Petroleum Supply Chain Risk Analysis in a Multinational Oil Firm in Nigeria

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Risk and uncertainty are quintessential issues facing petroleum industry. Managing petroleum supply chain risk represents one of the most daunting challenges confronting many of the multinational oil firms (MOFs) in Nigeria. As a result, petroleum supply chain risk management is top on the agenda of C-level executives of the MOFs. This paper leverages a decision support system to model risk management in the upstream petroleum supply chain of an MOF. The AHP is a typical multi-criteria methodology used to model risk management because it allows different types of risks to be assessed and evaluated.

INTRODUCTION

Identifying and quantifying supply chain risk in petroleum industry is essential. The objective of this research is to develop a framework to explore and quantify risk of disruptions in a multinational oil firm supply chain. The analysis is based on data collected from supply chain managers of an MOF in Nigeria. Managing petroleum supply chain risk in the energy sector is vitally essential for many reasons. Uninterrupted flow of oil and gas are important to the economic health of both developing and developed economies. For a developing country, Nigeria in particular, oil and gas industry can play an important role in its economic development. However, growing number of risks in today's global business environment have become serious challenge to petroleum supply chain stability. This paper will discuss an approach that can be used to manage petroleum supply chains risks. The petroleum supply chain risk management is imperative because lack of it can encourage a perception of uncertainty of oil and gas supplies in the global energy market which will in turn result to an increase in global crude oil and gas price and global economic crisis.

The remainder of the paper is organized as follows. Section 2 presents brief overview on the petroleum industry supply chain. Section 3 discusses sources of petroleum supply chain. Section 4 presents the research methodology. Section 5 describes the data collection. Finally, sections 6 and 7 present research finding and conclusions and managerial implications, respectively.

OVERVIEW OF PETROLEUM INDUSTRY SUPPLY CHAIN

The petroleum industry supply chain is considered to be inflexible and the most complex industry relative to other industries (Hussain, 2006). Because of the inflexibility and complexity linked to the petroleum industry supply chain managing it is a daunting challenge (Morton, 2003; Coia, 1999). Each stage in the supply chain pose a significant challenge (Jenkins and Wright, 1998) because the petroleum industry supply chain logistics network is very inflexible due to production capabilities of crude oil suppliers, long transportation lead times, and the limitations of modes of transportation (Hussain, et al., 2006). Also, improving the inflexibility and complexity of the petroleum industry supply chain is challenging because of its cultural reorientation, information systems and information sharing, integrated process management, and organizational restructuring (Ikram, 2004)

The petroleum industry supply chain is bifurcated into upstream and downstream supply chain operations. The upstream Petroleum supply chain operation encompasses exploration and appraisal, production and transportation of crude oil and gas to the refineries for conversion into finished products. Nnadili (2006) describes Petroleum upstream supply chain can be "defined as all logistics activities occurring through feedstock of exploration and movement into the refineries to refining operations" (Nnadili, 2006). Hussain et al (2006) describes upstream petroleum supply chain as a process of acquiring crude oil, including the exploration, forecasting, production, and delivery of crude oil from remotely located oil wells to refineries, while the downstream petroleum supply chain is the point of refinery where the crude oil is converted into end products which includes the process of forecasting, production, and the logistics management of delivering the crude oil derivatives to customers around the globe. Or, it entails the distribution and marketing activities associated with all the products derived from oil or the so called feedstock. Manzano (2005) defines "petroleum downstream [supply chain] as the activities which take place between the purchase of crude oil and the use of the oil products by the end consumer. This covers transporting the crude oil, performing supply and trading activities, refining the crude oil, and distributing and marketing the refined products output." The current research concentrates on the upstream petroleum supply chain operations with particular interest in mitigating upstream petroleum supply chain operation risk. According to Al-Thani (2008) "risk management can be applied effectively to oil and gas project like any other investment project."

