International Journal of Technology 15(1) 195-206 (2024)
Received February 2022 / Revised April 2023 / Accepted July 2023

International Journal of Technology

http://ijtech.eng.ui.ac.id

Policy Analysis of Coastal-Based Special Economic Zone Development Using System Dynamics

Armand Omar Moeis[1*], Agatha Ayu Gita[1], Arry Rahmawan Destyanto[1,2], Irvanu Rahman[1,3], Akhmad Hidayatno[1], Teuku Yuri Zagloel[1]

[1]*Department of Industrial Engineering, Faculty of Engineering, Universitas Indonesia, Kampus UI Depok, Depok 16424, Indonesia*
[2]*Faculty of Technology, Policy, and Management, Delft University of Technology, 2626BX Delft, the Netherlands*
[3]*Institute for Technology Assessment and Systems Analysis, Karlsruhe Institute of Technology, 76133 Karlsruhe, Germany*

Abstract. Special Economic Zone (SEZ) development is becoming a preferable policy by the Indonesian government to boost economic growth in less-developed local regions. This is because of the promise that SEZ could attract investment and job creation based on local competitive commodities. One of these areas is Bitung SEZ, North Sulawesi – Indonesia, a coastal-based SEZ, as its strategic position for logistics, fishery resources, and coconut plantation. To explore the promise of growth proposed by developing SEZ in Bitung, we developed a Systems Dynamics model of the interaction between economic growth, social development, and environmental impacts. Based on the model understanding and development, we identified three factors the Indonesian government should improve: coconut plantation productivity, fisheries ship management, and education index. With these three factors in mind, several policy options were tested in the model, resulting in a more substantial impact than the business-as-usual condition.

Keywords: Special Economic Zone (SEZ); System dynamics; Policy analysis

1. Introduction

As the world's biggest archipelago nation, Indonesia faces unique challenges due to its unique geographical setting. Those challenges are uneven interregional infrastructure in connectivity (logistics/ transport) and energy domains (Kemenkeu RI, 2017). Under such conditions, aggressive investment plans positively affect job creation (The United Nations Development Programme, 2016). The Government must formulate policies that promote economic development across all regions of Indonesia, aiming to contribute to the Gross Domestic Product (GDP) more evenly and reducing over-reliance on Java Island's growth. SEZs are among the policies that countries employ to stimulate trade, attract investments, and foster overall economic development (ASEAN, 2016). SEZ development will encourage economic growth in its region and distribute the economy evenly (Farole and Akinci, 2011). It can create technological improvements to increase national productivity and structural transformation in local areas (The Asian Development Bank, 2015).

Bitung is a district not far from Manado, the capital of the North Sulawesi province. It

*Corresponding author's email: armand.omar@ui.ac.id, Tel.: +62-21-78888805; Fax: +62-21-78885656
doi: 10.14716/ijtech.v15i1.5498

lies on the northern tip of Sulawesi Island. Given its proximity to the island of Papua, the Northern Moluccas, and the Southern Moluccas, Bitung is a good hub for the northeastern region of Indonesia (Moeis *et al.,* 2021).

Being the promising hub of the northeastern region of Indonesia, it goes without saying that Bitung is considered the potential primary motor of economic growth in that region. With its coastal characteristics, the development of Bitung SEZ (KKPIP, 2015) will attract more economic activities in that region and create the much-needed cargo that will be transported to the western part of Indonesia (Moeis *et al.,* 2017).

Bitung SEZ is one of the coastal-based Special Economic Zones (SEZs) that is vital in supporting Indonesia's maritime fulcrum program. This SEZ focuses on various potential industries, including fishery processing, coconut processing, pharmaceuticals, and electricity production (specifically for smelters), with logistics as supporting initiatives (BPS Kota Bitung, 2017). They are placed in the northern part of the border with the Pacific region, an essential point of the world trade era in the future.

The primary industry of Bitung SEZ is a fishery industry that utilizes marine resources; its management should apply the principle of sustainability that should consider economic, social, and environmental aspects. Therefore, with various factors that influence and be influenced by SEZ development, an analysis is needed to review the sustainability of Bitung SEZ development. SEZ development is a complex problem since it involves multiple stakeholders, has a long-term time dimension, and can be considered ill-structured. Those three characteristics are commonly answered using System Thinking and System Dynamics as the primary (modeling) approach. (Moeis *et al.,* 2020a; Destyanto, Hidayatno, and Amalia, 2017; Hidayatno, Rahman, and Muliadi, 2015; Yuliawati *et al.,* 2015).

The purposes of this research are (1) to understand a coastal-based SEZ using Bitung SEZ as an example and (2) to develop a System Dynamics model that explains the structure of a coastal-based SEZ and assess policy options that can be implemented within it. Thus, the central question of this research is," How does coastal-based SEZ policy affect the factors that could boost and support sustainable coastal-based SEZ development?"

2. Methodology: System Dynamics Modeling

2.1. System Diagram

System Diagram (Frantzeskaki and Walker, 2013) is a bare canvas for analysts to draw a conceptual model of a system. It was derived from the cybernetics framework. It consists of endogenous variables (the system and indicators) and exogenous variables (external factors and policy options). System Diagrams are widely used in policy modeling and analysis. Our (conceptual) model enriches the number of research/ studies that used the Frantzeskaki and Walker (2013) approach.

SEZs serve as one of the potential solutions to address the economic disparity between the eastern and western parts of Indonesia. By developing SEZs, goods will then be produced, thus lowering the trade imbalance between the western and the eastern regions. The Bitung SEZ System (Figure 1) was divided into economic, social, and environmental loops. Policy Options represent the policy measures that the problem owner (i.e., the Indonesian government) can take to alter the outcome of their interest (GDRP growth, employment rate, ocean acidification). External Factors represent the exogenous variables that the problem owner cannot control. The economic sector comprises a public (government) and private (per household) economy. Employment variables and innovation and education represent social items. The environmental section deals with how industries need natural resources as raw materials and how industrial emissions affect ocean acidification.

