FINAL PROJECT – TI 141501

VALUATING INDONESIAN UPSTREAM OIL MANAGEMENT SCENARIO THROUGH SYSTEM DYNAMIC MODELLING

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TUGAS AKHIR – TI 141501

VALUASI SKENARIO TATA KELOLA HULU MINYAK BUMI DENGAN PEMODELAN SISTEM DINAMIK

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APPROVAL SHEET

Valuating Indonesian Upstream Oil Management Scenario Through System Dynamic Modelling

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ABSTRACT

Under the existing regulation in Constitution Number 22 Year 2001 (UU No 22 Tahun 2001), *Production Sharing Contract* (PSC) continues to be the scenario in conducting oil and gas upstream mining activities as the previous regulation (UU No. 8 Tahun 1971). Because of the high costs and risks in upstream mining activities, the contractors are dominated by foreign companies, meanwhile National Oil Company (NOC) doesn't act much. The domination of foreign contractor companies also warned Indonesia in several issues addressing to energy independence and energy security.

Therefore, to achieve the goals of energy which is independence and security, there need to be a revision in upstream oil activities regulating scenario. The scenarios will be comparing the current scenario, which is PSC, with the "full concession" scenario for National Oil Company (NOC) in managing oil upstream mining activities. Both scenario will be modelled using System Dynamics methodology and assessed furthermore using financial valuation method of income approach. Under the 2 scenarios, the author will compare which scenario is better for upstream oil management in reaching the goals mentioned before and more profitable in financial aspect. From the simulation, it is gathered that concession scenario offers better option than PSC in reaching energy independence and energy security.

Keywords: Upstream Oil Management, Energy Independence, Energy Security, System Dynamics Methodology, and Financial Valuation

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VALUASI SKENARIO TATA KELOLA HULU MINYAK BUMI DENGAN PEMODELAN SISTEM DINAMIK

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ABSTRAK

Dibawah regulasi UU Nomor 22 Tahun 2001, *Production Sharing Contract* (PSC) tetap menjadi skenario dalam pengelolaan sektor hulu minyak bumi dan gas seperti yang terdapat pada UU Nomor 8 Tahun 1971. Tingginya biaya yang diperlukan dalam melakukan aktivitas hulu minyak dan gas serta tingginya risiko yang ada, kontraktor didominasi oleh perusahaan – perusahaan asing, sedangkan perusahaan minyak nasional (NOC) tidak melakukan banyak aktivitas di sektor ini. Dominasi kontraktor asing menyebabkan Indonesia rentan terhadap isu – isu kemandirian energi dan ketahanan energi.

Oleh karena itu, untuk mencapai tujuan kemandirian energi dan ketahanan energi, perlu adanya perbaikan terhadap skenario tata kelola hulu minyak. Dalam penelitian ini, akan dibandingkan skenario saat ini yaitu PSC dengan skenario konsesi bagi NOC untuk pengelolaan sektor hulu minyak. Kedua skenario akan dimodelkan dengan pendekatan Sistem Dinamik dan akan dinilai dengan metode valuasi menggunakan pendekatan pendapatan. Dari kedua skenario, akan dipilih skenario yang lebih baik untuk mencapai tujuan tata kelola hulu minyak. Hasil simulasi menunjukkan bahwa skenario konsesi menawarkan sistem tata kelola yang lebih baik dibandingkan PSC dalam mencapai kemandirian energi dan ketahanan energi.

Kata Kunci: Tata Kelola Hulu Minyak, Kemandirian Energi, Ketahanan Energi, Metodologi Sistem Dinamik, dan Valuasi Keuangan

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PREFACE

Alhamdulillah, the author would like to praise Allah SWT for all His mercy, blessings, and guidance given to the author therefore this final project report can be finished on time. Shalawat and salaam also delivered for our beloved Prophet Muhammad SAW.

This final project is written to fulfill the requirement in obtaining Bachelor Degree in Bachelor Program of Industrial Engineering. It can't be finished without the help of other people. Therefore, the author would also like to express gratitude and thankful feelings for these people who have helped the author in finishing this final project:

1. Author's beloved family; Father (Ir. Akhmad Masurkan), Mother (Afriana Herlinawati), Brother (Risyad Alauddin Zaidan), Sister (Nadin Almira Yasmin), Grandmothers, and big family for all the prayers, support, care, and attention.
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5. Author's beloved TI – 29 (CYPRIUM) who have shared knowledge and experience, prayers, and spirit in doing this final project.
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Finally, the author realized that this final project is imperfect. There might be some accidental mistakes or any other things that contributed to the imperfection of this final project. The author widely opens any supportive critics and recommendation from the reader, as the way for knowledge sharing between both parties, to make this final project better. With the release of this final project, the author wished that it can be useful and beneficial for the development of knowledge.

Surabaya, July 2017

Author

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INTRODUCTION

This chapter contains the background in doing this final project, the problems formulation that will be solved, the objective in conducting final project, the benefits of doing final project for both author and the company, research scope in form of limitations and assumptions, and final project writing systematics.

1.1 Background

Energy has become the main supporter of human life, such as oil and gas. Oil has become the major energy resource in the world since 1990s with the highest consumption, followed by coal and gas, as shown in the figure below.

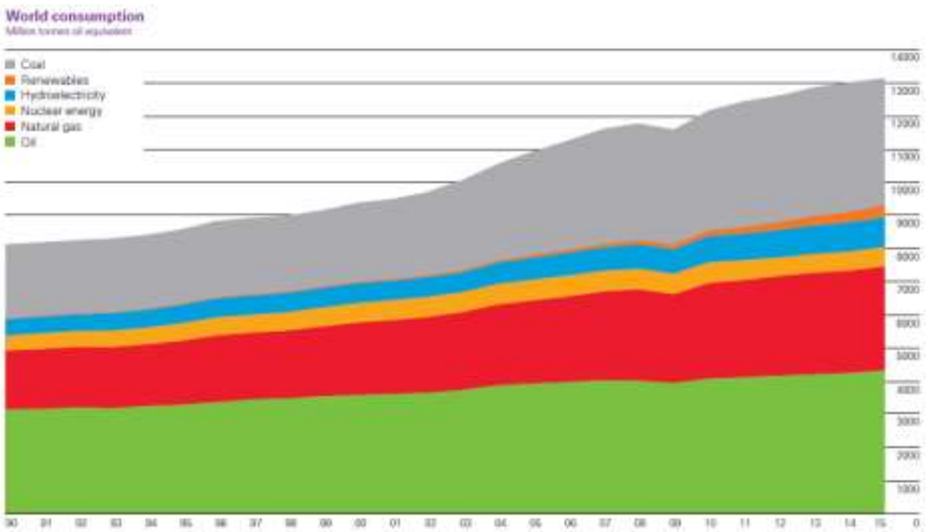


Figure 1.1 World Energy Consumption

Source: BP Statistical Review of World Energy, 2016

Since the 1990s until 2015, oil has been consumed for more than 4000 million tons/year in the world. Coal became the 2nd largest consumption, which is consumed for average 3500 million tons/year since 1990, followed by natural gas which is consumed for 1500 million tons/year in 1990 and increased up to 4500 million tons/year in 2015.

The domination of oil, coal, and gas also happened in Asia – Pacific region, including Indonesia, which still mainly rely on those resources. Oil dominates the usage of energy in Indonesia for around 32%, followed by coal for 23% and natural gas for 13% in 2014. Industrial sectors dominated the energy usage for 48%, followed by transportation sectors for 35%, household sectors for 11%, commercial sectors 4% and other sectors 2%.

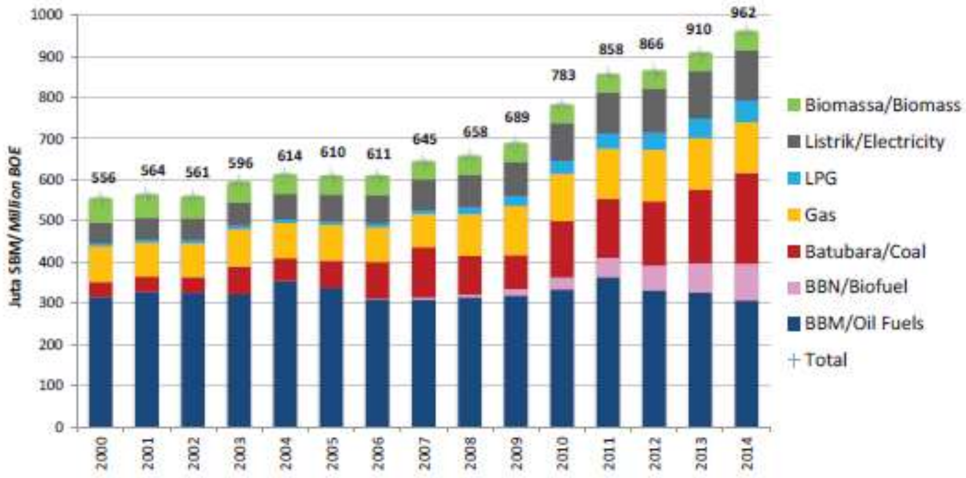


Figure 1. 2 Indonesia's Energy Consumption

Source: BPPT Energy Outlook, 2016

All the energy needs are projected to be rising for the years ahead due to the growth of Indonesian Gross Domestic Product (GDP) which is composed by the energy user sectors. With the basic scenario that there will be 6% increase in GDP per year since 2014, energy needs will increase for 5.8 times in 2050. The needs of oil will increase up to 40.7% in 2050 due to the high usage especially in transportation sector. Meanwhile, the needs of natural gas will only increase up to 13.8% in 2050. The certain increase in energy needs, especially oil and gas, unfortunately not followed by Indonesia's ability in fully supplying both oil and gas. Indonesia has been facing the supply deficit.

Indonesia has been producing oil since the era of Dutch colonialism in early 1900s and reached the "peak oil" era or the highest production two times, which is in 1980s where the production reached 1.7 million barrels/day and in 1991 – 1992 where the production reached 1.65 million barrels/day. The peak oil era, beside caused by the high production amount of oil, is also caused by the energy needs which is not as high as nowadays. Aside from the peak oil era, Indonesia's oil production continues to decline seriously. Since 2008, Indonesia could only produce oil and gas for 977 thousand oil barrels/day and continues to decline until 786 thousand oil barrels/day in 2015 (SKK Migas, 2015). Indonesia's oil production declined for 3.9% annually since 2009.

To fulfill the oil demand, Indonesia had to import both oil both in crude and refined forms, from several countries. In 2013, Indonesia imported 355.61 million barrels of crude oil, 237.41 million barrels refined oil, and 41.11 million barrels of gas. Indonesia, which became the 30th country with great oil reserves, even imported oil from South Korea and Taiwan which became the 94th country with great oil reserves (Indirasardjana, 2014). With the increase in oil and gas demand, as the consequences, the amount of oil and gas import also increases from 122 million barrels in 2014 to 1.235 million barrels in 2050 (BPPT, 2015). Indonesia has turned to the net importer of oil and gas since 2004, even Indonesia used to be the net exporter of oil and became one of OPEC (Organization of Petroleum Exporter Countries) members. Not only become an irony for Indonesia, oil import also drained Indonesia's revenue due to the unstable exchange rate against the US Dollar.

Besides the fact that Indonesia imported oil, Indonesia actually has great reserves of oil (both conventional and non-conventional reserves) which is remain undiscovered. Geologically, Indonesia has various potential oil basins as the conventional oil reserves. From 128 potential oil basins, 38 of them has been explored (Indirasardjana, 2014). Shale oil and gas reserves, which is the non-conventional reserves, haven't been explored yet, whereas the other countries such as the USA and Canada have commercially produced them while China, Argentina, and Russia are hunting for these new oil reserves. Indonesia mainly focused on exploring oil from western Indonesia's oil basins, which actually only produce a few amounts.

The decrease in oil production caused by various factors. The upstream oil mining activities is still concentrated on revitalizing the mature oil fields. Mature oil fields have no longer produce oil economically, even there's optimization effort on those fields using the water injection or Enhanced Oil Recovery (EOR). The most contributing factor is the lack of exploration activities of new oil and gas reserve in Indonesia. The new fact that 60% Indonesia's potential oil reserves located in Indonesian offshore deep-water and requires an advanced technology with high investment costs also caused the low rate of oil exploration and furthermore other upstream mining activities.

Since 1971, the upstream oil and gas mining activities are regulated by Constitution Number 8 Year 1971 (UU No 8 Tahun 1971) using Production Sharing Contract (PSC) scheme. Indonesian government act as the owner of all oil fields in Indonesia. National Oil Company (NOC) own the oil fields but doesn't do the upstream mining activities. The upstream mining activities are done by the contractors who signed the contract (Kontrak Kerja Sama/KKS) with SKK Migas as the regulator of oil and gas mining activities in Indonesia. Under the KKS, the ownership of oil fields held by Indonesian government from the beginning until the end of upstream mining activities. The production could only occur when the oil fields are proven economically-produced by the government. After production, there will be result sharing between the contractor and the government with specified percentage as stated in KKS. The KKS contractor must provide the whole initial investment costs for upstream mining activities but there is cost recovery scheme that will reimburse the "costs of oil" after the fields produce economically. When the fields can't produce economically, or even the exploration fails, the risks of loss will be owned by the contractors. Under the existing regulation in Constitution Number 22 Year 2001 (UU No 22 Tahun 2001), PSC continues to be the scheme in conducting oil and gas upstream mining activities. Because of the high costs and risks in upstream mining activities, the contractors are dominated by foreign companies, meanwhile NOC doesn't act much. The domination of foreign contractor companies also warned Indonesia in several issues addressing to energy independence and energy security.

Therefore, to achieve the goals of energy which is independence and security, there need to be a revision in upstream oil activities regulating scheme. The scenarios will be comparing the current scheme, which is PSC, with the "full concession" scenario for state-owned oil company in managing oil upstream mining activities. Both scenario will be modelled using System Dynamics methodology and assessed furthermore using financial valuation method of income approach.

System dynamics has been known as the systemic thinking discipline in system science. This methodology was firstly introduced by Jay Forrester from Massachusetts Institute of Technology (MIT) in 1963 and has been improved continuously. In its development, system dynamics has been used for analyzing and solving social, economic, managerial, political, and environmental issues which is complex, dynamic (fast-changing), and uncertain. System dynamics is important in studying system, offering comprehensive and integrated thinking which can simplify complexity without losing the essential object and also suitable in analyzing mechanisms, pattern, and system tendency based on analysis of system's complex, dynamic, and uncertain structure and behavior.

Value means the sum of economic benefits expected in the future by the owner, where each benefit is discounted to the present value with the adequate discount rate (Prawoto, 2004). Financial valuation method is used in this research to measure the value that will be got be the company before implementing the concession and after implementing the concession scenario.

Using the System Dynamics methodology and financial valuation, the author will compare which scenario is better for oil and gas management in reaching the goals mentioned before and more profitable in financial aspect. The chosen scenario will furthermore be the recommendation for the regulator in oil and gas management in Indonesia.

1.2 Problem Formulation

Based on the background explained, it's important to find out which scenario that offers better option for upstream oil management in Indonesia. This research will compare between the existing condition (Production Sharing Contract) to Concession scenario for NOC. The scenario must fulfill the goals to bring Indonesia to energy independence and energy security and also calculating the future financial benefits for the country.

1.3 Research Objective

The objective of conducting this research are as follows:

1. Finding the better upstream oil management scenario for National Oil Company to bring Indonesia to energy independence and energy security.
2. Valuating both the existing and the new oil management schenario using method in valuation.

1.4 Research Benefits

The benefits that can be attained from this research for the author are:

1. Understanding the application of knowledge gained from lecture in the real world.
2. Understanding the function of system dynamics methodology in evaluating a policy.
3. Sharing knowledge that the author had to the reader of this research.

The benefits that can be attained from this research for National Oil Company (NOC) are:

1. Receiving recommendation about the best oil and gas management scenario based on valid scientific research.

1.5 Research Scope

The scope of this research includes the limitations of this research and the assumptions that are used in conducting the research.

1.5.1 Limitations

The limitations applied in this research are:

1. The research will be conducted only for upstream oil mining activity.
2. Secondary data is used in conducting this research.
3. The method used for this research are limited to system dynamics and financial valuation.
4. The ability of NOC in managing new potential oil reserves (that may add the oil production) becomes the parameter of energy independence and the ability to supply oil demand becomes the parameter of energy security.

1.5.2 Assumptions

The assumptions that are used in this research are:

1. There's no structural change in National Oil Company (NOC) and also no change in any governmental law and constitution regarding to oil and gas.
2. Value of USD and other foreign currency are assumed stable during the making of financial model in this research.
3. Model is simplified by assuming that not all variables are dynamic.
4. Operational method in upstream oil mining activity is gathered from the expert.

1.6 Writing Systematics

This subchapter will explain the systematical writing used in this research. The systematics of this research are as follows:

CHAPTER I INTRODUCTION

This chapter explains the background of this research, the problems that are solved through this research, the objective of conducting this research, benefits of conducting research for both the author and the company, the research scope in the form of limitations and assumptions, and the writing systematics of this research.

CHAPTER II THEORETICAL FRAMEWORK

This chapter contains the fundamental theories and formulas that underlie this research. Literature review helped the author in determining which method that is useful to solve the problems in this research. Literature review in this research are taken from the trusted source such as books, journals, previous research, and others.

CHAPTER III RESEARCH METHODOLOGY

This chapter explains the step by step method used in conducting this research correctly. The methodology is drawn in a flowchart to understand the work flow during the research. The methodology started from literature study and early data collection, problem formulation, dynamic hypothesis, model formulation, model testing, scenario development and financial valuation, output analysis and interpretation, and conclusion and recommendation.

CHAPTER IV SIMULATION MODEL DESIGN

This chapter contains the current system identification, collection of secondary data that is used for conducting the research, variable identification, conceptual modelling using causal loop diagram, simulation modelling using stock and flow diagram, and model testing through verification and validation.

CHAPTER V SIMULATION OUTPUT ANALYSIS & SCENARIO DEVELOPMENT

This chapter contains the analysis of simulation result for both before concession and after concession scenario. Both of the scenarios will be compared and valuated to select the best scheme for managing upstream oil mining activity.

CHAPTER VI CONCLUSION AND RECOMMENDATIONS

This chapter contains the conclusion gathered from the research and the recommendations for National Oil Company (NOC) in managing upstream oil mining activity.

CHAPTER 2
THEORETICAL FRAMEWORK

This chapter contains the basic theories and methods that will be used in solving the problems formulated. The literature review consists of oil and gas management overview, oil and gas industry, system dynamics modelling, and financial analysis.

2.1 Oil and Gas Management

Oil and gas management review will explain more about the history of oil and gas management in Indonesia, the regulations for oil and gas activity in Indonesia, and oil and gas management model in other oil-producing countries.

2.1.1 History of Oil and Gas Management in Indonesia

Oil and gas management in Indonesia have existed for more than 130 years, started since the first discovery of oil in North Sumatra in 1885. The first oil discovery happened in Dutch colonialism era, making the management of oil and gas industry done by Dutch companies. As the long history of oil and gas, Indonesia has been running various management model to accommodate oil and gas consumption and production for all Indonesian people. The history of oil and gas management in Indonesia will be divided into 3 eras, which is colonialism era, post-independence era, and modern industrial era.

2.1.1.1 Colonialism Era

Oil and gas industry started to exist in Indonesia since the first oil discovery in 1885 by A. J. Zilijker in Langkat, North Sumatra. This phenomenon became the moment when Royal Shell (Dutch oil company) firstly built. Royal Shell conducted exploration and exploitation activity not only in Langkat, but also expanded to other area in Indonesia. The oil and gas industrial activity furthermore regulated by a constitution *Indische Mijnwett* (IM) in 1899 that explained about the concession of oil and gas activity for concession holder. In 1904, there was an amendment for IM constitution, changing the concession holder only limited to the Dutch, legal entity, or companies built in the Netherlands. Further amendment was done in 1918 by adding new clauses named Contract 5A. The Contract 5A stated that oil and gas mining activities can be done by the Netherland-Indies government. When the activities done by other party, the Netherland-Indies government will receive income from the concession holder. The foreign companies (not owned by the Netherland-Indies government) that held concession right were Standard of New Jersey (STANVAC) in 1925 and Standard of California (CALTEX) in 1936.

2.1.1.2 Post-Independence Era

After the independence of Indonesia in August 17th, 1945, the government released a constitution "UU No. 40 Tahun 1960" about oil and gas mining. UU No. 40 Tahun 1960, that became the extension of UUD 1945 Pasal 33 ayat 2, not only deleting the previous concession system but also holding the sovereignty of oil and gas resources. Some of the regulations in this constitution are:

- All oil, gas, and minerals located in Indonesian legal mining area are the national wealth managed by country.
- Oil and gas mining only undertaken by country and only conducted by national company.

As UU No. 40 Tahun 1960 applied in Indonesia, the existing foreign oil companies (Caltex, Stanvac, and Shell) are asked to adjust their operational activity with the new regulation. To implement this regulation, the government established three national companies, named Permina, Pertamin, and Permigas. Besides doing oil and gas mining activity, those companies also supervise the foreign oil companies operation.

When the negotiation with the three foreign oil companies became tough, Pan – American Oil made a deal with the government in 1962 with the terms and condition more compatible with UU No. 40 Tahun 1960. This accord furthermore became the model for the three foreign oil companies in doing operational changes in Indonesia. Caltex, Stanvac, and Shell signed the accord in September 1963, named "Kontrak Karya", and became the new oil and gas management concept in Indonesia. Some of the contents of Kontrak Karya are as follows:

- Caltex, Stanvac, and Shell discharging the concession right 5A and operating as the contractor of national company.
- Operational and managerial risk are on behalf of the contractors.
- Fund and expert human resources for operations are provided by the contractors.
- Kontrak Karya lasts for 20 years.
- Marketing and distribution facilities handed-over in 5 years.
- Oil refinery is handed – over in 10 – 15 years.
- Profit sharing between the government and contractor is 60% : 40%. The government will receive at least 20% of annual gross oil production.
- Contractor will hand 25% of its wealth as Domestic Market Obligation (DMO) and gained 0.2 $/barrel as fee.

As the foreign companies no longer holding the status as concession holder, the management is still held by them. In the implementation of this contract, there's almost no significant changes as the government role only limited to supervision and the foreign companies still doing operation as the previous system (concession). After G30S/PKI occurred in Indonesia in 1965, new regime ruled in Indonesia and led by Soeharto, changing the previous regime that was ruled by Soekarno. Permina then ruled by Dr. Ibnu Sutowo who criticized Kontrak Karya and stating that Kontrak Karya has no difference with concession. The system then continued to change to other system.

2.1.1.3 Modern Era

As Ibnu Sutowo led Permina and criticized Kontrak Karya, pushing the new system where both government and contractor taking role in oil and gas management. The big foreign companies once again couldn't accept this new changes and unready to (melepas) the management right as the terms and condition in PSC. This condition attracted smaller foreign oil company, Independence Indonesian American Oil Company (IIAPCO), to operate back in Indonesia in 1966. After 2 months negotiation, IIAPCO signed Production Sharing Contract (PSC) with Permina, and became the first PSC agreement in the history world oil and gas industry. Japan Petroleum Exploration Company (Japex), Refining Associates Ltd. Canada (REFICAN), Kyushu Oil Development Company Ltd., and Asamera Oil Indonesia Ltd. moreover following IIAPCO's footstep in signing PSC contract.

Behind the great achievement of PSC, the legality of PSC was still questioned due to the absence of regulation stating about PSC, since UU No. 44 Tahun 1960 only recognizing Kontrak Karya. Meanwhile, the other regulation, UU No. 1 Tahun 1967 about foreign investment (*Penanaman Modal Asing/*PMA), only regulating foreign investment about mining sector except oil and gas. Then in 1971, the government released UU No. 8 Tahun 1971 about Pertamina which become the legal foundation of PSC. PSC was stated in article 12 verse 1 and verse 2.

PSC development is divided into 3 phases as follows:

1. PSC First Generation (1966 – 1975)
    - Oil and gas company work as contractor of Pertamina
    - Pertamina holds all contractor's activity management
    - Cost Recovery limited to 40% of annual income
    - The difference between annual gross income and cost recovery (60%) is shared between Pertamina and contractor as much as 65%:35%. Government's take can increase up to 67.5% for certain bigger production rate.
    - Contractor must supply 25% of production rate for domestic demand (DMO) for 0.2$/barel.
2. PSC Second Generation (1976 – 1988)
    - Cost recovery isn't limited and based on Generally Accepted Accounting Principle (GAAP).
    - The difference between gross income and cost recovery shared between Pertamina and contractor for each 65.91%:34.09% (oil) and 31.82%:68.18% (gas).
    - Contractor's part will be taxed for 56% (composed of 45% income tax and 20% dividend tax), therefore the net sharing after tax is 85%:15% (for oil) and 70%:30% (for gas).

- With the existence of tax constitution year 1984, where the tax rate decrease from 56% to 48%, to defend the sharing percentage as mentioned before, production sharing before taxed is changed to 71.15%:28.85% (oil) and 42.31%:57.69% (gas).
- For the new field, contractor is given the investment credit for 20% of capital expenditure for production facility.
- Capital expenditure can be depreciated for 7 years using Double Declining Balance (DDB) method.

3. PSC Third Generation (1988 – now)

The 2nd PSC generation didn't provide cost recovery ceiling that can ensure government's income. Since the government needed income warranty, PSC 2nd generation was updated and First Tranche Petroleum (FTP) term was introduced. 20% of FTP amount (before subtracted by cost recovery) will be shared first between government and contractor. The difference between all generations of PSC is provided in the table below.

Table 2. 1 Comparison of PSC Generations

	PSC First Gen	PSC Second Gen	PSC Third Gen
First Tranche Petroleum	None	None	20%
Cost Recovery Ceiling	40%	100% (no ceiling)	80% (due to FTP)
Investment Credit		20%	17% to 20%
DMO	DMO was defined as 25% of equity oil at 0.2$/barrel	25% of equity oil, full price for the first 60 months and 0.2 $/barrel there after	25% of equity oil, full price for the first 60 months and 10% of export price there after
Equity to be Split			
Government : Contractor	65%:35%	85%:15%	85%:15%

Table 2. 1 Comparison of PSC Generations

	PSC First Gen	PSC Second Gen	PSC Third Gen
Oil : Gas	NA	70%:30% or 65%:35%	70%:30% or 65%:35%

2.2 Oil Industry

This subchapter will furthermore review about Indonesia's oil reserves, Indonesia's oil consumption, and Indonesia's oil production.

2.2.1 Indonesia's Oil Reserves

Oil and gas industrial activities have produced various vocabularies related to reserves. Collaboration of several oil and gas institutions in the world (SPE, AAGP, WPC, SPEE, and SEG) releases oil and gas resource management system called Petroleum Resources Management System (PRMS) with the latest edition released in November, 2011. PRMS is the integrated system for basic classification and categorization of petroleum reserves and resources. PRMS divided each project to 3 main classes called Reserves (satisfied commerciality), Contingent Resources (satisfied sub-commerciality), and Prospective Resources (undiscovered). The illustration of PRMS is provided below.

