Supply Chain Innovations in the Oil and Gas Industry

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Abstract

Organizations in the oil and gas industry often deal with a variety of logistic challenges. These organizations need to utilize innovative technologies to reduce costs and help achieve a lower-emissions environment. The industry involves a global supply-chain that is comprised of domestic and international transportation, inventory control, materials handling, import/export facilitation and information technology. Currently, the industry offers a classic model for executing supply-chain management techniques. However, companies can optimize their supply chains to generate more productivity for better financial returns. Applying some of the new techniques can diminish costs and reduce the uncertainty in the supply chain. The demand for digital oil-field attentions will grow once there is a reduction in oil costs. To improve supply chain management, it is necessary to use an optimization model. The objective of this paper is to review the various supply-chain techniques found within the oil and gas industry today, and offer an innovative solution of applying a linear programming model to optimize the transportation network of the supply chain. The model used in this study accounts for main cost components, as well the pumping and refinery costs. Optimization modeling is used to understand key factors needed to bring innovations to supply-chain management.

Keywords
Supply chain management, optimization, logistics, oil and gas

1. Introduction
In the new global market, managing the supply chain is a crucial factor in developing a powerful and competitive business. A supply chain is a system comprised of the various components (i.e. the manufacturers, suppliers, transporters, warehouses, and retailers) that are involved in the process of completing a customer request. In retrospect, a supply chain starts and ends with the customer. In the supply chain process, natural resources and/or raw materials are taken and transformed into a finished product that is delivered to the customer. In the gas and oil industry, crude oil is provided to the manufacturers by the suppliers for processing in a refinery. The crude oils are processed to yield a specific output. These outputs are, then, distributed to various retail centers to be sold as gasoline, engine oil, or other products.

The global supply chains of the gas and oil industry are often complex and interdependent, which make them vulnerable to risk and uncertainty. Risks within a supply chain can include fluctuations in supply, demand, and price. Overcoming these risks require innovation, which is essential for survival in any industry. Innovations can effect on the quality of service, for example, by improving customer satisfaction, optimizing the inventory costs and total costs, and more. Currently, supply chain innovations in the oil and gas industry are absolutely necessary.

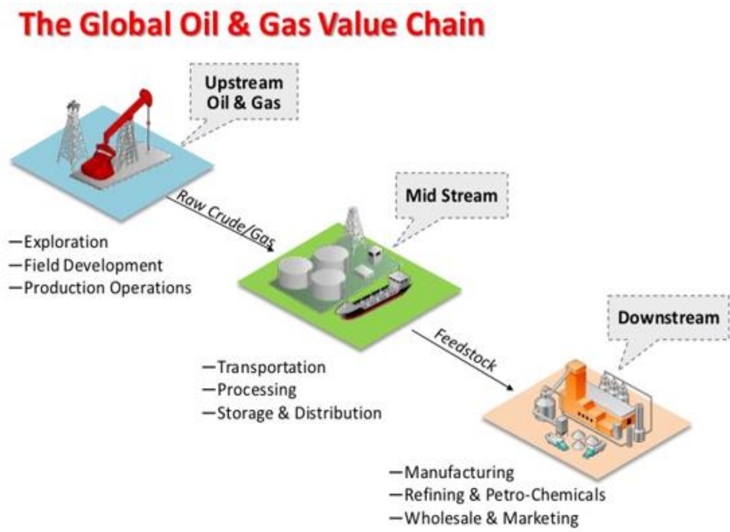

Figure 1: The global oil and gas value chain

When it comes to adapting new methods and technologies for improvement, the oil and gas industry fall behind most other industries. Some of the systems that are still in use today are based on traditional notions that require manual labor. These outdated methods are costly and inefficient. A major area for improvement in the oil and gas industry lies in the reduction and optimization of the operational costs. The three key components that can help reduce the operational costs, both upstream and downstream (see figure 1) along the supply chain, are: (i) increasing supply chain visibility, (ii) improving compliance, and (iii) enhancing supplier collaboration.