Each loop represents the connection between variables. There are six reinforcing loops and one balancing loop. The first reinforcing loop means private economics that Gross Domestic Regional Product (GDRP) will affect household income. As income increases, the investment amount will also be increased. Therefore, a higher number of investments will contribute positively to GDRP. The second reinforcing loop represents public economics, where GDRP affects household income and consumption, leading to government revenues (Moeis *et al.*, 2020b).

The third reinforcing loop represents the social aspect, which shows the same GDRP to government expenditure flow that led to the innovation and education index. A good index will lower the unemployment rate. A lower unemployment rate will increase industrial production and GDRP. The fourth reinforcing loop represents fishery, where a higher GDRP will lead to higher technology for the ships to catch fish and increase output and GDP.

Furthermore, the fifth reinforcing loop represents ocean acidification that will decrease because of technology. Nevertheless, the higher acidification affects the lower number of fish, leading proportionally to industry and GDRP. The sixth reinforcing loop represents coconut plantations that start from GDRP to investment, leading to a more considerable land plantation and coconut. Therefore, increased coconut production may lead to higher production and GDRP. The only balancing loop represents carbon impact from production to ocean acidification, affecting fewer fish and reducing production.

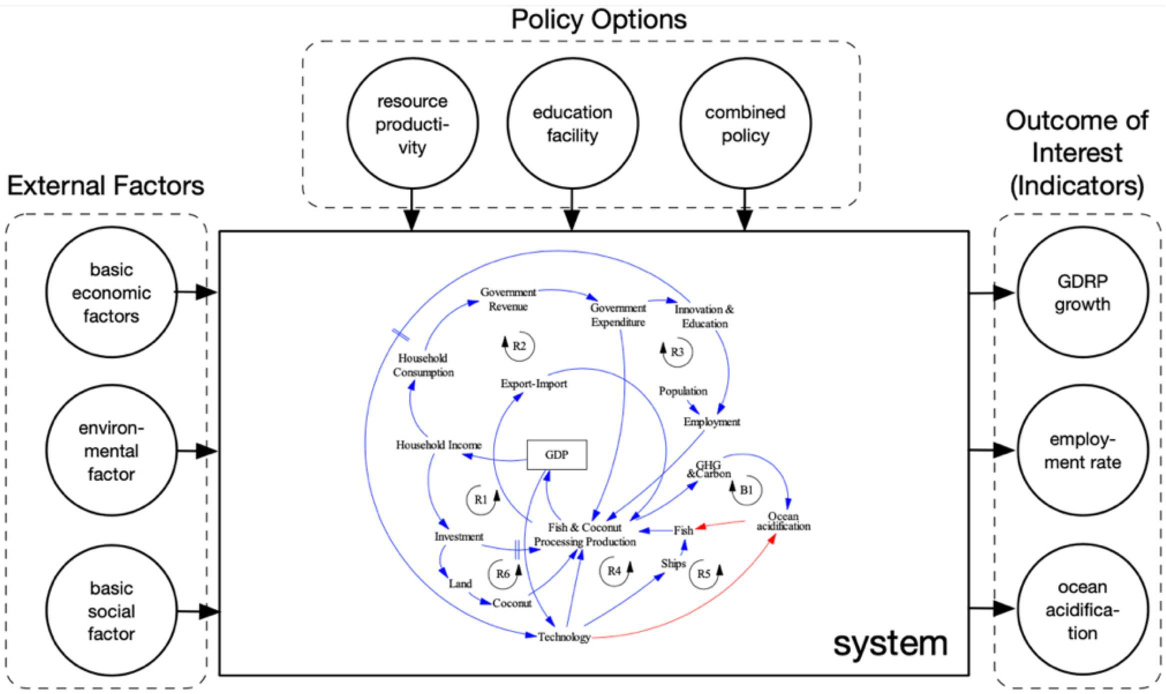

Figure 1 Bitung SEZ system diagram

2.2. Stock and Flow Diagram

The model has three main modules: the economy module, the social module, the environmental module, and its submodules.

<u>2.2.1. The Economy Module</u>

The economic module models the impact of a special economic zone on economic variables, both at the macro-state and micro-level of the industries. It calculates the money flow from investments and capital, contributing to valuable production that enhances the GDRP. This module is divided into the Local Economic and the Industrial sub-modules.

2.2.1.1. The Local Economy Submodule

The main stock in this sub-module is GDRP, with calculations based on expenditure, as shown in Figure 2. In calculating the GDRP of the following year, the aspect of Bitung's Special Economic Zone is combined using increments. Thus, two factors affect the magnitude of GDRP: the natural growth of GDRP, which influenced the amount of GDRP the previous year (which is the value of the stock), and the amount of GDRP from Bitung SEZ. Investments are coming from the government and the private sector. It matches the existing investment projections. They are then divided into investments for innovation facilities, fish processing, and coconut processing.

2.2.1.2. The Industry Submodule

Figure 3 shows two industries as the focus in the SEZ, namely the processing of coconut and fish. This sub-module starts with an allocated investment. The incoming investment will be processed by giving components such as raw materials and labor next year. The composition of capital for raw materials is quite large, with a percentage of over 60%. Furthermore, this investment can be calculated relative to the initial investment so that the effect can be multiplied by the amount of initial production. The result of production is assumed to be entirely exported as designed in the Master Plan. We also measure the environmental impacts on the industry's energy use and emissions.

