A System Dynamics Modelling for Converting Existing Tanker to FPSO

A Ariestya¹, D W Handani¹,² and K B Artana¹,²

¹Department of Marine Engineering, Faculty of Marine Technology, Insitut Teknologi Sepuluh Nopember, Surabaya, Indonesia
²Center of Excelence in Maritime Safety and Marine Installation (PUI-KEKAL), ITS Surabaya

Email: andraariestya91@gmail.com

Abstract. Floating, Production, Storage, and Offloading (FPSO) is an offshore installation that is used to process and store crude oil from wells and then transport it using tankers to oil refineries. One common scheme in the construction of an FPSO is by converting a tanker into FPSO. The project to convert a tanker to an FPSO requires a very well planning considering that this facility is a very important facility in the upstream oil and gas industry. This study aims to determine aspects that can reduce costs in the project of converting a tanker to FPSO. In this study, the variables that can influence the cost of conversion of a tanker into FPSO project are determined by approaching the principle of customer satisfaction, called Quality, Cost, and Delivery. The solution to the problem is carried out using a system dynamics model approach to determine the causality relationship between variables and its effect on the cost of conversion. The analysis is taken by sensitivity analysis and give the result of the biggest variables that lead in cost of conversion respectively are shipyard class, penalty during production, lead time, subcon factor, amount of worker, and the accuracy of pricing. The simulation model produced using system dynamics modelling is expected to be able to provide a solution to reduce the project cost of conversion a tanker to FPSO to support oil and gas exploitation activities in Indonesia.

1. Introduction

According to Ministry of Energy and Mineral Resources, the realization of the operational volume of lifting oil and gas in Indonesia in 2019 was recorded did not reach the target where the appointment of lifting only reached 88% of APBN target [1]. One of the contributing factors is the lack of application of appropriate technology in both exploitation and production. To face upcoming year is quite clear that the target of the Indonesian government is to increase oil and gas production as a source of state revenue. The application of appropriate technology in the oil and gas sector in Indonesia is expected to be able to help target the recovery of operational costs (Cost Recovery) so that the profits from exploitation can be maximally utilized by the state. The direction of developing petroleum exploitation technology globally shows the trend of floating facilities is one of the options that has a high level of efficiency and is proven to reduce the cost component in the petroleum supply chain [2].

Broadly speaking, the FPSO is a floating facility as a means of exploitation, recovery, storage, transportation in oil and gas installations. The FPSO minimizes the petroleum processing supply chain by bringing processing facilities to the drilling location. FPSOs are the first choice for offshore exploitation because they offer higher flexibility to accommodate the offshore exploration trend into...
deeper waters. FPSO offers a more minimalist concept of the supply chain while reducing the minimum amount of an oil field to be managed so that it reaches an economic point.

After the fall of oil prices in the past few years, the use of tankers has decreased in demand. The availability of tankers has the potential to be used as an FPSO. Technically, the conversion of a tanker to an FPSO can be made possible with a fairly good track record in the oil and gas industry [3]. Economically, the conversion of a tanker to a FPSO has a lower initial capital (CAPEX) than construction from the new build so that investment is more effective. Besides the condition of the waters in Southeast Asia, especially Indonesia, which has a spectrum that is not too extreme (harsh environment) makes the conversion of tankers to FPSO to be quite feasible.

The conversion of tanker to an FPSO requires very mature planning, considering that this facility is an important facility in the upstream oil and gas industry. Delays occurring during the project period will result in production setbacks and delays in revenue for both the State and the Contractor which will result in financial losses. Currently, there are around 8 FPSO were utilized in Indonesia with different sizes and production processes. Each installation is designed differently according to hydrocarbon characteristics, environmental conditions, existing infrastructure, and the economic aspects of oil and gas companies as operators.

2. Methodology
This paper presents study on variables that affect the cost of the conversion of tanker. To support this research, there are some methodology to make the model for calculating the conversion cost and to determine the variable that considered in change of cost conversion.

