resources sector.

This study aims to model the complexity of the relationships between aspects i.e., social, economic, and environmental, that are triggered by physical development factors. The analysis used is focused on a holistic approach through dynamic systems to simplify very complex phenomena. Models can be used for planning and making better sustainable development-related policies.

2. Methods

2.1 Modelling of System Dynamics

The main model adapted in this study is the T21 model developed by the Millennium Institute (Millennium Institute, 2005, 2007). It has been adapted by including development as a trigger for inter-sectoral interactions (Wiranatha & Smith, 2000). The T21 model, which is based on the system dynamics approach, has been perceived as capable of depicting the relationships between and dependencies of different sectors (Bassi, 2009). This system dynamics model consists of three main sub-systems: (a) socio-demographic sub-system; (b) economic sub-system; and (c) natural resource sub-system. A fourth sub-system, development, is positioned as triggering indirect interactions between these three sub-systems. The focus of this model is on the interactions between economic activities, natural resources, and socio-demographic factors. This includes carrying capacity, the environment's ability to sustainably support development and meet human needs (Figure 1).

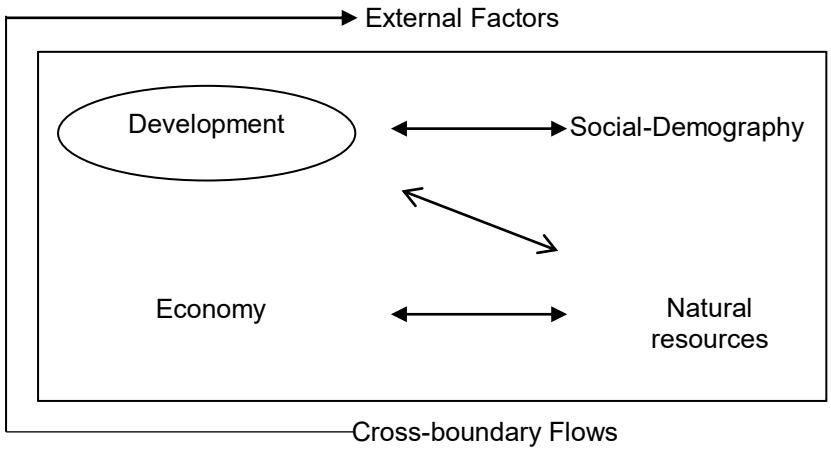

Figure 1. A General Model of Dynamic System-Based Development
(Source: Wiranatha & Smith, 2000)

Development activities in Yogyakarta City, such as the construction of hotels and other public infrastructure, have pushed economic growth (i.e. increased sectoral output, per capita income, and availability of jobs). Economic growth, combined with the availability of various public facilities, has provided further impetus for people from outside Yogyakarta City to access these facilities or even migrate to the city (i.e. had social effects), which has in turn impacted the population and environment (such as through traffic congestion, population density, and pollution). Development activities have also had a direct influence on the carrying capacity of the local environment, as clean water and green space has become scarcer.

2.2 System Needs

The systems related to sustainable development are obtained from the identification of the needs of each stakeholder. The first step in this process was carried out through interviews with 20 respondents

consisting of local governments, academics, business actors, NGOs, and the community in the April-June 2018 period. Key stakeholders were also involved in the discussion stage of developing conceptual models. The main issues identified include: (i) the impact of the population (residents, migrants, tourists) on traffic; (ii) the impact of tourism development on regional revenue and (iii) conflicts in groundwater use between business actors (especially hotels) and the community. The results of the interview show the matrix of the needs of each stakeholder, as presented in Table 1.

Table 1: Matrix of System Needs

Need Analysis	Government	Business	Society
Road Capacity	✓✓	✓✓	✓
Traffic Management	✓✓✓	✓✓	✓
Use of Public Transportation	✓✓	✓✓	✓✓✓
Toll Roads	✓✓✓	✓	-
Taxes	✓✓✓	✓✓✓	✓
Retributions	✓✓✓	✓✓	✓
Investment	✓✓✓	✓✓✓	✓
Monitoring	✓✓✓	✓✓✓	-
Price of Water	✓	✓✓✓	✓✓✓
Socialization	✓✓	✓✓	✓✓✓

Source: Authors' Analysis (2018)

3. Result and Discussion

3.1 Development and the Economy

Two important drivers of development in Yogyakarta City are education and tourism. Both sectors have had a significant multiplier effect on other sectors in the city (Wahyuni, 2009). The high numbers of tourists and students have given entrepreneurs considerable space for their economic activities, and the opportunities provided by these demographics has positively affected labor absorbtion. The higher the employment rate, the higher the per capita income of the city; this, in turn, will have a positive effect on the local economy. Meanwhile, a growing economy will draw increased government investment in the form of development. Development across various sectors will then have a positive effect on economic growth, as it will increase business opportunities and offer incentive for sustainable public and private investment. Figure 2 below presents a causal loop diagram (CLD) of development and the local economy.

