



Industrial Gas Production Capacity Planning Strategy using System Dynamics to Support the IKN Project

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Abstract

The increasing demand for industrial gas in East Kalimantan, driven by the construction of the new capital city (IKN) and rapid industrial growth, poses challenges for producers in meeting consumer needs effectively. PT XYZ, a key industrial gas provider, has struggled to balance its production capacity with market demand, leading to recurring backlog orders. This study aims to analyze the oxygen production capacity of PT XYZ using the System Dynamics method. A dynamic model was developed to capture the relationships between production variables, demand drivers, and external influences. The simulation of the current system revealed a consistent shortfall in meeting oxygen demand, with a projected backlog reaching 1,197,198 m³ by 2029. To address this, three policy scenarios were proposed: increasing the number of production machines, outsourcing production, and a combination of both. The simulation results indicated that the third scenario, which combines equipment expansion and outsourcing, provides the most sustainable solution. It eliminates backlog by the end of 2029 and generates a profit of IDR 20,289,156,114. These findings highlight the importance of strategic capacity planning and the effectiveness of integrated approaches in aligning production with future industrial gas demand, particularly in support of national infrastructure development.

Keywords: Industrial Gas Demand, Production Capacity, Scenario, Simulation, System Dynamics

1. Introduction

The relocation of Indonesia's government center to East Kalimantan through the development project of the Nusantara Capital City (IKN) has become a national strategic agenda driving significant growth in infrastructure, construction, and public services sectors. As the new administrative center, East Kalimantan faces a surge in demand for industrial resources, including industrial gases such as oxygen, nitrogen, and argon [1]. The need for industrial gases increases alongside the massive development of public facilities, hospitals, construction projects, and settlements spread across various locations within the IKN area.

PT XYZ, as one of the main producers and distributors of industrial gases in East Kalimantan, plays a crucial role in supporting these demands. However, the increase in demand, not matched by production capacity readiness, has caused the company to experience a growing backlog of oxygen orders each year. This serves as an early indicator of an imbalance between actual production capacity and the dynamic needs of consumers. Backlog in industrial product distribution reflects inefficiencies in the production system that directly impact customer satisfaction and service stability [2].

This situation calls for a comprehensive evaluation of PT XYZ's oxygen production system. If this imbalance is left unaddressed without proper planning, its effects will not only impact the economic sector but also hinder the development process of IKN. Industrial gases play a vital role in steel structure welding, construction material cutting, and emergency medical services, especially for referral hospitals such as RSUD Kanujoso Djatiwibowo in Balikpapan.

To tackle this complexity, a systemic approach is needed to model the relationships among production variables, demand, and distribution capacity. One suitable method is System Dynamics, which can illustrate the behavior of complex and nonlinear systems over the long term [3]. This method has been widely used for capacity planning and strategic decision-making in manufacturing and energy industries [4]. However, its application in the gas industry context remains rare, particularly in large-scale development projects like IKN.



This study is designed to fill that gap by building a dynamic system model representing the relationship between PT XYZ's oxygen production capacity and consumer demand in East Kalimantan. The model is used to evaluate three capacity enhancement scenarios: adding production machines, outsourcing, and a combination of both. The study aims to provide practical positive impacts for PT XYZ in sustainable capacity planning, as well as academic contributions in developing dynamic system models for the gas industry in Indonesia.

