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Analysis of the Development of Downstream Copper Industry in Indonesia to Obtain Maximum Added Value Using Dynamic Systems

Dedy Setyo Oetomo*, Eki Kania Dewi, Rizky Fajar Ramdhani

Sekolah Tinggi Teknologi Wastukancana Purwakarta

Correspondence Email: dedy@wastukancana.ac.id*

Abstract

This research aims to design a dynamic system model for the downstream copper processing industry. The secondary data obtained is data provided by the BKPM Strategic Investment Downstreaming Expert Team. Vensim software is used to simulate downstream development in the form of CLD and SFD from 2024 to 2045. The results of the value-added simulation resulted in an increase in the added value of copper cathode by 2.15 times, the added value of cathode slab by 1.62 times, the added value of copper billet by 1.65 times, the added value of copper bar &rods by 1.08 times, the added value of copper tube by 1.02 times, the added value of copper strip by 1.39 times, and the added value of copper wire by 1.58 times. After a sensitivity analysis of the selling price at CAGR and an increase in energy costs by 20%, there was a change in the average value-added margin, so that the increase in added value changed which resulted in an added value of copper cathode of 1.9 times, added value of cathode slab of 1.47 times, added value of copper billet of 1.49 times, added value of copper bar &rods of 1.26 times, added value of copper tube of 0.93 times, added value of copper strip of 0.98 times, and added value of copper wire of 1.44 times.

Keywords: copper, downstream industry, indonesia, dynamic systems, added value.

INTRODUCTION

Indonesia has a great opportunity to achieve the ideals of the Indonesia Emas 2045, to increase per capita income and achieve the Indonesia Emas 2045 downstream copper will provide great benefits for the country. Downstream helps reduce dependence on the mining sector and broaden the economic base. Indonesia occupies the 7th position in the world's production of copper raw materials with a total production of 840 thousand tons with total reserves of 3% or around 24 million tons of the world's total copper reserves of 1 billion tons (U.S. Geological Survey, 2024).

According to Ria Siombo, (2023) in 2023, the Indonesian government imposed an export ban on three mineral products including copper. However, Indonesia also still imports a considerable number of imports, especially for copper concentrate and copper wire. The

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Ministry of Industry is implementing a downstream policy of copper concentrate, copper cathode, copper billet, copper bars & rods, copper tube, copper strip, copper slab, and copper wire to increase the added value of natural resources in the country and reduce the amount of copper imports. In this effort to downstream copper, there are plans to build three refining facilities by PT Freeport Indonesia, PT Amman Mineral, and PT Kalimantan Surya Kencana (ESDM, 2023).

Based on the above conditions, it is necessary to design in the form of dynamic system modeling for the downstream copper processing industry. According to Rahmahwati et al. (2022) this study aimed to estimate the value added of the domestic copper metal industry chain. In order to achieve this aim, a system dynamics (SD) model of the copper industry chain was used to represent the supply conditions for the commodity of copper in Indonesia.

METHOD

The secondary data obtained is data provided by the BKPM Strategic Investment Downstreaming Expert Team. Vensim software is used to simulate downstream development in the form of CLD and SFD. This vensim model is a depiction of the structure and behavior of the system from 2024 to 2045. To measure the accuracy of the simulation results, validation is carried out using the Mean Absolute percentage Error (MAPE). According to Rahmahwati et al. (2022) When the model's performance is satisfactory (MAPE less than 10%), then the model can be used to simulate what may happen in the future (2024 to 2045). Making a vensim simulation has several stages namely Data Collection: Collect the data needed to support the simulation to be made. The data needed for this simulation is shown in Table 1.