Sources of Petroleum Supply Chain Risk

Petroleum supply chain operation is quintessentially a risky venture. Risk and uncertainty can have significant impact petroleum industry supply chain performance. Petroleum supply chain operation risks encompass risks that can impact a firm's financial performance and competitiveness, including geological and production risk, market risk, technological risk, country risk, price, costs and government action. A. T. Kearney's (2005) study in 2004 identified that the traditional risks affecting petroleum supply chain operation include government regulation/legal decision (64%), country financial risk (60%), currency/interest rate volatility (51%), political and social disturbances (46%), while emerging risks affecting petroleum supply chain are corporate governance issues (30%), theft of intellectual property (28%), terrorist attacks (26), and security threats to employees and assets (26%). Risk analysis is imperative for proactive risk management. Arguably, it has become increasingly imperative that petroleum economic actors manage the delicate balance of risks and rewards within and across their entire supply chain.

Petroleum industry supply chain is prone to uncertainty and risk. Petroleum industry supply chain uncertainties include oil reserve, exploration, crude price, supply and demand, and product price. Further, petroleum industry supply chain is impacted by 1) global risks such as political, legal, commercial, and environmental; and 2) element risks such as construction, operation, financing, and revenue generation. Both global and element risks affects upstream and downstream supply chain operations. Petroleum supply chain risk management is imperative because 1) both upstream and downstream risks must be managed to ensure commercial viability of an oil and gas project, 2) the upstream industry supply chain is characterized as "high-risk" as a result of the sizeable investment level, geological uncertainties cum risks associated with fiscal and political uncertainties with host producing countries, and 3) the downstream industry supply chain faces risk which is associated with uncertainty of the crude supply and the marketing of products.