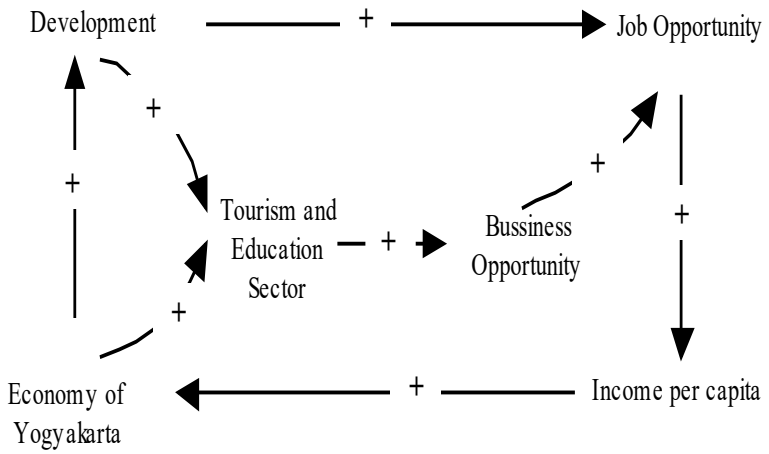

Figure 2. CLD of Development and the Economy

3.2 Development and the Environment

A region may be identified as having high or low levels of pollution based on its position relative to agreed-upon environmental standards. Increased development across all sectors, particularly tourism, has heavily affected the pollution levels in Yogyakarta City. The high number of tourists has resulted in the construction of such buildings as hotels, shopping malls, and tourist attractions, as well as public transportation infrastructure. This construction has resulted in vast expanses of land being repurposed,

with open green land becoming scarce. Such urban open spaces are necessary for environmental sustainability, including absorbing air pollution and providing clean water (Roy, Byrne, & Pickering, 2012). If this phenomenon continues, it will have a negative effect on community health (Figure 3).

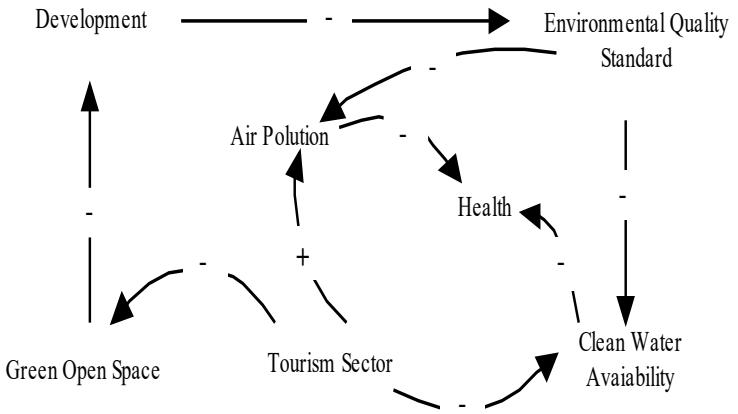

Figure 3. CLD of Development and the Environment

3.3 Development and Society

Higher levels of education produce graduates with broader knowledge, enabling them to create technology to ease their everyday lives and activities (Goldin & Lawrence F. Katz, 2009). Technological developments have indirectly affected development across various sectors, and end-customers' access to such technology has created a dynamic market with different needs and desires. This, in turn, has affected the development oriented towards meeting market demand. Furthermore, developments in education can produce more educated residents and reduce unemployment (Riddell & Song, 2011). On the other hand, in relation to society, development has a positive effect on community access to healthcare (Figure 4). Developments in healthcare have created greater concern for health, as well as improve life expectancy. Increased life expectancy, in turn, means population growth (Jaba, Balan, & Robu, 2014).