2.1. System Dynamics
System dynamics is a modelling based on the paradigm of complex system thinking. This model was introduced by Jay Forrester and developed at the Massachusetts Institute of Technology America. System dynamics which has given us an improved understanding of decision making and experience in analyzing and simulating the characteristics of complex systems [4]. System dynamics are concerned with the interaction of various system elements in a span of time and capturing dynamic aspects by including concepts such as availability, current, good feedback and delays and thus provide insight into the dynamic behaviour of a system over time [5]. System dynamics are based on the theory of nonlinear dynamics and feedback control, but also refers to cognitive, social psychology, organizational theory, economics and other social sciences to analyse a complex system behaviour [6]. A dynamical system model is formed because of a causal relationship. In representing activities in a cause-and-effect relationship two types of variables are used which are referred to as stock and flow.

2.2. Quality, Cost, Delivery
Quality, Cost, Delivery (QCD) is a concept of management approach that has been widely adapted by various manufacturing industry sectors. In economic activities, customers who buy goods and services have a major need, that is, they want to buy higher quality goods, at a lower cost, and better delivery times. Therefore, people who offer goods and services to these customers must meet these needs [7]. The assessment will provide feedback in the form of quantitative and qualitative data that is expected to help in making decisions to prioritize the future goals of a company or organization.

Both input and process have QCD elements that affect QCD output. Some of these interactions are direct, predictable and often managed. Poor or sloppy quality raw materials, poor processing quality will inevitably produce finished products of the same poor quality. High raw material costs or high processing costs can only mean high output costs. Delay in the delivery or procurement of raw materials or delays / disruptions in processing will not guarantee the delivery of goods ordered on time to the customer.

As we see in the Figure 1, there are some elements that effect on the quality, cost, and delivery in shipbuilding industries. Shipyard standard, material quality, engineering & database, company culture, facilities equipment and labour competence will affect the quality. While material cost, labour cost bank support, industry infrastructure, and government policy will affect the cost and delivery in
shipbuilding. Those elements in QCD are related to one another result in increase or decrease the value of either quality, cost, or delivery.

![Diagram](image.png)

**Figure 1.** Variables that affects Quality, Cost, and Delivery variables shipbuilding industries.

3. Result and Discussion

3.1. Modelling Approach

3.1.1. Causal Loop Relationship

The first step in system dynamic modelling is to understand the problem by representing into a causal loop diagram. Causal loop diagram is used to determine the relationship between complex variables and to see the interactions that occur in each variable that affects the cost of the conversion of a tanker to an FPSO. In the causal loop diagram, the feedback loop provides relationships between environment aspects. A positive feedback loop means that there is a positive relation between the connected aspects. Inversely, the negative feedback loop has a negative relation to them [8]. Figure 2 shows the causal loop which is developed based on these variables. The causal loop diagram was created using Vensim.

There are four main variables that have been determined in causal loop modelling on the cost of conversion of a tanker to an FPSO, those are Equipment Cost, Hull Cost, Tanker Cost, and Labour Cost. Each of these main variables has several variables in it that affect each other. Equipment costs are costs required for equipment and installations in conversion of a tanker to a FPSO. Costs that affect equipment costs include topside cost, offloading cost, mooring cost and installation cost. The hull cost is the cost required for the construction of the conversion of the tanker hull into a FPSO. Costs for the construction are influenced by outfitting cost, paint and corrosion protection cost, and steel cost. Tanker Cost is the cost required to purchase a second hand tanker which will be converted.
These costs are affected by the size and age of the tankers to be converted into FPSO. The vessel purchase must also comply with specifications, storage capacity and production capacity required. Labour cost is the cost required in the process of converting a tanker to a FPSO including the cost of the shipyard and the duration of the construction project. The duration of the project is influenced by the competence of the workforce carrying out the conversion work. The higher the competency of the workforce, the shorter the duration of the project work, but the costs needed will increase which will affect the cost of the shipyard. The cost of the shipyard is also influenced by the UMR (regional minimum wage) that applies at the location of the shipyard and the competency of the shipyard.