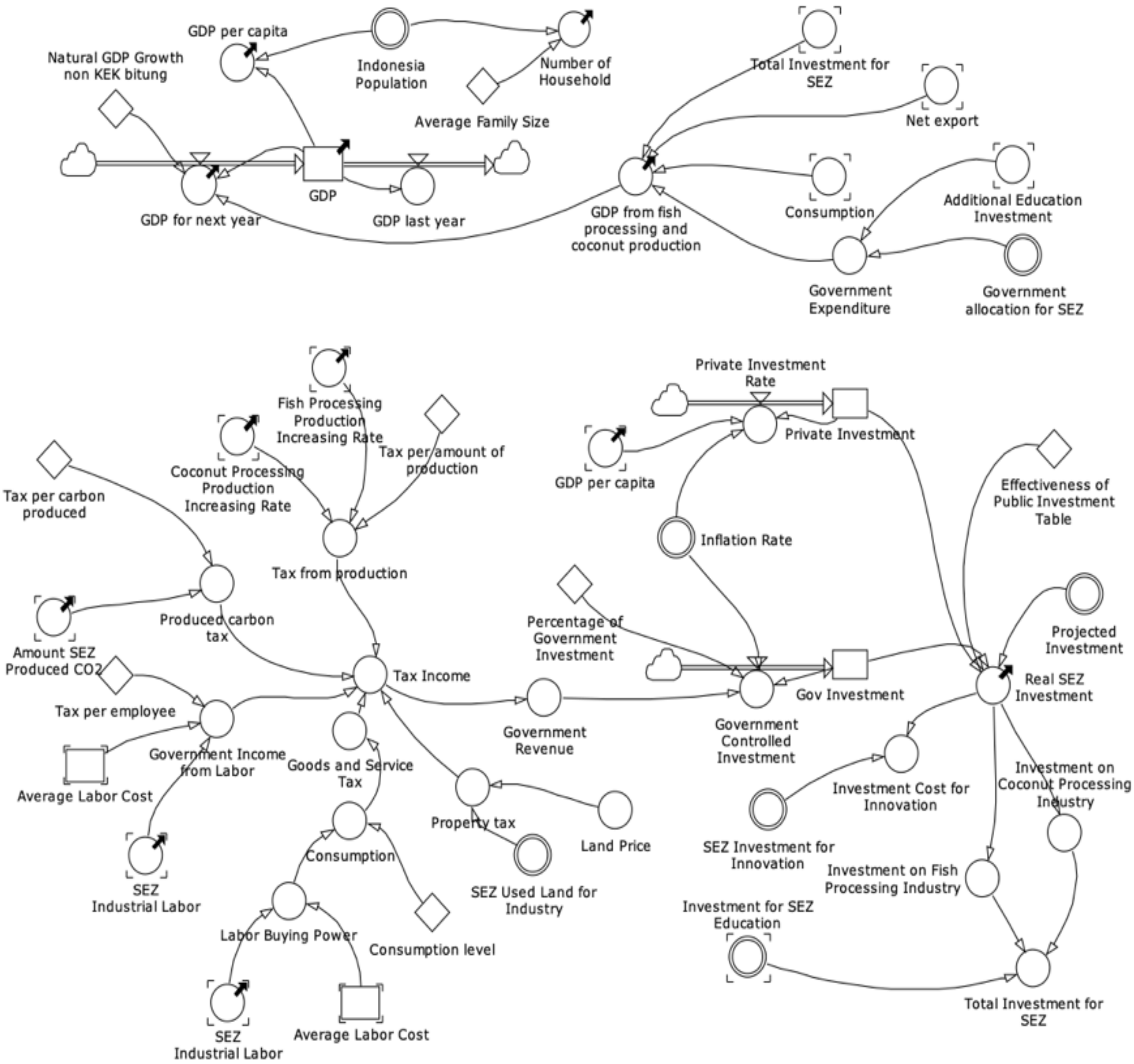

Figure 2 Stock and flow diagram of the local economy submodule

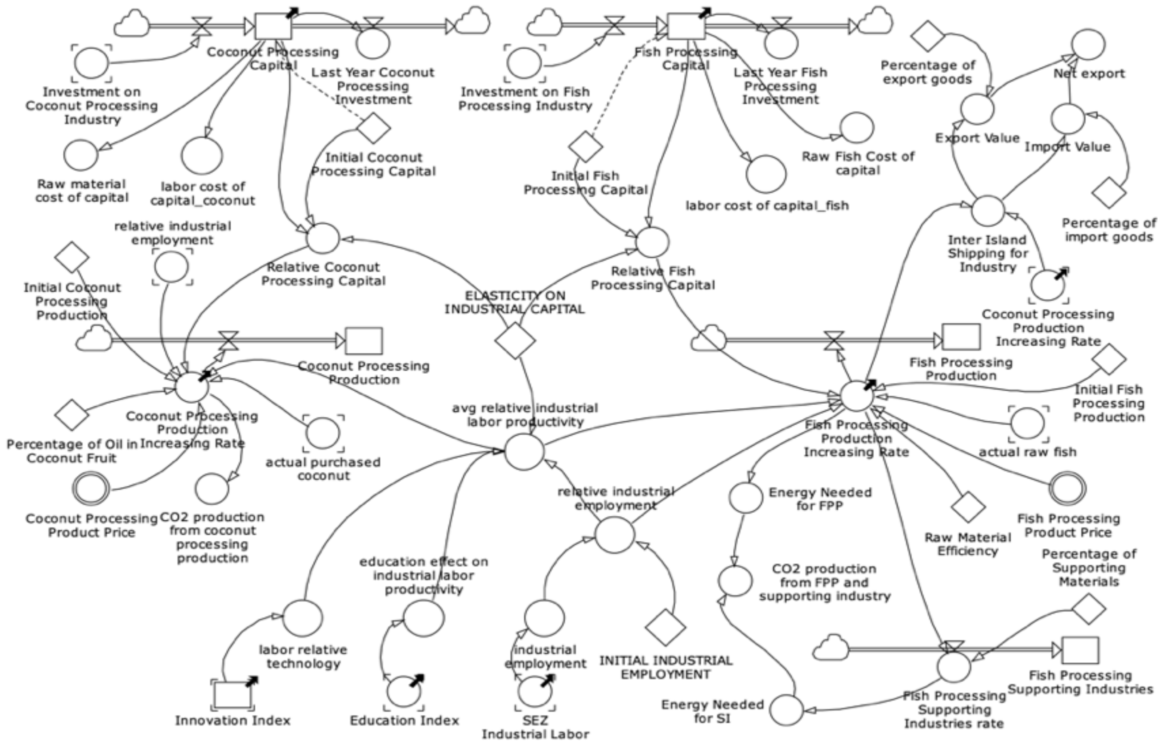

Figure 3 Stock and flow diagram of the industry submodule

2.2.2. The Social Module

The social module consists of the labor and the innovation & education sub-module. The basic assumption is that innovation and education will enhance labor quality, and good labor quality will also support innovation growth and better education standards.

2.2.2.1. The Labor Submodule

In the labor submodule, another influential sub-module variable is the allocation of capital for labor costs (the exact number of laborers that can be employed by considering the cost of workers per person). The workforce calculated as part of SEZ is sourced from industry, innovation, and education facilities. With the increased demand for such a workforce, there will be a corresponding rise in the number of people employed, thereby directly reducing the unemployment rate in the SEZ, as shown in Figure 4.

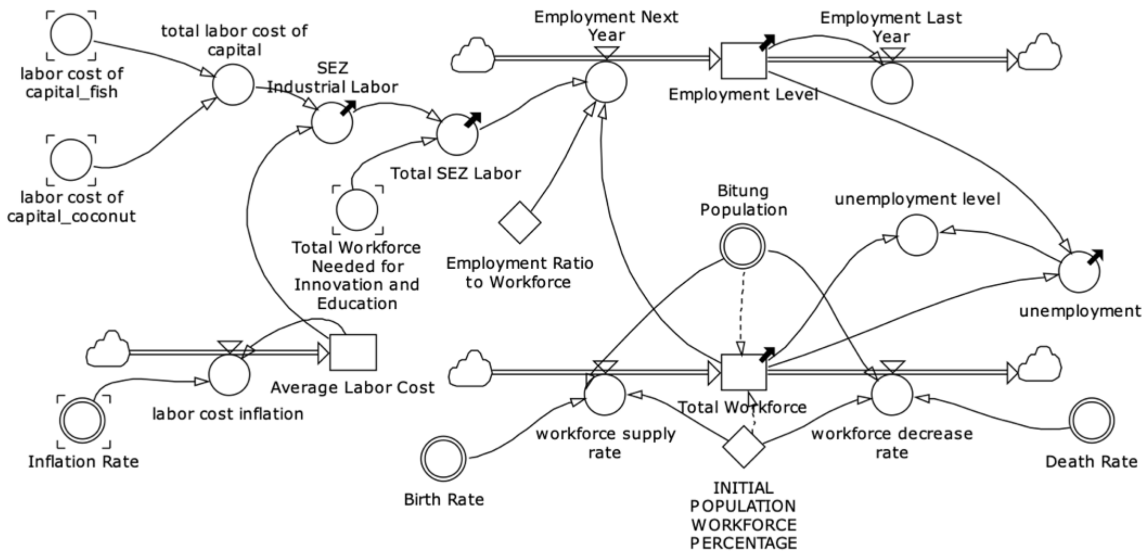

Figure 4 Stock and flow diagram of the labor submodule

2.2.2.2. The Innovation and Education Submodule

The two essential variables are modeled in this sub-module shown in Figure 5: the education and innovation index. The education index is calculated from the number of students considered in the labor force divided by the number of students. Junior High School, Senior High School, Higher Education, and Elementary students influence the Education Index. The Innovation Index is controlled by the New Innovation Facility and Tech Advance Parameter, respectively.

The Master Plan of Bitung SEZ has allocated a particular area to build educational facilities, so this development is part of the initial investment. In addition, Bitung SEZ also set up several places to build research facilities to generate innovations that would benefit industry players within the SEZ. The initial assumption is that Bitung SEZ has two research facilities for the coconut and fishery industries. This research facility's development level will affect technological progress, ultimately affecting the innovation index, which can be a multiplier factor for industrial productivity improvements.

