LNG SUPPLY CHAIN RESILIENCE

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Topic Areas: Risk Management, Resilience, LNG

Summary:
This capstone project used historical supply chain disruption data from the case study company to develop a model to prioritize response to multiple pipeline disruptions. Our case study company has its operations in two hubs, and response to pipeline disruptions are traditionally treated at individual hub level. Our study shows that a holistic treatment of the entire network, rather than in hubs, could improve supply chain resilience. We show that the BSR framework can be adopted to a gas pipeline network; this adoption will enable practitioners and managers to make informed risk-based business decisions, thus enhancing overall LNG supply chain resilience.

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KEY INSIGHTS

1. Quantitative assessment of resilience across a supply chain network allows a company to make an objective business case for mitigation and disruption restoration planning
2. Expected business Impact from multiple pipeline disruption can be reduced by designing business metric that captures value at risk and cost to repair for disruption scenarios
3. The ranking of mitigation option and extent of restorative investment depends on the additional improvement to baseline business impact

Introduction

Liquefied natural gas (LNG) global trade reached a record 258 Million Tonnes (MT) in 2016, with the market size set to reach US$ 20 billion in 2025. The trend is set to continue, with new supply from new LNG projects globally. As the LNG supply chain increases in scope, supply chain resilience will likely remain an important capability for firms due to the negative impacts that disruptions can have on a company's ability to compete. This is particularly true with the case study company for this capstone, a company that manages the upstream oil and gas pipeline infrastructure in Nigeria. The capstone project used historical supply chain disruption data of the case study company to develop a model for prioritizing response to multiple pipeline disruptions. Our case study company has operations in two hubs where response to pipeline disruptions are traditionally treated at individual hub level. Our study shows that a holistic treatment of the entire network rather than in hubs could potentially improve supply chain resilience. Resilience assessment frameworks can provide a structured approach to quantifying and visualizing the effect of disruptions in the supply chain. Some methods for risk assessment already exist, such as the Risk Exposure Index and Value-At-Risk. However, these methods focus on the risk component and the loss of revenue incurred when disruptions hit while little attention is given to the cost of restoration. As restorative costs are important in pipeline infrastructures, existing methods are inadequate for the case study company. Therefore, the objective of this capstone project was to adapt an existing risk assessment framework, the Balanced Scorecard of Resilience (BSR), for an integrated risk-based approach to (1) prioritize response to an oil and gas pipeline infrastructure disruption, and (2) provide insight to help the practitioner make decisions that may minimize business disruptions if adopted. This project scope will be the upstream portion of an LNG supply chain which is where the frequency of disruption is highest in case study setting,

Methodology

There are many similarities between an upstream oil and gas pipeline network and a traditional production supply chain. This can be observed from Figure 1. several studies have been conducted on the energy supply infrastructure of Nigeria. While studies had been conducted on events that caused supply disruptions, and their economic impact, none of these studies have assessed how pipeline infrastructure management companies can minimize the effect of disruption by prioritizing repair response during events of multiple pipeline disruptions.

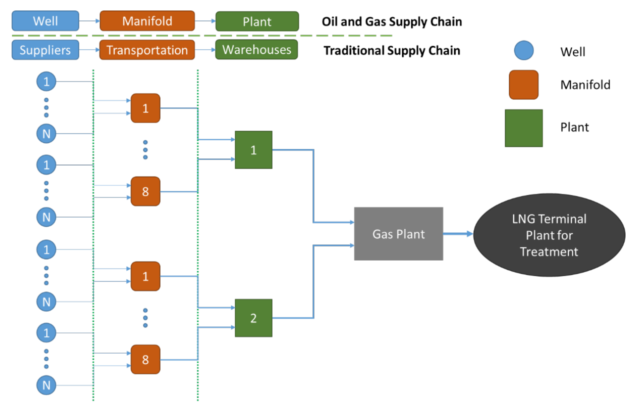

Figure 1:Similarities between a Traditional Product Supply Chain and an Upstream Oil and Gas pipeline Supply Chain

As pipelines are often left inoperable after attacks, the proper repair response is important to ensuring minimal disruptions to oil and gas flow. Some key supply chain management success factors need to be exercised for resilience management in gas pipeline network. After looking at all the research done on BSR, the focus for the capstone project was on the ability to respond to multiple disruptions. We therefore develop our assessment method for prioritizing repair response to improve supply chain resilience, working with a medium, pipeline infrastructure management company to develop and test our assessment tool.