A positive sign indicates that the two related nodes change in the same direction. If one node increases, the other node will also increase, if the node decreases, then the other node will also decrease. In example, if the bank interest increases, the result in equipment cost also increases. Otherwise, a negative sign indicates that the two related nodes change in the opposite direction. If one node goes down, then the other node will increase, and vice versa. In example, if the amount of labour increases, the duration of the conversion will decrease.

In the process of building a ship, the bank has an important role in lending the funds needed. In this case, the interest applied to bank loans greatly affects the construction of a ship. At present, the interest on loans for shipbuilding is around 12-15% with a tenor of 5-6 years. In this paper, bank interest will affect the costs needed to meet equipment costs and hull costs where there will be additional costs due to interest on loans from banks worth 13%. The government also plays a role in the construction of a ship, where the government will determine the amount of the import tax imposed due to import activities. As it is known that most of the components used in ship building are imported components, there will be additional costs due to taxes. Therefore, in this study all tax values originating from government policies are grouped into tax policies which will add to the cost of conversion of a tanker to FPSO.

3.1.2. Stock and Flow Diagram

After making the causal loop diagram, the next step is to make a stock and flow diagram. Stock and flow diagram are carried out to accumulate the calculation in the modelling on the cost of conversion.
of a tanker to FPSO. Stocks accumulate the effect of the flows and the only way to change a stock is by changing the action of the flows. When there are no flows or the inflows and the outflows are the same, then the stock will remain the same [9]. The modelling was built using Powersim software.

Figure 3. Stock and flow diagram that leading changes in cost of conversion.

3.2. Sensitivity Analysis
Sensitivity analysis is carried out to see the effect that will occur due to changes in a variable input value. Sensitivity analysis helps to build confidence in the model by studying the uncertainties that are often associated with parameters in models [10]. The next thing to do in this research is to determine the variables that are considered sensitive and to analyse the changes that occur on the cost of conversion of a tanker to FPSO. The variables that considered sensitive is because this variable will support the conversion project and give the major impact in cost of conversion, its value can be controlled by the shipyard to reduce the cost of conversion. There are some variables which are considered sensitive in this research, i.e.:

- Shipyard Class
- Amount of Worker
- Penalty During Production
- Lead Time
- Subcon Factor
- Pricing Accuracy
Table 1. Scenario on variable value.

| Shipyard Class (level) | Amount of Worker (person) | Penalty during production | Lead time | Subcon Factor | Pricing Accuracy |
|------------------------|---------------------------|---------------------------|-----------|---------------|-----------------|
| Low                    | 80                        | No Penalty                | On Time   | Low           | Low             |
| Medium                 | 150                       | Bad                       | Bad       | Medium        | Medium          |
| High                   | 300                       | Very Bad                  | Very Bad  | High          | High            |

3.3. Result and Analysis

The result of sensitivity analysis is to know how far the change on cost of conversion by adjusting the variable value that considered sensitive based some scenario that has been chosen. As we can see the effect on the figure below on each graph.

**Figure 4.** Shipyard class on the cost of conversion.

The difference value input of shipyard selection reaching a peak at Rp6,901,629,643,035,00 and the lowest value at Rp5,726,650,217,097,00, gave the highest percentage at 20.51%. The duration of shipyard selection decreased gradually from low class to high class by 4 months per each class of shipyard with the fastest duration in 24 months.

**Figure 6.** Lead time on the cost of conversion.

The lead time changes gave the highest value at Rp7,420,227,559,807,00 for the worst condition and the lowest value at Rp6,288,835,528,078,00 for on time condition, gave the highest percentage at 17.99%. The duration of the lead time has major increased from normal condition to bad condition by 2 months and 6 months for very bad condition.
The subcon factor gave the top level at Rp6,663,526,601,710.00 for very bad condition and Rp6,474,491,156,244.00 for bad condition, gave the highest percentage at 5.95%. The duration added in subcon factor gave respectively 2 months for each condition.