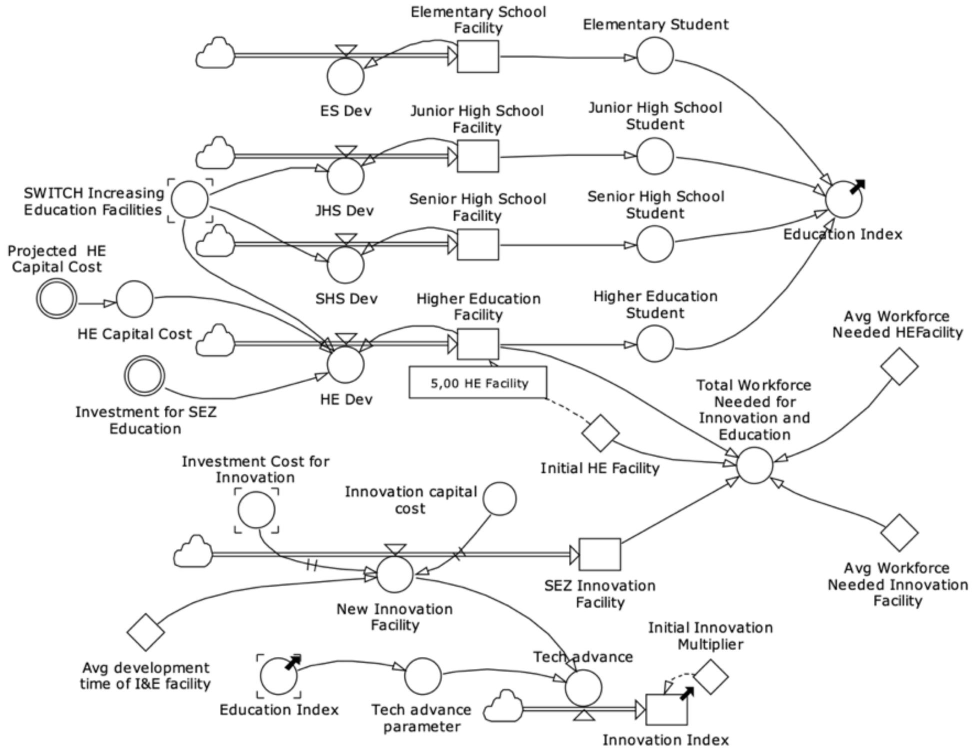

Figure 5 Stock and flow diagram of the innovation and education submodule

2.2.3. The Environment Module

According to various studies, environmental factors are sometimes barriers to a rapidly growing industry due to limited resources and how the industry's output disturbs ecological stability. This module comprises the coconut, the fisheries, and the ocean acidification sub-modules.

2.2.3.1. The Coconut Submodule

Figure 6 shows the modeling of coconut plantations and their potential to be the industry with the highest added value compared to other coconut products. This coconut potential is seen first from land use for coconut plantations that produce coconuts for raw materials. There may be a difference between the harvested coconut and the processed coconut. Thus, the existence of the 'coconut to or from outer Bitung' variable becomes a variable which, if positive, means that coconut production exceeds the demand for raw materials for the processing plant. The assumption is that raw materials are often purchased from outside Bitung (only 60% are supplied from within).

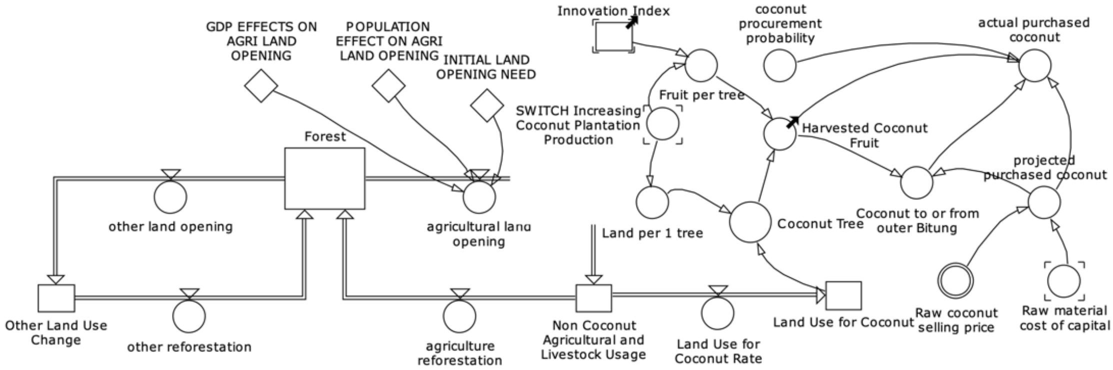

Figure 6 Stock and flow diagram of coconut submodule

2.2.3.2. The Fisheries Submodule

Figure 7 shows that the potential of fish influences the number of fish caught in the catchment area. Moreover, the model shows the relationship between plankton and the number of fish catches. The comparison between plankton and big pelagic fish that became the seed of Bitung is 1 : 10000 (Sverdrup, Duxbury, and Duxbury, 2006).

The number of plankton, ships, capacity, and average travel also affect fish catches. Like the coconut submodule, there is a possibility that the production of fisheries in Bitung will be surplus. Otherwise, there is a 50% chance that raw materials will not be met if purchased from another region.