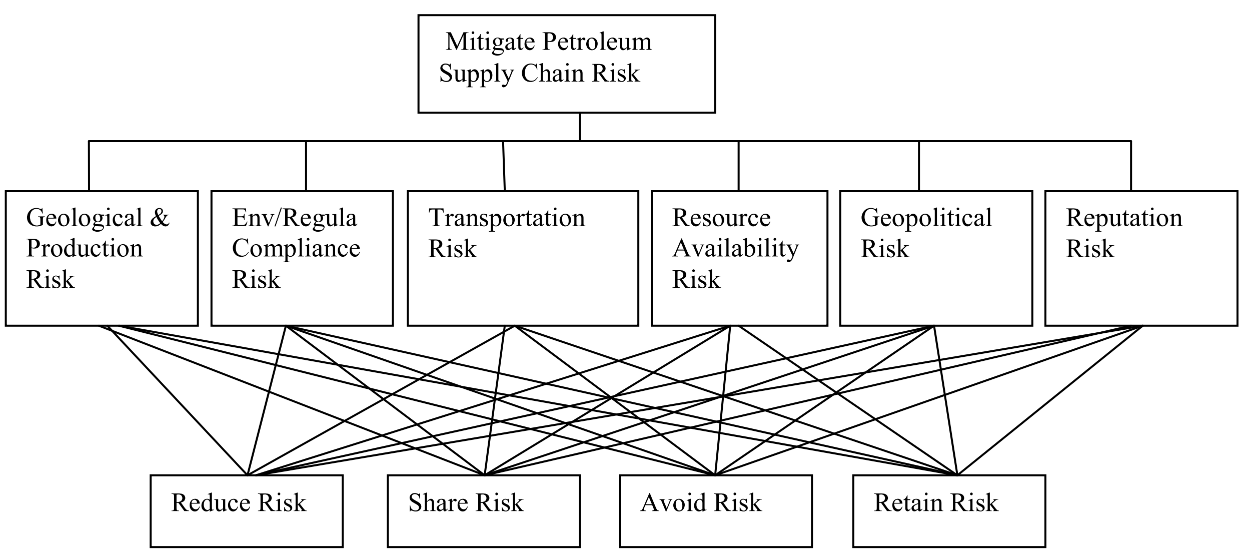
RESEARCH METHODOLOGY

A decision-making environment entails multiple criteria called the multi-criteria decision making (MCDM). Evaluation and management of petroleum supply chain risk represents a typical MCDM problem that entails multiple criteria that can be both qualitative and quantitative. An example of MCDM selected to model risk management in the petroleum supply chain is AHP developed by Saaty (1980). It is chosen because it allows decision-makers to model a complex problem in a hierarchical structure showing the relationships of the overall goal, objectives, and alternatives. Because of its usefulness, AHP has been widely used in research. For example, it has been used in marketing (Dyer and Forman, 1992), pharmaceutical marketing and management (Ross and Nydick, 1994), pharmaceutical supply chain (e.g., Enyinda, 2008; Enyinda et al., 2009), and supplier selection (e.g., Enyinda et al., 2010). Following Saaty (1980), the hierarchy structure of the petroleum supply chain risk is shown in Figure 1.

1. Define an unstructured problem and determine the overall goal. The overall goal is to manage risk in pharmaceutical supply chain outsourcing.

2. Build the hierarchy from the top through the intermediate levels to the lowest level which usually contains the list of alternatives. The major decision criteria occupy the second level of the hierarchy. The decision maker defines the criteria that will be used to judge the alternative options. The decision risk criteria considered are geological and production, environmental and regulatory compliance risk, transportation risk, oil resource availability, geopolitical, and reputation risks. The alternative response considered by petroleum supply chain managers are retain risk, share risk, mitigate (reduce risk), and avoid risk. According to Flanagan and Norman (1993) and Lowe and Whitworth (1996), response strategy to risk can be achieved through risk reduction; risk avoidance; risk transfer; and risk retention.

FIGURE 1
STRUCTURE OF PETROLEUM SUPPLY CHAIN RISK



3. Construction of pairwise comparison matrix. Build a set of pairwise comparison matrices for each level of the hierarchy and then conduct all the pairwise comparisons. The pairwise comparison matrix A, where element a_{ij} of the matrix is the relative importance of i^{th} factor with respect to j^{th} factor, can be determined as follows:

$$A = [a_{ij}] \tag{1}$$

Where the entry in row *i* and column *j* of A (a_{ij}) indicates how much more important objective (criteria) *i* is than objective j. Each entry in matrix A is positive ($a_{ij} > 0$) and reciprocal (($a_{ij} = 1/a_{ji}$) for all *i, j* = 1, 2, 3,…*n*). "Importance" is measured on an integer-valued 1-9 scale for pairwise comparisons. It allows the transformation of qualitative judgments and/or intangible attributes into preference weights (level of importance) or numerical values. The pairwise comparisons are accomplished in terms of which element dominates or influences the order. With AHP model, a group of supply chain managers can make pairwise comparisons of the criteria using Saaty's nine-point scale. The nine-point scale seeks to know the dependence criteria, which one will influence the common criteria more and if so how much more. For example, a value of 1 between two criteria indicates that both equally influence the affected node, while a value of 9 indicates that the influence of one criterion is extremely more important than the other.

4. n(n – 1)/ judgments are needed to develop a set of matrices in step #3. Reciprocals are assigned in each pairwise comparison automatically.

5. Utilizing the hierarchical synthesis to weight the eigenvectors according to the weights of the criteria. The total is for all weighted eigenvectors corresponding to those in the next lower level of the hierarchy.

6. After completing all the pair-wise comparisons, the consistency can be evaluated using the eigenvalue (λ_{max}), to derive the consistent index (CI). Specifically, Saaty (1990) recommended that the maximum eigenvalue, λ_{max}, can be determined as

$$\lambda_{max} = \sum_{j=1}^{n} a_{ij} \; W_j/W_i, \tag{2}$$

Where λ_{max} is the principal or maximum eigenvalue of positive real values in judgment matrix, W_j is the weight of j^{th} factor, and W_i is the weight of i^{th} factor.