Table 1. Required Data

Data Source	Required Data
Copper Industry Across Indonesia	Opex Cost Input Capacity Selling Price

Conceptual Modelling: Conceptual modeling using cause and effect. Simulation Model Creation Modeling this dynamic system using Vensim PLE software. Model Verification: This model verification is to ensure that the model that has been created actually works as expected. There are two types of verification based on modelling, model verification and unit verification. Model Validation: Validation is carried out to ensure that the model used is in accordance with the wishes of the model. In validating the model, the mathematical formulation Mean Absolute percentage Error (MAPE) will be used with the following formula:

$$E_1 = \frac{\left|\bar{S} - \bar{\bar{A}}\right|}{\bar{\bar{A}}}$$

Description:
S = The output generated from the simulation
A = Actual data

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Draw conclusions based on the simulation results, determine recommendations or improvements that need to be made.

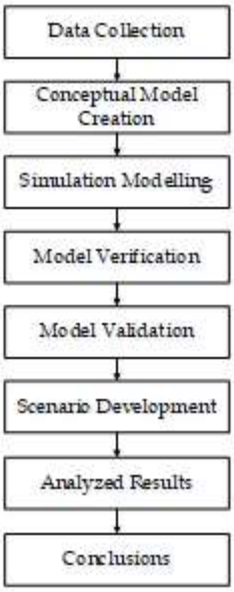

Figure 1. Simulation Creation

RESULT AND DISCUSSION

According to the Investment Coordinating Board (BKPM) in 2024, Indonesia has two operating copper refining industries:

Table 2. Operating Smelter Facilities

No	Company	Input Capacity (Ton)	Output Capacity (Ton)
1.	PT Smelting	1.000.000	300.000
2.	PT Batutua Tembaga Raya	1.400.000	25.000

Indonesia also has two new processing and refining facilities that will be completed in 2022:

Table 3. Smelter Facilities that have been Completed

No	Company	Input Capacity (Ton)	Output Capacity (Ton)
1.	PT Freeport Indonesia	2.000.000	550.000
2.	PT Amman Mineral Internasional	900.000	300.000

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The new smelter construction plan for copper processing and refining is as follows:

Table 4. Planned Smelter Facilities

No	Company	Input Capacity (Ton)	Output Capacity (Ton)
1.	PT Kalimantan Surya Kencana	-	25.000
2.	PT IMIP	1.000.000	-

In making efforts to strengthen the added value of copper minerals, it is necessary to know the selling price per ton, the percentage of opex costs, and the Compound Annual Growth Rate (CAGR) per each copper industry tier as follows:

Table 5. Selling Price, Percentage Opex Cost, and CAGR

No	Component	Selling Price USD/Ton	Percentage	CAGR
1	Concentrate	3689,77	30%	6%
2	Cu Cathode	9899	30%	5%
3	Cu Slab	8300	30%	5%
4	Cu Billet	8000	30%	5%
5	Cu Strip	7140	30%	5%
6	Cu Tube	16550	30%	5%
7	Cu Bar & Rods	7500	30%	5%
8	Cu Wire	10990	30%	5%

Causal Loop Diagram

To understand the conditions of model development in determining the maximum added value of the copper industry, a conceptual model is created to manage changes in the dynamic system. In the causal loop diagram, the positive feedback system produces a growth rate or is denoted by R (Rate), while the negative feedback system describes changes in stock variables over time or can be denoted by B (Balance) (Almalik, 2021).