Increasing chain visibility requires balancing the high cost of downtime with the expense of carrying slow-moving parts and supply inventories. This must be done meticulously in order to reduce costs. Companies should place emphasis on the importance of using real-time RFID data to provide real-time supply chain visibility.

In supply chain industry, it is always better to be prepared with all of the relevant information in its entirety. Improving compliance entails having a good understanding of the clearance policies, the regulations, and the documentation requirements for each country, prior to the clearance stage of the logistics process.

Enhancing supplier collaboration can involve procuring goods from international suppliers. In a global supply chain, procuring activities can occur between any two companies located at any two countries at complete opposite ends of the world. Thus, procurement activities are often strained with many complexities. However, companies can utilize an interactive supplier portal for effective communication and prompt decision making.

In the gas and oil industry, a successful supply chain involves minimization of material procurement, maximization of manufacturing capacity, meeting demand, and maximizing throughput. While there are many external factors that cannot be controlled, effective utilization of resources within the supply chain can help resolve problems with ease. Organizations should focus on removing inefficiencies from daily operations by increasing supply chain visibility, improving compliance, and enhancing supplier collaboration by challenging current outdated practices and adopting the latest innovations. The objective of this paper is to offer an innovative solution of applying a linear programming model to optimize the transportation network of the supply chain.

2. Literature Review

The complexities and inflexibility of the oil and gas supply chain result in uncertainties that have direct impact on the economy and even political situations within a number of different countries [5, 17]. Managing uncertainty is a main objective of supply chain management [6]. Supply chain design involves making important strategic decisions, which often require large investments, have long-term impacts and are difficult to reverse. Thus, it is important to design the supply chain so that it can easily adapt to uncertainties in the future [20].

In the supply chain, a company is linked to its upstream suppliers and downstream distributors as materials, information, and capital flow through the chain [1]. It is common practice for companies to manage increasing demands to reduce costs, increase quality, and improve customer service while ensuring the continuity of their supply [18]. The oil and gas industry is involved in a global supply chain that consists of domestic and international transportation, value-chain strategic warehouse management (see figure 1), order and inventory visibility and control, materials handling, import/export facilitation, and information technology [1].

By replacing the more traditional, manual methods in the supply chain with the latest innovations, other industries have benefited from the rewards of standardization, simpler processes and more precise intelligence, which result in more efficient operations and tighter cost control. Innovation generation in a supply chain setting involves changes in a product, process, or service that either reduce costs or improve efficiency. The concept of efficiency results in increased end-of chain customer satisfaction [11].

The supply chain of the oil and gas industry is divided into two different, yet closely related, major segments: the upstream and the downstream supply chains (see figure 1) [13]. The upstream supply chain involves the acquisition of crude oil, which is the specialty of the oil companies. The upstream process includes exploration, forecasting, production, and logistics management of delivering crude oil from remotely located oil wells to refineries. The downstream supply chain starts at the refinery, where the crude oil is manufactured into the consumable products that are the specialty of refineries and petrochemical companies. The downstream supply chain involves the process of forecasting, production, and the logistics management of delivering the crude oil derivatives to customers around the globe. Despite many enhancements in the processes and technologies introduced over the years, downstream distribution remains the main contributor to supply chain operation costs and process inflexibility [19]. This paper seeks to add value by signifying and indicating optimization as a way to address uncertainties and points out a way to utilize resources efficiently in order to obtain cost savings in the long term [10].

3. Model of Innovation Generation

The conceptual framework (see figure 2) demonstrates that buyer-seller interactions in supply chain relationships generate incremental and radical innovations. The link between interactions and innovation generation is controlled by several factors, which are grouped into two categories: (1) those that are internal to the inter-firm buyer-seller relationship and that can be managed through managerial action on either side (IT adoption, commitment, and trust), and (2) those that are external to the relationship and are generally not under the control of the dyad (applications of technology, stability of demand, and network connections). Internal factors include IT adoption and the traditional relationship factors of trust and commitment, which is central to the buyer-seller relationships. The three external factors are tacit technology, nature of demand, and network connections. Applications of technology is crucial to understanding innovation, while the nature of demand illustrates the agility of the supply chain [11].