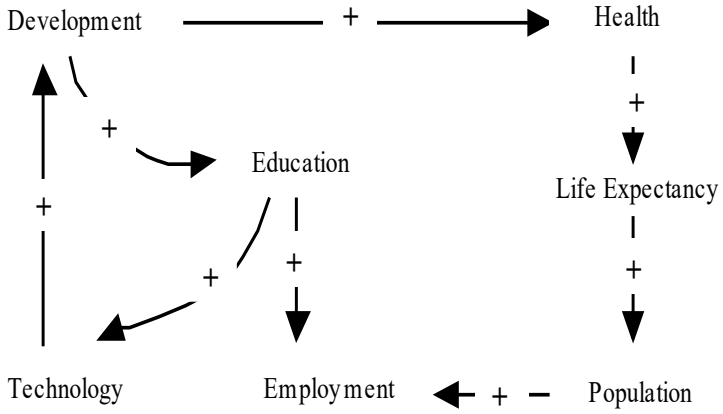

Figure 4. CLD of Development and the Environment

3.4 Conceptual Model of the System Dynamics of Yogyakarta City

It is recognized that the variables of sustainable development have complex relationships and are mutually influential. As such, the scope of this research is the sectors that have received greater emphasis in Yogyakarta City's development, primarily the hotel and restaurant sector, service sector, and tourism sector. In CLD, the variables depicted must be interconnected or mutually influential, and must refer in return to the existing system (Appendix).

Over the past ten years, the economy of Yogyakarta City has been increasingly reliant on secondary and tertiary sectors such as the processing industry, trade, hotels, restaurants, transportation, telecommunication, finance, rental, and service provision (Bappeda Kota Yogyakarta, 2016). The increased investment in sectors related to tourism shows that investors are increasingly interested in Yogyakarta City. An increased GDP will positively affect regional revenue through the increased potential for taxation and regional retributions (Muibi & Sinbo, 2013). Increased revenue will lead to the local government allocating more money for the development of social welfare, with a focus on education and

healthcare. Good education will improve the quality of human resources, and this in turn will combine with development to promote a higher labor absorption rate. Furthermore, education will improve the ability of community members to create new technologies for development (Goldin & Lawrence F. Katz, 2009).

Aside from technological development, increased healthcare will guarantee the availability of a labor force that can be absorbed into sectors that are connected to tourism, including the trade, transportation, hotel, and service sectors. The increased demand from these sectors for labor will drive migration, further increasing population. On the other hand, the number of visitors and tourist destinations will result in increased traffic congestion in Yogyakarta City. Furthermore, there will be increased demand for clean water, and the use of groundwater by the trade and hotel sectors will reduce its carrying capacity.

The use of groundwater is influenced by the regional water body (PDAM), as well as socialization and monitoring. If socialization or monitoring of local society and its practices is maximal, the use of groundwater can be minimized; conversely, if socialization or monitoring is lacking, the use of groundwater will increase. With decreased groundwater use, water absorption in Yogyakarta City can be restored to a sustainable level. Furthermore, traffic has become increasingly congested, not only because the number of vehicles has increased, but also because roads have become narrower as a result of widespread construction. This increased traffic congestion, in turn, has led to increased air pollution, which has been detrimental to societal health.

4. Conclusion

This study aims to model the complexity of the relationships between aspects of sustainable development triggered by physical development factors. The method used by dynamic systems consists of 3 (three) subsystems, i.e., social, economic, and environmental. From the results of interviews with stakeholders, a system needs matrix was obtained, which included: road capacity, traffic management, public transportation users, paid roads, taxes, fees, clean water prices, monitoring pollution levels and traffic congestion, socialization of legislation. The results of modeling the dynamic system of the economic subsystem found that an increase in income would encourage the government to allocate a larger budget to two essential service sectors, education, and health. As for the sectors that contribute to the increase in income are services, trade, and tourism.

In social subsystems, system movements are triggered by population increases due to improved health and life expectancy. The increase in population and service sector activities, trade, tourism causes higher levels of traffic density and clean water needs. On the other hand, road capacity and community behavior in terms of the use of transportation types (public and private) affect traffic density. Variable paid road (ERP) can be used as an alternative solution to reduce traffic congestion. The increase in economic sector activity and traffic density will further affect water demand and pollution in the environmental subsystem. The fact is that the increase in the need for clean water is fulfilled through the use of underground water. It will negatively impact the availability of underground water reserves, causing conflicts between business people and the community.

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APPENDIX: CLD Model of the Dynamic System of Sustainable Development in Yogyakarta City