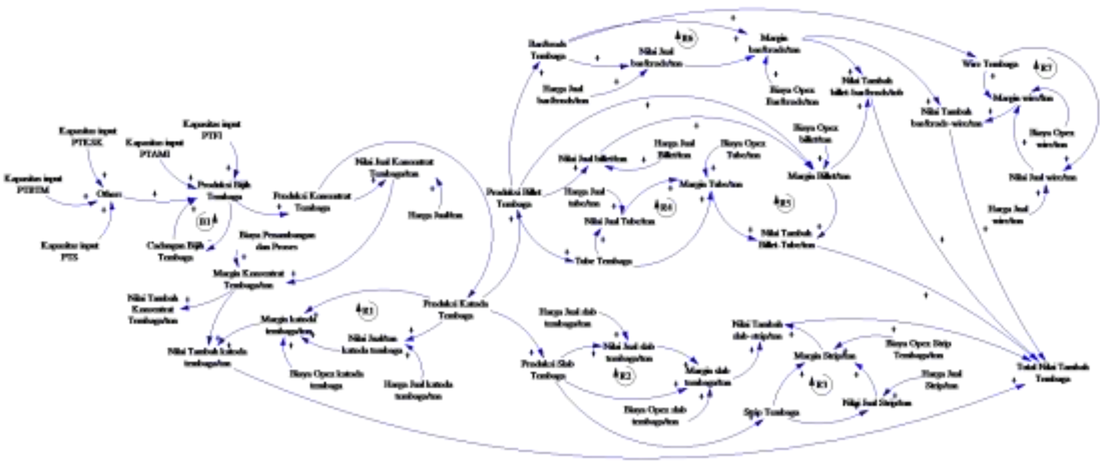

Figure 2. Causal Loop Diagram

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Simulation Modelling

The next step in the simulation of this research model is to make a stock and flow diagram. In this stock and flow diagram, there are additional variables in Opex costs, namely energy costs or mining and processing costs.

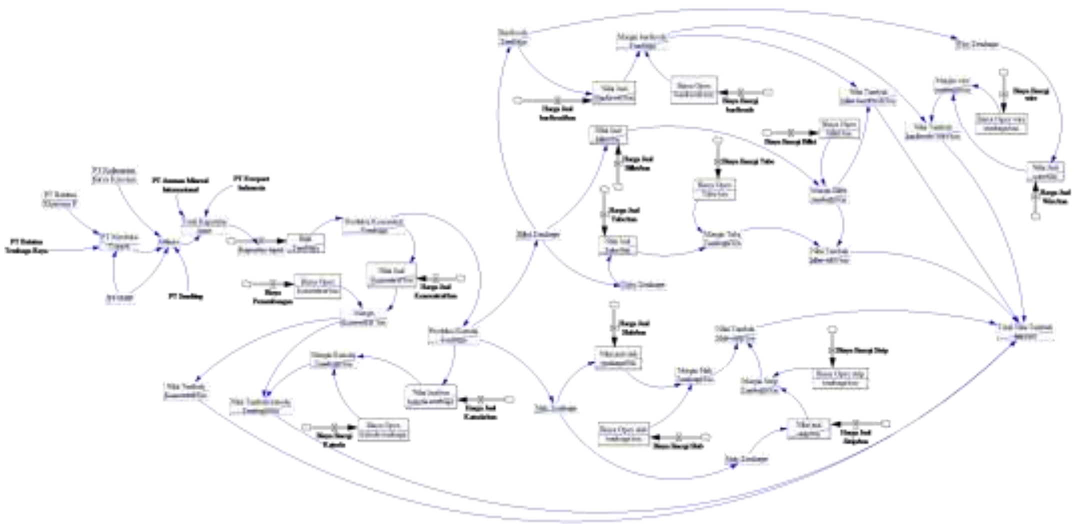

Figure 3. Stock and Flow Diagram

For the equation on input capacity at PT Batutua Tembaga Raya by 1,400,000 tons, PT Smelting by 1,000,000 tons, PT Amman Mineral International by 900,000 tons, PT Freeport Indonesia by 2,000,000 tons, and PT Batutua Kharisma Permai by 1,300,000 tons. In addition, the production conversion formulation for copper concentrate is 70%, copper cathode conversion is 80%, copper billet conversion is 95% and copper slab conversion is 90%, copper strip conversion is 100% of copper slab, bar & rod proportion is 70% and copper tube proportion is 30%, and copper wire conversion is 100% of copper bar & rod.