7. Consistency Test. Each pairwise comparison which has several decision elements for CI measures the entire consistency judgment for each comparison matrix and the hierarchy structure. Thus, CI and consistency ratio (CR) are used to determine the consistency of the comparison matrix. A matrix is assumed to be consistent if and only if $a_{ij} * a_{jk} = a_{jk} \; \forall_{i\,jk}$ (for all *i, j, and k).* To ascertain that the priority of elements is consistent, the maximum eigenvector or relative weights/λ_{max} can be determined. Specifically, CI for each matrix order *n* is determined by using (3).

$$CI = (\lambda_{max} – n)/n – 1 \tag{3}$$

Where n is the matrix size or the number of items that are being compared in the matrix.
Based on (2), the consistency ratio (CR) in (4) can be determined as below:

$$CR = CI/RI = [(\lambda_{max} – n)/n – 1]/RI \tag{4}$$

CR is acceptable, if its value is less than or equal to 0.10. However, if it is greater than 0.10, the judgment matrix will be considered inconsistent. To rectify the judgment matrix that is inconsistent, decision-makers' judgments should be reviewed and improved.

Data Collection

A survey questionnaire approach was used for gathering relational data to assess the order of importance of the petroleum supply chain risk criteria. From the hierarchy tree, a questionnaire was developed to enable pairwise comparisons between all the risk criteria at each level in the hierarchy. The pairwise comparison process elicits qualitative judgments that indicate the strength of the decision markers' preference in a specific comparison according to Saaty's 1-9 scale. Operations and supply chain managers were requested to respond to several pairwise comparisons where two categories at a time were compared with respect to the goal. The result of the survey questionnaire technique was then used as input for the AHP. The matrix of pairwise comparisons of the risk criteria given by the MNOE in the case study is shown in Table 1. The judgments are entered employing Saaty's pairwise comparison preference scale explained in no. 3. The data collected were then analyzed with the aid of AHP using Expert Choice Software 11.5.

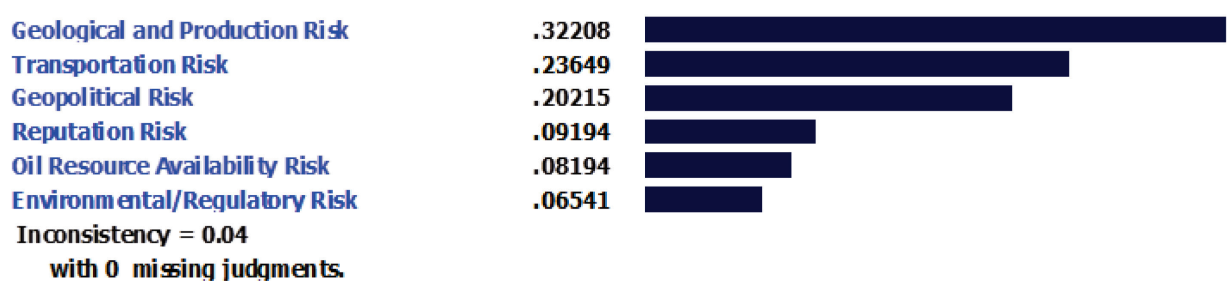
TABLE 1
PAIRWISE COMPARISON MATRIX WITH RESPECT TO GOAL

Goal	GPR	ERR	TR	OAR	GR	RR
Geological and Production Risk (GPR)	1	5	1	3	3	3
Environmental and Regulatory Risk (ERR)	1/5	1	3	2	3	1
Transportation Risk (TR)	1	1/3	1	3	1	3
Oil Availability Risk (OAR)	1/3	1/2	1	1	1/3	1/2
Geopolitical Risk (GR)	1/3	1/3	1	3	1	3
Reputation Risk (RR)	1/3	1	1/3	2	1/3	1

EMPIRICAL RESULTS AND DISCUSSION

The pairwise comparison of the major criteria priority shown in Figure 2 indicates that geological and production risk is the most important risk criterion with a priority of 0.23649 followed by transportation risk (0.23649), and geopolitical risk (0.20215), while reputation (0.09194) is considered the most lowest followed by oil resource availability risk (0.08194), and environmental and regulatory risk (0.06541).