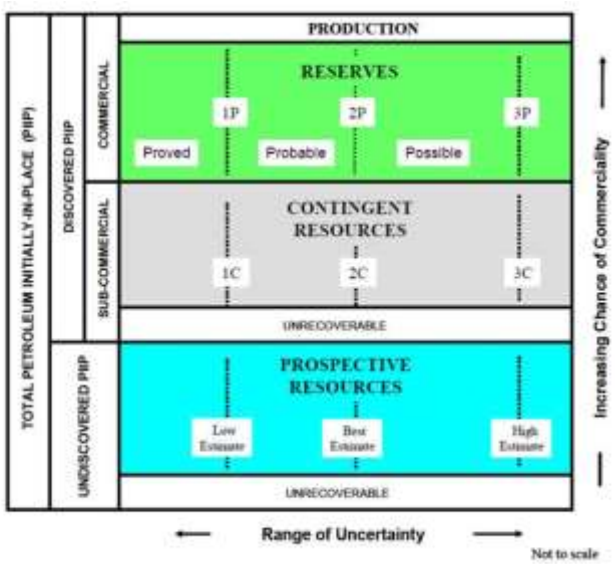


Figure 2. 1 Reserve and Resource Classification Framework in PRMS 2011

Source: Petroleum Resources Management System, 2011

To fulfill the commerciality terms, the amount of project reserves can be estimated. Based on this classification, reserves are classified into 3 kinds, those are proved (1P), probable (2P), and possible or potential (3P). Where the uncertainty ranges from low estimation (1C), best estimation (2C), and highest estimation (3C). The amount of oil and gas reserves can be shown in the figure below.

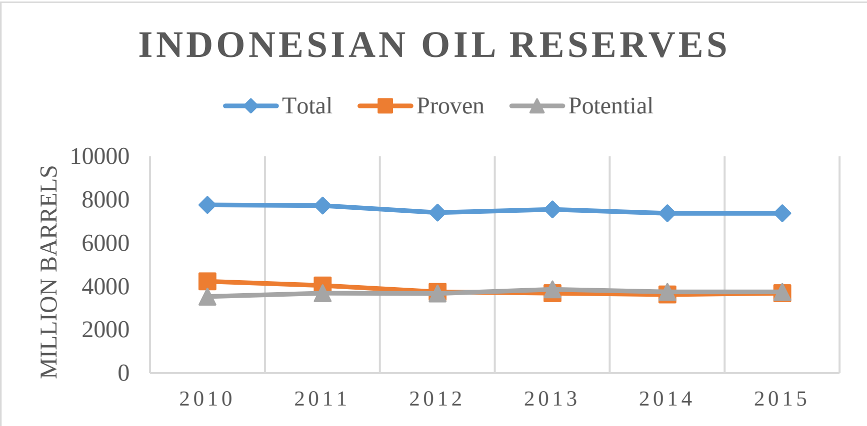


Figure 2. 2 Indonesia’s Oil Reserves Chart 2010 – 2015

Source: SKK Migas Annual Report, 2015

Indonesian potential oil reserves have been decreasing slightly each year from 2010 to 2015. While the proven oil reserves declined gradually since 2010 to 2015. This phenomenon caused the almost stable total oil reserves from 2010 to 2015.

2.2.2 Indonesia’s Oil Consumption and Production

Oil and gas are needed as the energy that fueled many sectors in our life. In 2010, Indonesian oil consumption was 1402 thousand barrels/day and it exceeds the production ability which was only 1003 thousand barrels/day (British Petroleum, 2016). Oil consumption, instead of align with the production capacity, raised gradually since 2010. In 2011, oil consumption raised to 1589 thousand barrels/day until 1676 thousand barrels/day in 2014. The condition turned when in 2015, oil consumption decreased slightly to 1628 thousand barrels/day.

Despite the rising demand of oil, the oil production showed conversely performance. Oil production has never exceeded oil consumption since 2010, which was only 1003 thousand barrels/day. Oil production continued to decrease until it reached 852 thousand barrels/day in 2014 with the decease rate of 5% per year (BPPT, 2016). Production raised slightly to 876 thousand barrels/day in 2015, yet it still couldn't fulfill the oil demand in 2015. The dynamics of Indonesian oil consumption and production can be seen in the graph below.

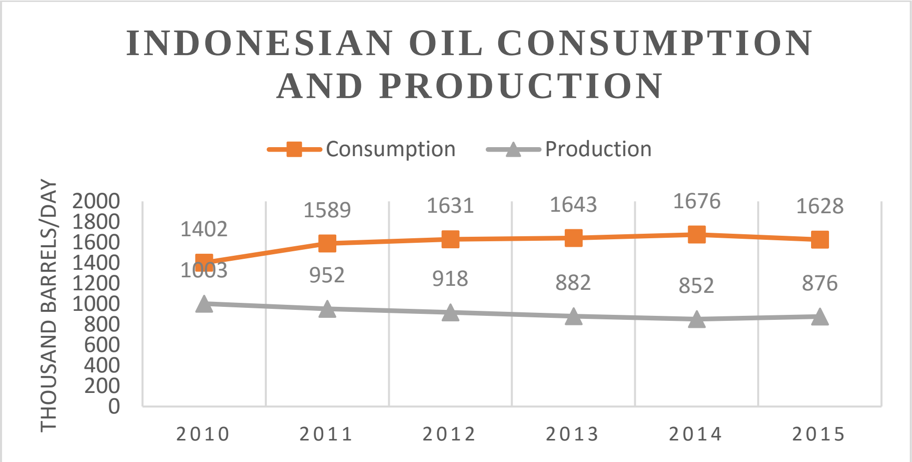


Figure 2. 3 Indonesia's Oil Consumption and Production Chart 2010 – 2015

Source: BP Statistical Review of World Energy, 2016

For several years coming, the demand of oil is projected to increase. The demand of oil will increase 3 times compared to 2014 (BPPT, 2016). Meanwhile, oil production is projected to decrease continuously until 52 million barrels in 2050.

As the consequence of declining production and demand of oil, the government allowed importing oil. Amount of oil import is projected to increase to 933 million barrels in 2050 (basic scenario) and 1,235 million barrels (high scenario).

2.3 National Oil Company

The term NOC refers to National Oil Company which is the oil company owned by a country or mostly owned by the country. There is only 1 NOC that operates in Indonesia and 100% owned by Indonesian government which is PT Pertamina (Persero). According to Peraturan Pemerintah Nomor 31 Tahun 2003, *Perusahaan Pertambangan Minyak dan Gas Bumi Negara* transformed to PT

Pertamina (Persero) that doing upstream to downstream oil and gas mining. Indonesian NOC has the vision "to be world class national energy company" and brings the mission "to carry out integrated core business in oil, gas, renewable, and new energy based on strong commercial principles". NOC has 2 main goals as follows:

1. Implementing and supporting Government's policies and programs in Economic and National Development in general particularly in the Organization of Oil and Gas Business both domestic and overseas as well as other activities which are related to or support business activities in the oil and gas sectors, and
2. Development on the resource optimization owned by the Company to produce high-quality goods and/or services and strong competitive as well as to pursue profit in order to improve company's value by applying the Limited Liability Company principles.

As a limited liability company, NOC main business can be divided into 4 sectors, those are upstream sector; gas, new, and renewable energy sector; refinery sector; and marketing sector. The subsidiary companies of NOC which is involved in those sectors are presented in the figure below.

Upstream Sector	Gas, New, and Renewable Energy Sector	Refinery Sector	Marketing Sector
• PT Pertamina EP • PT Pertamina EP Cepu • PT Pertamina Hulu Energi • PT Pertamina Geothermal Energy • PT Pertamina Drilling Services Indonesia • PT Pertamina Internasional Eksplorasi dan Produksi • PT Elnusa Tbk • Conoco Phillips Algeria Ltd • PT Pertamina EP Cepu ADK	• PT Pertamina Gas	• Refinery Unit II Dumai • Refinery Unit III Plaju • Refinery Unit IV Cilacap • Refinery Unit V Balikpapan • Refinery Unit VI Balongan • Refinery Unit VII Kasim	• PT Pertamina Trans Kontinental • PT Pertamina Retail • PT Pertamina Lubricants • PT Pertamina Patra Niaga • Pertamina Internasional Timor S.A

Figure 4. 1 Subsidiary Companies of NOC

Source: Annual Report PT Pertamina (Persero) 2015

Since the focus in this final project is upstream sector, therefore the data collection will be limited to the activities conducted in upstream sector. Currently, the subsidiary companies of NOC managing oil field across Indonesia and also overseas, conducting upstream oil and gas mining activities such as exploration of new oil reserves onshore and offshore. Not only exploration, the subsidiary companies also do exploitation of oil from the proven reserves. The list of oil field managed by NOC's subsidiary companies and also the capacity of each field (in million barrels/year unit) is provided in the table below.

Table 4. 1 Oil Field Managed by NOC

Subsidiary Companies	Oil field capacity 2015 (MBBLs)
PEP	
Asset 1	160.446
Asset 2	268.474
Asset 3	262.923
Asset 4	48.147
Aset 5	138.732
KBT	161.862
KSO	274.146
Project	10.207
SUBTOTAL	1.324.937
PHE	
Java (JOB)	6.637
Java (own operation)	138.355
Sumatra	37.551
Kalimantan	14.310
Overseas	1.346
SUBTOTAL	198.199
Pertamina EP Cepu	
Cepu Block	120.073
ConocoPhillips Algeria	
Algeria	77.230
Pertamina Internasional	
Pertamina Iraq	193.150
Pertamina Malaysia	104.254

Table 4. 1 Oil Field Managed by NOC

Subsidiary Companies	Oil field capacity 2015 (MBBLs)
SUBTOTAL	297.404
TOTAL	**2.017.843**

According to Lubiantara (2012), 80% of Indonesian oil production is generated by International Oil Company (IOC) and the rest 20% is generated by NOC, which is relatively small compared to the participation of NOC in other country such as Algeria (minimum 51%), Venezuela (minimum 50 – 60%), United Arab Emirates (minimum 60%), Malaysia (minimum 60%), and Saudi Arabia (100% production by Saudi Aramco). The portion of Indonesian oil producer is shown in the figure below.

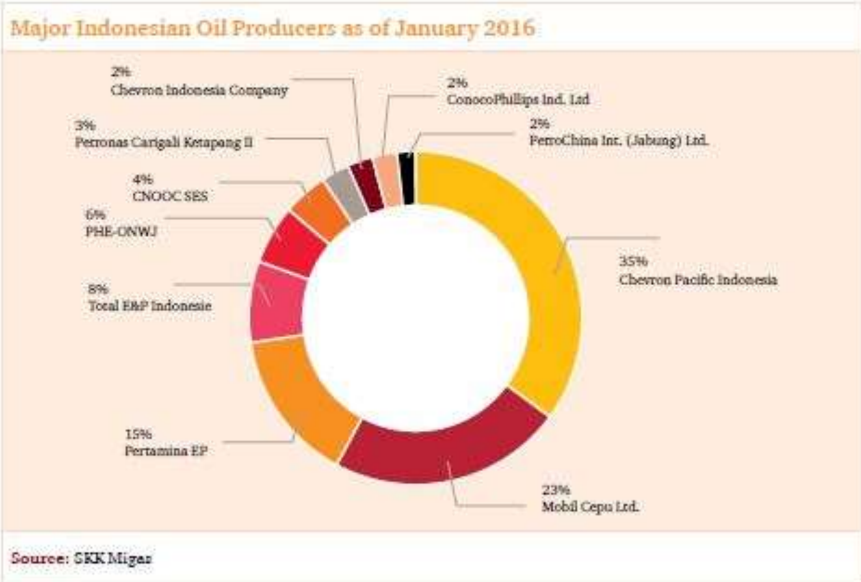


Figure 2. 4 Major Indonesian Oil Producers as of January 2016

Source: PWC Indonesia Oil and Gas Survey, 2016

The small participation of Indonesian NOC needs to be evaluated since IOC and NOC has different business purpose. IOC focuses on generating profit, while NOC focuses on government strategy, local politics, technological access, accountability, and etc. As the resource of oil and gas is getting limited, the contract model for both NOC and IOC must be adjusted so the Indonesian government (through NOC) could earn more reserves, produce more oil and gas, fulfill the domestic and international demand, generate income, and be the stronger and valuable energy company.

2.4 System Approach

As the object observed in this research, system must be approached with systemic approach. System is the whole interaction of elements in an object bounded in an environment to reach a goal (Muhammadi, 2001). Interaction defined as the connector of elements that differ one object to other object and affecting the behavior of object. Element defined as things (either physical or non-physical) that compose the object of system. Elements are also called as sub-system. Object defined as the system that becomes the focus in a particular boundary so the viewer could differ between system and environment. All the things outside the system boundary are called as environment.

Boundary between the system and environment created the property of system. There are basically 2 types of system, closed system and open system. In open system, the boundary could be affected by the environment and do interaction with the environment. Meanwhile, in closed system the boundary couldn't be affected by environment and assumed doesn't do interaction with the environment. The illustration of system can be seen in the figure below.

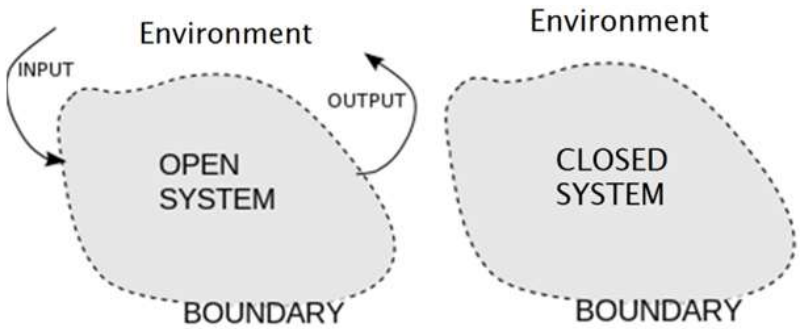


Figure 2. 5 Illustration of System

Source: Lesswrong.com, 2016

To understand systemic thinking, the viewer must see an event as a system (systemic approach). Systemic approach can be done through several steps, those are:

1. Identifying the Transformation Process that produce Actual State
2. Identifying the Desired State
3. Identifying the Gap between Actual and Desire State
4. Identifying the Mechanism that Covers the Gap
5. Policy Analysis

2.5 System Dynamics Methodology

System dynamics has been known as the systemic thinking discipline in system science. This methodology was firstly introduced by Jay Forrester from Massachusetts Institute of Technology (MIT) in 1963 and has been improved continuously. System dynamics was used limitedly as industrial problem-solving tool in its early emergence. In its development, system dynamics has been used for analyzing and solving social, economic, managerial, political, and environmental issues which is complex, dynamic (fast-changing), and uncertain.

There are 3 common perspectives in analyzing system, those are black box system (input-output analysis and econometrics), grey box system (operation research), and white box system (soft-system methodology, viable system, hyper-game, and system dynamics). Black box and grey box systems are commonly used in Indonesia, meanwhile white box is rarely used. System dynamics is important in studying system, offering comprehensive and integrated thinking which can simplify complexity without losing the essential object and also suitable in analyzing mechanisms, pattern, and system tendency based on analysis of system's complex, dynamic, and uncertain structure and behavior. Studying system comprehensively doesn't mean that there's no boundary between the system and environment. Non-significantly influential variables will be the boundary in system analysis and causing the closed system.

2.5.1 Causal Loop Diagram

A system which has causal loops can't be analyzed partially and this causes system dynamics better than partial analysis in analyzing system that has causal loops. Causal loop diagram illustrates the causal relationships between elements using inter-related arrows so it creates causal loop where the beginning of arrow means the cause and the end of arrow means the effect. The illustration of causal loop diagram can be seen in the figure below.

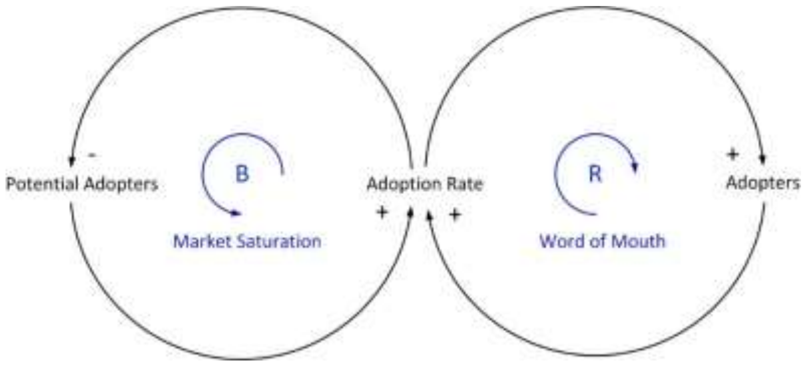


Figure 2. 6 Causal Loop Diagram of Adoption
Source: Timreview.ca, 2016

As seen in the figure above, adoption rate negatively affects the potential adopters. Higher adoption rate decreases the number of potential adopters. Otherwise, potential adopters positively affect the adoption rate. Higher number of potential adopters increase the adoption rate. This causal relation creates the causal loop between those variables.

There are two types of causal loop, those are positive loop and negative loop. To determine the type of loop, the viewer must see whether the whole interaction producing one-way process or opposite direction. One-way process [(+) * (+)] will result in positive loop, showing accelerating or decelerating behavior. Meanwhile the opposite direction [(-) * (+)] will result in negative loop and show approaching limit behavior.

Causal loop diagram is constructed with many elements involved in it. Therefore, before simulating the system, causal loop diagram is often used as the conceptual mapping of the system to simplify complexity. Causal loop diagram must be made as real as it could be to illustrate the nature of the studied system.

2.6 Modelling and Simulation

To understand the behavior of system, the viewer could make a model instead of doing trial-and-error research. Model is the representation of system in the real world by emphasizing the main elements of the system. Building a model could be cheaper and time-saving rather than doing trial-and-error study in the real system. Model can be made in conceptual form and simulation form. Conceptual model is a non-software specific description of the simulation model that is to be developed, describing the objectives, inputs, outputs, content, assumptions and simplifications of the model. Meanwhile, simulation model can be made through system dynamics software, such as Vensim, Powersim, and Stella © (iSee System). Stella © (iSee System) could build the simulation model visually using computer and could see the behavior of system quickly.

Simulation can be conducted through the procedures as follows.

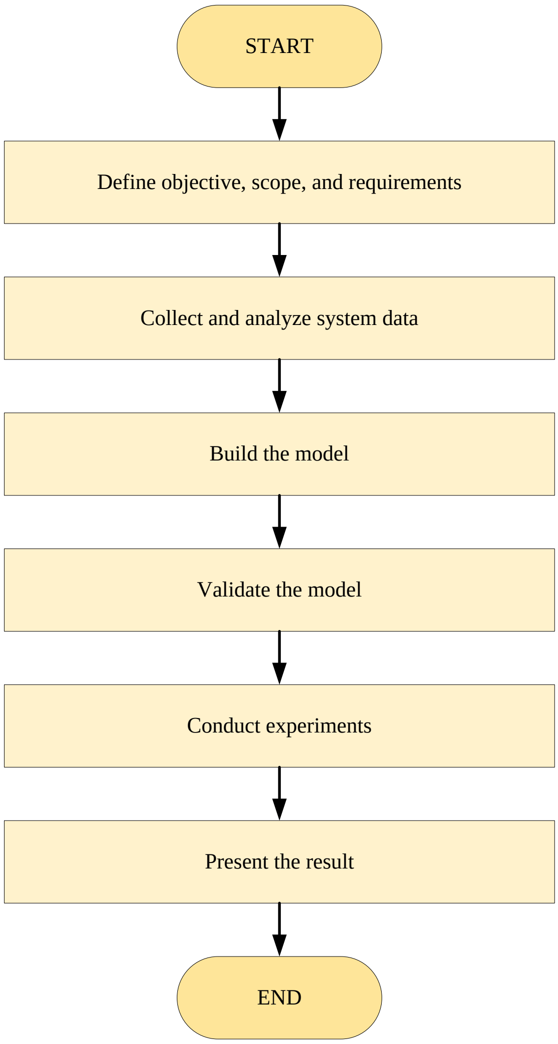


Figure 2. 7 Simulation Procedure

Source: Industrial System Simulation Lecture Note, 2016

In simulation model, variables will be connected one to each other forming a system that can represent the real world. Simulation model in Stella © is called Stock and Flow Diagram. There are several symbols used in Stock and Flow Diagram, such as Stock (showing accumulation of an entity in a certain period), Rate (process that contributes to entity accumulation in a certain period), Converter (value giver to stock, rate, and others), and Information Flow (connector between an entity to other entity). The symbols used in Stock and Flow Diagram are shown in the figure below.

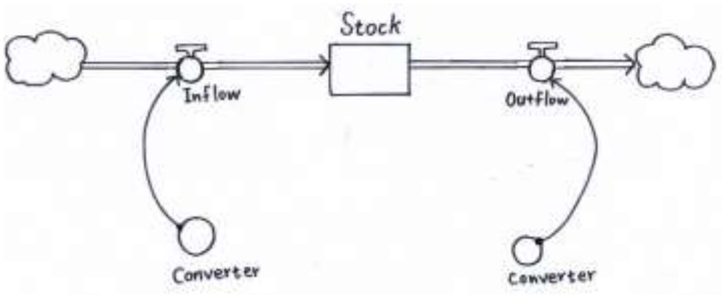


Figure 2. 8 Symbols in Stock and Flow Diagram

Source: Nwsystems.files.wordpress.com, 2016

Stock and Flow Diagram illustrates the structure of model and the simulation will produce graph that shows the behavior of system.

2.7 Model Verification and Validation Testing

Model verification is the process to determine whether the simulation model correctly reflects the conceptual model. Testing is conducted to verify whether the simulation results absolutely predictable outcomes based on test data. Simulation models often generate slightly different result depending on configuration and input data. Verification is the process of debugging the model, seeking for the bug-free model.

Meanwhile model validation is the process of establishing confidence in the soundness and usefulness of a model (Forrester in Richardson, 2016). Verification and validation must be conducted simultaneously throughout the model development process (Forrester and Senge in Richardson, 2016). Several testing methods are required for validating the simulation model, including the usage of statistical testing techniques. Some of the testing methods by Forrester and Senge (1980) are as follows:

1. Structure Testing

   Model structure testing is conducted to find out whether the structure of the model is suitable with the real system. All of the factors that affect other factors must be reflected in the model. Model structure testing is conducted by the people who understand the concept of the modelled system. Model structure testing is also called calibration, used to describe the process of iteratively making model adjustments suitable to the behavior in real world.

2. Parameter Testing

   Parameter testing can be done by comparing model parameters to knowledge of the real system to determine if parameters correspond conceptually and numerically to real life.

3. Boundary Adequacy Testing

   Boundary adequacy is conducted by developing a convincing hypothesis relating proposed model structure to a particular issue addressed by the model. This test requires an evaluator to be able to unify criticisms of model boundary with criticisms of model purpose.

4. Sensitivity Testing

   Sensitivity testing aims to find which variable most affective to the main purpose of the research. Sensitivity testing is conducted to check whether rational shifts in model parameter can cause a model to fail the previously passed behavior test.

5. Extreme Conditions Testing

   The structure of system dynamics model should permit extreme combinations of levels in the system being represented. To conduct extreme conditions testing, the evaluator must examine each rate equation in a model, trace it back through any auxiliary equations to the level on which the rate depends, and consider the implications of imaginary maximum and minimum values of each state variable and combinations of state variables to determine the rational of the resulting rate equation.

2.8 Financial Valuation

From the financial aspect, value means the sum of economic benefits expected in the future by the owner, where each benefit is discounted to the present value with the adequate discount rate (Prawoto, 2004). Value of a company (Market Value of Invested Capital/MVIC) is the capital market value which is the sum of liability value and equity value where equity value comes from the book value of equity plus the market added value. American Society of Appraisers divided valuation to 3 approaches, those are market approach, asset-based approach, and income approach.

Market approach is conducted based on relative valuation where the value of business interest defined as the market value of similar business interests which is compatible and proportional. There are 3 methods in market approach valuation, those are guideline publicly traded company method, guideline merger and acquisition method and prior transaction, and offers and buy-sell agreement method.

The next approach in valuation is asset-based approach. Asset-based principle's valuation is based on accounting principle where the value of business interests defined as same as the costs incurred to gather that business interests at the time valuation happened and the equity value defined as same as the net company value of basic adjusted value. There are 2 methods in asset-based approach valuation, those are adjusted net asset method and excess earning method.

Income approach is conducted based on anticipation principle where business interest defined as the sum of economic benefits generated by that business interest in the future. Company value is estimated by quantifying income flow generated by investments and converted to present value by opportunity cost of capital. Income approach is divided into Discounted Cash Flow (DCF) method and Capitalization method. Income approach is used in this research.

2.8.1 Discounted Cash Flow (DCF) Method

Discounted cash flow uses projection of all economic benefits in the future such as free cash flows or other income variable and discounting each benefit to present value with a particular discount rate that reflects the cost of investment capital. DCF method uses time value of money theory. DCF method also based on principles that the value of investment determined by its ability in generating future cash flows, a new investment is valuable if that investment could give bigger return than the costs incurred for that investment, and the value of assets is present value of expected cash flows from that asset investment in the future. To determine the value of company, there are 3 things that needed to do, such as:

1. Future stream of economic income
2. Discount rate: Weighted Average Cost of Capital (WACC)

3. Continuing value of company

The basic formula used in DCF is shown below

$$PV=\sum_{i=1}^{n}\frac{E_i}{(1+k)^i} \text{ ....} (2.1)$$

where PV = present value

E_i = economic income expected in period-i

k = discount rate

i = period in the future where the economic income will be received

Economic benefit meaning can be various depending on the valuation object and purpose of valuation. Generally, economic benefits are dividends, net profit, Earnings Before Interests and Taxes (EBIT), Earnings Before Interests Taxes Depreciation and Amortization (EBITDA), Net Income After Tax (NIAT), and net cash flow to equity. Net cash flow to equity's formula is shown below.

$$NCFe = NIAT + NCC - CAPEX - NCWC + NCLTD \text{.........................} (2.2)$$

where NIAT = Net Income After Tax

NCC = Non-Cash Charges (Depreciation, Amortization, and Retained Tax)

CAPEX = Capital Expenditures

NCWC = Changes in Net Working Capital

NCLTD = Net Changes in Long-Term Debt

Discount rate defined as the return percentage to convert the amount of money that is expected in the future to present value. Discount rate can be in the form of Minimum Attractive Rate of Return (MARR) or Weighted Average Cost of Capital (WACC).

2.8.2 Direct Capitalization Method

In direct capitalization method, capitalization rate is more comprehensive method where the capitalization rate only changes one single income flow to present value. The formula of Present Value in direct capitalization method can be seen below.

$$PV=\frac{E}{c} \quad \text{(2.3)}$$

where E = Expected economic income (constant)

c = Capitalization rate

Constant expected economic income happened in perpetuity period where the discount rate and capitalization rate will be in the same amount. There's no additional CAPEX or working capital in perpetuity period so there's no growth in perpetuity period. When using this method, capitalization rate can't be used to discount the prospective cash flows or expected economic income to present value.