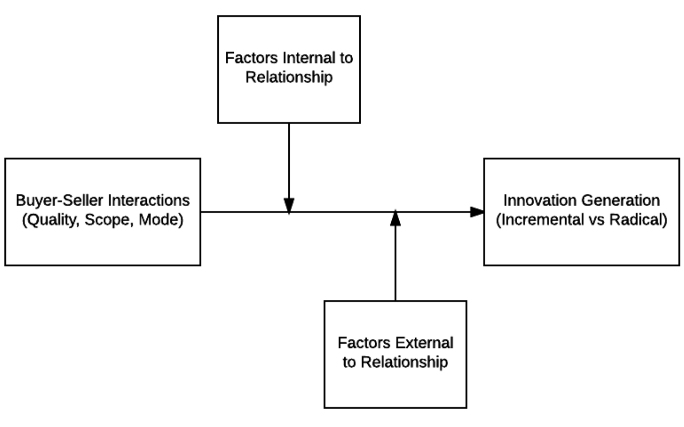

Figure 2: A model of innovation generation in supply chain relationships

The mathematical model proposed in this study has to be checked with further change in experimental parameters and real-world data. Furthermore, it's important to consider which other costs could be incorporated for the case of greater fluctuation in market demand, while taking lead time into consideration.

4. Logistics Optimization

The logistics of petroleum products account for a major part of the costs incurred by the oil and gas industries. The products, which are obtained as output from the refineries, have very high transportation cost to reach the service channels before they are available to customers. This results into a high price commodity for the consumers.

Figure 3: Flow of refined petroleum products through various channels

The figure above demonstrates the flow of refined petroleum products through various channels (see figure 3). A simple solution for this is optimization through linear programming for transportation. The equation below is a linear programming model that can be used to optimize the transportation network illustrated above (see equation 1).

$$Min\ Z = \sum_{i=1}^{a}\sum_{j=1}^{b} c_{ij}x_{ij} + \sum_{j=1}^{b}\sum_{k=1}^{c} c_{jk}x_{jk} + \sum_{k=1}^{c}\sum_{l=1}^{d} c_{kl}x_{kl} + \sum_{l=1}^{d}\sum_{m=1}^{e} c_{lm}x_{lm} \qquad (1)$$

$s.t.$

$$\sum_{i=1}^{a}\sum_{j=1}^{b} x_{ij} \le \sum_{i=1}^{a} Capacity_i \qquad \sum_{i=1}^{m} x_{ij} \ge D_j \text{ for all } j = 1, \ldots, n. \quad D_j = \text{Demand}$$

$$\sum_{j=1}^{b}\sum_{k=1}^{c} x_{jk} \le \sum_{i=1}^{a}\sum_{j=1}^{b} x_{ij} \qquad \sum_{k=1}^{c}\sum_{l=1}^{d} x_{kl} \le \sum_{j=1}^{b}\sum_{k=1}^{c} x_{jk} \qquad \sum_{l=1}^{d}\sum_{m=1}^{e} x_{lm} \le \sum_{k=1}^{c}\sum_{l=1}^{d} x_{kl}$$

The parameters in the above model are explained below:

i = 1, 2,…, a, are the refineries from where products are obtained;
j = 1, 2,…, b, are pumping stations from where they are pumped forward through pipelines;
k = 1, 2,…, c, are receiving stations where they are collected from pipelines;
l = 1, 2,…, d, are distribution channels to supply products further; and
m = 1, 2,…, e, are service channels (i.e. gas stations) from where they are available to customers.

Here, $capacity_i$ the supply capacity of refinery *i*; c_{ij} is cost of transportation of one unit of petroleum product from *i* to *j*; and x_{ij} is amount of petroleum product transported from *i* to *j*. Similarly, c_{jk}, c_{kl}, c_{lm} are respective costs and x_{jk}, x_{kl}, x_{lm} are respective amounts, and *Z* is the total cost of transportation which is to be minimized. Here, all of the four constraints mentioned are supply constraint originating from the capacities of refineries. The demand is uncertain.