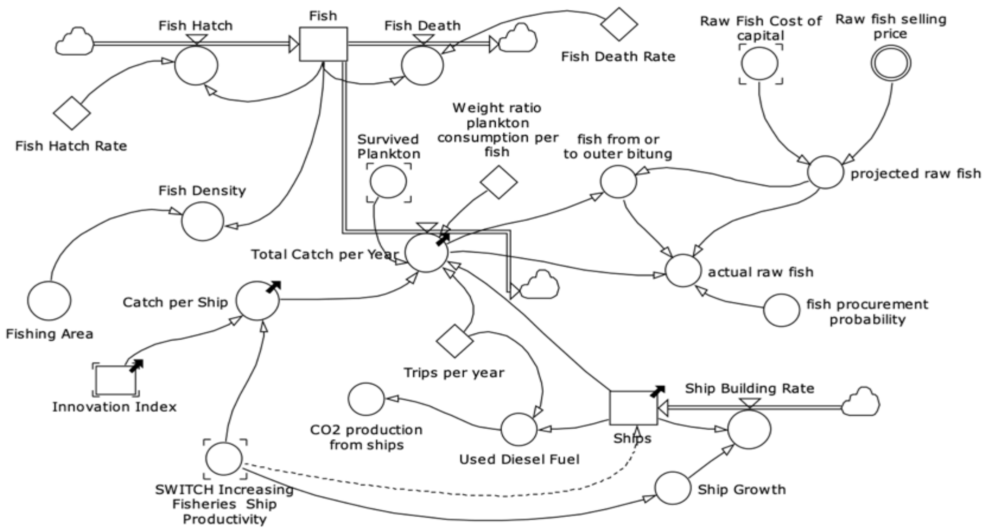

Figure 7 Stock and flow diagram of the fisheries submodule

2.2.3.3. The Ocean Acidification Submodule

In Figure 8, the real impact of SEZ is the electricity consumption that leads to CO_2 emissions expenditure. The CO_2 is then absorbed into the oceans by about 30% of the total produced (Millero, 1995). The CO_2 gets denser in the seawater solution with the absorption, thus affecting the CO_2 pressure. The present ocean conditions around the Pacific Ocean are 8.1 pH, indicating 511 μatm pCO_2. By calculating the pCO_2, it becomes possible to map the effect of ocean acidification by considering the natural increase predicted by experts, which suggests that the ocean's acidity will decrease and become more acidic by 0.4 by the year 2100 (Caldeira and Wickett, 2003). The current level of ocean acidification will affect the level of defense of phytoplankton, the most diminutive living creature in the sea. The number of phytoplankton was measured by multiplication of the area of capture multiplied by the amount of phytoplankton in 1 hectare, which is 1 million cells per mL weighing 14 femtograms per cell (Mora *et al.*, 2013).

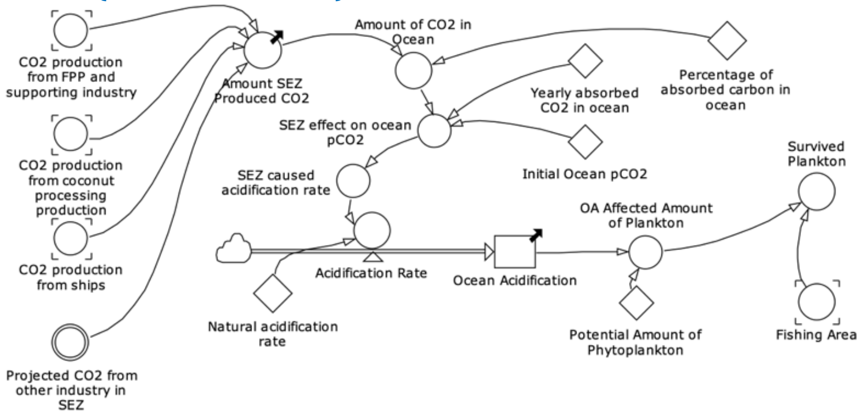

Figure 8 Stock and flow diagram of the ocean acidification submodule

2.3. Model Validation

2.3.1. Sensitivity Analysis

In this simulation, the tested variable was the effect of the employment-technological relative variable on the production value of coconut processing. This relationship is considered valid if it is proved that a higher level of technology in employment and industry will lead to higher industrial production value. Figure 9 shows that both variables show consistent trends.

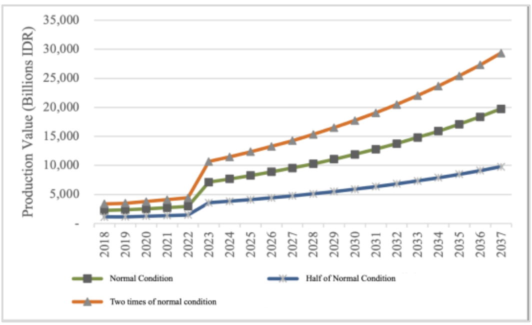

Figure 9 Effects of the relative labor and the technology variables on the production value of coconut processing industries

2.3.2. Error Integration Test

The test was done by simulating the model with three different time steps (1 year, six months, and 30 days). Based on the results obtained, there is no significant difference between the three time steps (Figure 10).

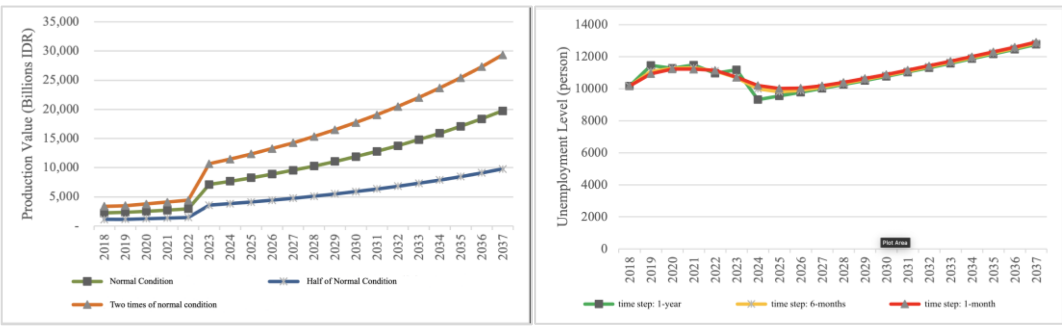

Figure 10 Integration test: the Bitung SEZ GDRP - in billions IDR (left), the level of unemployment – in person (right)

2.3.3. Behavioral Reproduction Test

The first Behavioral Reproduction Test was conducted by comparing the investment value of business actors in Bitung SEZ with the prediction of the Bitung SEZ Master Plan. Figure 11 shows that the total business investment (simulation result) is relatively the same as the projected investment value calculated by the Indonesia Board of SEZs (the error rate is 0.88%).