2.9 Previous Researches

Research related to oil and gas management scheme using system dynamics modelling and financial valuation tools is rarely conducted due to differences of oil and gas management policy in every country. However, the author found similar researches that used system dynamics modelling as tool for different object (not oil and gas). Researches that used financial valuation method are also used as reference. The lists are provided in the table below.

Table 2. 2 Previous Researches

Number	Author	Title	Year
1	Galih Mahendra Irawan	Valuation of Company Reinvestment by Using Divestment Source of Fund Asset on Business Development PT X	2015
2	Edwin Ardiansyah Umar	Determining the Value and Benefits of Synergy for Strategic Plan through Merger on Ready	2015

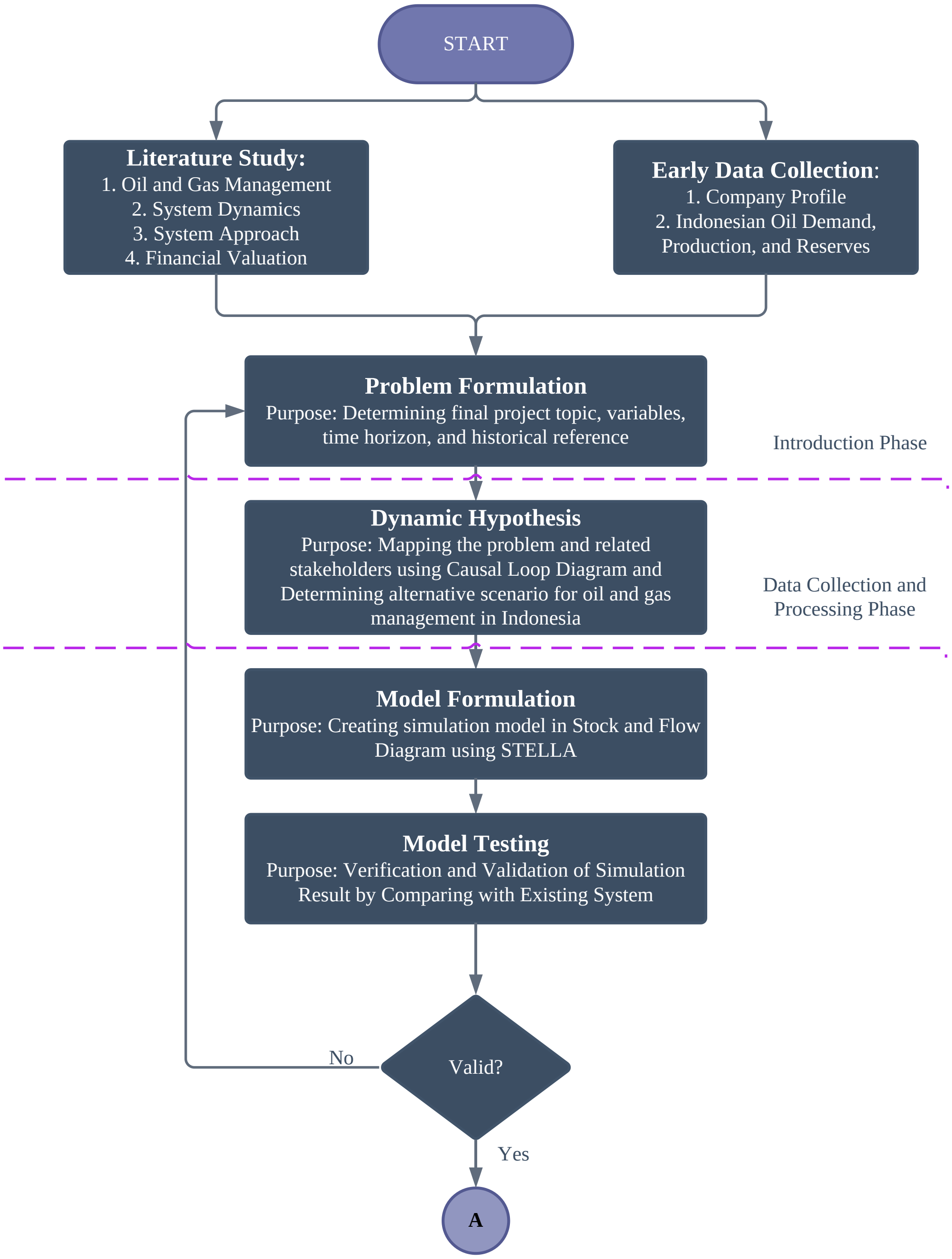
Table 2. 2 Previous Researches

Number	Author	Title	Year
		Mix Concrete Industry PT X and PT Y	
3	M. Caesario Baruza	System Dynamic Approach for Transportation Sector Development based on Calculation of Investment of Surabaya Mass Rapid Transit (SMART)	2015
4	Atikah Aghdhi Pratiwi	Selection of Strategy Scenario to Enhance the Competitive Advantage of Surabaya, East Java's Shipbuilding Industrial Cluster (KIKAS)	2016

CHAPTER 3
RESEARCH METHODOLOGY

This chapter contains the methodology that is used in conducting the research in form of flowchart and also the explanation of methodology flowchart.

3.1 Flowchart of Research Methodology



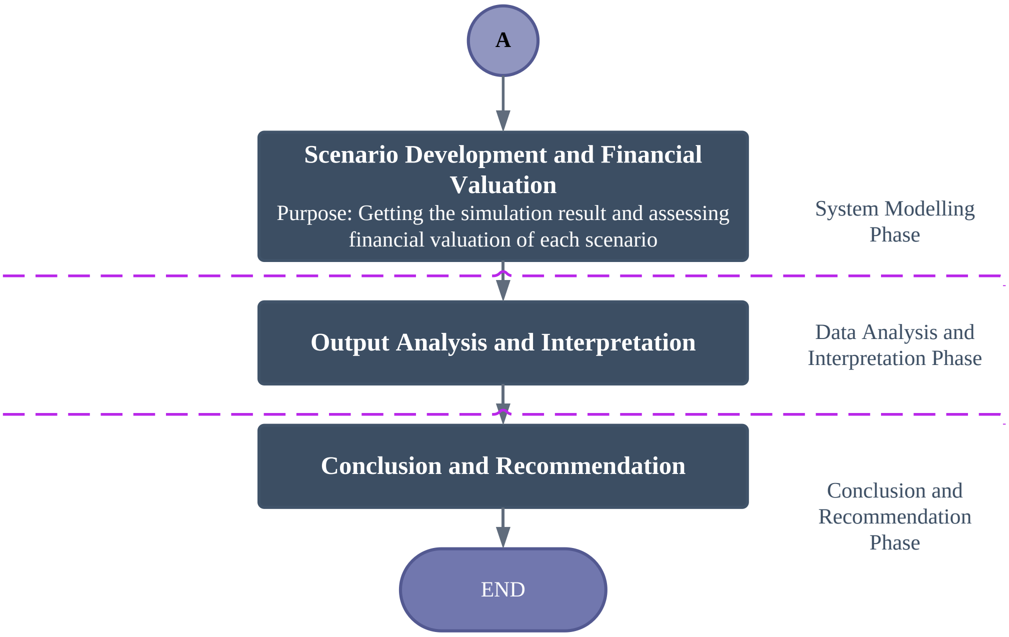


Figure 3. 1 Flowchart of Research Methodology

Source: Author's Documentation

3.2 Introduction Phase

Introduction phase becomes the early stage in this research. Introduction phase consists of literature study, early data collection, and problem formulation. The explanations of introduction phase are as follows.

3.2.1 Literature Study

Literature study is the early phase of this research. Literature study is conducted through finding trusted and credible resources such as books, journals, lecture materials, and etc. to find theoretical framework about oil and gas management in Indonesia, system dynamics methodology for problem solving, and financial valuation theories and methods. The theoretical framework is used to support the research with valid theories.

3.2.2 Early Data Collection

Data collection is done parallelly with literature study. All data which is related to the research are collected for supporting the research. The data needed for model building are oil reserves, oil consumption, and oil production. The data are collected from NOC and other supportive resources such as books, journals, and internet.

3.2.3 Problem Formulation

After gathering data, the problem must be formulated to figure out what is actually wrong with the system that needs to be fixed through research. The final project topic must be determined in this phase, as well as the variables related in the system, the time horizon for study, and historical reference for the problem.

3.3 Data Collection and Processing Phase

After the introduction phase, the research continues to data collection and processing phase. In this phase, dynamic hypothesis is conducted to conceptually modelling the system using Causal Loop Diagram. The explanation of this phase is shown below.

3.3.1 Dynamic Hypothesis

After formulating the problem, the existing system of upstream oil management in Indonesia must be modelled using Causal Loop Diagram to map the problem and understanding the relation between stakeholders. Furthermore, the alternative scenarios for upstream oil management in Indonesia must be determined as comparison for the system improvement.

3.4 System Modelling Phase

Following the data collection and processing phase is system modelling phase using System Dynamics software such as Stella © (iSee System). The explanation of this phase are as follows.

3.4.1 Model Formulation

The Causal Loop Diagram (CLD) that has been made in previous phase can't be simulated directly to produce the result. CLD elements must be transformed into stock, rate, and converter to convert the CLD into Stock and Flow Diagram. STELLA is one of the system dynamics modelling software. Stock and Flow

Diagram furthermore needs to be simulated to gain the result. The result furthermore will be collected and tested.

3.4.2 Model Testing

Simulation model must be credible in order to represent the real system correctly. Every model used in simulation must be verified and validated to test the credibility of the model. Verification is the process to check whether the operational logic of the model compatible with the logic in flow diagram. Verification can be done by the software. Meanwhile validation is the process to determine whether the model is the accurate representation of the real world. Validation is done through 5 methods, those are model structure testing, boundary sufficiency testing, model parameter testing, mean comparison testing, and extreme condition testing.

3.4.3 Scenario Development and Financial Valuation

After verifying and validating the simulation model, as the improvement of the system, the scenario must be developed. There will be only 1 scenario as the comparison of the current system, which is concession scheme for upstream oil management. The new scenario will also be simulated. After getting the results, both scenario will be analyzed and valuated to find which scenario that will be more valuable for NOC (which represents the government's interest).

3.5 Data Analysis and Interpretation Phase

The output of system simulation is furthermore analyzed and interpreted in this phase as explained in the paragraph below.

3.5.1 Output Analysis and Interpretation

The simulation results gained need to be analyzed and interpreted to know the evaluation of the existing system. The new scenario of upstream oil management scheme will be analyzed to know which scenario that will accomplish the goal of energy security and energy independence. Not only that, the scenario must also bring more monetary value for the NOC that represents the government. The best scenario will be determined as the new scheme for upstream oil management in Indonesia.

3.6 Conclusion and Recommendation Phase

The final phase of this research is conclusion and recommendation phase which is explained in the paragraph below.

3.6.1 Conclusion and Recommendation

The last phase of this research is concluding the whole research from the initial phase until the analysis phase to answer the problem formulation stated in chapter 1. Recommendation will also be made as the improvement for the existing upstream oil management in Indonesia.

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CHAPTER 4
SIMULATION MODEL DESIGN

This chapter contains the steps needed in conducting system dynamics simulation modelling. Before conducting the simulation, the current system which is needed in the simulation must be identified. The current system then will be the input in formulating dynamic hypothesis which consists of variable identification, conceptual model, and the simulation model. Furthermore, verification and validation will be conducted to the simulation and the simulation result will be provided as the closing of this chapter.

4.1 Current System Identification

This subchapter will explain about the current upstream oil management system in Indonesia, including the upstream oil mining activity, oil consumption pattern, oil market, investment made for upstream oil mining, and the revenue gathered from upstream oil mining.

4.1.1 Upstream Oil Mining Activity (Production)

Before oil is produced, there is a long way step that must be undertaken. Oil, specifically crude oil, is located under the earth's crust and usually found in various geological structure, such as fault traps, anticlines, and salt domes. Multidisciplinary knowledge and expertise, such as geography, geology, geophysics, and even petroleum engineering are needed to survey and determine the potential location of the crude oil. This process is called "exploration", where the geoscientists explore the oil and gas resources below the earth's crust. Exploration of oil is the primary process for oil and gas company, which will help the company to find and develop new oil reserves to support the production process. Even though exploration is definitely important, this process requires a huge amount of capital with big risks because of the uncertain result. There will be no certain result about oil or gas presence after exploration is done. There might be huge amount of oil or gas reserves that can be furthermore developed, otherwise there will be “dry hole”. After exploration is done, if it’s successful, there will be potential oil wells with random amount, depends on the condition of the reserves. In the current upstream oil management scheme, exploration can be done either by the company who undertakes the project or other company that has been selected.

Potential oil wells still can’t produce crude oil. It must be developed through “exploitation” to technically prove the existence of oil or gas. After the exploitation process, the oil wells turn into proven oil wells that are ready to be drilled and crude oil can be lifted from the earth’s surface.

Oil production depends on several parameters, including the age of the oil wells, primary recovery factor, and after-production effect. New proven oil wells will produce more oil until its peak amount and after it reached 12% of total amount, the production will decline. As the wells are aging, the production amount will also decline. Oil wells can’t be drained until there’s no oil left. Until the left amount of oil reached 26% of the total amount, the oil can’t be lifted anymore so there will be no more oil production. The company needs to look for new reserves through exploration if it wants to keep producing oil.

4.1.2 Oil Market

In the context of this research, oil market is defined as the crude oil available in the market to fulfill the demand of crude oil. Oil lifting will result in crude oil production that are ready to be sold to the customers. Crude oil also furthermore can be processed through refinery process to produce various form of product to suit the needs of the market. Because of the high domestic demand of crude oil, the production can’t fully supply the demand. There need to be crude oil import to add the deficit of oil supply in the market. When the amount of the crude oil exceeds the domestic needs, it can be exported to other country. It can be concluded that oil can be supplied from production process and import, where the demand comes from domestic and overseas consumption.

4.1.3 Crude Oil Consumption

Indonesia currently becomes the 4th largest population country in the world. Following the amount of population which is around 250 million people, Indonesian energy consumption is also high (as previously showed in chapter 2). The energy consumer is classified into 4 categories which is household, industry, vehicles, and others. The historical data of each category (shown in unit) and also the year-to-year growth is provided in the table below.

Table 4. 2 Number of Household

Year	Population	Household (thousand units)	Household growth (year to year)	Industry (units)	Industry growth (year to year)	Vehicles (units)	Vehicle growth (year to year)
2005	218869	55119		20729		37623432	
2006	222192	55942	1,49%	20468	-1,3%	43313052	15%
2007	225642	56411	0,84%	27998	36,8%	54802680	27%
2008	228523	57131	1,28%	25694	-8,2%	61685063	13%
2009	234432	60249	2,26%	24468	-4,8%	67336644	9%
2010	237641	61165	4,69%	23345	-4,6%	76907127	14%
2011	238519	62630	1,50%	23370	0,1%	85601351	11%
2012	245425	63097	1,64%	23592	0,9%	94373324	10%
2013	248818	63938	1,33%	23698	0,4%	104000000	10%
2014	252165	64767	1,30%	24529	3,5%	114000000	10%
2015	255462	65582	1,26%				

With the increasing amount of household, industrial, and vehicle (transportation) sectors, the amount of oil consumption by each category is increasing as well. The amount of oil consumption by each category and also the year-to-year increase are provided in the figure below.

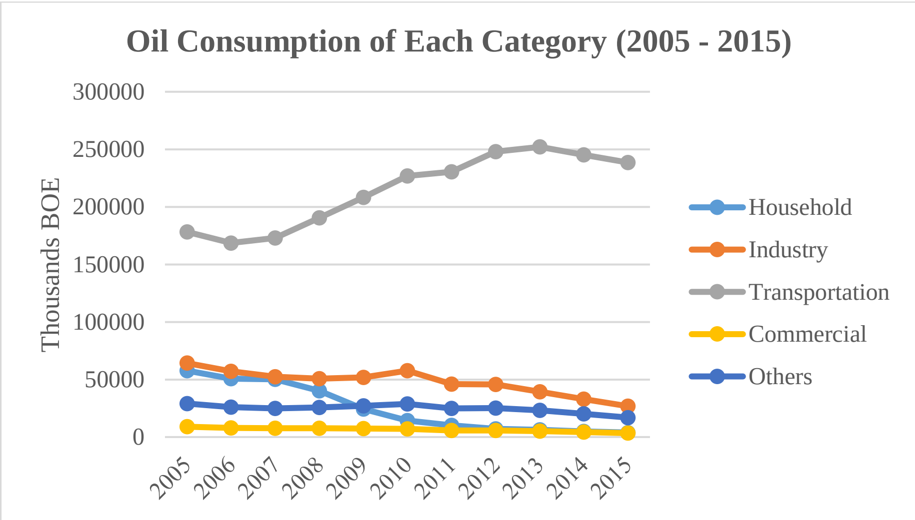

Figure 4. 2 Oil Consumption of Each Category (2005 – 2015)

Source: Handbook of Energy & Economic Statistics of Indonesia 2015

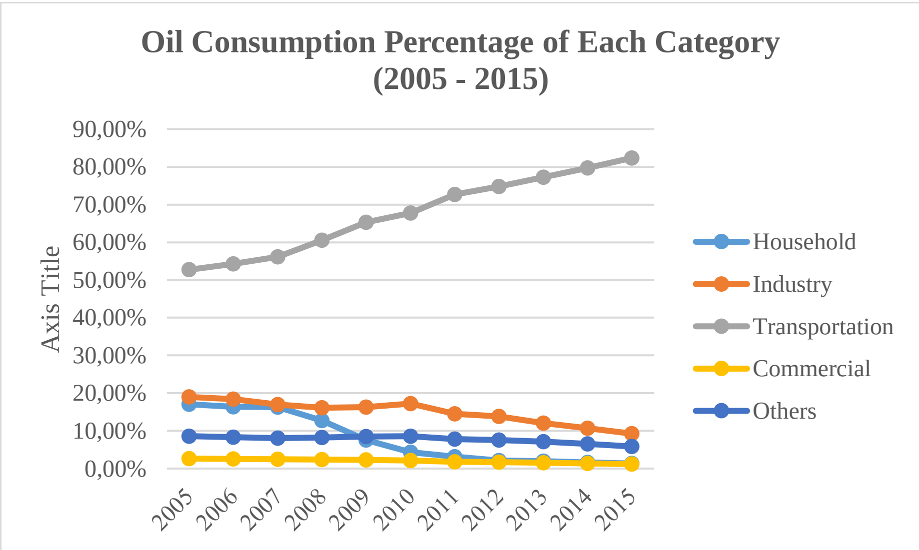

Figure 4. 3 Oil Consumption Percentage of Each Category (2005 – 2015)

Source: Author's Documentation

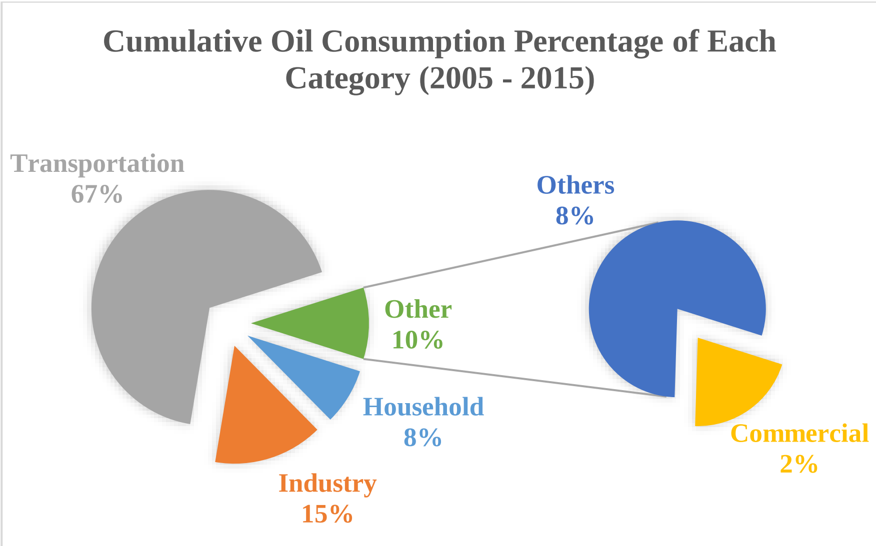

Figure 4. 4 Cumulative Oil Consumption Percentage of Each Category (2005 – 2015)

Source: Author's Documentation

From the figures above, it can be concluded that transportation mostly consumes oil than the other categories. Transportation, which consists of vehicles such as cars, trucks, motorcycles, airplanes, ships, dominated the oil consumption due to the fuel usage (*Bahan Bakar Motor/BBM*). The oil consumption by transportation is also rising from 2005 – 2015, meanwhile the other category consumption is falling. The oil consumption per capita is shown in the table below.

Table 4. 3 Oil Consumption per Capita (barrel)

Year	Household	Industry	Transportation
2005	1,047	3098,99	4,741
2006	0,909	2794,75	3,893
2007	0,890	1872,21	3,156
2008	0,702	1972,87	3,086
2009	0,403	2122,40	3,094
2010	0,236	2467,42	2,949
2011	0,161	1966,24	2,694
2012	0,111	1943,88	2,627
2013	0,100	1660,98	2,424
2014	0,076	1345,10	2,151
2015	0,060	1091,37	1,848

Table 4. 3 Oil Consumption per Capita (barrel)

Year	Household	Industry	Transportation
2016	0,056	1580,80	2,269
2017	0,053	2289,71	2,786
2018	0,050	3316,53	3,420
2019	0,047	4803,82	4,199
2020	0,044	6958,09	5,155
2021	0,042	10078,43	6,329
2022	0,039	14598,09	7,770
2023	0,037	21144,59	9,540
2024	0,035	30626,86	11,712
2025	0,033	44361,44	14,380

4.1.4 Investment in Upstream Oil Mining

Upstream oil mining activity requires high investments for both capital expenditure and operational expenditure in order to be able to do the whole activity and oil production. The activity in upstream oil investment is triggered by suitable production volume of oil which is defined by NOC and the ability of investing to find new potential resource of oil. Available fund furthermore determined the ability to invest. The amount of investment activity is provided in the table below.

Table 4. 4 Amount of Investment in Upstream Oil Mining

Year	Suitable Production Volume		Investment for Each Barrel of Oil	
	Domestic (MMBOE)	Overseas (MMBOE)	Offshore (USD/barrel)	Onshore (USD/barrel)
2005	70,01	70,01	266,20	266,20
2006	70,63	70,63	266,20	266,20
2007	71,76	71,76	266,20	266,20
2008	73,55	73,55	266,20	266,20
2009	98,61	98,61	266,20	266,20
2010	101,60	101,60	266,20	266,20
2011	101,60	101,60	266,20	266,20
2012	101,60	101,60	266,20	266,20
2013	101,60	101,60	266,20	266,20
2014	101,60	101,60	266,20	266,20
2015	101,60	101,60	266,20	266,20
2016	214,09	214,09	266,20	266,20

Table 4. 4 Amount of Investment in Upstream Oil Mining

Year	Suitable Production Volume		Investment for Each Barrel of Oil	
	Domestic (MMBOE)	Overseas (MMBOE)	Offshore (USD/barrel)	Onshore (USD/barrel)
2017	214,09	214,09	266,20	266,20
2018	214,09	214,09	266,20	266,20
2019	214,09	214,09	266,20	266,20
2020	214,09	214,09	266,20	266,20
2021	348,34	348,34	266,20	266,20
2022	348,34	348,34	266,20	266,20
2023	348,34	348,34	266,20	266,20
2024	348,34	348,34	266,20	266,20
2025	370,11	370,11	266,20	266,20

The suitable production volume for both domestic and overseas are assumed to be same as well as the investment data.

4.1.5 Revenue Stream of Upstream Oil Mining

Revenue stream is one of the key activities in upstream oil mining that will provide the information about the income that will be gathered from upstream oil mining. Amount of crude oil production and the oil price defined the amount of gross income. Gross income will be subtracted by First Tranche Petroleum, Equity to be Split, Domestic Market Obligation, and Tax. The net income from the upstream oil mining activity is called Government Take (GT) for government and Contractor Take for contractor. The revenue stream can be seen in the figure below.

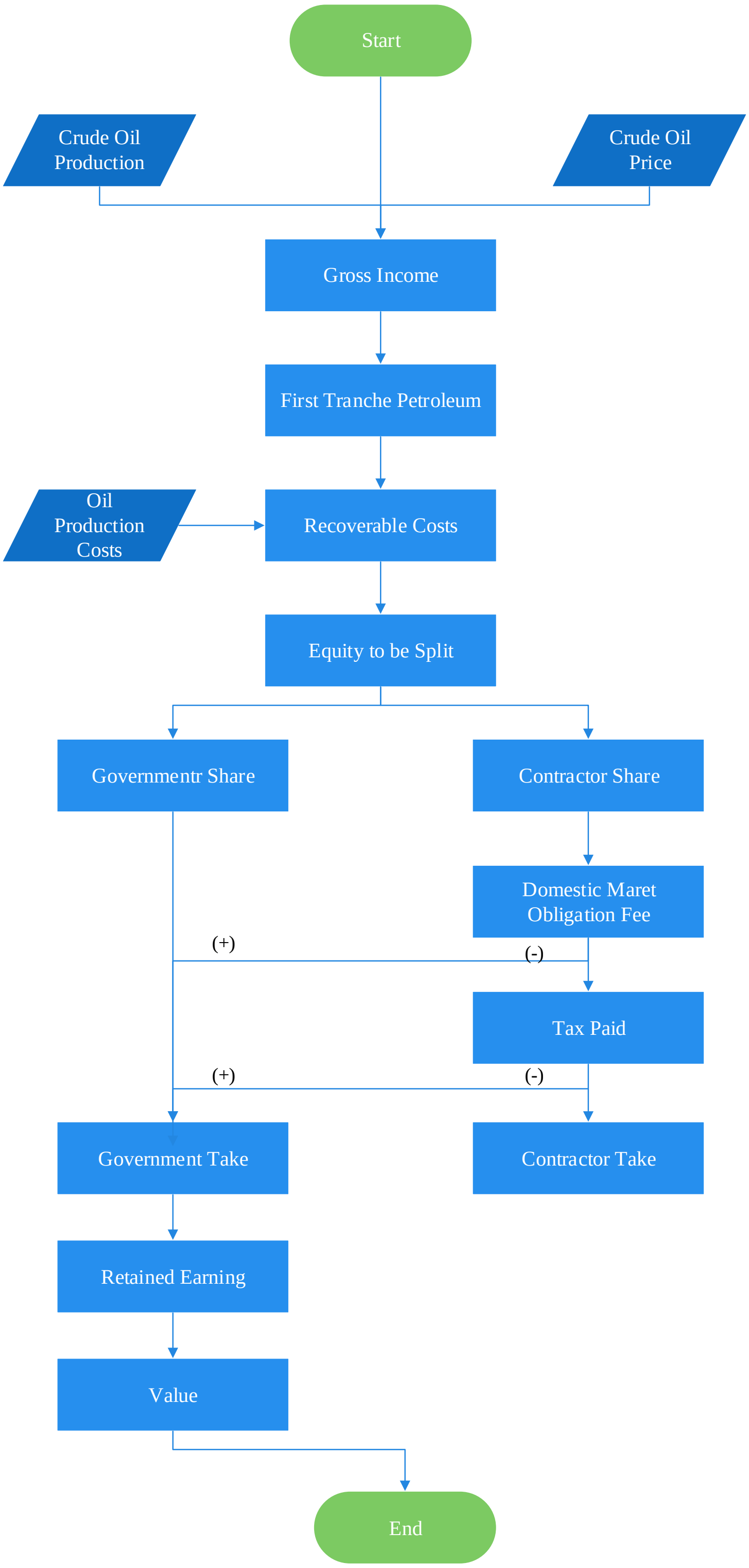

Figure 4. 5 Revenue Stream in Upstream Oil Mining

Source: Author's Documentation

The amount of retained earnings will contribute to both investment activity and capital structure strengthening.