Gathering real-world data for each of the above mentioned channels and finding an optimal solution, using the linear programming model above, can yield reduced cost for the overall transportation within the oil and gas industry.

In the scenario below, we have assumed: (1) maximum capacity is 500 (randomly taken); (2) maximum demand is 300 (randomly taken); (3) the quantities of key elements (refineries, pumping and receiving stations, distribution and service channels); and (4) fixed transportation costs.

Table 1: Parameters for SAS configuration scenario

	Elements	Parameters	Quantity
a	Refineries	i	3
b	Pumping	j	3
c	Receiving	k	3
d	Distribution	l	3
e	Service	m	3

Transportational Cost (cij)

i \ j	1	2	3
1	25	30	34
2	78	87	56
3	45	12	23

Transportational Cost (cjk)

j \ k	1	2	3
1	56	45	87
2	78	45	32
3	98	67	43

Transportational Cost (cjk)

l \ k	1	2	3
1	78	45	66
2	98	67	44
3	88	66	30

Transportational Cost (cjk)

m \ l	1	2	3
1	56	34	60
2	78	45	44
3	33	51	66

The SAS System

The OPTMODEL Procedure

Solution Summary	(1)	(2)	(3)	(4)
Solver	LP	LP	LP	LP
Algorithm	Dual Simplex	Dual Simplex	Dual Simplex	Dual Simplex
Objective Function	total_cost	total_cost	total_cost	total_cost
Solution Status	Optimal	Optimal	Optimal	Optimal
Objective Value	19600	27800	34900	23400
Primal Infeasibility	0	0	0	0
Dual Infeasibility	0	0	0	0
Bound Infeasibility	0	0	0	0
Iterations	7	7	7	8
Presolve Time	0.00	0.00	0.00	0.00
Solution Time	0.00	0.00	0.00	0.00

x	Refinery1	Refinery2	Refinery3
Pumping1	200	0	0
Pumping2	100	0	100
Pumping3	0	100	0

x	Pumping1	Pumping2	Pumping3
Receiving1	200	0	0
Receiving2	100	100	0
Receving3	0	0	100

x	Receiving1	Receiving2	Receving3
Distribution1	100	100	0
Distribution2	200	0	0
Distribution3	0	0	100

x	Pumping1	Pumping2	Pumping3
Receiving1	200	0	0
Receiving2	0	100	100
Receving3	100	0	0

MIN Z = $105,700

Figure 4: SAS configuration for the example scenario

The calculations were done using SAS 9.4. The demand, capacity and transportation costs were fixed amounts, while the number of units transported was determined using OPTMODEL procedure. In the above scenario, the SAS configuration minimized the total cost by a reduction of $105,700/year (see figure 4).

5. Discussion and Conclusion

Recent developments in oil and gas industry include increased demand for better and faster customer service, globalization of the oil and gas business, and the availability of information technology to facilitate information exchange. Some possible solutions to these challenges include the implementation of known concepts, such as the Internet of Things and Vertical Integration in supply chain. The table below shows possible solutions by segment. However, further study is required to effectively formulate the implementation plans of the latest innovations.

Table 2: Analysis of IOT values by oil and gas industry segments

O&G Segment	Primary Business Objective	Dominant Value Drivers	Likeliest Value Loop Bottleneck	Potential Solution
Upstream	Optimization	Scope and latency	Aggregate	Standards

Midstream	Reliability	Scale, accuracy, timeliness	Create	Sensors
Down Stream	New value creation	Scope, timeliness, security	Act	Ecosystem Management

In this paper we have proposed an optimization model which should be further studied with respect to the real data and analysis. Although the linear programming model may be a good initial step for logistics optimization, there is opportunity for development of better optimization techniques. Moreover, logistics is not the only area for improvement by innovation in the oil and gas industry supply chain. Inputs from executives of the oil and gas industry in the research could prove more helpful to the ongoing research in this field. Supply chain innovations in oil and gas industry is still an area of concern at highest priority, considering the environmental, socio-economical, and political effects of this on the global population.

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