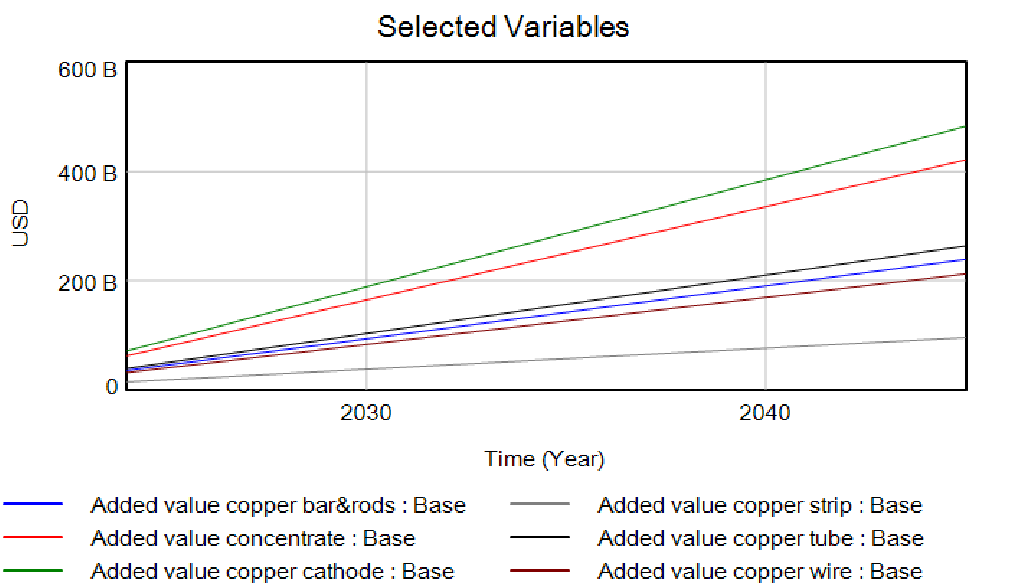

Figure 4. Value-Added Graph

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Table 6. Average Margin

No	Component	Average Margin
1	Concentrate	$ 232.972.000.000
2	Cu Cathode	$ 500.018.000.000
3	Cu Slab	$ 377.325.000.000
4	Cu Billet	$ 383.891.000.000
5	Cu Strip	$ 324.590.000.000
6	Cu Tube	$ 238.252.000.000
7	Cu Bar & Rods	$ 251.929.000.000
8	Cu Wire	$ 369.159.000.000

It can be calculated mathematically the increase in the added value of the downstream copper industry in each tier.

1. Cu Cathode
   = average margin Cu cathode /average margin Cu concentrate
   = 500.018.000.000 / 232.972.000.000
   = 2,15 times
2. Cu Slab
   = average margin Cu slab /average margin Cu concentrate
   = 377.325.000.000 / 232.972.000.000
   = 1,62 times
3. Cu Billet
   = average margin Cu billet /average margin Cu concentrate
   = 383.891.000.000 / 232.972.000.000
   = 1,65 times
4. Cu Bar & Rods
   = average margin Cu bar & rods /average margin Cu concentrate
   = 251.929.000.000 / 232.972.000.000
   = 1,08 times
5. Cu Tube
   = average margin Cu tube /average margin Cu concentrate
   = 238.252.000.000 / 232.972.000.000
   = 1,02 times
6. Cu Strip
   = average margin Cu strip /average margin Cu concentrate
   = 324.590.000.000 / 232.972.000.000
   = 1,39 times
7. Cu Wire
   = average margin Cu wire /average margin Cu concentrate
   = 369.159.000.000 / 232.972.000.000
   = 1,58 times

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Model Validation

This validation stage is to compare the output results of dynamic system simulations with actual data. It is said that the simulation results are valid, if the error value is less than 5%. The following is a mathematical way of calculating the error value:

Simulation results on copper concentrate margins = USD 61.988.100.000

Actual data on copper concentrate margins

- Selling point = production*selling price
  = (24.000.000-7.600.000)* 3689,77
  = 60.512.228.000
- Margin Cu concentrate = selling point – Opex cost
  = 60.512.228.000 – 4,48
  = 60.512.227.995,52
- Validation of simulation results using the following formula:

$$E_1 = \frac{|\bar{S} - \bar{\bar{A}}|}{\bar{\bar{A}}}$$

Description:
S = The output generated from the simulation
A = Actual data
E = 61.988.100.000 – 60.512.227.995,52 / 60.512.227.995,52
= 1.475.872.004,48 / 68.380.662.520,52
= 2 %

The resulting average error value is 2%. It can be concluded that the value-added simulation on the dynamic system performed above is valid.