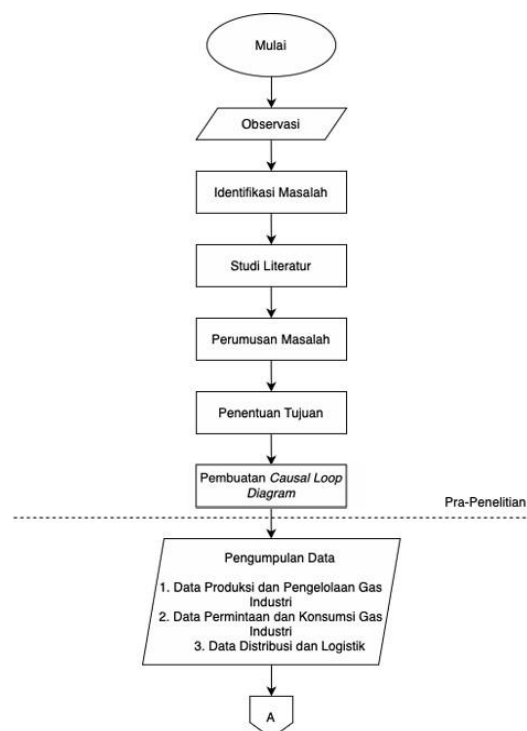
2. Literature Review

Production capacity is the maximum capability of a system or facility to produce products within a certain period. This capacity is divided into design capacity, effective capacity, and actual capacity, each reflecting different performance levels based on operating conditions [5]. A mismatch between production capacity and market demand can lead to operational inefficiencies, order backlogs, and lost revenue opportunities [6]. Demand represents consumers' desire to purchase a certain quantity of goods or services at a given price level within a specific time frame. However, demand exceeding available production capacity will cause imbalances in the distribution and production system [7]. In the context of the massive development of IKN, the need for industrial gases such as oxygen has increased significantly to support construction projects, healthcare services, and other supporting industries. Industrial gases are gases used in various industrial applications such as welding, manufacturing, chemical processes, and medical services. Industrial oxygen is one of the most demanded gases, both for production processes and healthcare services [3]. To address the complexity of production capacity planning, system dynamics is an effective approach. System dynamics is a feedback-loop based modeling method used to understand the behavior of complex systems over the long term [8]. This method utilizes components such as Causal Loop Diagrams (CLD) and Stock Flow Diagrams to structurally represent interactions among system variables [9].

Previous studies using system dynamics include Karima et al. in the cement industry, which showed that a 20% annual increase in demand could cause supply shortages if not matched by capacity expansion [4]. Donoriyanto et al. developed a production capacity model to reduce order backlog using a 24-month simulation approach [10]. Meanwhile, Rachma demonstrated cost efficiency in production through optimized planning with a system dynamics approach [2]. However, these studies have rarely addressed the gas industry sector, especially in the context of large-scale development such as the Nusantara Capital City. Therefore, this research aims to contribute both theoretically and practically by adopting system dynamics to design industrial oxygen production capacity in a more adaptive and precise manner under sustainable high-demand scenarios.

3. Methods

This study was conducted to analyze the gap between oxygen production capacity and demand at PT XYZ, East Kalimantan, particularly in supporting the development needs of the Nusantara Capital City (IKN). The System Dynamics method was used to model the dynamic relationships among production variables, demand, and other external factors influencing the system. The model was developed to identify the imbalance (gap) between actual production capacity and consumer needs, as well as to evaluate strategic policy scenarios that can be implemented to improve overall system performance. Furthermore, the simulation results were used to assess the most effective and sustainable improvement scenarios to reduce order backlogs and maximize company profits. The research process was systematically structured, starting from observation, data collection, building the system dynamics model (Causal Loop Diagram and Stock Flow Diagram), model verification and validation, to simulation of various policy scenarios. This process is illustrated in Figure 1, which shows the overall research flow diagram.



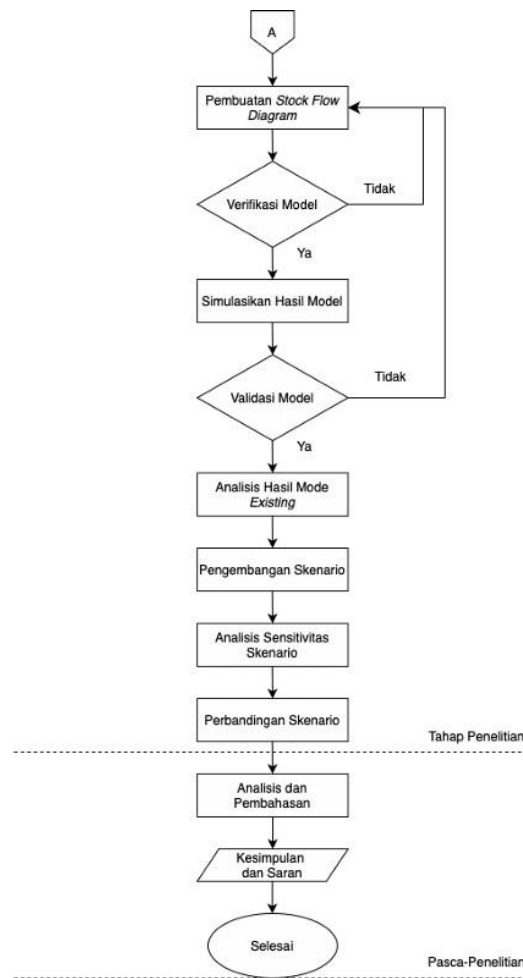


Fig. 1. Research Flow Chart

Based on Figure 1 above, the research flow diagram represents the sequence or process carried out in the study to achieve the predetermined objectives.

