“Improvement in the Energy Supply Chain Risk Management of Oil and Petroleum Industries” – Using the concept of ANN embedded in SCM

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Abstract

Modern life without energy supply is unimaginable. Energy supply is the backbone of almost all economic activities which is powering systems and infrastructures required for functioning of modern economies and societies. Energy must be delivered to the consumers, regardless of where and how they are produced. Any disruption in the energy supply chain can degenerate into national crises. One of the major challenges globally is to sustain an undisrupted production and supply of energy resource to its consumers. The other challenge is to maximize profit and also maximize the safety while minimizing the cost of the product and considering the minimal impact on the environment. The study discusses a framework for the energy supply chain using artificial neural networks for the transformation.

Keywords: Supply Chain Management, Optimization, Artificial Neural Network, Energy Supply Chain, Production.

1. INTRODUCTION

Modern life without energy supply is unimaginable. We can say that energy in form of Electricity and Hydrocarbons play a very important role globally. But the global challenge is to make this resource available to end-users on a consistent, uninterrupted basis. And thus the motivation is required to acknowledge this global challenge.

With the global relevance of the energy, its supply and demand dynamics, the associated environment and its safety requirements, its complex production system, the processes adopted and its infrastructure, the capital outlay, etc., the energy supply chain appears to be at a significant risk. As there is no escape from the presence of risk, the high impact industries with great opportunity are searching for risk optimization schemes throughout the globe.

In this paper, we are considering a platform for data service and incorporating the concept of artificial neural networks in the supply chain management system. This paper presents how the concept of artificial neural network improves the supply chain of the industries. If we incorporate the concept of ANN with the supply chain Management solutions, there will be great improvement in the energy supply chain.

The paper also presents a simple and easy to adopt frameworks in energy supply chain to identify, quantify and mitigate risks in a systematic, structured manner. The paper also energy supply chain in general and a brief review of concepts of risk and risk management. It also describes the theory and application of NN. In the last section we have presented the result in the form of graph, the benefits and conclusion of the research.

1.1 Energy Supply Chain

In the modern world, the life without energy supply is unimaginable. But the uninterrupted supply of energy in supply chain is constrained by several bottlenecks. The classification of energy source can be primary and secondary source. The definition of primary and secondary source as given United Nations Technical report on concepts and methods in energy statics [1] is as follows:

“Primary Energy sources should be used to designate those sources that only involve extraction or capture, with or without separation from contiguous material., cleaning or grading, before the energy embodied in that source can be converted into heat or mechanical work”[1].

“Secondary Energy should be used to designate all sources of energy that results from transformation of primary sources”[1].

For primary energy, the distinguishing factor is ‘the process of extraction’ while for secondary energy, the distinguishing factor is ‘transformation processes’. Electricity is secondary source of energy transformed from coal, Natural gas and uranium and all its simplest form. So, here the supply chain includes generation, transmission and distribution. Unlike the other supply chains, there are no commercialized storage technologies for the electricity supply chain. Other simple classifications of energy are Renewable and non-Renewable sources. The definitions of Renewable and non-Renewable sources are given as:

Renewable energy is the energy which is generated from natural sources i.e. sun, wind, rain, tides and can be generated again and again as and when required. They are available in plenty and by far most the cleanest sources of energy
available on this planet [10]. Renewable energy sources include biomass, geothermal energy, hydropower, solar and wind energy. Non-Renewable energy is the energy which is taken from the sources that are available on the earth in limited quantity and will vanish fifty-sixty years from now. Non-renewable sources are not environmental friendly and can have serious affect on our health. They are called non-renewable because they cannot be re-generated within a short span of time [10]. Non-Renewable energy sources include coal, natural gas, propane, uranium and petroleum [2].

In our study, we included the case of downstream industry of the petroleum supply chain. The petroleum supply chain is initiated with the exploration of crude oil and this chain ends with the delivery of separated and converted products to the end-users. This petroleum supply chain can be shown as: Figure-1[12]

![Figure 1: Simplified Petroleum Supply Chain.](image)

The downstream industry of petroleum supply chain includes:

- Refining.
- Storage.
- Distribution.

We can summarize, the petroleum Refining by three major processes; Separation, Conversion and Purification [29]. These processes results in the production of several products and chemicals for the powering of our modern economics. The petroleum Refinery process chart [23] is shown as (Figure-2).

![Fig-2: Petroleum Refinery Process chart.](image)

The main aim of Petroleum Refinery is consistent undistributed supply of these products to end-users is the motivation for supply Risk Mitigation framework.