FIGURE 2
MAJOR CRITERIA PRIORITY WITH RESPECT TO GOAL



Overall Priority

Table 2 reports the overall priority with respect to the alternative risk management strategies. According the result findings, the most important risk management strategy to select is to reduce risk (0.40936) followed by risk avoid risk 0.28762), share risk (0.17709), and retain risk (0.12597).

TABLE 2
OVERALL PRIORITY WITH RESPECT TO ALTERNATIVE CONTRACTOR

Alternative Risk Mgmt Strategy	Major Risk Criteria (CR: 0.04 < 0.10)						Overall Priority
	GPR 0.32208	ERR 0.06541	TR 0.23649	OAR 0.08194	GR 0.20215	RR 0.09194	
Reduce Risk	0.35639	0.36586	0.51088	0.45587	0.39189	0.36173	0.40936
Share Risk	0.25076	0.12381	0.13572	0.22906	0.14391	0.08958	0.17705
Avoid Risk	0.29464	0.27777	0.26138	0.13015	0.32030	0.40598	0.28762
Retain Risk	0.09821	0.23256	0.09203	0.18492	0.14391	0.14270	0.12597
CR	0.02<0.10	0.02<0.10	0.03<0.10	0.07<0.10	0.01<0.10	0.02<0.10	

SENSITIVITY ANALYSIS

Sensitivity analysis identifies the effect of changes in the priority of attributes or criteria on the major decision criteria. The sensitivity analyses are important because changing the importance of attributes requires different levels of geological and production, transportation, geopolitical, reputation, oil resource availability, and environmental and regulatory compliance risks. Figure 3-4 show two scenarios of two dimensional sensitivity analyses. Upon obtaining the initial solution with the given weight of the priorities, two dimensional sensitivity analyses mainly geological and production versus transportation risk and geological and production risk versus geopolitical risk were conducted to explore the response of the overall utility of risk management alternatives to changes in the relative importance of each attribute. The two dimensional sensitivity analyses in Figure 3 shows that reduce risk and avoid risk are the most important risk treatments. In Figure 4 the two dimensional sensitivity analyses also indicate that reduce and avoid risk treatments are the best.

FIGURE 3
TWO-DIMENSIOANL SENSITIVITY FOR NODES BELOW Goal (SCENARIO 1)