4. Result and Discussion

4.1 Simulation Results and Existing Conditions

The developed and verified system dynamics model was used to simulate the existing conditions at PT XYZ. Based on the simulation results, it was found that the available oxygen production capacity is insufficient to meet the entire demand from consumers in East Kalimantan. This has caused the oxygen order backlog to increase every year. Table 1 shows the amount of oxygen backlog from 2025 to 2029, which serves as a key indicator of the imbalance between production capacity and demand.

Table 1. Simulation Results of Oxygen Order Backlog for 2025-2029

Years	Demands (m^3)	Production (m^3)	Backlog Order (m^3)
2025	618.428	600.000	18.428
2026	726.899	600.000	126.899
2027	871.512	600.000	271.512
2028	1.055.060	600.000	455.060
2029	1.197.198	600.000	597.198

The results indicate that without any corrective actions, the order backlog will continue to increase each year. This highlights the urgency of re- planning oxygen production capacity to be more adaptive to the projected demand in the IKN development area.

4.2 The Simulation of Three Improvement Scenarios

To address the backlog issue, simulations were conducted on three production capacity enhancement policy scenarios:

Scenario 1: Increasing the Number of Production Machines.

Scenario 2: Utilizing Outsourcing Services to meet part of the demand.

Scenario 3: A Combination of Increasing the Number of Machines and Outsourcing Services.