4.2 Dynamic Hypothesis

To understand the dynamics of the system, the historical data that related to the system are collected. This final project set time horizon for 20 years, which consists of 10 years historical data (since 2005 – 2015) and 10 years future projection (started from 2015 – 2025). The data then led to theory development, called dynamic hypothesis, to account for the problematic behavior of the system. Dynamic hypothesis consists of variable identification of the system and conceptual modelling using Causal-Loop Diagram to show the intercorrelation of the system elements.

4.2.1 Variable Identification

Before creating the conceptual model of the system, all variables that are related to oil management system must be identified to understand the function and relation of each variable in affecting the work of the system. Oil management system, in this case, will be divided into 5 submodels to understand the role of the variables in the system. The submodels are Production, Consumption, Oil Market, Investments, and Income. List of all the variables used in the submodel Production is provided in the table below.

Table 4. 5 Variables in Submodel Production

No	Entity	Description	Unit	Variable
1	Randomized oil field average capacity	The average capacity of newly found oil field	barrels	*Converter*
2	Randomized oil field standard deviation	Standard deviation of newly found oil field	barrels	*Converter*

Table 4. 5 Variables in Submodel Production

No	Entity	Description	Unit	Variable
3	Randomized oil field capacity	Normal distribution of oil field capacity, consists of mean and standard deviation of oil field capacity	barrels	*Converter*
4	Exploration	Rate of oil field exploration activity	barrels/year	*Flow*
5	Potential oil found	Number of potential oil reserves found on land	barrels	*Stock*
6	Randomized oil wells age average	The average age of oil wells	years	*Converter*
7	Randomized oil wells age standard deviation	Standard deviation of oil wells age	years	*Converter*
8	Randomized oil wells age	Normal distribution of oil wells age, consists of average and standard deviation of oil wells age	years	*Converter*
9	Produced capacity	Ability of producing oil	barrels	*Converter (ghost)*
10	Exploitation	Rate of exploitation activity	barrels/year	*Flow*
11	Proven oil found	Number of proven oil field ready to be produced	barrels	*Stock*
12	Average end life of all oil wells	Stock of average end life of all oil wells in Indonesia	years	*Stock*

Table 4. 5 Variables in Submodel Production

No	Entity	Description	Unit	Variable
13	Oil wells lifetime portion	Ratio of average age of all oil wells and average end life of all oil wells	unitless	*Converter*
14	Average age of all oil wells	Stock of average age of all oil wells in Indonesia	years	*Stock*
15	Average End (AE)	The average end life of all oil wells in Indonesia	years	*Converter*
16	AE Rate	Changes of average end life of all oil wells in Indonesia	unitless	*Flow*
17	Average Age (AA)	The average end life of all oil wells in Indonesia	years	*Converter*
18	AA Rate	Changes of average age of all oil wells in Indonesia	unitless	*Flow*
19	Primary recovery factor	The percentage amount of reserves that won't be able to be produced anymore	unitless	*Converter*
20	Effect of oil wells on production	The percentage amount when the oil production starts to decline after it has been produced for this percent	unitless	*Converter*
21	Oil production	The amount of oil production	barrels	*Converter*

Table 4. 5 Variables in Submodel Production

No	Entity	Description	Unit	Variable
22	Depletion	Rate of oil wells decrease in production	barrels/year	*Flow*

After the submodel Production, the variables identification continues to submodel Consumption. List of all the variables used in the submodel Consumption is provided in the table below.

Table 4. 6 Variables in Submodel Consumption

No	Entity	Description	Unit	Variable
1	Amount of household	Number of household in Indonesia	unitless	*Converter*
2	Household consumption	Amount of oil consumption done by household	barrels	*Stock*
3	Oil consumption per household	Average consumption done by household divided by number of household	barrels	*Converter*
4	Change in household's consumption	Changes in household consumption each year	barrels/year	*Flow*
5	Household consumption rate	The rate of total household consumption	barrels/year	*Flow*
6	Amount of transportation	Number of vehicles (fossil-fueled) in Indonesia	unitless	*Converter*
7	Transportation consumption	Amount of oil consumption done by vehicles	barrels	*Stock*
8	Oil consumption per transportation	Average consumption done by transportation divided by number of vehicles	barrels	*Converter*

Table 4. 6 Variables in Submodel Consumption

No	Entity	Description	Unit	Variable
9	Change in transportation's consumption	Changes in transportation's consumption each year	barrels/year	*Flow*
10	Transportation consumption rate	The rate of total transportation consumption	barrels/year	*Flow*
11	Amount of industry	Number of industries in Indonesia	unitless	*Converter*
12	Industry consumption	Amount of oil consumption done by industry	barrels	*Stock*
13	Oil consumption per industry	Average consumption done by industry divided by number of industries	barrels	*Converter*
14	Change in industrial's consumption	Changes in industry's consumption each year	barrels/year	*Flow*
15	Industrial consumption rate	The rate of total industrial consumption	barrels/year	*Flow*
16	Change in consumption	Changes in total oil consumption by all sectors each year	barrels/year	*Flow*
17	Total domestic consumption	Number of oil consumed in Indonesia	barrels	*Stock*
18	Domestic consumption rate	The rate of total domestic oil consumption each year	barrels/year	*Flow*

The variables identification then continues to submodel Oil Market. List of all the variables used in the submodel Oil Market is provided in the table below.

Table 4. 7 Variables in Submodel Oil Market

No	Entity	Description	Unit	Variable
1	Oil production	Amount of oil production	barrels	*Converter*
2	Production rate	Changes in amount of domestic oil production each year	barrels/year	*Flow*
3	Export rate	Changes in amount of oil export each year	barrels/year	*Flow*
4	Oil stock	Amount of oil stock in domestic market	barrels	*Stock*
5	Import rate	Changes in amount of oil import each year	barrels/year	*Flow*
6	Consumption rate	Changes in amount of domestic oil consumption each year	barrels/year	*Flow*
7	Total domestic consumption	Number of oil consumed in Indonesia	barrels	*Stock*

After identifying the variables in submodel Oil Market, the identification continues to submodel Investment. List of all the variables used in the submodel Investment is provided in the table below.

Table 4. 8 Variables in Submodel Investments

No	Entity	Description	Unit	Variable
1	Primary recovery factor	The percentage amount of reserves that won't be able to be produced anymore	unitless	*Converter*

Table 4. 8 Variables in Submodel Investments

No	Entity	Description	Unit	Variable
2	Effect of oil wells on production	The percentage amount when the oil production starts to decline after it has been produced for this percent	unitless	*Converter*
3	Depletion	Rate of oil wells decrease in production	barrels/year	*Flow*
4	Forecasted demand	Amount of oil demand forecasted	barrels	*Converter*
5	Next year production	Amount of oil production projected for next year	unitless	*Converter*
6	Average age of all oil wells	Stock of average age of all oil wells in Indonesia	years	*Stock*
7	Average end life of all oil wells	Stock of average end life of all oil wells in Indonesia	years	*Stock*
8	Forecasted gap	The amount of gap between next year production and production	barrels	*Converter*
9	Required investment	Amount of investment required to produce oil	USD	*Converter*
10	Production gap	The amount of gap between actual gap and forecasted gap	barrels	*Converter*
11	Actual gap	The amount of gap between difference of production compared to the investment	USD	*Converter*
12	Difference of production	The gap between production and suitable production volume	barrels	*Converter*

Table 4. 8 Variables in Submodel Investments

No	Entity	Description	Unit	Variable
13	Suitable production volume	Total amount of suitable oil production volume to fulfill demand	barrels	*Converter*
14	Oil suitable production volume domestic	The amount of suitable domestic oil production volume to fulfill demand	barrels	*Converter*
15	Oil suitable production volume overseas	The amount of suitable overseas oil production volume to fulfill demand	barrels	*Converter*
16	Operation effectiveness	The percentage amount where operation can be said effective	unitless	*Converter*
17	Construction time	The duration to construct the production facility	years	*Converter*
18	Investment rate	Change of investment per year	USD/year	*Flow*
19	Non utilized investment	The amount of unutilized investment	USD	*Stock*
20	Utilized investment	Change of utilization each year	USD/year	*Flow*
21	Produced capacity	The ability of producing oil	barrels	*Converter*
22	Investment for producing each barrel	Total investment needed to produce each barrel of oil	USD	*Converter*
23	Onshore investment for each barrel	Amount of investment needed to produce oil onshore	USD	*Converter*
24	Offshore investment for each barrel	Amount of investment needed to produce oil offshore	USD	*Converter*

Table 4. 8 Variables in Submodel Investments

No	Entity	Description	Unit	Variable
25	Available fund	The amount of available investment fund	USD	*Converter*
26	Retained earning	The amount of government earning dedicated for NOC investment	USD	*Stock*
27	Oil production	Amount of oil production	barrels	*Converter (ghost)*
28	Debt required	Amount of debt needed to complement the available funds for investment	USD	*Converter*

The last identification is conducted for the variables of submodel Income. List of all the variables used in the submodel Income is provided in the table below.

Table 4. 9 Variables in Submodel Income

No	Entity	Description	Unit	Variable
1	Gross income	Total income gained from the selling of oil stock	USD	*Converter*
2	Oil stock	Amount of oil stock in domestic market	barrels	*Stock*
3	Oil price	WTI oil price	USD/barrels	*Converter*
4	First Tranche Petroleum	Amount of FTP that must be paid by contractor	USD	*Converter*
5	FTP percentage	Percentage amount of FTP from gross production	unitless	*Converter*

Table 4. 9 Variables in Submodel Income

No	Entity	Description	Unit	Variable
6	FTP for government	Amount of FTP for the government	USD	*Converter*
7	Government FTP percentage	Percentage amount of FTP that will be received by government	unitless	*Converter*
8	FTP for contractor	Amount of FTP for the contractor	USD	*Converter*
9	Contractor FTP percentage	Percentage amount of FTP for contractor	unitless	*Converter*
10	FTP tax	Percentage amount of FTP tax for contractor	unitless	*Converter*
11	Oil costs	The costs incurred for producing each barrel of oil	USD	*Converter*
12	Recoverable costs	Amount of operation and production costs that will be reimbursed by the government	USD	*Converter*
13	Equity to be Split	Amount of equity that will be shared for both government and contractor	USD	*Converter*
14	Government ETS	Amount of ETS taken by the government	USD	*Converter*
15	Government ETS percentage	Amount of ETS percentage for the government	unitless	*Converter*
16	Government Take	Total monetary value earned by the government	USD	*Converter*

Table 4. 9 Variables in Submodel Income

No	Entity	Description	Unit	Variable
17	Contractor ETS	Amount of ETS taken by the contractor	USD	*Converter*
18	Contractor ETS percentage	Amount of ETS percentage for the contractor	unitless	*Converter*
19	DMO volume	Amount of oil volume taken for Domestic Market Obligation (DMO)	barrels	*Converter*
20	DMO percentage	Percentage amount of DMO for the market	unitless	*Converter*
21	DMO fee	DMO that must be paid by the contractor	USD	*Converter*
22	Net DMO	The rest DMO that can be taken by the contractor	USD	*Converter*
23	Taxable Income	The income of contractor that will be charged of tax	USD	*Converter*
24	Tax percentage	Percentage amount of tax that must be paid by contractor	unitless	*Converter*
25	Tax paid	Amount of tax that must be paid by contractor	USD	*Converter*
26	Contractor take	Total income earned by the contractor	unitless	*Converter*
27	Retained earning rate	Changes in annual retained earning	USD/year	*Flow*
28	Retained earning	Stock of retained earning owned by government	USD	*Stock*

Table 4. 9 Variables in Submodel Income

No	Entity	Description	Unit	Variable
29	Investments	Changes in investments each year	USD/year	*Flow*
30	Investment rate	Change of investment per year	USD/year	*Flow*
31	Discount rate	Interest rate to count NPV	unitless	*Converter*
32	Net Present Value	Net present value of the project	USD	*Stock*
33	Change in NPV	Change in NPV per year	USD/year	Flow

After identifying all variables involved in the oil management system, the process then can be continued to creating the conceptual model. The conceptual model will be explained in the next subchapter.

4.2.2 Causal – Loop Diagram

Causal-Loop Diagram is a tool for conceptual modelling used to illustrate the causal relationships between elements using inter-related arrows so it creates causal loop where the beginning of arrow means the cause and the end of arrow means the effect. There are two types of causal loop, those are positive loop and negative loop. To determine the type of loop, the viewer must see whether the whole interaction producing one-way process or opposite direction. One-way process [(+) * (+)] will result in positive loop, showing accelerating or decelerating behavior. Meanwhile the opposite direction [(-) * (+)] will result in negative loop and show approaching limit behavior. The Causal-Loop Diagram of Indonesian oil management system can be shown in the figure below.

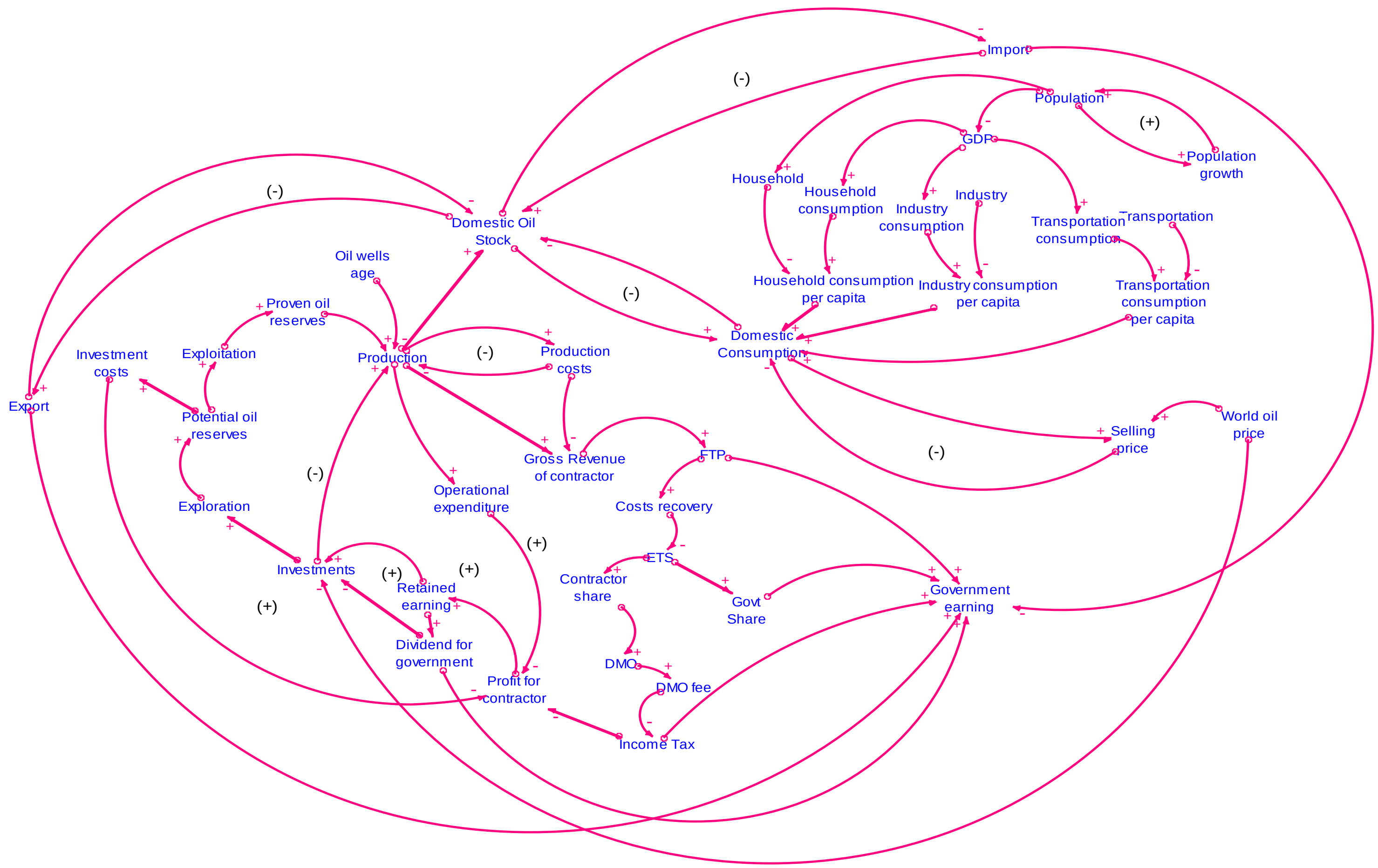

Figure 4. 6 Causal Loop Diagram of Indonesian Oil Management

Source: Author's Documentation

4.3 Stock and Flow Diagram

Causal-Loop Diagram may conceptualize the whole system and the intercorrelation between the elements. However, it can't be used in software simulation. To be able to simulate the system, Stock and Flow Diagram is needed as the detailed information about the variables of the system. Stock and Flow Diagram consists of Stock (showing accumulations of an entity), Flow (activity rate per unit time), Converter (showing information flow that has constant value), and Connector (showing the relation of variables). In this final project, Stock and Flow Diagram will be divided into 5 submodels, those are submodel Production, Consumption, Oil Market, Investments, and Income.

4.3.1 Main Model

Main model is used as a basic guidance in developing the Stock and Flow Diagram. There are 6 main entities that will be developed in Stock and Flow Diagram, those are production, oil stock, consumption, income, investments, and oil reserves. The relation between the entities can be shown in the figure below.

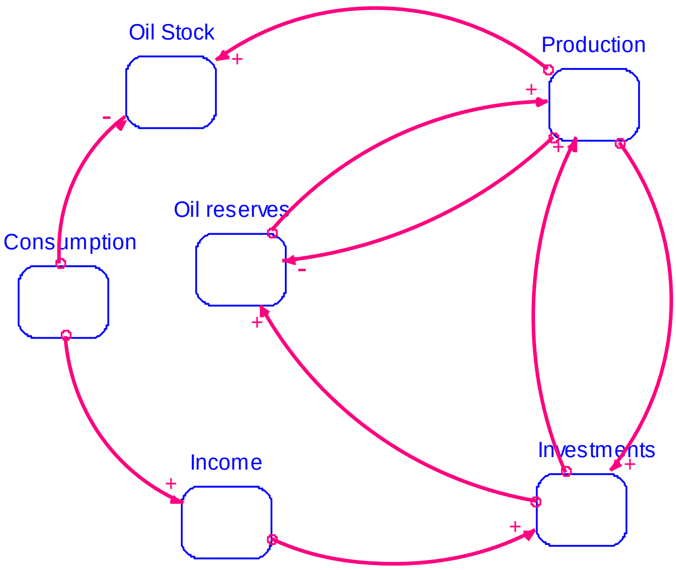

Figure 4. 7 Main Model of Indonesian Oil Management

Source: Author's Documentation

Production of oil will add the amount of oil stock available in the market. The more production will add more oil stock available, shown in positive relation of both entities. However, due to consumption, this activity will reduce the amount of oil stock. The more consumption occurs, the less oil stock available in the market. Then, when consumption occurs, the consumers will spend funding to consume oil. Consumption activity will generate income for oil producer (in this term NOC) and moreover for the government (due to the ownership of NOC by government, the income of NOC will be shared to government too). The more income that NOC and government have, the more investment in oil upstream mining activity will occur. When there are more investments, there will be more oil upstream mining activity such as exploration that will reveal new oil reserves both onshore and offshore. The more oil reserves available may increase oil production activity. More investments also led to more production activity due to the availability of fund to produce oil. Finally, the bigger oil production will result in bigger oil stock available for the market. This main model will be developed in 5 submodels where oil reserves and production are merged into a submodel.

4.3.2 Submodel Production

Submodel production is built to generate the amount of production based on potential oil reserves in Indonesia and proven oil which is able to be exploited and produced. There are several factors that affect the amount of oil production. Potential oil reserves are affected by the randomized oil capacity. When there's more exploration activity, there will be more potential oil reserves due to the addition of randomized oil capacity. Potential oil reserves that can be exploited (depends on the randomized oil wells age and produced capacity) will add the amount of proven oil. The amount of proven oil will furthermore affect the oil production, along with other variables such as primary recovery factor, effect of oil wells on production, and oil wells life time portion The relation in submodel production can be shown in the figure below. Variable of oil production then affects the depletion of proven oil. The relation of all variables can be shown in the figure below.

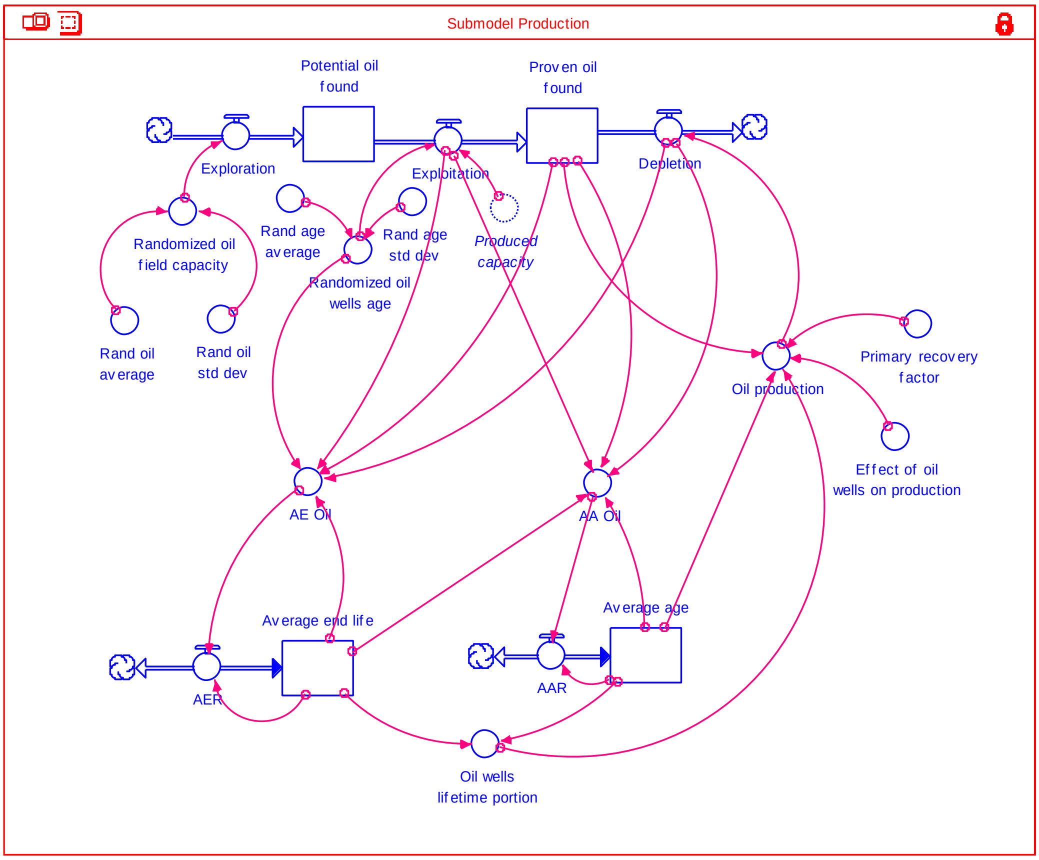

Figure 4. 8 Submodel Production

Source: Author's Documentation

The data and assumptions that become the input of the submodel follows:

- Randomized oil wells age mean = 15 years
- Randomized oil wells age standard deviation = 3 years
- Average end life of oil wells = 15 years
- Average age of oil wells = 10 years
- Primary recovery factor = 26%
- Effect of oil wells on production = 12%

4.3.3 Submodel Consumption

Submodel consumption draws the total domestic oil consumption done by 3 main sectors, those are household, transportation (fossil – fueled vehicles), and industry. All sectors amount is projected to increase following the historical data found. However, the amount of consumption of all sectors are different. Household oil consumption is projected to decrease due to the usage of LPG rather than kerosene. Meanwhile, transportation and industry continue to consume more oil for the next 10 years. The relation of all variables can be shown in the figure below.

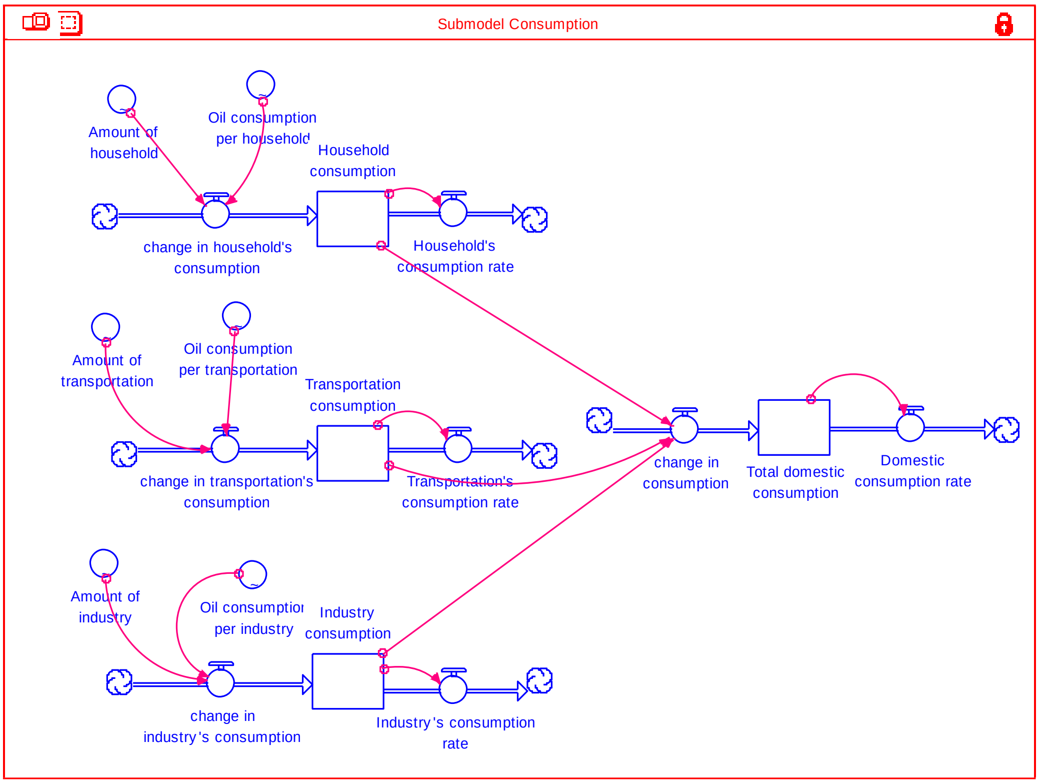

Figure 4. 9 Submodel Consumption

Source: Author's Documentation

4.3.4 Submodel Oil Market

Submodel oil market shows the amount of available oil stock in the market that can be used for consumption. There are 2 inputs in the form of production rate and import rate that will add the amount oil stock. Oil stock will be decreased due to the rate of consumption and export. Oil production becomes the driver of production rate, meanwhile total domestic consumption becomes the driver of consumption rate. The relation of all variables can be shown in the figure below.