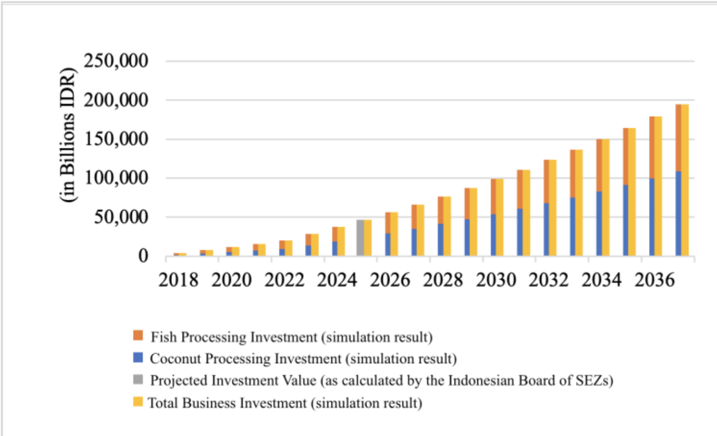

Figure 11 Investments model/simulated vs. projection/data (in a million Rupiahs)

3. Results and Discussion

3.1 Business-as-Usual (BaU) Result Analysis

Figure 12 (left) shows the economy module simulation results, especially economic growth from the contribution of the Bitung SEZ, the fisheries, and the coconut processing industry. However, the GDRP generated is from the industry and the investment, consumption, export-import values, and government expenditure value, which is intended for the Bitung SEZ from 11.69% (natural growth) to 11.75%. The coconut industry also contributes to the GDRP but can be improved by maximizing the production capacity and supply of raw materials.

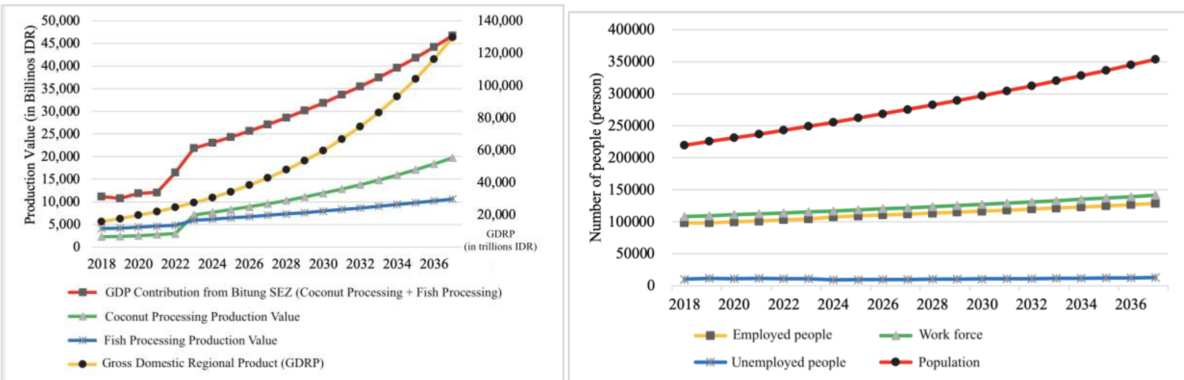

Figure 12 The economy module (left) and the social module (right) simulation results for business-as-usual scenario

The job creation within the SEZ is attributed to the growth of industries, innovation, and education facilities. However, a concerning issue has been identified with the education index, which shows a decline from 0.59 in 2018 to 0.49 in 2037 due to the inequality of educational facilities and the rapid growth of primary school development compared to secondary schools and colleges.

The environment module simulation results show that emissions increased from 121,292 tons in 2018 to 546,752 tons in 2037. The most significant contributors to emissions are the fish processing industry, the coconut processing industry, the marine ship emissions, and others. Of the produced emissions, 30% are absorbed by the sea, but Bitung only has 0.0077% of the total global emissions annually. Hence, the share and impacts of Bitung SEZ emissions in ocean acidification are tiny. By 2037, the sea acidity rate of 7.95 is still in line with expert predictions (Caldeira and Wickett, 2003). However, the number of phytoplankton directly affected by the acidity of the sea is still within safe limits.

3.2. Alternative Policies Development

Three policy scenarios are analyzed:

1. Natural Resource Productivity (NRP) transforms productive coconut varieties and fishing management strategies. Two productivity improvements targeted resources are coconut and fisheries. Coconut harvesting (production) is improved by planting a better-quality tree, while for fishing, the means is improving catching equipment.
2. Facilitate the Development of Education Facilities (DEF) from junior high schools to vocational schools and colleges. With this development, the targeted variable to be indicated is raising the educational index and increasing the industry's productivity.
3. Combination of NRP and DEF Policies. In this combined policy, the two approaches above are partly applied in a 20-year simulation to obtain the excellent effect of changing the size of the resource as raw material as input factor and the contribution of the education index to labor productivity as the production factor of the industry.

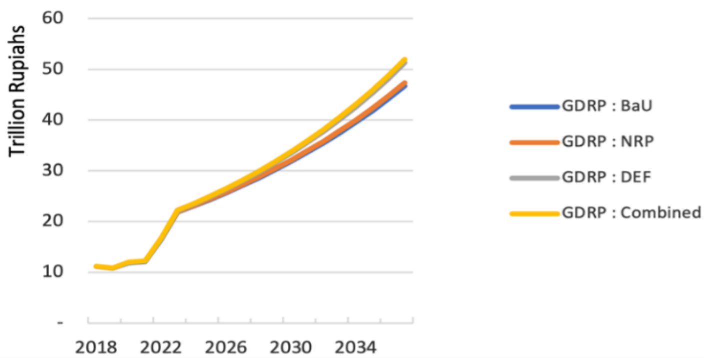

Figure 13 GDRP Generated for Each Policy Option

The assigned Policy Options directly affect indicators of the system (GDRP growth, employment rate, and ocean acidification) positively. This shows that the system archetype that exists in this system is "Escalation."

4. Conclusions

The System Diagram (and the preceding Causal Analysis) helps to construct our understanding of coastal-based SEZ. Moreover, that knowledge was then used to build a System Dynamics model that was being used to assess a set of possible policy scenarios. This study explores the promise of SEZ development policy taken by the Indonesian government with the "coastal-based" mindset of Bitung SEZ in North Sulawesi with the help of the System Dynamics model. The simulation results show that Bitung SEZ can positively impact economic growth GDP, reduce unemployment, and sustain its environment. This study offers some practical insights for policymakers; based on the model, there are three factors that they should focus on. Those are fishing productivity, coconut harvest productivity, and the education index. Based on these factors, three alternative policy scenarios were tested in the model: NRP (Natural Resources Productivity), DEF (Development of Education Facility), and combined policy. The DEF policy option offers a better cost-to-benefit ratio. This result shows that investment in education (and research), with its knowledge spillover, will increase the economic, social, and environmental benefits of an SEZ.