The difference value of penalty during production process gave the highest value at Rp7,463,951.091.665 and reach Rp6,752,156,043.120 for bad condition, gave the highest percentage at 18.68%. The duration increased 1.5 months for bad condition and 4 months for very bad condition.
The amount of worker changes gave the value at Rp6,286,801,166,943,00 for the total amount of 300 workers and the lowest value at Rp6,277,819,577,479,00 for the total amount of 150 workers. The duration decreased about 10 days by adding the amount of worker for 150 workers and 20 days for 300 workers.

The accuracy of pricing in shipyard gave the difference at Rp18,183,804,134,00 for 0.5% error accuracy and gave the highest difference at Rp31,821,657,234 for 1.2% error accuracy.

The changing of the value of variables in the model does make some difference in cost of conversion. By comparing the value based on real situation in the shipyard industries, the biggest percentage that lead changes in cost of conversion respectively are shipyard class, penalty during production, lead time, subcon factor, amount of worker, and the accuracy of pricing. Hopefully, the result of sensitivity analysis that has been done can be considered by making recommendation to increase the readiness of the government and shipyard to support the local shipbuilding in oil and gas industry.

4. Conclusion
One of the ways the Indonesian government in increasing the use of domestic products for upstream oil and gas business activities is that the government will require contractors (KKKS) to use domestic-made Floating, Production, Storage and Offloading (FPSO) either by making new buildings or conversion. The purpose is to increase the contribution of the national shipping industry to the upstream oil and gas industry, this regulation is also expected to have a positive impact on efforts to increase state revenue from the oil and gas sector. The research is modelled by system dynamics and QCD approach to determine the variables that lead to changes in cost of conversion. Then sensitivity analysis taken to know how much the variable can effects the change in cost of conversion that can be controlled by shipyard industries. The biggest percentage that lead changes in cost of conversion respectively are shipyard class, penalty during production, lead time, subcon factor, amount of worker, and the accuracy of pricing. The recommendation must be made by the shipyard by considering the variable that gave the major impact to minimize the cost of conversion and to improve the shipbuilding industry in infrastructure, procurement, financial and human resource. Thus, the facilities needed by the upstream oil and gas industry can be guaranteed in terms of quality and availability.

Future Research
There are broadly aspects that can be improve on this research. There are so many variables that can be taken into account to influence on the cost of conversion of a tanker to FPSO. Some points of the improvement that can lead to the future direction of this research are:
• Due to lack of the historical project data of tanker conversion to FPSO, some variables that can lead to the changes on the cost of conversion can be built more detail
• Improve the research by calculating the net profit value, internal rate of return and payback period to measure the feasibility of the conversion project.

5. References

[1] Kemenentrian Energi dan Sumber Daya Mineral, “Laporan Tahunan Capaian Pembangunan 2018,” 2018.
[2] Oil & Gas iQ, “2019 State of FPSO Nation Report,” Oil & Gas iQ, Singapore, 2019.
[3] P. Love and J. E. David, “The Latent Causes of Rework in Floating Production Storage Offloading Projects,” Journal of Civil Engineering and Management, vol. 20, pp. 315-329, 2014.
[4] J. Forrester, "Industrial Dynamics: a Major Breakthrough for Decision Makers," Harvard Business Review, vol. 36, 1958.
[5] T. Vijay and S. Vijay, “System Dynamics Origin Development and Future Prospects of A Method,” in Research Seminar in Engineering System, 2001.
[6] J. Sterman, Business Dynamics: Systems Thinking and Modeling for a Complex World, Boston : Irwin McGraw Hill, 2000.
[7] Keyence, “Pengantar Peningkatan QCD”. Tingkatkan QCD dengan Seri IM.
[8] D. W. Handani and M. Uchida, “Modeling Optimum Operation of Ship Machinery by Using System Dynamics,” Journal of the JIME, vol. 49, no. 1, pp. 132-141, 2014.
[9] F. I. Pratyasari, D. W. Handani, A. Dinariyana and M. Prakoso, “Feasibility Study of Diesel Engine Replacement On Passenger Ships: A System Dynamic Approach,” WMU Journal of Maritime Affairs, vol. 18, pp. 281-296, 2019.
[10] L. Breierova and M. Choudhari, “An Introduction to Sensitivity Analysis,” September 6, 1996, September 1996.