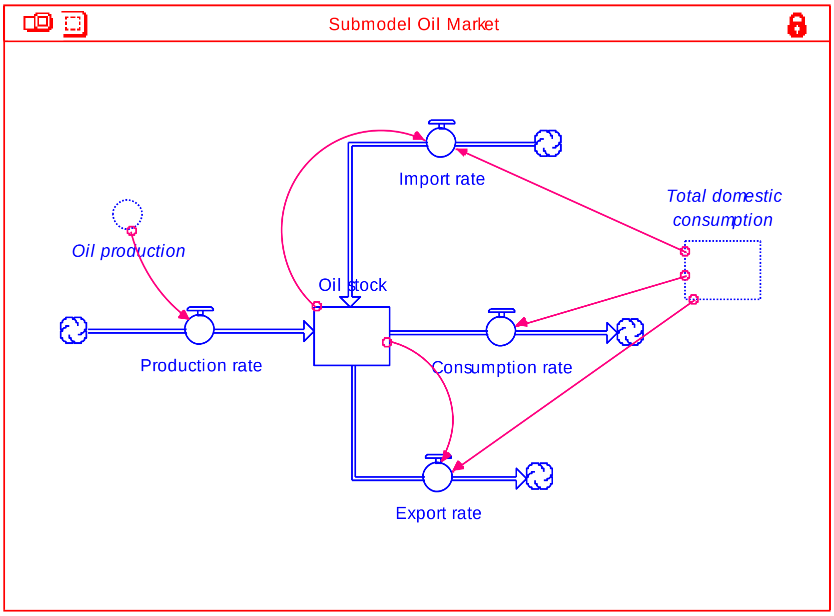

Figure 4. 10 Submodel Oil Market

Source: Author's Documentation

4.3.5 Submodel Investment

Submodel investments mainly driven by next year production, forecasted demand, forecasted gap, difference of production, suitable production volume, actual gap, investment for producing each barrel, required investments, retained earnings, available fund, investment rate, non-utilized investment, utilized investment, construction time, operation effectiveness, and produced capacity. The amount of available fund ready to fulfill the required investment will contribute to investment rate. Only some of the investment that will be used, therefore the remaining investments will be accumulated in non-utilized investment. The relation of all variables can be shown in the figure below.

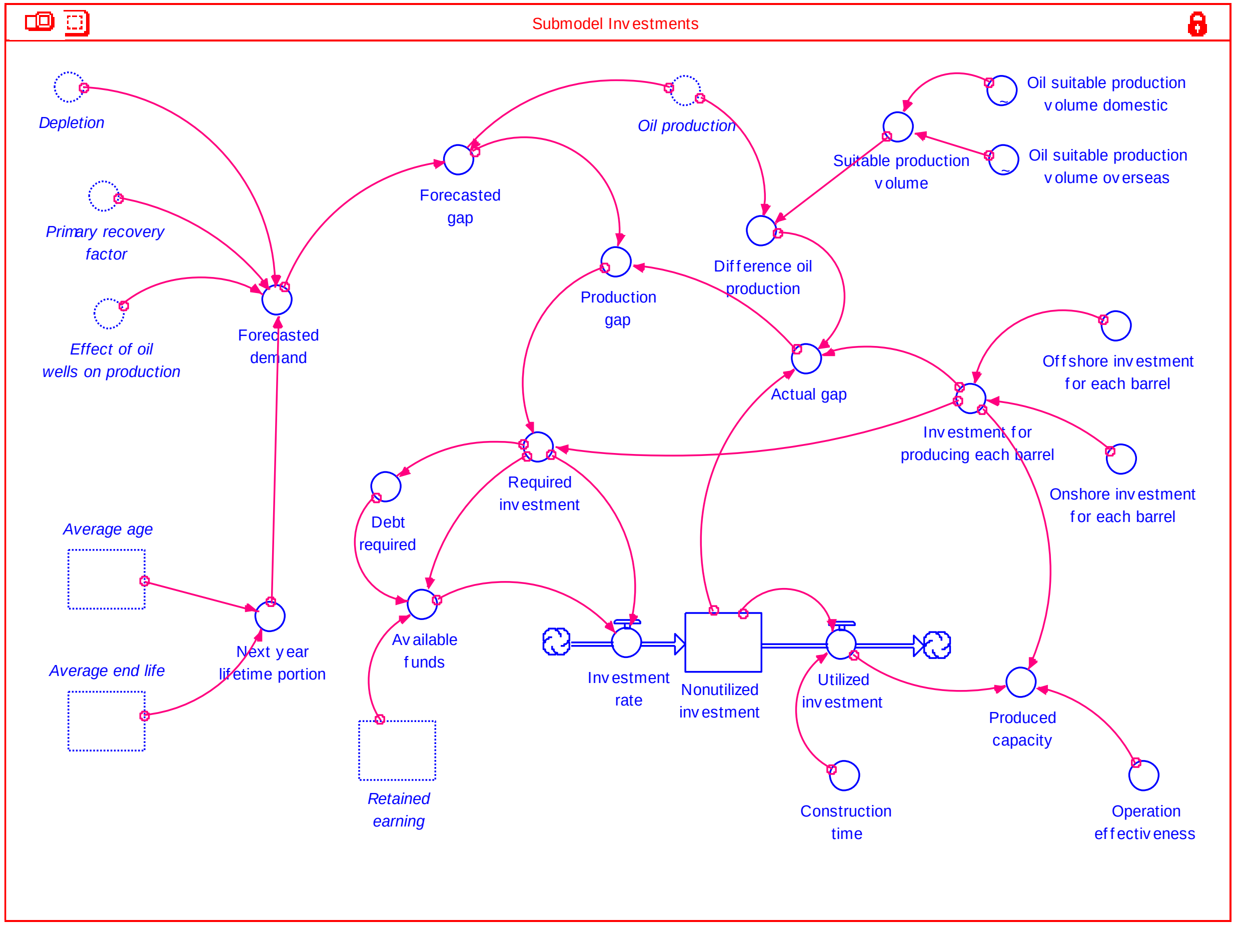

Figure 4. 11 Submodel Investments

Source: Author's Documentation

4.3.6 Submodel Income

Submodel income illustrates the flow income generated from oil production and selling activity done by contractor (in this case NOC). All of the variables used in this submodel are created based on the governmental regulation on oil upstream mining activity. Gross production, resulted from the amount of oil produced multiplied by the oil price, will be deducted by First Tranche Petroleum (20% of gross production), Cost Recovery, Equity to be Split (between government and contractor), Domestic Market Obligation, and Income Tax. The government will earn income through all of those deductions. Government income will be spent as retained earning that affects the investments. Submodel income also will result financial value in form of NPV. When NOC is given the concession, NOC will be able to earn more income that furthermore dedicated for the government. The more income of NOC will be able to increase the amount of investments and more value. The relation of all variables can be shown in the figure below.

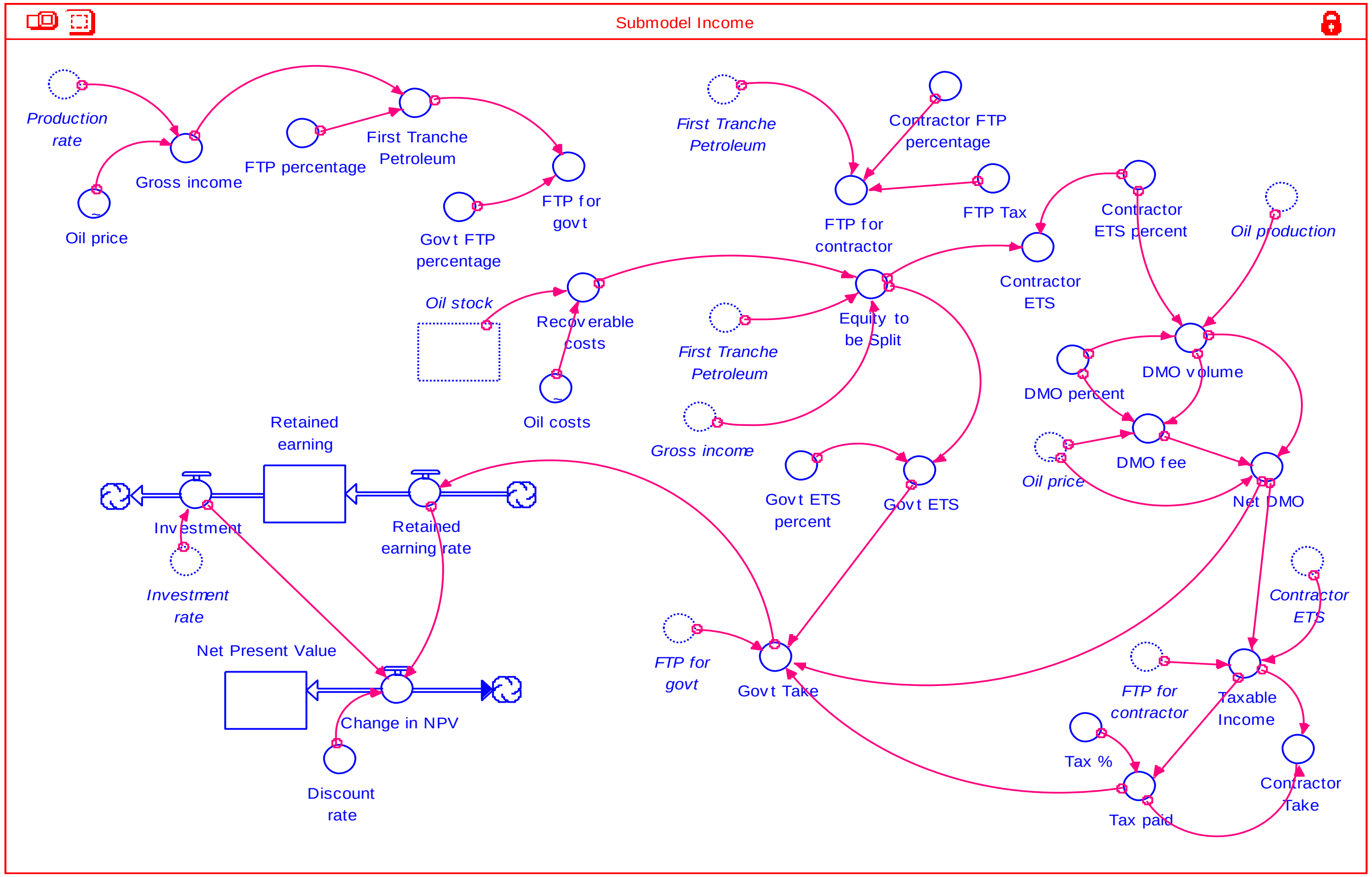

Figure 4. 12 Submodel Income

Source: Author's Documentation

The data and assumptions that become the input of the submodel follows:

- FTP percentage = 20% of gross production
- Government's FTP percentage = 73,2143% of FTP
- Contractor's FTP percentage == 26,7857% of FTP
- Contractor's ETS percentage = 26,7857% of ETS
- Government's ETS percentage = 73,2143% of ETS
- DMO percentage = 25%
- DMO volume = 25% x 26,7857% x gross production
- DMO fee = 25% x oil price x DMO volume
- Tax percentage = 44% of Taxable Income

4.4 Verification and Validation

After creating the simulation model, the model must be tested through verification and validation. Both steps will be explained below.

4.4.1 Model Verification

Verification is the process to determine whether the simulation model correctly reflects the real world. Testing is conducted to verify whether the simulation results absolutely predictable outcomes based on test data. In STELLA, verification can be done by 2 processes, those are units checking and verify/repair model menu.

Units checking is conducted to know whether all units used in the model are consistent or not. Units consistency is a crucial thing in simulation model, otherwise the simulation will not be able to run. The result of units checking can be shown in the figure below.

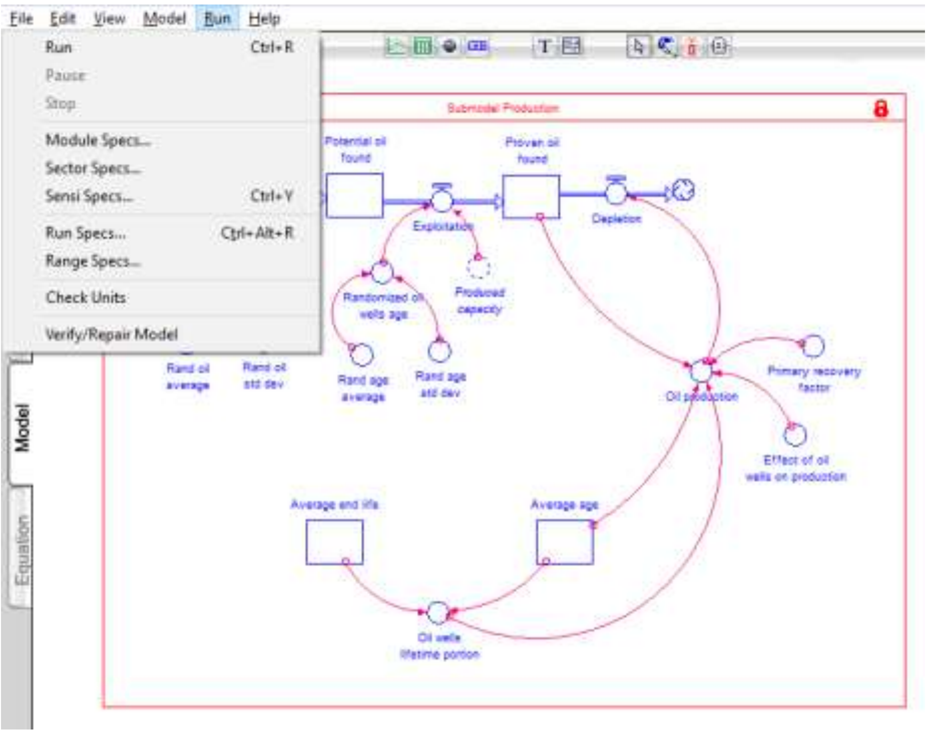

Figure 4. 13 Check Unit Menu

Source: Author's Documentation

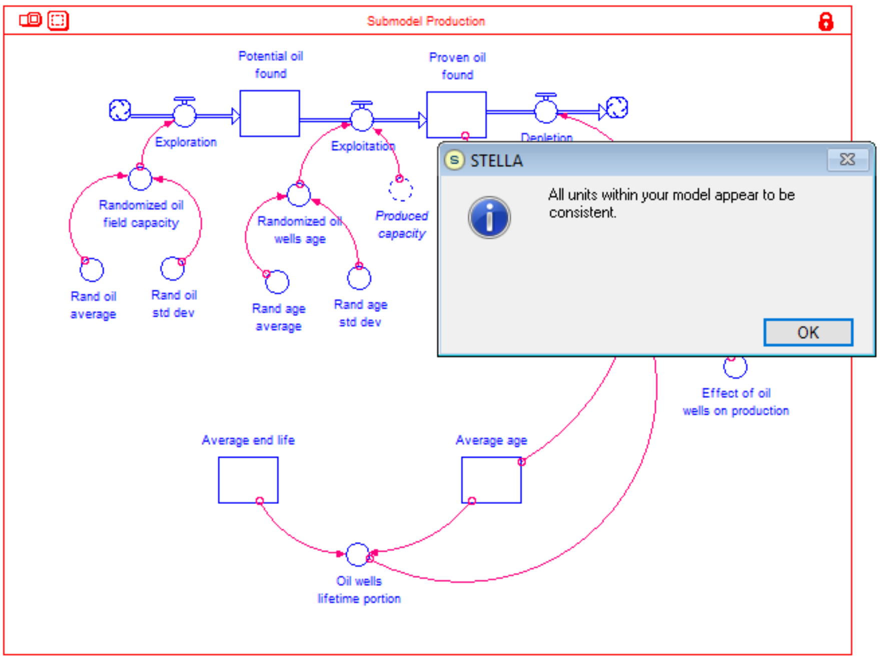

Figure 4. 14 Unit Consistency Proof

Source: Author's Documentation

After units checking, verification can be done through verify/repair model menu in STELLA to see whether there are any errors in the model and to see whether the total count of all entities in the model. There are 2 modes of verification, those are verbose and quiet. Verbose mode is used to make the notification appears every time there's an error, while Quiet mode is used to make verification process occurs in the end of simulation so when there's any error, the notification will only appear in the end of simulation. The result of verification can be shown below.

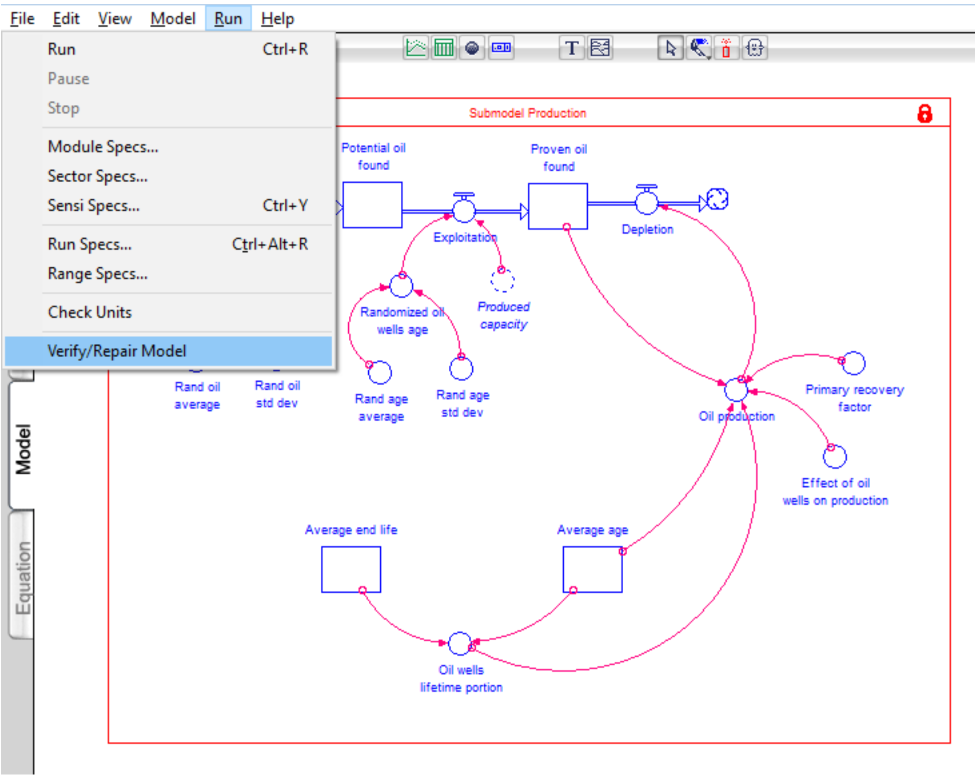

Figure 4. 15 Verify/Repair Model Menu

Source: Author's Documentation

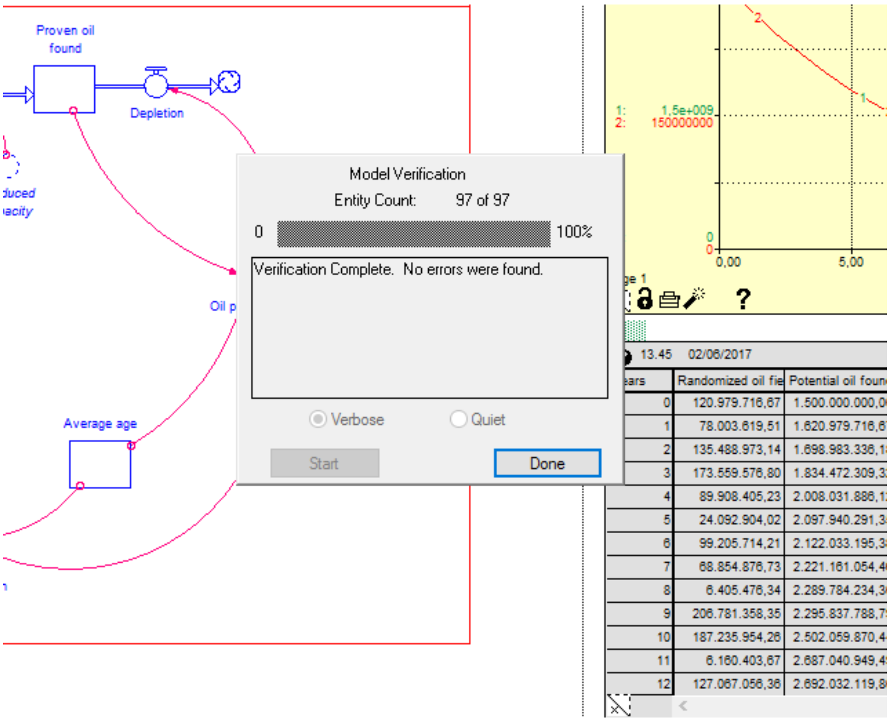

Figure 4. 16 Model Verification

Source: Author's Documentation

From the figures shown above, there is no error found in the model. Therefore, it can be concluded that the model is already verified or it has reflected the real system.

4.4.2 Model Validation

Model validation is the process of establishing confidence in the soundness and usefulness of a model (Forrester in Richardson, 2016). Validation aims to know whether the simulation result is appropriate with the modelled process. Model can be considered as good when its simulation result has relatively small mistakes. Several testing methods are required for validating the simulation model, including the usage of statistical testing techniques. The processes of model validation are provided below.

4.4.2.1 Structure Testing

Model structure testing is conducted to find out whether the structure of the model is suitable or similarly represent the real system. This testing can be done through matching the simulation model with the Causal-Loop Diagram that has been made before. When the simulation model could represent the variables in Causal-Loop Diagram or furthermore could explain more detail, it can be concluded that the simulation model's structure is valid. Structure assessment testing is done through interview with the system owner which is NOC. All variables in each submodel has been assessed and considered to be valid qualitatively.

4.4.2.2 Parameter Testing

Parameter testing is conducted to determine whether the variables used in the system are consistent or not. Parameter testing can be done through validating the logic between related variables in the model. The formulas made in the model have to follow the logic relationship of the variables as shown in the Causal-Loop Diagram. To conduct the parameter testing, some graphs of the simulation result are provided below.

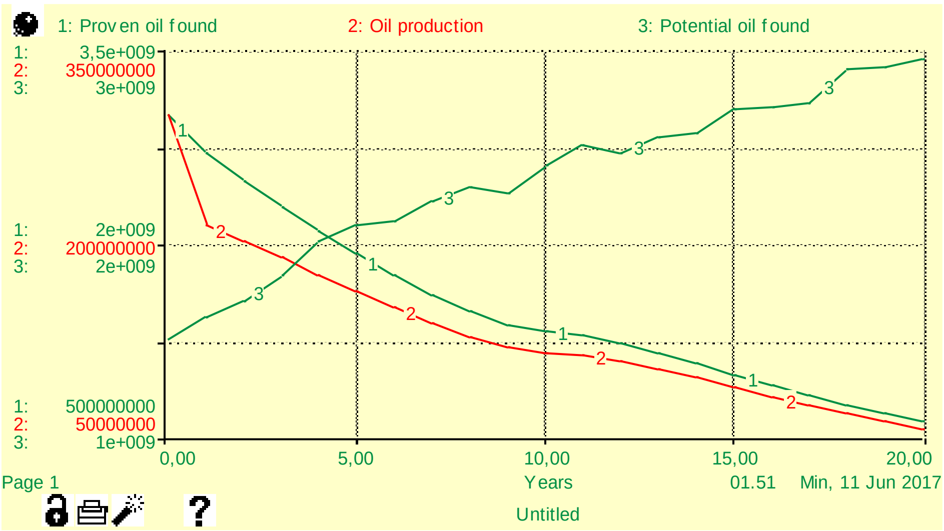

Figure 4. 17 Simulation Output of Submodel Production

Source: Author's Documentation

According to the simulation output of submodel production, the amount of exploration activity (represented by randomized oil field capacity) rises and resulted in the addition of the amount of potential oil found. As the nature of oil production, not all of potential oil reserves can be proven oil reserves. Therefore, the amount of proven oil reserves declines. Oil production, following the declining of proven oil reserves, also declines as the simulation run. The parameter testing then conducted for submodel consumption.

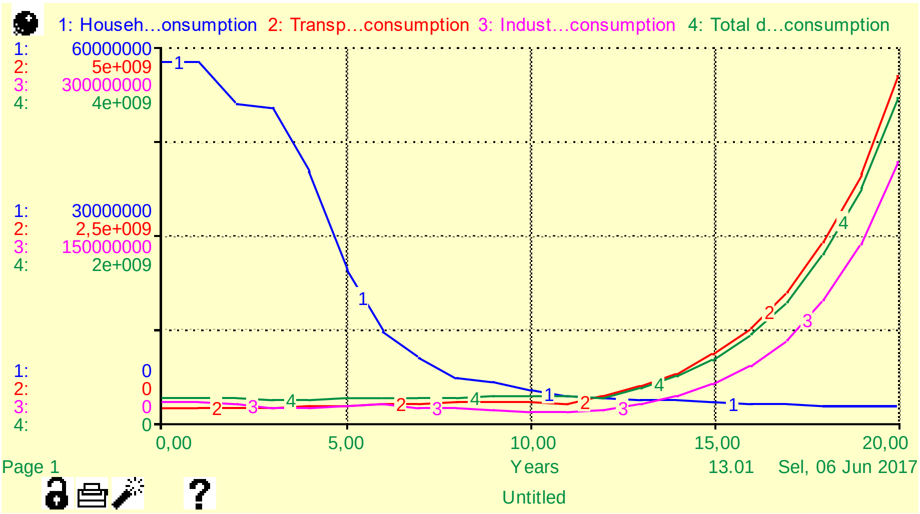

Figure 4. 18 Simulation Output of Submodel Consumption

Source: Author’s Documentation

According to the simulation output of submodel consumption, the rising amount of household, transportation (fossil-fueled vehicles), and industry contribute to the rising amount of total domestic consumption. The total domestic consumption shows the exponential behavior due to the exponential behavior of transportation’s consumption and industry’s consumption. Meanwhile the household consumption shows the exponential decline due to the decline of crude oil usage (in the form kerosene) for household usage. The parameter testing then conducted for submodel oil market.