References

Association of Southeast Asian Nations (ASEAN), 2016. Association of Southeast Asian Nations (ASEAN) Guidelines for Special Economic Zones (SEZs) Development and Collaboration, Available Online at: http://asean.org/storage/2016/08/ASEAN-Guidelines-on-SEZ- Development.pdf, Accessed on March 25, 2020

Badan Pusat Statistik (BPS) Kota Bitung, 2017. Kota Bitung dalam Angka (Bitung city in Figures). In: *Badan Pusat Statistik Kota Belitung*

Caldeira, K., Wickett, M.E., 2003. Anthropogenic Carbon and Ocean pH. *Nature*, Volume 425(6956), pp. 365–365

Destyanto, A.R., Hidayatno, A., Amalia, A., 2017. Analysis of The Effects of CO_2 Emissions from Coal-Fired Power Plants on the Gross Domestic Regional Product in Jakarta. *International Journal of Technology*. Volume 8(7), pp. 1345–1355

Farole, T., Akinci, G., 2011. Special Economic Zones: Progress, Emerging Challenges, and Future Directions. In: *World Bank Publications*

Frantzeskaki, N., Walker, W.E., 2013. Appendix: Concepts and Methods for Policy Analysis. Series in Operations Research and Management Science 179. In: *Thissen, W.A.H., Walker, W.E., (Ed.), Public Policy Analysis: New Developments*. pp. 263-278

Hidayatno, A., Rahman, I., Muliadi, R.,2015. Policy Analysis of the Jakarta Carbon Mitigation Plan using System Dynamics to Support Decision Making in Urban Development–options for Policymakers. *International Journal of Technology*. Volume 6(5), pp. 886–893

Kementerian Keuangan Republik Indonesia (Kemenkeu RI), 2017. Laporan Perkembangan Perekonomian Bulan April 2017 (Economic Development Report for April 2017). Available Online at http://www.anggaran.depkeu.go.id/content/Publikasi /2017LaporanPerkembanganEkonomiApril.pdf, Accessed on September 28, 2020

Komite Percepatan Penyediaan Infrastruktur Prioritas (KKPIP), 2015. Indonesia Bitung Special Economic Zone: Final report. *Komite Percepatan Penyediaan Infrastruktur Prioritas (KKPIP)*

Millero, F.J., 1995. Thermodynamics of the carbon dioxide system in the oceans. *Geochimica et Cosmochimica Acta*, Volume 59(4), pp. 661–677

Moeis, A.O., Desriani, F., Destyanto, A.R., Zagloel, T.Y., Hidayatno, A., Sutrisno, A., 2020. Sustainability Assessment of the Tanjung Priok Port Cluster. *International Journal of Technology*, Volume 11(2), pp. 353–363

Moeis, A.O., Marcheline, S., Destyanto, A.R., Yuri Zagloel, T., Hidayatno, A., 2020. Indonesian Port Cluster Simulation Game: Understanding Complex System Through Simulation Game. *Jurnal Penelitian Transportasi Laut (Journal of Marine Transportation Research)*, Volume 22(1), pp. 13–20

Moeis, A.O., Wirawan, N.F., Destyanto, A.R., Setiawan, A.D., Putra, B.H.H., Zagloel, T.Y., Hidayatno, A., 2021. Locating a Hub Port in Eastern Indonesia Using Network Analytics. *Jurnal Penelitian Transportasi Laut (Journal of Marine Transportation Research)*, Volume 23(2), pp. 49–54

Moeis, A.O., Zagloel, T.Y., Hidayatno, A., Komarudin, K., Guo, S., 2017. Designing Indonesian Liner Shipping Network. *Jurnal Teknik Industri (Journal of Industrial Engineering)*, Volume 19(1), pp. 47–54

Mora, C., Wei, C.-L., Rollo, A., Amaro, T., Baco, A.-R., Billett, D., Bopp, L., Chen, Q., Collier, M., Danovaro, R., Gooday, A.-J., Grupe, B.-M., Halloran, P.-R., Ingels, J., Jones, D.-O.B., Levin, L.-A., Nakano, H., Norling, K., Ramirez-Llodra, E., Rex, M., Ruhl, H.-A., Smith, C.-R., Sweetman, A.-K., Thurber, A.-R., Tjiputra, J.-F., Usseglio, P., Watling, L., Wu, T., Yasuhara, M., 2013. Biotic and Human Vulnerability to Projected Changes in Ocean Biogeochemistry Over the 21st Century. *PLos Biology*, Volume 11(10), p. e1001682

Sverdrup, K.A., Duxbury, A., Duxbury, A.C., 2006. Fundamentals of Oceanography. In: *McGraw-Hill Higher Education*

The Asian Development Bank, 2015. Asian Economic Integration Report 2015: How can special economic zones catalyze economic development? Available Online at: https://www.adb.org/sites/default/files/publication/177205/asian-economic-integration-report-2015.pdf, Accessed on April 20, 2019

The United Nations Development Programme, 2016. Human Development Report 2016: Human Development for Everyone. Available online at: http://report2016.archive.s3-website-us-east-1.amazonaws.com/, Accessed on April 24, 2020

Yuliawati, E., Hadiwardoyo, S.P., Susantono, B., Tjahjono, T., 2015. System Dynamics Model for Airport Characterization in Hub-and-Spoke Networks. *International Journal of Technology*. Volume 6(5), pp. 733-742