Update BSR Model

The updated model in this capstone project explore different treatment of the probability of disruption and probability of repair on the estimation of Expected business impact(E[BI]). Hence, an update to the BSR model, shown in the equation below was proposed.

$$E[BI] = E[VaR] + E[CtR]$$

In these equations, the $E[VaR]$ (Value at Risk) and $E[CaR]$ (Cost to Repair) are both functions of the probability of disruption interval P(disruption interval) as shown in the equation below. The histogram of the acquired disruption data for each manifold was mapped with possible probability function and the two most occurring distributions that fitted our data pattern were the normal and discrete uniform distribution.

$$P(Disruption\ Interval) \sim N(Mean\ Interval, Standard\ Deviation\ Interval)$$

$$E[VaR] = P(Disruption\ Interval) * Value\ Loss/Day$$

$$E[CtR] = Material\ Cost + Mobilization\ Cost + E[Variable\ Cost]$$

$$E[Variable\ Cost] = P(Disruption\ Length) * Variable\ Cost\ per\ Day$$

$$P(Repair) \sim Discrete\ Uniform\ Distribution\ (Min\ Repair\ Time, Max\ Repair\ Time)$$

Equation: P(Disruption Interval) 1

Studies of LNG supply chain resilience have revealed that the rate of disruptions is higher in the upstream pipeline network of the case study country, Nigeria(see value LNG value chain Figure 2). This capstone considered how an appropriate resilience framework can possibly improve a company's response to multiple pipeline supply chain disruptions. The core simplifying assumption for modifying

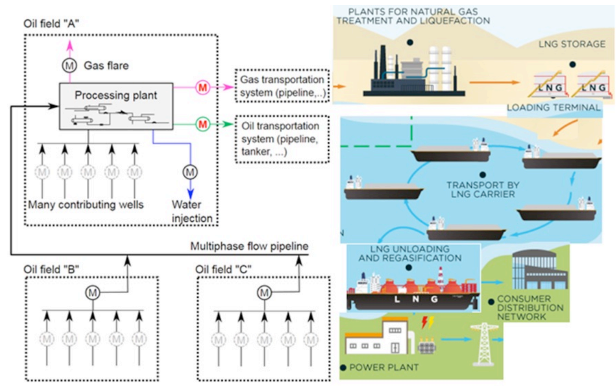

Figure 2::Pipeline Network showing flowlines, Manifold(M),Processing plant and LNG distribution

the Balanced Scorecard of Resilience (BSR) was to select a probability distribution function that best represent the disruption data-set at each node.

Model Outcome

The three methods used to develop the models were i) a baseline model using average values of disruption data, ii) BSR with normal distribution, and iii) BSR with discrete uniform distribution. The BSR was then used to generate the EBI, which is the sum of the value at risk and the costs associated with disruptions at individual nodes. It was observed that the discrete uniform model estimation of EBI was reflective of actual production value at risk as shown in figure 3.

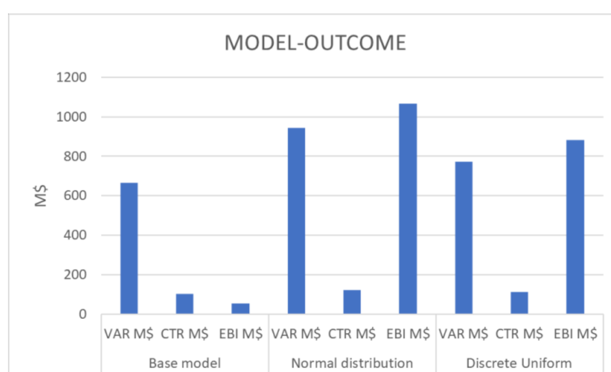

Figure 3:Comparison of Three BSR Models

Therefore, the outputs of the model using discrete uniform distribution was selected in creating a simulation tool for ranking and prioritizing response to repair activities. The methodology and framework developed solely for traditional supply chains has been adapted to a pipeline infrastructure in the context of the upstream of an LNG market.

Final Insight

The global demand for Liquefied Natural Gas (LNG) has continued to grow in the past decade, with increasing numbers of disruptions and plant outages. Considering these dynamics, oil and gas companies need to prepare their operations to meet increasing demand with agile response to disruptions. This is particularly true for the case study company for this capstone, a company that manages the upstream oil and gas pipeline infrastructure in Nigeria. First, an existing resilience framework, the Balanced Scorecard of Resilience (BSR) model, was adapted to the unique characteristics of the gas pipeline network to determine the expected business impacts at each node. Second, the expected business impacts and cost of restoring operations after disruption were used to rank response to repair activities.

The aim of adapting the BSR to prioritize response to gas pipeline disruption was incorporated into the model developed. This modelling of quantitative metrics for decision support may be a useful tool to help companies improve their disruption recovery strategies, which in turn could possibly help improve their supply chain resilience. Similar pipeline infrastructure companies could possibly also utilize the BSR as a decision support tool for integrated evaluation for supply chain resilience. This study involved using an existing framework to quantitatively assess the expected business impact from disruptions and then applied a new method for incorporating the probability of the disruptions. Rather than using an average based on historical rate of disruptions at each node, we applied several different probability distributions and modelled the business impact to identify priorities for disruption response. This is an experimental approach and warrants additional study and application to make assertions regarding the utility of this approach. As with many emerging research areas, there are many facets of the challenge to study and this study represents a small but hopefully useful inquiry into identifying how to make resilience investment decisions. Therefore, we propose that there may be additional utility for future research in developing methods to understand how to prepare for disruptions and invest in resilience.