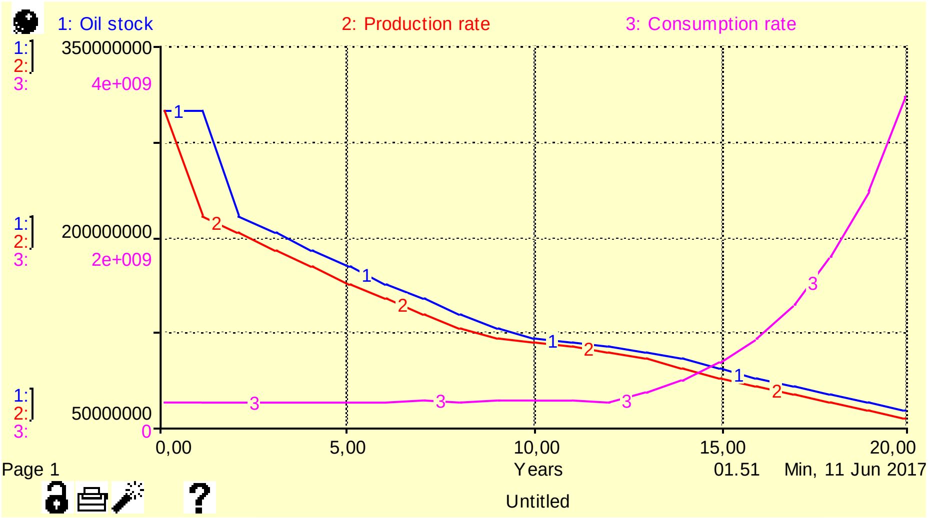

Figure 4. 19 Simulation Output of Submodel Oil Market

Source: Author's Documentation

According to the simulation output of submodel oil market, as the production rate declines (due to the decline of oil production), the amount of oil stock also declines as the consumption rate that consumes oil increases exponentially. The oil stock then fulfilled by crude oil import activity, therefore the amount could fulfill the demand. From the parameter testing, it is proven that the variables in the model are consistent with the logic of the variables.

4.4.2.3 Boundary Adequacy Testing

Boundary adequacy testing is conducted to adjust the boundary of the model with the goals that want to be achieved through the simulation. All variables made in the simulation model must have their influence in achieving the energy independence and energy security. The unrelated variables are omitted to make the model more representative. One of the example of boundary adequacy testing that has been done is eliminating the population variable and population growth from submodel consumption. This elimination occurs as population isn't directly related to oil consumption. Household, which is the group of population, is more suitable to be used because household consumes oil instead of population personally.

4.4.2.4 Extreme Conditions Testing

The structure of system dynamics model should permit extreme combinations of levels in the system being represented. To conduct extreme conditions testing, the evaluator must examine each rate equation in a model, trace it back through any auxiliary equations to the level on which the rate depends, and consider the implications of imaginary maximum and minimum values of each state variable and combinations of state variables to determine the rational of the resulting rate equation. Extreme condition testing can be done through *Sensitivity Analysis* menu in the software. The graph below shows the sensitivity analysis that has been applied to submodel production.

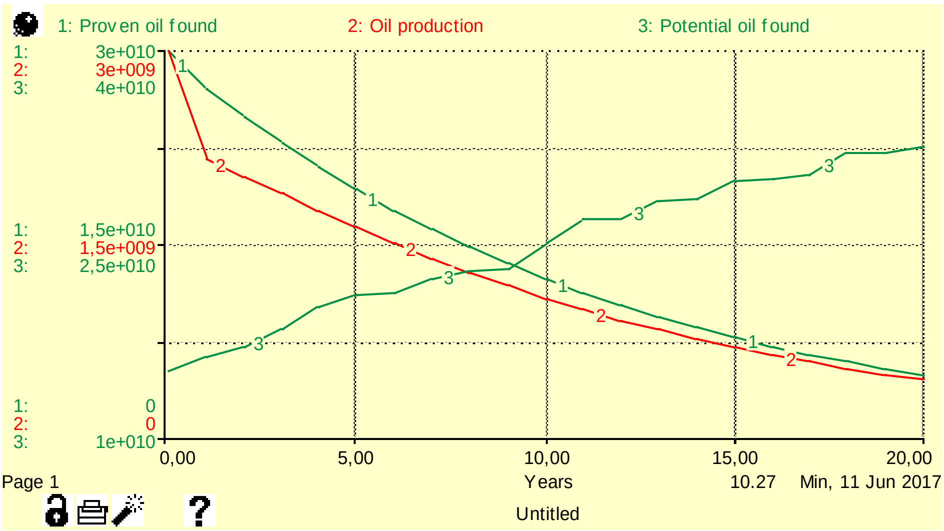

Figure 4. 20 Extreme Condition Testing Result of Submodel Production

Source: Author's Documentation

Four variables are tested in this submodel to figure out whether the behavior of the model can survive the extreme condition. The amount of potential oil found, proven oil found, randomized oil capacity average, and randomized oil capacity standard deviation were tested with minimum value 0 and maximum value 10 times of the input value. Compared to figure 4.16, there is no damage in the graphical result of the submodel. This submodel could resist the extreme value and can be used for extreme decision making.

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CHAPTER 5
SIMULATION OUTPUT ANALYSIS & SCENARIO DEVELOPMENT

This chapter contains the simulation output analysis of the current upstream oil mining scenario (before concession). The current scenario will be compared to the new scenario (after concession). Both of the scenario will be valuated to select the better scenario for managing upstream oil mining activity.

5.1 Before Concession Scenario (As-Is)

The analysis of simulation output is divided into 3 parts, those are amount of oil reserves, oil supply and demand, and Net Present Value (NPV). The explanation are as follows.

5.1.1 Amount of Oil Reserves

The amount of potential oil reserves is determined by the addition of new potential oil reserves explored from exploration activity. Potential oil found will determine the amount of proven oil and furthermore the oil production. Behavior of those variables is shown in the figure below.

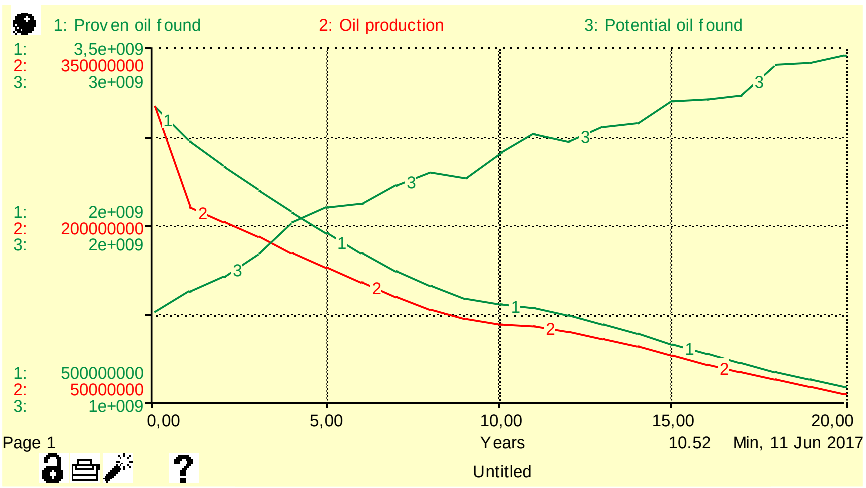

Figure 5. 1 Simulation Output of Oil Reserves Before Concession

Source: Author’s Documentation

Besides the graph, the numerical amount of potential oil found and proven oil are provided in the table below.

Table 5. 1 Numerical Output of Oil Reserves Before Concession

Year	Randomized Oil Field Capacity (barrel)	Potential Oil Found (barrel)	Randomized Oil Wells Age (years)	Produced Capacity (barrel)	Exploitation (barrel/year)	Proven Oil Found (barrel)	Depletion (barrel/year)
0	120.979.716,67	1.500.000.000,00	15,54	0,00	0,00	3.000.000.000,00	300.000.000,00
1	78.003.619,51	1.620.979.716,67	14,09	0,00	0,00	2.700.000.000,00	215.169.230,77
2	135.488.973,14	1.698.983.336,18	16,03	0,00	0,00	2.484.830.769,23	202.302.527,24
3	173.559.576,80	1.834.472.309,32	17,31	0,00	0,00	2.282.528.241,99	188.708.556,41
4	89.908.405,23	2.008.031.886,12	14,49	0,00	0,00	2.093.819.685,58	175.246.683,48
5	24.092.904,02	2.097.940.291,35	12,27	0,00	0,00	1.918.573.002,10	162.247.479,56
6	99.205.714,21	2.122.033.195,38	14,80	0,00	0,00	1.756.325.522,54	149.864.925,70
7	68.854.876,73	2.221.238.909,59	13,78	101.974,52	1.405.374,60	1.606.460.596,84	138.170.977,48
8	6.405.476,34	2.288.688.411,72	11,68	2.421.382,17	28.273.484,64	1.469.694.993,97	127.315.073,97
9	206.781.358,35	2.266.820.403,43	18,43	3.462.199,33	63.811.215,19	1.370.653.404,63	119.510.906,45
10	187.235.954,26	2.409.790.546,59	17,77	4.523.716,60	80.395.484,38	1.314.953.713,37	115.342.141,06
11	6.160.403,67	2.516.631.016,47	11,25	4.837.977,97	54.441.863,38	1.280.007.056,69	112.899.278,37
12	127.067.056,36	2.468.349.556,76	15,74	2.418.988,99	38.084.159,51	1.221.549.641,70	108.299.130,29
13	29.958.368,55	2.557.332.453,61	12,47	1.209.494,49	15.083.009,31	1.151.334.670,91	102.567.727,52
14	139.928.396,52	2.572.207.812,85	16,18	604.747,25	9.783.214,93	1.063.849.952,70	95.205.385,37
15	13.134.973,71	2.702.352.994,43	11,02	302.373,62	3.331.529,07	978.427.782,27	87.937.340,06

Table 5. 1 Numerical Output of Oil Reserves Before Concession

Year	Randomized Oil Field Capacity (barrel)	Potential Oil Found (barrel)	Randomized Oil Wells Age (years)	Produced Capacity (barrel)	Exploitation (barrel/year)	Proven Oil Found (barrel)	Depletion (barrel/year)
16	20.148.862,29	2.712.156.439,07	12,14	151.186,81	1.835.385,11	893.821.971,28	80.660.741,99
17	181.411.073,99	2.730.469.916,25	17,58	75.593,41	1.328.603,56	814.996.614,39	73.832.398,16
18	3.863.650,51	2.910.552.386,68	11,33	37.796,70	428.253,23	742.492.819,79	67.512.669,06
19	42.275.566,92	2.913.987.783,97	12,89	18.898,35	243.518,36	675.408.403,95	61.629.763,42
20	6.047.725,28	2.956.019.832,53	11,26	9.449,18		614.022.158,89	

From the table above, the amount of randomized oil field capacity followed the normal distribution where the amount of mean is 105 MMBOE and standard deviation of 89 MMBOE. The amount of randomized oil field capacity added the amount of potential oil found. Since not all of the potential oil can be exploited, therefore not all of the potential oil found amount can be transformed to proven oil found. The amount of exploitation that drained the potential oil found is not as much as the addition of randomized oil field capacity, therefore the amount of potential oil found keeps growing. The final amount of the potential oil found under the current scenario is projected to be 2.956.019.832,53 barrels or 2.956 MMBOE in 2025.

Proven oil found (which represents the current oil wells) is depleted to produce the crude oil. Since the amount of exploitation decreased annually, the addition of proven oil found is not as much as the potential oil found. The amount of proven oil found continued to decrease annually due to oil production. The final amount of the proven oil found under the current scenario is projected to be 614.022.158,89 barrels or 614 MMBOE in 2025.

5.1.2 Oil Supply and Demand

Oil supply and demand determined energy security in Indonesia. The demand of oil is determined by total domestic consumption. Meanwhile, oil supply is determined by oil production. Behavior of those variables is shown in the figure below.

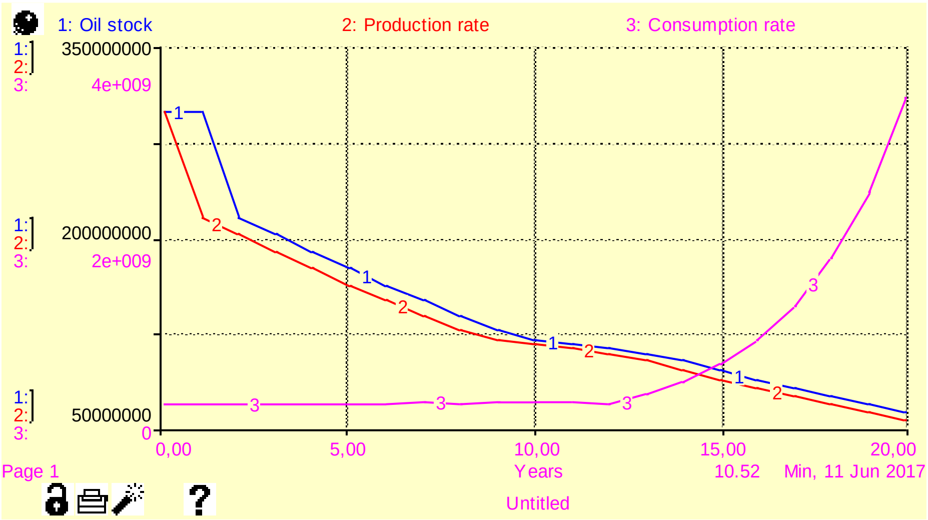

Figure 5. 2 Simulation Output of Oil Supply and Demand Before Concession

Source: Author's Documentation

Besides the graph, the numerical amount of oil supply, demand, and stock are provided in the table below.

Table 5. 2 Numerical Output of Oil Supply and Demand Before Concession

Year	Production Rate (barrel/year)	Oil Stock (barrel)	Consumption Rate (barrel/year)	Import Rate (barrel/year)	Export Rate (barrel/year)
0	300.000.000,00	300.000.000,00	251.578.281,11	0	48.421.719
1	215.169.230,77	300.000.000,00	251.578.281,11	0	48.421.719
2	202.302.527,24	215.169.230,77	251.578.281,11	36.409.050	0
3	188.708.556,41	202.302.527,24	233.706.422,69	31.403.895	0
4	175.246.683,48	188.708.556,41	232.879.817,98	44.171.262	0
5	162.247.479,56	175.246.683,48	240.892.684,37	65.646.001	0
6	149.864.925,70	162.247.479,56	244.038.435,54	81.790.956	0
7	138.170.977,48	149.864.925,70	254.743.182,02	104.878.256	0
8	127.315.073,97	138.170.977,48	251.645.426,39	113.474.449	0

Table 5. 2 Numerical Output of Oil Supply and Demand Before Concession

Year	Production Rate (barrel/year)	Oil Stock (barrel)	Consumption Rate (barrel/year)	Import Rate (barrel/year)	Export Rate (barrel/year)
9	119.510.906,45	127.315.073,97	265.925.837,20	138.610.763	0
10	115.342.141,06	119.510.906,45	268.057.244,80	148.546.338	0
11	112.899.278,37	115.342.141,06	258.012.080,50	142.669.939	0
12	108.299.130,29	112.899.278,37	248.944.541,00	136.045.263	0
13	102.567.727,52	108.299.130,29	344.787.608,88	236.488.479	0
14	95.205.385,37	102.567.727,52	478.338.959,40	375.771.232	0
15	87.937.340,06	95.205.385,37	664.539.087,93	569.333.703	0
16	80.660.741,99	87.937.340,06	923.931.216,20	835.993.876	0
17	73.832.398,16	80.660.741,99	1.285.243.671,67	1.204.582.930	0
18	67.512.669,06	73.832.398,16	1.788.812.453,00	1.714.980.055	0
19	61.629.763,42	67.512.669,06	2.489.952.985,35	2.422.440.316	0
20		61.629.763,42			

The amount of oil stock available in the market is determined from the production, consumption, import, and export activity. Production and import will add the amount of oil stock, meanwhile consumption and export will subtract the amount of oil stock.

The decreasing amount of production rate led to the decreasing of oil stock in the market. With the rising trend of consumption rate, the crude oil production by NOC couldn't fulfill the demand. In the early period of simulation (2005 – 2006), crude oil still could be exported due to the excessive stock. Then, since 2007, the crude oil production couldn't fulfill the demand. Therefore, there need to be oil import to fulfill the demand. The amount of oil import increasing until the end of simulation period. In the end of simulation period, the amount of oil stock is projected to be 61.629.763,42 barrels or 61,6 MMBOE.

5.1.3 Net Present Value

Net Present Value defines the value of NOC's and its ability in doing investment for business expansion both in onshore and offshore upstream mining activity and also for overseas expansion. The behavior of NPV is shown in the graph below.

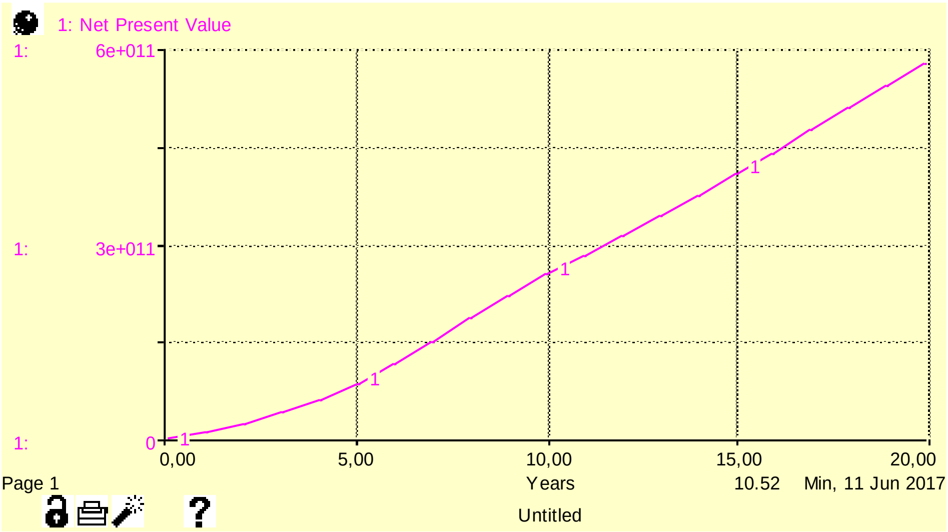

Figure 5. 3 Simulation Output of Net Present Value Before Concession

Source: Author's Documentation

Besides the graph, the numerical amount of retained earnings and NPV are shown the table below.

Table 5. 3 Numerical Output of Income Before Concession

Year	Gross Income (USD)	First Tranche Petroleum (USD)	Equity To Be Split (USD)	Net DMO (USD)	Government Take (USD)	Contractor Take (USD)
0	16.977.000.000,00	3.395.400.000,00	4.581.600.000,00	795.796.875,00	7.095.836.872,68	480.991.197,89
1	13.393.854.276,92	2.678.770.855,38	1.415.083.421,54	627.836.919,23	3.706.602.529,83	71.539.636,09
2	13.606.058.772,03	2.721.211.754,41	3.999.431.633,01	637.784.004,94	5.968.586.264,66	431.343.051,32
3	13.391.513.997,14	2.678.302.799,43	4.037.227.798,80	627.727.218,62	5.961.211.686,36	438.661.964,57
4	14.605.759.587,63	2.921.151.917,53	5.079.808.195,73	684.644.980,67	7.083.533.089,59	573.148.588,43
5	16.234.482.805,00	3.246.896.561,00	6.678.705.638,86	760.991.381,48	8.761.329.670,65	781.602.781,47
6	11.565.975.505,86	2.313.195.101,17	3.249.623.660,89	542.155.101,84	4.944.543.601,60	345.648.740,36
7	9.039.974.372,32	1.807.994.874,46	1.537.112.321,24	423.748.798,70	3.002.254.312,99	129.767.886,16
8	9.668.815.977,51	1.933.763.195,50	2.208.213.682,98	453.225.748,95	3.696.289.676,85	217.779.518,00
9	10.240.411.530,32	2.048.082.306,06	2.972.411.191,52	480.019.290,48	4.459.746.911,29	319.365.586,10
10	10.962.117.086,30	2.192.423.417,26	3.630.724.691,57	513.849.238,42	5.160.046.134,61	404.709.352,13
11	10.668.304.410,63	2.133.660.882,13	3.459.589.321,89	500.076.769,25	4.958.256.229,94	383.526.932,80
12	10.277.804.063,13	2.055.560.812,63	3.028.876.445,32	481.772.065,46	4.515.257.500,95	326.917.361,86
13	9.971.429.334,09	1.994.285.866,82	2.778.785.213,18	467.410.750,04	4.243.230.537,76	294.799.833,29
14	9.149.808.766,25	1.829.961.753,25	2.294.028.364,50	428.897.285,92	3.673.617.972,79	234.698.196,21
15	8.202.795.080,61	1.640.559.016,12	1.706.761.410,68	384.506.019,40	2.992.538.821,11	161.430.110,49
16	5.367.004.450,64	1.073.400.890,13	-367.075.462,56	251.578.333,62	681.926.337,89	-102.108.804,91
17	3.528.154.978,55	705.630.995,71	-1.613.816.826,70	165.382.264,62	-732.073.987,81	-259.275.451,90
18	3.039.015.285,25	607.803.057,05	-1.777.234.467,01	142.453.841,50	-963.533.756,42	-277.531.547,06
19	2.899.828.280,35	579.965.656,07	-1.663.384.850,50	135.929.450,64	-891.494.970,85	-260.277.282,30

Table 5. 3 Numerical Output of Income Before Concession

Year	Gross Income (USD)	First Tranche Petroleum (USD)	Equity To Be Split (USD)	Net DMO (USD)	Government Take (USD)	Contractor Take (USD)
20	2.894.996.887,11	578.999.377,42	-1.443.418.058,94	135.702.979,08	-703.221.582,69	-229.436.274,77

Table 5. 4 Numerical Output of NPV Before Concession

Year	Tax Paid (USD)	Retained Earnings (USD)	Net Present Value (USD)
0	377.921.655,48	0	0
1	56.209.714,07	7.095.836.872,68	7.095.836.872,68
2	338.912.397,46	10.802.439.402,51	20.642.434.538,71
3	344.662.972,16	16.771.025.667,17	37.252.340.080,63
4	450.331.033,77	22.732.237.353,54	58.346.532.823,65
5	614.116.471,16	29.815.770.443,12	83.512.313.358,74
6	271.581.153,14	38.577.100.113,77	113.076.410.631,74
7	101.960.481,98	43.159.974.083,83	147.586.050.096,43
8	171.112.478,43	37.755.227.781,13	184.447.428.543,69
9	250.930.103,36	33.466.168.229,42	218.787.452.952,57
10	317.985.919,53	28.021.433.751,10	251.308.497.420,52
11	301.342.590,05	24.044.842.103,79	281.730.361.047,62
12	256.863.641,46	29.003.098.333,73	310.758.453.561,62
13	231.628.440,45	33.518.355.834,68	341.366.399.312,58
14	184.405.725,59	37.761.586.372,44	373.282.254.326,90

Table 5. 4 Numerical Output of NPV Before Concession

Year	Tax Paid (USD)	Retained Earnings (USD)	Net Present Value (USD)
15	126.837.943,95	41.435.204.345,23	406.315.484.561,04
16	-80.228.346,71	44.427.743.166,34	440.228.149.730,28
17	-203.716.426,49	45.109.669.504,23	474.792.078.536,99
18	-218.060.501,26	45.109.669.504,23	509.490.922.834,22
19	-204.503.578,95	45.109.669.504,23	544.189.767.131,46
20	-180.271.358,75	45.109.669.504,23	578.888.611.428,69

From table 5.3, it can be interpreted that the decreasing amount of oil production led to the decreasing trend of gross income. In the early period of simulation, the oil price was higher than current oil price and fluctuated the gross income. The drop of oil price (West Texas Intermediate) resulted in the decreasing amount of gross income. Since the amount of gross income is decreasing, the amount of FTP, ETS, net DMO, government take, contractor take, and tax paid are also decreasing.

The different trend happened to retained earnings. Retained earnings is gathered from government take. Even the amount of government take is decreasing, it is not as much as the addition to the retained earnings. Therefore, the retained earnings keep growing and projected to be US$45.109.669.504,23 in the end of simulation period. Retained earnings also contribute to the value of NOC. Under the valuation method, the value of NOC is projected to be US$ 578.888.611.428,69 in the end of simulation period.

5.2 After Concession Scenario

The analysis of simulation output is divided into 3 parts, those are amount of oil reserves, oil supply and demand, and Net Present Value (NPV). The explanation are as follows.

5.2.1 Amount of Oil Reserves

The amount of potential oil reserves is determined by the addition of new potential oil reserves explored from exploration activity. Potential oil found will determine the amount of proven oil and furthermore the oil production. Behavior of those variables is shown in the figure below.