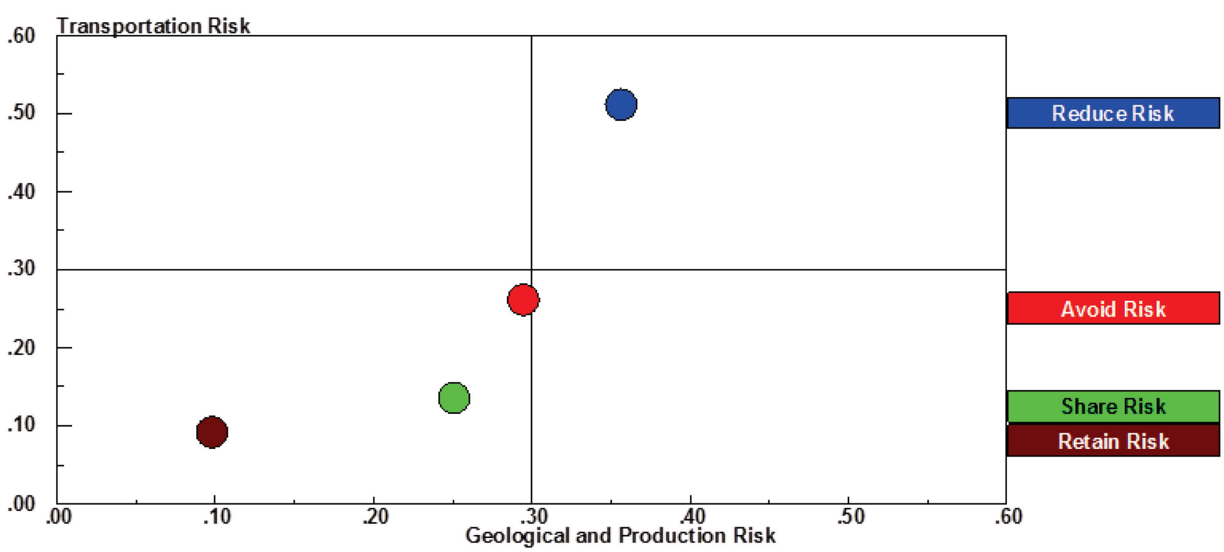
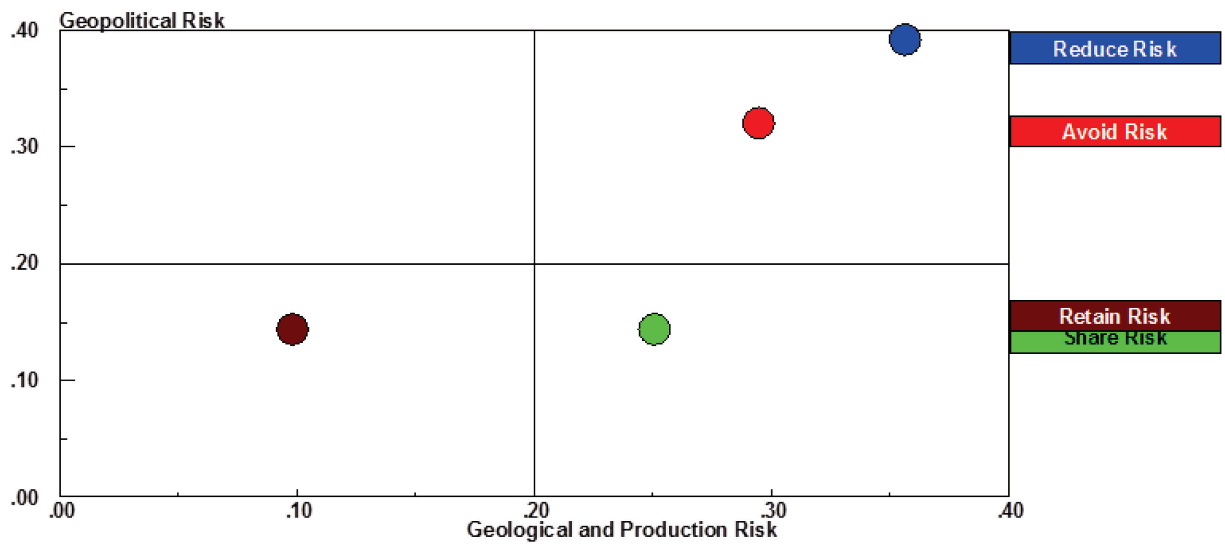


FIGURE 4
TWO DIMENSIONAL SENSITIVITY FOR NODES BELOW GOAL (SCENARIO 2)



CONCLUSION AND MANAGERIAL IMPLICATIONS

Many initiatives such as globalization, global sourcing, reduction in supplier base, and lean manufacturing to ameliorate supply chain efficiency and effectiveness have equally fueled the growth in global supply chain risks. Unmanaged risks can lead to petroleum supply chain disruption. Petroleum supply chain disruption can lead to energy shortages and the economy through fluctuating price, poor customer service, poor labor management relations, and reduction in shareholders' value. Managing risk in the petroleum supply chain can improve C-level executives' confidence in improving the commercial viability of oil and gas projects (Al-Thani, 2008).

The implications of the identified risks for petroleum supply chain operations can be significant, including supply disruptions, increase in the cost of energy, among others. Hence petroleum supply chain operation risk management must become an essential component of MNOE's overall risk management strategy. Petroleum supply chain operation risks consist of risks that a firm's earnings, shareholder's value, supply, increase in price of gasoline, among many others. Those firms that pay attention to mitigating their supply chain risks proactively will capture value, increase shareholders' value, meet global market demand, and thrive well into the future. Mitigating risks in the petroleum industry supply chain is imperative "… for maintaining continuous supplies of crude oil, the reduction of lead times, and lowering of production and distribution costs."

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