Sensitivity Analysis

After the simulation is made and valid, the next step is to conduct a sensitivity analysis of the selling price and mining costs according to the CAGR (Compounded Annual Growth Rate) growth rate over a certain period of time. With an energy cost increase rate of 20% and a concentrate CAGR of 6%, while copper cathode to copper wire and copper strip CAGR value of 5%.

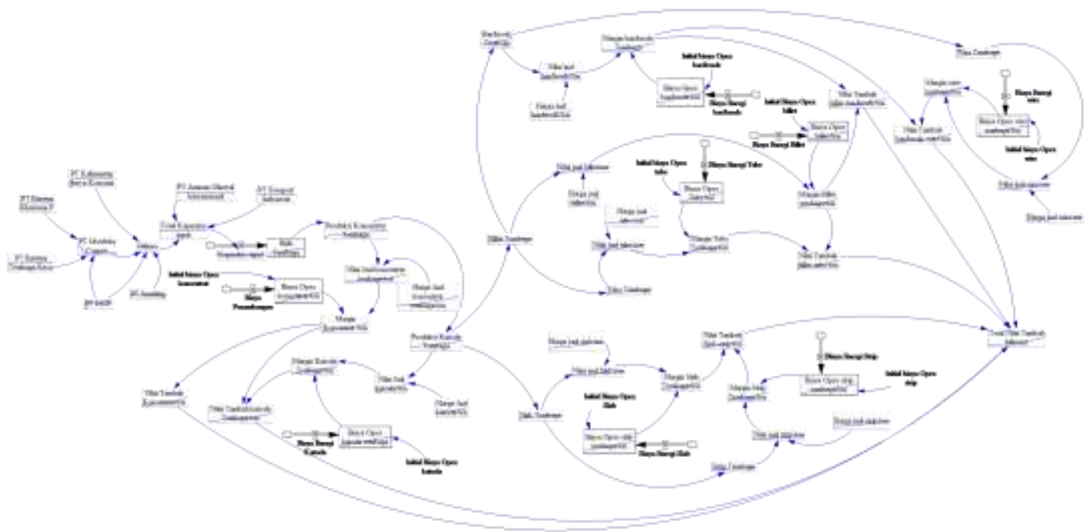

Figure 5. Stock and Flow Sensitivity Analysis

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Table 7. Average Margin Sensitivity Analysis

No	Component	Average Margin
1	Concentrate	$ 226.417.000.000,00
2	Cu Cathode	$ 441.991.000.000,00
3	Cu Slab	$ 333.525.000.000,00
4	Cu Billet	$ 339.345.000.000,00
5	Cu Strip	$ 286.921.000.000,00
6	Cu Tube	$ 210.607.000.000,00
7	Cu Bar & Rods	$ 222.685.000.000,00
8	Cu Wire	$ 326.317.000.000,00