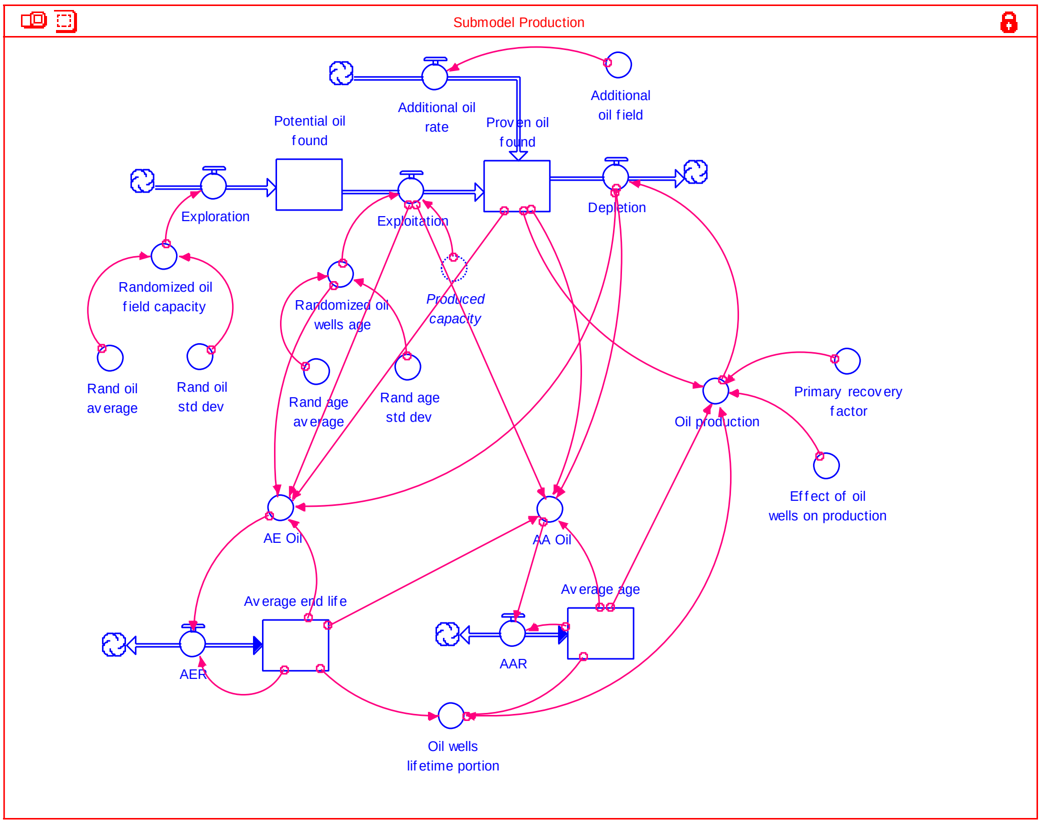

Figure 5. 4 Variables in Submodel Production After Concession

Source: Author's Documentation

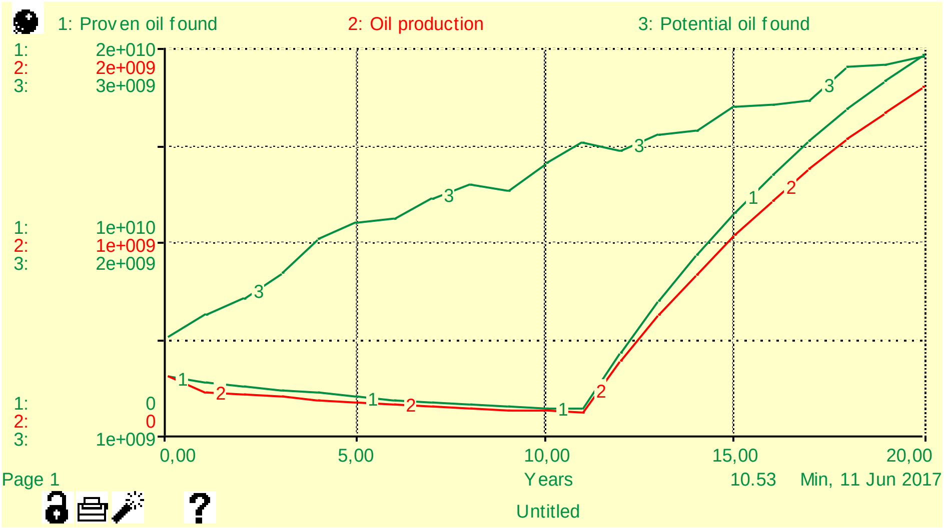

Figure 5. 5 Simulation Output of Oil Reserves After Concession

Source: Author's Documentation

Besides the graph, the numerical amount of potential oil found and proven oil are provided in the table below.

Table 5. 5 Numerical Output of Oil Reserves After Concession

Year	Randomized Oil Field Capacity (barrel)	Potential Oil Found (barrel)	Randomized Oil Wells Age (years)	Produced Capacity (barrel)	Exploitation (barrel/year)	Additional Oil Rate (barrel/year)	Proven Oil Found (barrel)	Depletion (barrel/year)
0	120.979.716,67	1.500.000.000,00	15,54	0,00	0,00	0,00	3.000.000.000,00	300.000.000,00
1	78.003.619,51	1.620.979.716,67	14,09	0,00	0,00	0,00	2.700.000.000,00	215.169.230,77
2	135.488.973,14	1.698.983.336,18	16,03	0,00	0,00	0,00	2.484.830.769,23	202.302.527,24
3	173.559.576,80	1.834.472.309,32	17,31	0,00	0,00	0,00	2.282.528.241,99	188.708.556,41
4	89.908.405,23	2.008.031.886,12	14,49	0,00	0,00	0,00	2.093.819.685,58	175.246.683,48
5	24.092.904,02	2.097.940.291,35	12,27	0,00	0,00	0,00	1.918.573.002,10	162.247.479,56
6	99.205.714,21	2.122.033.195,38	14,80	0,00	0,00	0,00	1.756.325.522,54	149.864.925,70
7	68.854.876,73	2.221.238.909,59	13,78	101.974,52	1.405.374,60	0,00	1.606.460.596,84	138.170.977,48
8	6.405.476,34	2.288.688.411,72	11,68	2.421.382,17	28.273.484,64	0,00	1.469.694.993,97	127.315.073,97
9	206.781.358,35	2.266.820.403,43	18,43	3.462.199,33	63.811.215,19	0,00	1.370.653.404,63	119.510.906,45
10	187.235.954,26	2.409.790.546,59	17,77	4.523.716,60	80.395.484,38	0,00	1.314.953.713,37	115.342.141,06
11	6.160.403,67	2.516.631.016,47	11,25	4.837.977,97	54.441.863,38	3.000.000.000,00	1.280.007.056,69	112.899.278,37
12	127.067.056,36	2.468.349.556,76	15,74	2.418.988,99	38.084.159,51	3.000.000.000,00	4.221.549.641,70	374.270.630,58
13	29.958.368,55	2.557.332.453,61	12,47	1.209.494,49	15.083.009,31	3.000.000.000,00	6.885.363.170,62	613.389.252,02
14	139.928.396,52	2.572.207.812,85	16,18	604.747,25	9.783.214,93	3.000.000.000,00	9.287.056.927,91	831.111.758,19
15	13.134.973,71	2.702.352.994,43	11,02	302.373,62	3.331.529,07	3.000.000.000,00	11.465.728.384,66	1.030.495.498,27
16	20.148.862,29	2.712.156.439,07	12,14	151.186,81	1.835.385,11	3.000.000.000,00	13.438.564.415,45	1.212.728.558,29
17	181.411.073,99	2.730.469.916,25	17,58	75.593,41	1.328.603,56	3.000.000.000,00	15.227.671.242,27	1.379.506.561,06
18	3.863.650,51	2.910.552.386,68	11,33	37.796,70	428.253,23	3.000.000.000,00	16.849.493.284,77	1.532.069.702,72

Table 5. 5 Numerical Output of Oil Reserves After Concession

Year	Randomized Oil Field Capacity (barrel)	Potential Oil Found (barrel)	Randomized Oil Wells Age (years)	Produced Capacity (barrel)	Exploitation (barrel/year)	Additional Oil Rate (barrel/year)	Proven Oil Found (barrel)	Depletion (barrel/year)
19	42.275.566,92	2.913.987.783,97	12,89	18.898,35	243.518,36	3.000.000.000,00	18.317.851.835,28	1.671.463.169,02
20	6.047.725,28	2.956.019.832,53	11,26	9.449,18			19.646.632.184,62	

From the table above, the amount of randomized oil field capacity followed the normal distribution where the amount of mean is 105 MMBOE and standard deviation of 89 MMBOE. The amount of randomized oil field capacity added the amount of potential oil found. Since not all of the potential oil can be exploited, therefore not all of the potential oil found amount can be transformed to proven oil found. The amount of exploitation that drained the potential oil found is not as much as the addition of randomized oil field capacity, therefore the amount of potential oil found keeps growing. The final amount of the potential oil found under the current scenario is projected to be 2.956.019.832,53 barrels or 2.956 MMBOE in 2025.

The different point of concession scenario lays in the addition of proven oil reserves found from the acquisition of other oil field. The acquisition is assumed to be started in 2016 (12^{th} period of simulation period) with the constant rate of 3000 MMBOE/year. Proven oil found (which represents the current oil wells) is depleted to produce the crude oil. With the addition of proven oil found, unlike the current scenario, under the concession scenario the proven oil found amount started to increase in 2016 after decreasing since the early period of simulation. The final amount of the proven oil found under the concession scenario is projected to be 19.646.632.184,62 barrels or 19.646,6 MMBOE in 2025.

5.2.2 Oil Supply and Demand

Oil supply and demand determined energy security in Indonesia. The Demand of oil is determined by total domestic consumption. Meanwhile, oil supply is determined by oil production. Behavior of those variables is shown in the figure below.

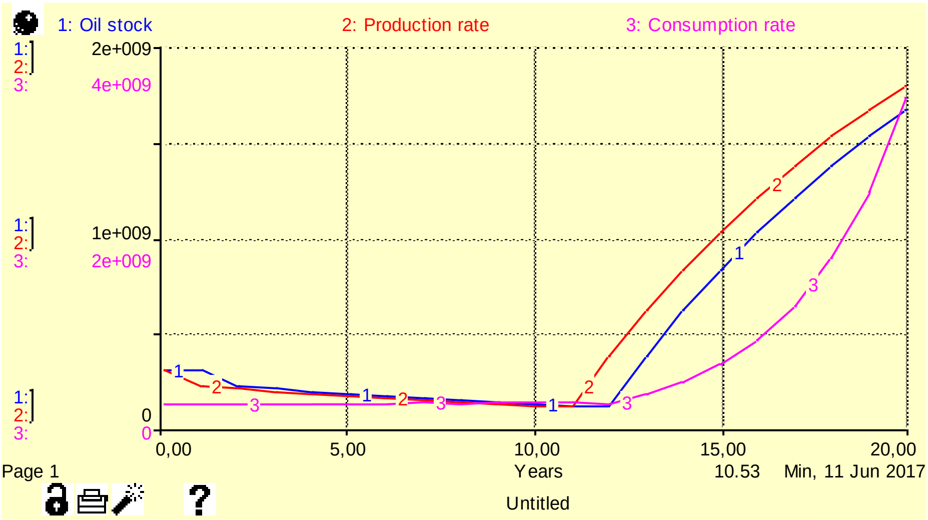

Figure 5. 6 Simulation Output of Oil Supply and Demand After Concession

Source: Author's Documentation

Besides the graph, the numerical amount of oil supply, demand, and stock are provided in the table below.

Table 5. 6 Numerical Output of Oil Supply and Demand After Concession

Year	Production Rate (barrel/year)	Oil Stock (barrel)	Consumption Rate (barrel/year)	Import Rate (barrel/year)	Export Rate (barrel/year)
0	300.000.000,00	300.000.000,00	251.578.281,11	0	48.421.719
1	215.169.230,77	300.000.000,00	251.578.281,11	0	48.421.719
2	202.302.527,24	215.169.230,77	251.578.281,11	36.409.050	0
3	188.708.556,41	202.302.527,24	233.706.422,69	31.403.895	0
4	175.246.683,48	188.708.556,41	232.879.817,98	44.171.262	0
5	162.247.479,56	175.246.683,48	240.892.684,37	65.646.001	0
6	149.864.925,70	162.247.479,56	244.038.435,54	81.790.956	0
7	138.170.977,48	149.864.925,70	254.743.182,02	104.878.256	0
8	127.315.073,97	138.170.977,48	251.645.426,39	113.474.449	0

Table 5. 6 Numerical Output of Oil Supply and Demand After Concession

Year	Production Rate (barrel/year)	Oil Stock (barrel)	Consumption Rate (barrel/year)	Import Rate (barrel/year)	Export Rate (barrel/year)
9	119.510.906,45	127.315.073,97	265.925.837,20	138.610.763	0
10	115.342.141,06	119.510.906,45	268.057.244,80	148.546.338	0
11	112.899.278,37	115.342.141,06	258.012.080,50	142.669.939	0
12	374.270.630,58	112.899.278,37	248.944.541,00	136.045.263	0
13	613.389.252,02	374.270.630,58	344.787.608,88	0	29.483.022
14	831.111.758,19	613.389.252,02	478.338.959,40	0	135.050.293
15	1.030.495.498,27	831.111.758,19	664.539.087,93	0	166.572.670
16	1.212.728.558,29	1.030.495.498,27	923.931.216,20	0	106.564.282
17	1.379.506.561,06	1.212.728.558,29	1.285.243.671,67	72.515.113	0
18	1.532.069.702,72	1.379.506.561,06	1.788.812.453,00	409.305.892	0
19	1.671.463.169,02	1.532.069.702,72	2.489.952.985,35	957.883.283	0
20		1.671.463.169,02			

The amount of oil stock available in the market is determined from the production, consumption, import, and export activity. Production and import will add the amount of oil stock, meanwhile consumption and export will subtract the amount of oil stock.

The decreasing amount of production rate led to the decreasing of oil stock in the market in 2005 - 2015. After the addition of proven oil resources, the production rate decreases annually. The rising trend of consumption rate could be accommodated by NOC. In the early period of simulation (2005 – 2006), crude oil still could be exported due to the excessive stock. Then, since 2007, the crude oil production couldn’t fulfill the demand. After 2016, there is no more import because of the excessive oil stock available. In 2016 crude oil can be exported to add income for NOC. Oil import will be happened again in 2022 since the production couldn’t fulfill the demand. This condition might be changed if more potential oil reserves acquisition is conducted. In the end of simulation period, the amount of oil stock is projected to be 1.671.463.169,02 barrels 1.671,5 MMBOE.

5.2.3 Net Present Value

Net Present Value defines the value of NOC's and its ability in doing investment for business expansion both in onshore and offshore upstream mining activity and also for overseas expansion. The behavior of NPV is shown in the graph below.

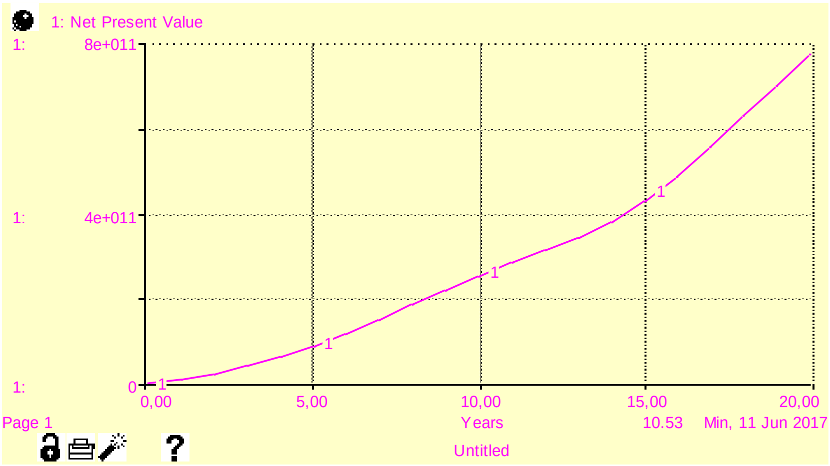

Figure 5. 7 Simulation Output of Net Present Value After Concession

Source: Author's Documentation

Besides the graph, the numerical amount of retained earnings and NPV are shown the table below.

Table 5. 7 Numerical Output of Income After Concession

Year	Gross Income (USD)	First Tranche Petroleum (USD)	Equity To Be Split (USD)	Net DMO (USD)	Government Take (USD)	Contractor Take (USD)
0	16.977.000.000,00	3.395.400.000,00	4.581.600.000,00	795.796.875,00	7.576.828.070,57	480.991.197,89
1	13.393.854.276,92	2.678.770.855,38	1.415.083.421,54	627.836.919,23	3.778.142.165,92	71.539.636,09
2	13.606.058.772,03	2.721.211.754,41	3.999.431.633,01	637.784.004,94	6.399.929.315,98	431.343.051,32
3	13.391.513.997,14	2.678.302.799,43	4.037.227.798,80	627.727.218,62	6.399.873.650,93	438.661.964,57
4	14.605.759.587,63	2.921.151.917,53	5.079.808.195,73	684.644.980,67	7.656.681.678,02	573.148.588,43
5	16.234.482.805,00	3.246.896.561,00	6.678.705.638,86	760.991.381,48	9.542.932.452,12	781.602.781,47
6	11.565.975.505,86	2.313.195.101,17	3.249.623.660,89	542.155.101,84	5.290.192.341,96	345.648.740,36
7	9.039.974.372,32	1.807.994.874,46	1.537.112.321,24	423.748.798,70	3.132.022.199,14	129.767.886,16
8	9.668.815.977,51	1.933.763.195,50	2.208.213.682,98	453.225.748,95	3.914.069.194,85	217.779.518,00
9	10.240.411.530,32	2.048.082.306,06	2.972.411.191,52	480.019.290,48	4.779.112.497,39	319.365.586,10
10	10.962.117.086,30	2.192.423.417,26	3.630.724.691,57	513.849.238,42	5.564.755.486,75	404.709.352,13
11	10.668.304.410,63	2.133.660.882,13	3.459.589.321,89	500.076.769,25	5.341.783.162,73	383.526.932,80
12	35.519.031.383,69	7.103.806.276,74	23.221.858.301,77	1.664.954.596,11	29.488.430.713,84	2.915.404.997,42
13	59.632.476.302,53	11.926.495.260,51	29.740.990.773,99	2.795.272.326,68	40.261.864.128,46	3.600.211.272,99
14	79.874.826.632,73	15.974.965.326,55	33.843.787.957,38	3.744.132.498,41	47.935.990.517,44	3.983.312.486,68
15	96.124.620.078,78	19.224.924.015,76	34.512.996.395,27	4.505.841.566,19	51.472.127.003,30	3.923.440.974,32
16	80.692.532.811,39	16.138.506.562,28	9.937.764.840,72	3.782.462.475,53	24.174.234.144,01	628.741.919,63
17	65.921.100.526,80	13.184.220.105,36	-13.963.190.284,42	3.090.051.587,19	-2.332.823.862,76	-2.577.801.630,45
18	68.964.585.598,10	13.792.917.119,62	-23.460.205.501,93	3.232.714.949,91	-11.292.881.318,71	-3.936.144.722,09
19	78.646.353.614,10	15.729.270.722,82	-27.475.029.569,01	3.686.547.825,66	-13.599.564.764,11	-4.589.712.885,99

Table 5. 7 Numerical Output of Income After Concession

Year	Gross Income (USD)	First Tranche Petroleum (USD)	Equity To Be Split (USD)	Net DMO (USD)	Government Take (USD)	Contractor Take (USD)
20	92.629.642.736,88	18.525.928.547,38	-27.855.539.120,86	4.342.014.503,29	-11.513.022.416,37	-4.775.126.430,75

Table 5. 8 Numerical Output of NPV After Concession

Year	Tax Paid (USD)	Retained Earning (USD)	Net Present Value (NPV)
0	377.921.655,48	0	0
1	56.209.714,07	7.576.828.070,57	7.576.828.070,57
2	338.912.397,46	11.354.970.236,49	22.041.681.659,83
3	344.662.972,16	17.754.899.552,47	39.628.966.791,18
4	450.331.033,77	24.154.773.203,40	62.024.613.542,35
5	614.116.471,16	31.811.454.881,41	88.791.460.109,74
6	271.581.153,14	41.354.387.333,53	120.312.503.594,88
7	101.960.481,98	46.282.910.043,96	157.220.283.665,52
8	171.112.478,43	41.007.931.627,42	196.657.175.175,89
9	250.930.103,36	36.936.651.593,70	233.633.250.324,49
10	317.985.919,53	31.811.282.701,48	268.882.705.307,07
11	301.342.590,05	28.239.400.406,31	302.156.108.707,41
12	2.290.675.355,12	33.581.183.569,04	334.177.589.153,62
13	2.828.737.428,78	63.069.614.282,88	367.901.126.337,00

Table 5. 8 Numerical Output of NPV After Concession

Year	Tax Paid (USD)	Retained Earning (USD)	Net Present Value (NPV)
14	3.129.745.525,25	103.331.478.411,34	410.166.411.512,52
15	3.082.703.622,68	151.267.468.928,78	463.033.903.869,68
16	494.011.508,28	202.739.595.932,08	527.376.891.235,36
17	-2.025.415.566,78	226.913.830.076,09	602.921.713.118,04
18	-3.092.685.138,79	226.913.830.076,09	683.249.278.350,86
19	-3.606.202.981,85	226.913.830.076,09	763.576.843.583,69
20	-3.751.885.052,73	226.913.830.076,09	843.904.408.816,51

From table 5.7, it can be interpreted that the decreasing amount of oil production led to the decreasing trend of gross income. In the early period of simulation, the oil price was higher than current oil price and fluctuated the gross income. The drop of oil price (West Texas Intermediate) resulted in the decreasing amount of gross income. Since the amount of gross income is decreasing, the amount of FTP, ETS, net DMO, government take, contractor take, and tax paid are also decreasing. The addition of proven oil reserves in 2016 led to the increasing amount of production that helped in increasing the amount of gross income. The amount of gross income is projected to be US$ 92.629.642.736,88 in the end of simulation period.

The different trend happened to retained earnings. Retained earnings is gathered from government take. Even the amount of government take is decreasing, it is not as much as the addition to the retained earnings. Therefore, the retained earnings keep growing and projected to be US$ 226.913.830.076,09 in the end of simulation period. Retained earnings also contribute to the value of NOC. Under the valuation method, the value of NOC is projected to be US$ 843.904.408.816,51 in the end of simulation period.

5.3 Comparison between Both Scenario

To provide the concise information about the result difference, the highlighted result of the simulation is summarized in the table below.

Table 5. 9 Comparison Result of Both Existing and Concession Scenario

	Existing Scenario	Concession Scenario	Difference (Concession vs. Existing)
Potential Oil Found (barrels)	2.956.019.832,53	2.956.019.832,53	0%
Proven Oil (barrels)	614.022.158,89	19.646.632.184,62	3100%
Oil Stock (barrels)	61.629.763,42	1.671.463.169,02	2612%
Gross Income (USD)	2.894.996.887,11	92.629.642.736,88	3100%
Retained Earnings (USD)	45.109.669.504,23	226.913.830.076,09	403%
NPV (USD)	578.888.611.428,69	843.904.408.816,51	46%

From table 5.9, it can be interpreted that the concession scenario offers better option for upstream oil management in Indonesia because it resulted in the distinctive difference to achieve the goal of energy independence and energy security. Concession scenario will also strengthen the value of NOC to help NOC in doing upstream oil mining activity such as investment for finding new oil reserves.

CHAPTER 6
CONCLUSION AND RECOMMENDATION

This chapter contains the conclusion of the final project and the recommendations for the improvement of the final project.

6.1 Conclusion

The conclusion of this final project are as follows:

1. Concession scenario offers the better result than the existing scenario. Addressing to energy independence goal, when NOC is given the concession, NOC could earn more proven oil due to the acquisition of oil wells. The amount of proven oil handled by NOC could up to 19.646.632.184,62 barrels, much higher than the existing scenario which is 614.022.158,89 barrels. There will be more oil wells managed by NOC, such as through the takeover of Mahakam Block, ONWJ Block, Sanga – Sanga Block (under discussion), and East Kalimantan Block (under discussion). When NOC is given more priority to manage oil fields, the more reserves and stock that NOC will handle and the more independent NOC is.
2. The acquisition of oil field will also help NOC in securing the amount of oil available in the market (oil stock). Before the concession scenario occurs, the amount of oil stock is 61.629.763,42 barrels. After implementing concession, the amount of oil stock will turn into 1.671.463.169,02 barrels. The higher amount of oil fields managed by NOC will lead to higher amount of production that will result in the higher amount of oil stock. Besides that, with concession scenario, NOC could minimize the amount of oil import because of its ability in fulfilling the demand. Therefore, the goal of energy security in fulfilling domestic oil demand can be accomplished.
3. Under the valuation method, the existing scenario has the value of US$ 578.888.611.428,6. Concession scenario offers the higher valur which is US$ 775.492.486.128,98. With 34% difference of value amount between two scenarios, concession scenario offers higher value for NOC (where NOC represents the government). The higher value adds the power of NOC's

capital and will add the ability of NOC in doing upstream oil mining operation both domestic and overseas and also the possibility of developing the non-conventional oil.

6.2 Recommendation

The recommendations for this final project are as follows:

1. Some of the parameters used in the simulation are still deterministic. Further research can hopefully accommodate stochastic parameters.
2. To provide more comprehensive model, there should be a consideration about the downstream oil investment.
3. Further research can be conducted in finding the scenario in gas management which behave slightly the same as oil management.