In our case study, we have considered the Public Sector Undertaking Organization in India. These PSUs organization sources its crude oil requirement from East, Gulf Region, Mediterranean, West Africa and Latin American sources, then stores the crude oil in a specialized underground storage facility and feeds the Refinery through a network of pipelines. The Refinery processes liters of crude oil per minutes. The refinery makes products. These products are then send to the customers through different transportation modes such as rail, trucks, and pipelines depending on the destination.
1.2 Supply Chain Management
The concept of SCM is based on two core ideas. The first is that energy products that reach an end-user represents the cumulative effort of multiple organizations, these organizations are referred to collectively as supply chain. The second idea is that while supply chain have existed for a long time, most organizations have only paid attention to what was happening within their four walls. The SCM is the active manager of supply chain activities to maximize customer’s value and achieve a sustainable competitive advantage. Supply Chain activities covers everything from product development, sourcing, production and logistics, as well as information system indeed to coordinate these activities. The organizations that make up the supply chain are linked together through physical flows and information flows. Physical flow involves the transformation movement and storage of goods and materials. They are most visible piece of supply chain. Information flows allow the various supply chain partners to coordinate their long-term plans and to control the day-to-day flows of goods and material up and down supply chain.

1.3 Risk and Risk Management Concepts
1.3.1 Risk: With every supply chain of the products from the industries to the end-users, risk is associated. As the word is ambiguous, so its meaning depends upon context users [3] and also in the field of application [4, 5]. As risk is considered as multi-dimensional construct, so it has no single definition which is applicable or appropriate in all the circumstances. But for the common understanding, we can define identify, evaluate and manage it [3, 6].

So in general, we can say risk is associated with an outcome for which one is uncertain, means that there is exposure and there is uncertainty [7]. Authors have given various definitions of risk. One says it is generally estimated in terms of likelihood and consequences [8]. Others say, it is exposure to the possibly of an undesired outcome [9]. It is a measure of degree of uncertainty surrounding the bad results of a decision [11]. It is the variation of the actual outcome from the expected outcome [13]. It is jeopardy, failure, injury, destruction [14]. Kaplan and Garrick introduced the triplet concept [15]. Defining risk as triplet,

Risk is denoted as:

\[ R = \{<Si, Pi, Xi>\}, \text{ where} \]

- \[ i = 1, 2, 3, \ldots \ldots n. \]
- \[ Si \rightarrow \text{Scenario identification} \]
- \[ Pi \rightarrow \text{Probability of that Scenario.} \]
- \[ Xi \rightarrow \text{Consequences or evaluation measure of that scenario.} \]

1.3.2 Supply Chain Risk: Tasking the triplet into consideration, Kirsten et. al. [16], narrowed the supply chain risk as: “The damage assessed by its probability of occurrence that is caused by an event within a company, within its supply chain or its environment affecting the business processes of more than one company in the supply chain negatively.”

This concept of risk was supported by Kaplan [17], William [18] and Pitchie [19]. Other authors also classified supply chain risk in meaningful categories: Christopher and Peck [20], Ann and Els [21] classified supply chain risk as supply, environmental, process, control and demand risks while sinha et. Al. [22] classified it as standards, supplier, technology and practices risks.

So in all the classifications the main factor is the ability to detect, evaluate and manage risks with the aim of minimizing either the possibility of occurrences or impact of occurrences.

1.3.3 Risk Management: The ISO 31000 standard [6] simply defines risk management as structured and systematic activities to direct and control an organization with regard to risk. Norsworthy [25] expresses it as detecting threats and putting in place plans to deter its occurrence or impact should it happen. Borge [7] expresses it as conscious actions to increase the chance of good outcomes.

From all the definitions given by authors, we can infer that the process of risk management involves structured application of policies, systems and practices to the activities of establishing the context and identifying, analyzing, evaluating, treating, monitoring and reviewing risk. This is supported by Dave et al [26]. According to Pritchrd [27] various management options are Tolerate (accept), Terminate (Avoid), Treat (reduce) and transfer (Share). Thus, because of its nature, Risk management is of critical importance in the energy supply chain.