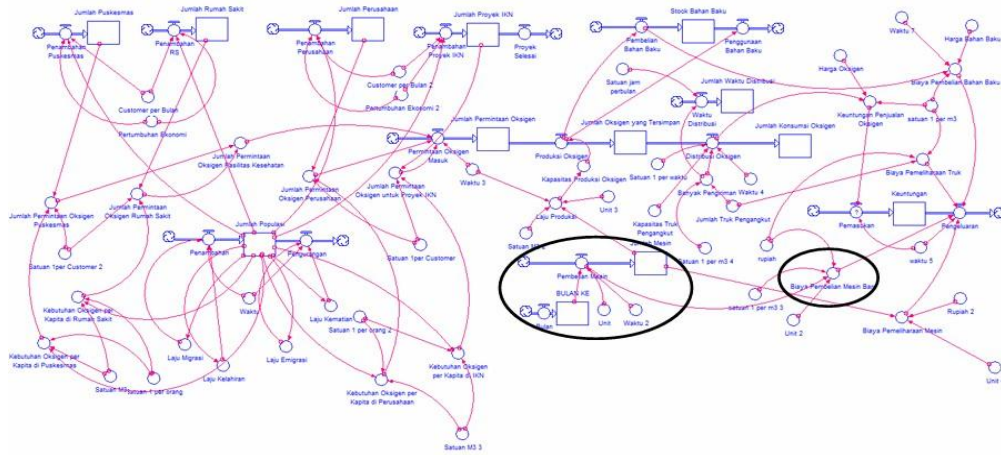


Fig. 2. Stock Flow Diagram Scenario 1

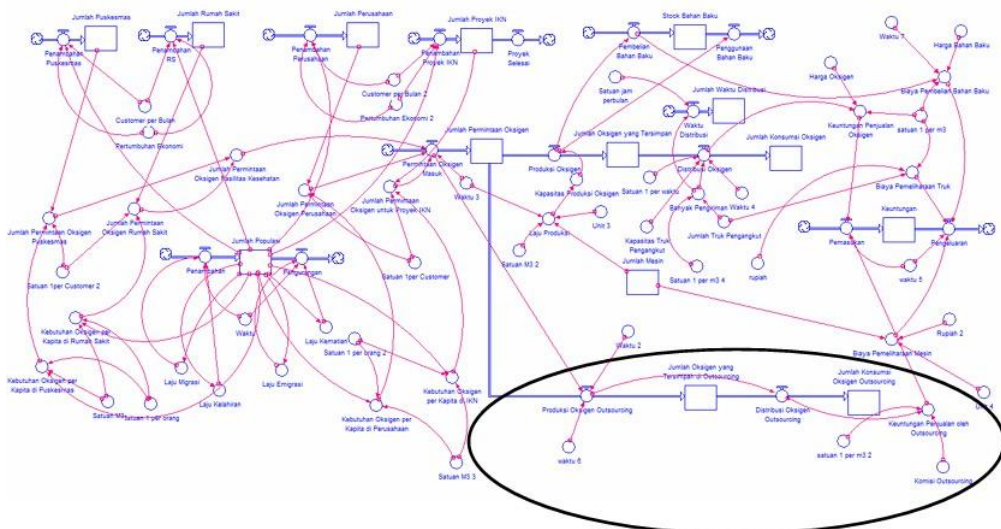


Fig. 3. Stock Flow Diagram Scenario 2

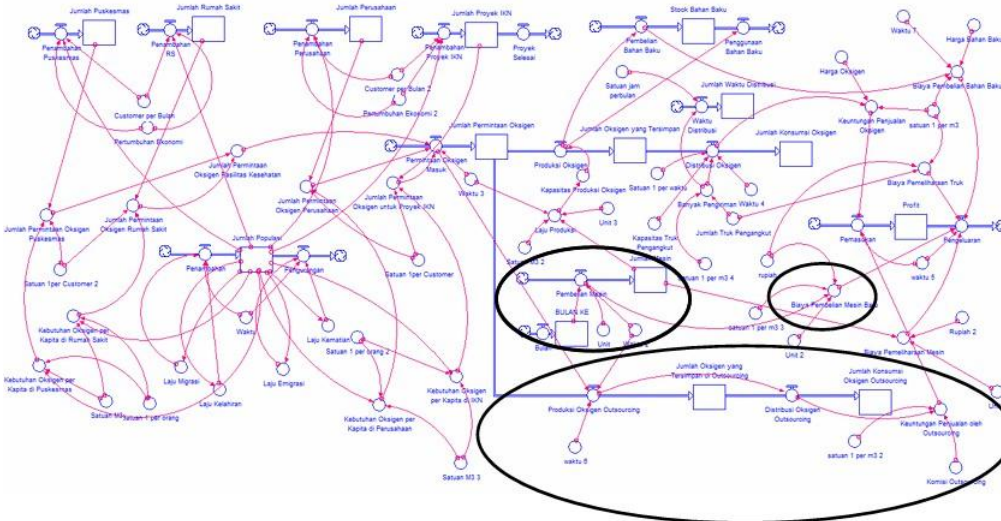


Fig. 4. Stock Flow Diagram Scenario 3

Based on the simulation results, it can be concluded that Scenario 1 successfully reduces the backlog gradually but still results in a small backlog by the end of 2029. Scenario 2 reduces the backlog at a lower cost; however, it carries a relatively high risk of dependency on third parties. Scenario 3 provides the most optimal outcome, achieving zero backlog by the end of 2029 and a total company profit of IDR 20,289,156,144.

Table 2. Summary of 2029 Simulation Results for Three Scenarios

Scenario	Backlog Order (m^3)	Profit (Rp)	Note
1	121.000	15.482.000.000	Increase in the number of machines
2	85.500	17.230.540.000	Outsourcing service usage
3	0	20.289.156.114	Increase the machine and outsourcing service usage

Theoretically, the results of this study align with the basic principles of System Dynamics in operational management, which emphasize the importance of understanding feedback loops and delay dynamics within production systems. The imbalance between capacity and demand represents a negative balancing loop that can reduce company performance if not addressed systemically [9]. The application of system dynamics simulation has proven effective in evaluating various policy alternatives without disrupting company operations. These findings reinforce the study by Karima et al., which stated that strategic planning based on dynamic models can provide more realistic long-term predictions compared to static approaches [4]. Furthermore, this study offers practical contributions by providing data-driven solutions for investment decision-making in capacity enhancement.

5. Conclusions

This study concludes that PT XYZ experiences an imbalance between oxygen production capacity and consumer demand during the period 2025–2029. This is evidenced by a continuously increasing order backlog each year, with a cumulative backlog reaching 1,197,198 m^3 by the end of 2029 under existing conditions. Through system dynamics modeling, the relationships among production variables, demand, machine capacity, and distribution can be comprehensively mapped, providing a thorough understanding of the company's operational system. Simulation of three policy scenarios indicates that the combination of increasing machine capacity and utilizing outsourcing services is the most optimal solution to sustainably meet consumer demand. This scenario not only eliminates the order backlog but also yields the highest financial benefit for the company, amounting to IDR 20,289,156,114. The system dynamics approach offers an advantage in evaluating long-term policy decisions based on realistic data-driven predictions. However, the model has limitations as it heavily depends on assumptions and the quality of input data. Future research could be expanded by integrating financial modeling and risk analysis to provide more strategic decision recommendations and by extending the study to other industrial gas products that also have high demand in supporting the development of the Nusantara Capital City.

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