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APPENDIX

Appendix 1

List of Formula Used in Before Concession Model

Average_age(t) = Average_age(t - dt) + (- AAR) * dt

INIT Average_age = 10

OUTFLOWS:

AAR = Average_age/AA_Oil

Average_end_life(t) = Average_end_life(t - dt) + (- AER) * dt

INIT Average_end_life = 15

OUTFLOWS:

AER = Average_end_life/AE_Oil

Household_consumption(t) = Household_consumption(t - dt) + (change_in_household's_consumption - Household's_consumption_rate) * dt

INIT Household_consumption = change_in_household's_consumption*dt

INFLOWS:

change_in_household's_consumption = Amount_of_household*Oil_consumption_per_household*1/dt

OUTFLOWS:

Household's_consumption_rate = Household_consumption *1/dt

Industry_consumption(t) = Industry_consumption(t - dt) + (change_in__industry's_consumption - Industrial_consumption_rate) * dt

INIT Industry_consumption = change_in__industry's_consumption*dt

INFLOWS:

change_in__industry's_consumption = Amount_of_industry*Oil_consumption_per_industry*1/dt

OUTFLOWS:

Industrial_consumption_rate = Industry_consumption *1/dt

Net_Present_Value(t) = Net_Present_Value(t - dt) + (Change_in_NPV) * dt

INIT Net_Present_Value = 0

INFLOWS:

Change_in_NPV = NPV(Retained_earning_rate-Investment,Discount_rate)

Nonutilized_investment(t) = Nonutilized_investment(t - dt) + (Investment_rate - Utilized_investment) * dt

INIT Nonutilized_investment = 0

INFLOWS:

Investment_rate = MIN(Available_funds,Required_investment)*1/dt

OUTFLOWS:

Utilized_investment = Nonutilized_investment/Construction_time

Oil_stock(t) = Oil_stock(t - dt) + (Import_rate + Production_rate - Export_rate - Consumption_rate) * dt

INIT Oil_stock = (Production_rate)*dt

INFLOWS:

Import_rate = IF Oil_stock < Total_domestic_consumption THEN Total_domestic_consumption-Oil_stock ELSE 0

Production_rate = Oil_production*1/dt

OUTFLOWS:

Export_rate = IF Oil_stock>Total_domestic_consumption THEN Oil_stock-Total_domestic_consumption ELSE 0

Consumption_rate = Total_domestic_consumption*1/dt

Potential_oil_found(t) = Potential_oil_found(t - dt) + (Exploration - Exploitation) * dt

INIT Potential_oil_found = 1500000000

INFLOWS:

Exploration = Randomized_oil_field_capacity*1/DT

OUTFLOWS:

Exploitation = Produced_capacity*Randomized_oil_wells_age*1/dt^2

Proven_oil_found(t) = Proven_oil_found(t - dt) + (Exploitation - Depletion) * dt

INIT Proven_oil_found = 3000000000

INFLOWS:

Exploitation = Produced_capacity*Randomized_oil_wells_age*1/dt^2

OUTFLOWS:

Depletion = Oil_production*1/dt

Retained_earning(t) = Retained_earning(t - dt) + (Retained_earning_rate - Investment) * dt

INIT Retained_earning = 0

INFLOWS:

Retained_earning_rate = Govt_Take*1/dt

OUTFLOWS:

Investment = Investment_rate

Total_domestic_consumption(t) = Total_domestic_consumption(t - dt) + (change_in_consumption - Domestic_consumption_rate) * dt

INIT Total_domestic_consumption = (Industry_consumption+Household_consumption+Transportation_consumption)

INFLOWS:

change_in_consumption = (Household_consumption+Industry_consumption+Transportation_consumption)* 1/dt

OUTFLOWS:

Domestic_consumption_rate = Total_domestic_consumption *1/dt

Transportation_consumption(t) = Transportation_consumption(t - dt) + (change_in_transportation's_consumption - Transportation's_consumption_rate) * dt

INIT Transportation_consumption = change_in_transportation's_consumption*dt

INFLOWS:

change_in_transportation's_consumption = Amount_of_transportation*Oil_consumption_per_transportation*1/dt

OUTFLOWS:

Transportation's_consumption_rate = Transportation_consumption *1/dt

AA_Oil = ((Proven_oil_found*Average_end_life/dt)+(Exploitation*Average_end_life)-(Depletion*Average_age))*dt/(Proven_oil_found+(Exploitation*dt))

Actual_gap = Max(Difference_oil_production-(Nonutilized_investment/Investment_for_producing_each_barrel),0)

AE_Oil = (Proven_oil_found-(Depletion*Average_end_life)+(Exploitation*Randomized_oil_wells_age))*dt/(Proven_oil_found+((Depletion-Exploitation)*dt))

Available_funds = if(Retained_earning/Required_investment)>0.3 THEN (Required_investment*0.3)+Debt_required ELSE 0

Contractor_ETS = Equity_to_be_Split*Contractor_ETS_percent

Contractor_Take = Taxable_Income-Tax_paid

Debt_required = 0.7*Required_investment

Difference_oil_production = Max(Suitable_production_volume-Oil_production,0)

DMO_fee = DMO_percent*Oil_price*DMO_volume

DMO_volume = Oil_production*DMO_percent*Contractor_ETS_percent

Equity_to_be_Split = Gross_income-First_Tranche_Petroleum-Recoverable_costs

First_Tranche_Petroleum = Gross_income*FTP_percentage

Forecasted_demand = IF Next_year_lifetime_portion<=Primary_recovery_factor THEN Depletion/(1-Primary_recovery_factor) * dt ELSE

IF Next_year_lifetime_portion<=0.4 THEN Depletion/(1-Effect_of_oil_wells_on_production) * dt ELSE

Depletion * dt

Forecasted_gap = (Forecasted_demand-Oil_production)

FTP_for_contractor = (First_Tranche_Petroleum*Contractor_FTP_percentage)-(First_Tranche_Petroleum*Contractor_FTP_percentage*FTP_Tax)

FTP_for_govt = First_Tranche_Petroleum*Govt_FTP_percentage

Govt_ETS = Govt_ETS_percent*Equity_to_be_Split

Govt_Take = FTP_for_govt+Govt_ETS+Net_DMO+Tax_paid

Gross_income = Production_rate*Oil_price*dt

Investment_for_producing_each_barrel = Onshore_investment_for_each_barrel+Offshore_investment_for_each_barrel

Net_DMO = (DMO_volume*Oil_price)-DMO_fee

Next_year_lifetime_portion = (Average_age-1)/Average_end_life

Oil_production = IF Oil_wells_lifetime_portion<=Primary_recovery_factor THEN (Proven_oil_found/Average_age)*(1-Primary_recovery_factor)*dt ELSE

IF Oil_wells_lifetime_portion<=0.4 THEN (Proven_oil_found/Average_age)*(1-Effect_of_oil_wells_on_production)*dt ELSE (Proven_oil_found/Average_age)*dt

Oil_wells_lifetime_portion = ABS(Average_age/Average_end_life)

Produced_capacity = (Utilized_investment/Investment_for_producing_each_barrel)*Operation_effectiveness *dt

Production_gap = Actual_gap-Forecasted_gap

Randomized_oil_field_capacity = ABS(NORMAL(Rand_oil_average,Rand_oil_std_dev,100))

Randomized_oil_wells_age = ABS(NORMAL(Rand_age_average,Rand_age_std_dev,100))

Recoverable_costs = Oil_stock*Oil_costs

Required_investment = Production_gap*Investment_for_producing_each_barrel

Suitable_production_volume = Oil_suitable_production_volume_domestic+Oil_suitable_production_volume_overseas

Taxable_Income = FTP_for_contractor+Contractor_ETS-Net_DMO

Tax_paid = Taxable_Income*Tax_%

Amount_of_household = GRAPH(TIME)

(0.00, 5.5e+007), (1.00, 5.6e+007), (2.00, 5.6e+007), (3.00, 5.7e+007), (4.00, 6e+007), (5.00, 6.1e+007), (6.00, 6.3e+007), (7.00, 6.3e+007), (8.00, 6.4e+007), (9.00, 6.5e+007), (10.0, 6.6e+007), (11.0, 6.6e+007), (12.0, 6.6e+007), (13.0, 6.6e+007), (14.0, 6.6e+007), (15.0, 6.6e+007), (16.0, 6.6e+007), (17.0, 6.6e+007), (18.0, 6.6e+007), (19.0, 6.6e+007), (20.0, 6.6e+007)

Amount_of_industry = GRAPH(TIME)

(0.00, 5000), (1.05, 5100), (2.11, 5200), (3.16, 5300), (4.21, 5400), (5.26, 5500), (6.32, 5600), (7.37, 5700), (8.42, 5800), (9.47, 5900), (10.5, 6000), (11.6, 6100), (12.6, 6200), (13.7, 6300), (14.7, 6400), (15.8, 6500), (16.8, 6600), (17.9, 6700), (18.9, 6800), (20.0, 7000)

Amount_of_transportation = GRAPH(TIME)

(0.00, 3.8e+007), (1.00, 4.3e+007), (2.00, 5.5e+007), (3.00, 6.2e+007), (4.00, 6.7e+007), (5.00, 7.7e+007), (6.00, 8.6e+007), (7.00, 9.4e+007), (8.00, 1e+008), (9.00, 1.1e+008), (10.0, 1.3e+008), (11.0, 1.5e+008), (12.0, 1.7e+008), (13.0, 1.9e+008), (14.0, 2.1e+008), (15.0, 2.4e+008), (16.0, 2.7e+008), (17.0, 3.1e+008), (18.0, 3.5e+008), (19.0, 3.9e+008), (20.0, 4.5e+008)

Oil_consumption_per_household = GRAPH(TIME)

(0.00, 1.05), (1.00, 0.909), (2.00, 0.89), (3.00, 0.702), (4.00, 0.403), (5.00, 0.236), (6.00, 0.161), (7.00, 0.111), (8.00, 0.1), (9.00, 0.076), (10.0, 0.06), (11.0, 0.056), (12.0, 0.053), (13.0, 0.05), (14.0, 0.047), (15.0, 0.044), (16.0, 0.042), (17.0, 0.039), (18.0, 0.037), (19.0, 0.035), (20.0, 0.033)

Oil_consumption_per_industry = GRAPH(TIME)

(0.00, 3099), (1.00, 2795), (2.00, 1872), (3.00, 1973), (4.00, 2122), (5.00, 2467), (6.00, 1966), (7.00, 1944), (8.00, 1661), (9.00, 1345), (10.0, 1091), (11.0, 1581), (12.0, 2290), (13.0, 3317), (14.0, 4804), (15.0, 6958), (16.0, 10078), (17.0, 14598), (18.0, 21145), (19.0, 30627), (20.0, 44361)

Oil_consumption_per_transportation = GRAPH(TIME)

(0.00, 4.74), (1.00, 3.89), (2.00, 3.16), (3.00, 3.09), (4.00, 3.09), (5.00, 2.95), (6.00, 2.69), (7.00, 2.63), (8.00, 2.42), (9.00, 2.15), (10.0, 1.85), (11.0, 2.27), (12.0, 2.79), (13.0, 3.42), (14.0, 4.20), (15.0, 5.16), (16.0, 6.33), (17.0, 7.77), (18.0, 9.54), (19.0, 11.7), (20.0, 14.4)

Oil_costs = GRAPH(TIME)

(0.00, 30.0), (1.00, 31.0), (2.00, 32.0), (3.00, 33.0), (4.00, 35.0), (5.00, 36.0), (6.00, 37.0), (7.00, 38.0), (8.00, 40.0), (9.00, 41.0), (10.0, 43.0), (11.0, 44.0), (12.0, 46.0), (13.0, 48.0), (14.0, 49.0), (15.0, 51.0), (16.0, 53.0), (17.0, 55.0), (18.0, 57.0), (19.0, 59.0), (20.0, 61.0)

Oil_price = GRAPH(TIME)

(0.00, 56.6), (1.67, 66.0), (3.33, 72.2), (5.00, 100), (6.67, 61.9), (8.33, 79.5), (10.0, 95.0), (11.7, 94.1), (13.3, 98.0), (15.0, 93.3), (16.7, 48.7), (18.3, 44.1), (20.0, 51.5)

Oil_suitable_production_volume_domestic = GRAPH(TIME)

(0.00, 7e+007), (1.00, 7.1e+007), (2.00, 7.2e+007), (3.00, 7.4e+007), (4.00, 9.9e+007), (5.00, 1e+008), (6.00, 1e+008), (7.00, 1e+008), (8.00, 1e+008), (9.00, 1e+008), (10.0, 1e+008), (11.0, 2.1e+008), (12.0, 2.1e+008), (13.0, 2.1e+008), (14.0, 2.1e+008), (15.0, 2.1e+008), (16.0, 3.5e+008), (17.0, 3.5e+008), (18.0, 3.5e+008), (19.0, 3.5e+008), (20.0, 3.7e+008)

Oil_suitable_production_volume_overseas = GRAPH(TIME)

(0.00, 7e+007), (1.00, 7.1e+007), (2.00, 7.2e+007), (3.00, 7.4e+007), (4.00, 9.9e+007), (5.00, 1e+008), (6.00, 1e+008), (7.00, 1e+008), (8.00, 1e+008), (9.00, 1e+008), (10.0, 1e+008), (11.0, 2.1e+008), (12.0, 2.1e+008), (13.0, 2.1e+008), (14.0, 2.1e+008), (15.0, 2.1e+008), (16.0, 3.5e+008), (17.0, 3.5e+008), (18.0, 3.5e+008), (19.0, 3.5e+008), (20.0, 3.7e+008)

List of Constants Used in Before Concession Model

Construction_time = 2

Contractor_ETS_percent = 0.25

Contractor_FTP_percentage = 0.267857

Discount_rate = 0.1

DMO_percent = 0.25

Effect_of_oil_wells_on_production = 0.12

FTP_percentage = 0.2

FTP_Tax = 0.44

Govt_ETS_percent = 0.75

Govt_FTP_percentage = 0.732143

Offshore_investment_for_each_barrel = 266

Onshore_investment_for_each_barrel = 266

Operation_effectiveness = 0.3

Primary_recovery_factor = 0.26

Rand_age_average = 15

Rand_age_std_dev = 3

Rand_oil_average = 105000000

Rand_oil_std_dev = 89000000

Tax_% = 0.44

Appendix 2

List of Formulas Used in After Concession Model

Average_age(t) = Average_age(t - dt) + (- AAR) * dt

INIT Average_age = 10

OUTFLOWS:

AAR = Average_age/AA_Oil

Average_end_life(t) = Average_end_life(t - dt) + (- AER) * dt

INIT Average_end_life = 15

OUTFLOWS:

AER = Average_end_life/AE_Oil

Household_consumption(t) = Household_consumption(t - dt) + (change_in_household's_consumption - Household's_consumption_rate) * dt

INIT Household_consumption = change_in_household's_consumption*dt

INFLOWS:

change_in_household's_consumption = Amount_of_household*Oil_consumption_per_household*1/dt

OUTFLOWS:

Household's_consumption_rate = Household_consumption *1/dt

Industry_consumption(t) = Industry_consumption(t - dt) + (change_in__industry's_consumption - Industrial_consumption_rate) * dt

INIT Industry_consumption = change_in__industry's_consumption*dt

INFLOWS:

change_in__industry's_consumption = Amount_of_industry*Oil_consumption_per_industry*1/dt

OUTFLOWS:

Industrial_consumption_rate = Industry_consumption *1/dt

Net_Present_Value(t) = Net_Present_Value(t - dt) + (Change_in_NPV) * dt

INIT Net_Present_Value = 0

INFLOWS:

Change_in_NPV = NPV(Retained_earning_rate-Investment,Discount_rate)

Nonutilized_investment(t) = Nonutilized_investment(t - dt) + (Investment_rate - Utilized_investment) * dt

INIT Nonutilized_investment = 0

INFLOWS:

Investment_rate = MIN(Available_funds,Required_investment)*1/dt

OUTFLOWS:

Utilized_investment = Nonutilized_investment/Construction_time

Oil_stock(t) = Oil_stock(t - dt) + (Import_rate + Production_rate - Export_rate - Consumption_rate) * dt

INIT Oil_stock = (Production_rate)*dt

INFLOWS:

Import_rate = IF Oil_stock < Total_domestic_consumption THEN Total_domestic_consumption-Oil_stock ELSE 0

Production_rate = Oil_production*1/dt

OUTFLOWS:

Export_rate = IF Oil_stock>Total_domestic_consumption THEN Oil_stock-Total_domestic_consumption ELSE 0

Consumption_rate = Total_domestic_consumption*1/dt

Potential_oil_found(t) = Potential_oil_found(t - dt) + (Exploration - Exploitation) * dt

INIT Potential_oil_found = 1500000000

INFLOWS:

Exploration = Randomized_oil_field_capacity*1/DT

OUTFLOWS:

Exploitation = Produced_capacity*Randomized_oil_wells_age*1/dt^2

Proven_oil_found(t) = Proven_oil_found(t - dt) + (Exploitation + Additional_oil_rate - Depletion) * dt

INIT Proven_oil_found = 3000000000

INFLOWS:

Exploitation = Produced_capacity*Randomized_oil_wells_age*1/dt^2

Additional_oil_rate = PULSE(Additional_oil_field*1/dt,11,1)

OUTFLOWS:

Depletion = Oil_production*1/dt

Retained_earning(t) = Retained_earning(t - dt) + (Retained_earning_rate - Investment) * dt

INIT Retained_earning = 0

INFLOWS:

Retained_earning_rate = Govt_Take*1/dt

OUTFLOWS:

Investment = Investment_rate

Total_domestic_consumption(t) = Total_domestic_consumption(t - dt) + (change_in_consumption - Domestic_consumption_rate) * dt

INIT Total_domestic_consumption = (Industry_consumption+Household_consumption+Transportation_consumption)

INFLOWS:

change_in_consumption = (Household_consumption+Industry_consumption+Transportation_consumption)* 1/dt

OUTFLOWS:

Domestic_consumption_rate = Total_domestic_consumption *1/dt

Transportation_consumption(t) = Transportation_consumption(t - dt) + (change_in_transportation's_consumption - Transportation's_consumption_rate) * dt

INIT Transportation_consumption = change_in_transportation's_consumption*dt

INFLOWS:

change_in_transportation's_consumption = Amount_of_transportation*Oil_consumption_per_transportation*1/dt

OUTFLOWS:

Transportation's_consumption_rate = Transportation_consumption *1/dt

AA_Oil = ((Proven_oil_found*Average_end_life/dt)+(Exploitation*Average_end_life)-(Depletion*Average_age))*dt/(Proven_oil_found+(Exploitation*dt))

Actual_gap = Max(Difference_oil_production-(Nonutilized_investment/Investment_for_producing_each_barrel),0)

AE_Oil = (Proven_oil_found-(Depletion*Average_end_life)+(Exploitation*Randomized_oil_wells_age))*dt/(Proven_oil_found+((Depletion-Exploitation)*dt))

Available_funds = if(Retained_earning/Required_investment)>0.3 THEN (Required_investment*0.3)+Debt_required ELSE 0

Contractor_ETS = Equity_to_be_Split*Contractor_ETS_percent

Contractor_Take = Taxable_Income-Tax_paid

Debt_required = 0.7*Required_investment

Difference_oil_production = Max(Suitable_production_volume-Oil_production,0)

DMO_fee = DMO_percent*Oil_price*DMO_volume

DMO_volume = Oil_production*DMO_percent*Contractor_ETS_percent

Equity_to_be_Split = Gross_income-First_Tranche_Petroleum-Recoverable_costs

First_Tranche_Petroleum = Gross_income*FTP_percentage

Forecasted_demand = IF Next_year_lifetime_portion<=Primary_recovery_factor THEN Depletion/(1-Primary_recovery_factor) * dt ELSE

IF Next_year_lifetime_portion<=0.4 THEN Depletion/(1-Effect_of_oil_wells_on_production) * dt ELSE

Depletion * dt

Forecasted_gap = (Forecasted_demand-Oil_production)

FTP_for_contractor = (First_Tranche_Petroleum*Contractor_FTP_percentage)-(First_Tranche_Petroleum*Contractor_FTP_percentage*FTP_Tax)

FTP_for_govt = First_Tranche_Petroleum*Govt_FTP_percentage

Govt_ETS = Govt_ETS_percent*Equity_to_be_Split

Govt_Take = FTP_for_govt+Govt_ETS+Net_DMO+Tax_paid+Contractor_Take

Gross_income = Production_rate*Oil_price*dt

Investment_for_producing_each_barrel = Onshore_investment_for_each_barrel+Offshore_investment_for_each_barrel

Net_DMO = (DMO_volume*Oil_price)-DMO_fee

Next_year_lifetime_portion = (Average_age-1)/Average_end_life

Oil_production = IF Oil_wells_lifetime_portion<=Primary_recovery_factor THEN (Proven_oil_found/Average_age)*(1-Primary_recovery_factor)*dt ELSE

IF Oil_wells_lifetime_portion<=0.4 THEN (Proven_oil_found/Average_age)*(1-Effect_of_oil_wells_on_production)*dt ELSE
(Proven_oil_found/Average_age)*dt
Oil_wells_lifetime_portion = ABS(Average_age/Average_end_life)
Produced_capacity = (Utilized_investment/Investment_for_producing_each_barrel)*Operation_effectiveness *dt
Production_gap = Actual_gap-Forecasted_gap
Randomized_oil_field_capacity = ABS(NORMAL(Rand_oil_average,Rand_oil_std_dev,100))
Randomized_oil_wells_age = ABS(NORMAL(Rand_age_average,Rand_age_std_dev,100))
Recoverable_costs = Oil_stock*Oil_costs
Required_investment = Production_gap*Investment_for_producing_each_barrel
Suitable_production_volume = Oil_suitable_production_volume_domestic+Oil_suitable_production_volume_overseas
Taxable_Income = FTP_for_contractor+Contractor_ETS-Net_DMO
Tax_paid = Taxable_Income*Tax_%
Amount_of_household = GRAPH(TIME)
(0.00, 5.5e+007), (1.00, 5.6e+007), (2.00, 5.6e+007), (3.00, 5.7e+007), (4.00, 6e+007), (5.00, 6.1e+007), (6.00, 6.3e+007), (7.00, 6.3e+007), (8.00, 6.4e+007), (9.00, 6.5e+007), (10.0, 6.6e+007), (11.0, 6.6e+007), (12.0, 6.6e+007), (13.0, 6.6e+007), (14.0, 6.6e+007), (15.0, 6.6e+007), (16.0, 6.6e+007), (17.0, 6.6e+007), (18.0, 6.6e+007), (19.0, 6.6e+007), (20.0, 6.6e+007)
Amount_of_industry = GRAPH(TIME)
(0.00, 5000), (1.05, 5100), (2.11, 5200), (3.16, 5300), (4.21, 5400), (5.26, 5500), (6.32, 5600), (7.37, 5700), (8.42, 5800), (9.47, 5900), (10.5, 6000), (11.6, 6100), (12.6, 6200), (13.7, 6300), (14.7, 6400), (15.8, 6500), (16.8, 6600), (17.9, 6700), (18.9, 6800), (20.0, 7000)
Amount_of_transportation = GRAPH(TIME)

(0.00, 3.8e+007), (1.00, 4.3e+007), (2.00, 5.5e+007), (3.00, 6.2e+007), (4.00, 6.7e+007), (5.00, 7.7e+007), (6.00, 8.6e+007), (7.00, 9.4e+007), (8.00, 1e+008), (9.00, 1.1e+008), (10.0, 1.3e+008), (11.0, 1.5e+008), (12.0, 1.7e+008), (13.0, 1.9e+008), (14.0, 2.1e+008), (15.0, 2.4e+008), (16.0, 2.7e+008), (17.0, 3.1e+008), (18.0, 3.5e+008), (19.0, 3.9e+008), (20.0, 4.5e+008)

Oil_consumption_per_household = GRAPH(TIME)

(0.00, 1.05), (1.00, 0.909), (2.00, 0.89), (3.00, 0.702), (4.00, 0.403), (5.00, 0.236), (6.00, 0.161), (7.00, 0.111), (8.00, 0.1), (9.00, 0.076), (10.0, 0.06), (11.0, 0.056), (12.0, 0.053), (13.0, 0.05), (14.0, 0.047), (15.0, 0.044), (16.0, 0.042), (17.0, 0.039), (18.0, 0.037), (19.0, 0.035), (20.0, 0.033)

Oil_consumption_per_industry = GRAPH(TIME)

(0.00, 3099), (1.00, 2795), (2.00, 1872), (3.00, 1973), (4.00, 2122), (5.00, 2467), (6.00, 1966), (7.00, 1944), (8.00, 1661), (9.00, 1345), (10.0, 1091), (11.0, 1581), (12.0, 2290), (13.0, 3317), (14.0, 4804), (15.0, 6958), (16.0, 10078), (17.0, 14598), (18.0, 21145), (19.0, 30627), (20.0, 44361)

Oil_consumption_per_transportation = GRAPH(TIME)

(0.00, 4.74), (1.00, 3.89), (2.00, 3.16), (3.00, 3.09), (4.00, 3.09), (5.00, 2.95), (6.00, 2.69), (7.00, 2.63), (8.00, 2.42), (9.00, 2.15), (10.0, 1.85), (11.0, 2.27), (12.0, 2.79), (13.0, 3.42), (14.0, 4.20), (15.0, 5.16), (16.0, 6.33), (17.0, 7.77), (18.0, 9.54), (19.0, 11.7), (20.0, 14.4)

Oil_costs = GRAPH(TIME)

(0.00, 30.0), (1.00, 31.0), (2.00, 32.0), (3.00, 33.0), (4.00, 35.0), (5.00, 36.0), (6.00, 37.0), (7.00, 38.0), (8.00, 40.0), (9.00, 41.0), (10.0, 43.0), (11.0, 44.0), (12.0, 46.0), (13.0, 48.0), (14.0, 49.0), (15.0, 51.0), (16.0, 53.0), (17.0, 55.0), (18.0, 57.0), (19.0, 59.0), (20.0, 61.0)

Oil_price = GRAPH(TIME)

(0.00, 56.6), (1.67, 66.0), (3.33, 72.2), (5.00, 100), (6.67, 61.9), (8.33, 79.5), (10.0, 95.0), (11.7, 94.1), (13.3, 98.0), (15.0, 93.3), (16.7, 48.7), (18.3, 44.1), (20.0, 51.5)

Oil_suitable_production_volume_domestic = GRAPH(TIME)

(0.00, 7e+007), (1.00, 7.1e+007), (2.00, 7.2e+007), (3.00, 7.4e+007), (4.00, 9.9e+007), (5.00, 1e+008), (6.00, 1e+008), (7.00, 1e+008), (8.00, 1e+008), (9.00, 1e+008), (10.0, 1e+008), (11.0, 2.1e+008), (12.0, 2.1e+008), (13.0, 2.1e+008), (14.0, 2.1e+008), (15.0, 2.1e+008), (16.0, 3.5e+008), (17.0, 3.5e+008), (18.0, 3.5e+008), (19.0, 3.5e+008), (20.0, 3.7e+008)

Oil_suitable_production_volume_overseas = GRAPH(TIME)

(0.00, 7e+007), (1.00, 7.1e+007), (2.00, 7.2e+007), (3.00, 7.4e+007), (4.00, 9.9e+007), (5.00, 1e+008), (6.00, 1e+008), (7.00, 1e+008), (8.00, 1e+008), (9.00, 1e+008), (10.0, 1e+008), (11.0, 2.1e+008), (12.0, 2.1e+008), (13.0, 2.1e+008), (14.0, 2.1e+008), (15.0, 2.1e+008), (16.0, 3.5e+008), (17.0, 3.5e+008), (18.0, 3.5e+008), (19.0, 3.5e+008), (20.0, 3.7e+008)

List of Constants used in After Concession Scenario

Additional_oil_field = 3000000000

Construction_time = 2

Contractor_ETS_percent = 0.25

Contractor_FTP_percentage = 0.267857

Discount_rate = 0.1

DMO_percent = 0.25

Effect_of_oil_wells_on_production = 0.12

FTP_percentage = 0.2

FTP_Tax = 0.44

Govt_ETS_percent = 0.75

Govt_FTP_percentage = 0.732143

Offshore_investment_for_each_barrel = 266

Onshore_investment_for_each_barrel = 266

Operation_effectiveness = 0.3

Primary_recovery_factor = 0.26

Rand_age_average = 15

Rand_age_std_dev = 3

Rand_oil_average = 105000000

Rand_oil_std_dev = 89000000

Tax_% = 0.44

BIOGRAPHY

Fariza Aulia Putri was born in Sidoarjo, October 22nd, 1996. She is the first child in her family. She completed her study in SDN Sidokare IV Sidoarjo in 2008, SMPN 1 Sidoarjo in 2011, and SMAN 1 Sidoarjo in 2013. She also attended bachelor study in Institut Teknologi Sepuluh Nopember (ITS) Surabaya majoring Industrial Engineering.

During her life journey, she was involved in several activities and organizations. She joined OSIS SMPN 1 Sidoarjo in 2008 – 2009 and MPK SMAN 1 Sidoarjo in 2011 – 2012. When she entered ITS, she was more involved in many annual events as the committee (IE Games 2014 & 2015, Inchall 2015, YES Summit 2014 & 2015, and Gerigi ITS 2014) and became Trainer LKMM FTI ITS in 2014 – 2016 who conducted LKMM pra – TD, LKMM TD, and PP LKMM training for 2 years. She also became the Head of Strategic Studies Forkastra HMTI ITS in 2015 – 2016 and Assistant of PSMI Laboratory IE ITS in 2015 – 2017. Without forgetting Tri Dharma Perguruan Tinggi, she also involved in social activities such as HMTI Mengajar in 2014 – 2015 and Voluntary Teaching in China in August, 2015. She also has ever become the participant of Future Leader Summit 2014, finalist of PIMNAS 28 in Kendari, finalist of iSMEC's UB 2015, Pelatihan Pemimpin Bangsa 10 BEM KM UGM, and finalist of 14th ECONOMIX FEB UI 2016.

She mastered Indonesian, English, and a little French language. She has great interest in financial and economic matters. She also has the ability in several software besides main Ms. Office, such as Ms. Project, Ms. Access, STELLA for System Dynamic, Minitab, Expert Choice, and Weibull. She loves traveling so much, reading, playing guitar and piano, and discussion about national and international issues. She loves to expand networking and making new friends. She can be traced by email fariza.putri@hotmail.co.uk and Instagram @frzauliaicha.