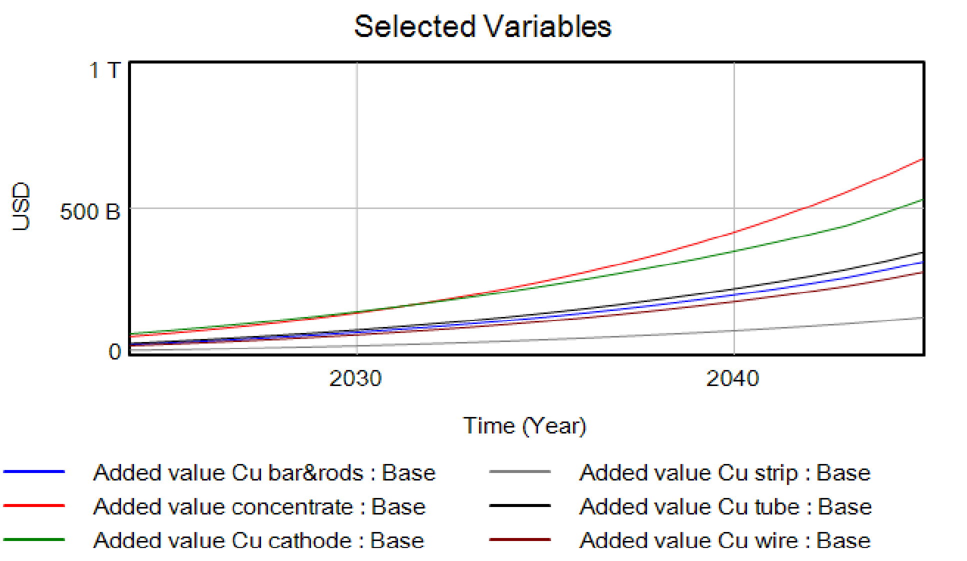

Figure 6. Sensitivity Analysis Value-Added Graph

It can be calculated mathematically the increase in the added value of the downstream copper industry in each tier.

1. Cu Cathode
   = average margin Cu cathode / average margin Cu concentrate
   = 441.991.000.000 / 226.417.000.000
   = 1,9 times
2. Cu Slab
   = average margin Cu slab / average margin Cu concentrate
   = 333.525.000.000 / 226.417.000.000
   = 1,47 times
3. Cu Billet
   = average margin Cu billet / average margin Cu concentrate
   = 339.345.000.000 / 226.417.000.000
   = 1,49 times

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4. Cu Strip
   = average margin Cu strip /average margin Cu concentrate
   = 286.921.000.000 / 226.417.000.000
   = 1,26 times
5. Cu Tube
   = average margin Cu tube /average margin Cu concentrate
   = 210.607.000.000 / 226.417.000.000
   = 0,93 times
6. Cu Bar & Rods
   = average margin Cu bar & rods /average margin Cu concentrate
   = 222.685.000.000 / 226.417.000.000
   = 0,98 times
7. Cu Wire
   = average margin Cu wire /average margin Cu concentrate
   = 326.317.000.000 / 226.417.000.000
   = 1,44 times

Sensitivity analysis conducted in this simulation model is used to determine the impact of changes in the selling value/ton of each copper tier and the Opex cost of each copper tier on the added value of downstream copper of each tier.

CONCLUSION

Based on the results of the simulation, conclusions can be obtained in this study. The value-added simulation resulted in an increase in the added value of copper cathode by 2.15 times, added value of cathode slab by 1.62 times, added value of copper billet by 1.65 times, added value of copper bar &rods by 1.08 times, added value of copper tube by 1.02 times, added value of copper strip by 1.39 times, and added value of copper wire by 1.58 times.

However, after conducting a sensitivity analysis of the selling price based on CAGR and an increase in energy costs by 20%, there is a change in the average value-added margin, so that the increase in added value has changed, resulting in a value-added copper cathode of 1.9 times, a value-added cathode slab of 1.47 times, a value-added copper billet of 1.49 times, a value-added copper bar &rods of 1.26 times, a value-added copper tube of 0.93 times, a value-added copper strip of 0.98 times, and a value-added copper wire of 1.44 times..

Therefore, the downstreaming of the copper commodity industry in Indonesia must continue to develop, especially in the focus of downstreaming to achieve the ideals of Indonesia Emas 2045. The downstreaming of the copper commodity industry can provide benefits to increase state revenue (Ika, 2017).

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