1.4 Artificial Neural Network:
ANN is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. ANNs, like people, learn by example. [24], the diagram of Artificial Neural Network is as follows:
In the above figure the first diagram shows the training phase and other shows the Prediction phase. The training is also called as supervised learning phase while the Prediction phase represents that period when the training network is applied to a dataset it has never seen before. We will be discussing about the neural network learning, necessary conditions and stop criteria of the network.

a) Learning Process: Neural network have ability to learn from examples rather than following the set of rigid rules defined by human experts [28]. During learning/ training, network weights are adjusted to enable the network generates a response to the input as close as possible to the desired output. Then both the outputs of the networks ie., output (x) and the desired or expected output (d) are compared to generate error (e=d-x) used for network parameter adjustments. To measure how close the desired output (d) is to the output (x), the correlation coefficient is used, which is defined as:

\[ r = \frac{\sum (x_i - \bar{x})(d_i - \bar{d})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (d_i - \bar{d})^2}} \]  

This equation indicates

\[ r = 1 \] → a perfect positive linear correlation between x and d
\[ r = -1 \] → a perfect linear negative correlation if x=-1
\[ r = 0 \] → no correlation between network and desired output

b) Necessary conditions for Neural Network: A clear understanding of the problem to be modeled is required. A representative data is required from right environment and also adequate data size for network training and testing is a necessity for the neural network.

c) Termination of training (Stop criteria): To prevent the network from overtraining, appropriate cross validation method needs to be applied to terminate training at a point when error begins to rise [31].

1.5 Applications of Neural network
Artificial Neural Network concept and methodology is applicable in our day to day life. Some of the real world applications [33] are as follows:

- Financial modeling – predicting the stock market
- Time series prediction – climate, weather, seizures
- Computer games – intelligent agents, chess, backgammon
- Robotics – autonomous adaptable robots
- Pattern recognition – speech recognition, seismic activity, and sonar signals
- Data analysis – data compression, data mining
- Bioinformatics – DNA sequencing, alignment

2. Model Formulation and Methodology of Supply Chain Management using Neural Network

For the formulation and methodology of supply chain management using the concept of Artificial Neural Network, supply chain risk is categorized into supply risk (purchasing procurement), process or operational (such as manufacturing, quality assurance) and demand (distribution, sales) risks. The categories of supply chain risk are:

The supply and demand risks are External risks and Operational Risk is the Internal Risks. In order to formulate the key risks indicators for each of these categories methodologies of the management are applied such as interviews, surveys from experts, questioners from production units. Then after getting the information or data it is used as input factors to the neural network model. Some of the inputs actual delivery and are compared with target delivery times, actual production is compared with planned or target production. Using a neural network program, [30], Figure 6 shows the procedure followed in formulation and training network.
So if the concept of artificial neural network is applied to the current supply chain management of the organization then we can improve the production of the organizations without much risk. Here to arrive at the best network topology, training should be done for a few times with different random initial conditions but saving the best network weights each time for further analysis.

This supply chain covers from crude imports to delivery of the products to the end users; the fault may occur when the right quantity of refined products does not reach the customers at the right time.

3. Results:

Indian refining Industry such as Indian Oil Corporation Ltd. has done exceedingly well in establishing itself as a major player globally. India is emerging as a Refinery Hub and refining capacity exceeds the demand. In the last decade tremendous growth can be seen in refining sector. The country’s Refining capacity has increased from 62 Million Metric Tons per Annum in 1998 to 215.066 Million Metric Tons per Annum at present, comprising of 22 Refineries. This can be shown as:

![Graph showing Million Metric Tones per Annum from 1998 to 2013](image)

Out of 22 Refineries, 17 are under public sector, 3 under private sector and 2 under joint venture. During the survey it was found that IOCL has implemented Honeywell’s Supply chain Management solution to integrate and optimize the supply chain of the five separate refineries. The project has resulted in the following benefits [32]:

- Integrated supply chain planning which optimizes the entire supply chain providing higher margins and increased profitability.
- Crude selection and allocation which takes into account product demands, refining capabilities and effect of crudes already procures.
- Optimal refinery production planning considering crude arrays, unit capacities, product specifications and demands and feedstock availability.
- Optimal distribution planning considering transportation costs, taxes and duties and transportation constraints.

IOCL experimented major benefits on account of:

- Improved visibility into its supply chain process across the 5 selected refineries.
- Investment analysis for refinery units, pipelines etc.
- Analysis to formulate strategies to meet future scenarios like change in specifications [32].

SCM solutions provide the following [32] modes:

- Demand planning: For demand forecasting and aggregation of the final demand numbers.
- Integrated planning: for complete IOCL refinery supply chain
- Distribution Planning: for generating operational plans for feedback allocation and product distribution.
- Production Planning: for generating operational plans for production.

Benefits:

- Optimize the supply chain with real time knowledge collaboration and visibility across the enterprise.
- Decisions are made quickly.
- Disruptions are minimized.
- Improves profitability through measurable inventory and product cost reduction.
- Faster reaction to market opportunities.
- Improved customer’s relations.
- True collaborations with suppliers and customers [32].
4. Conclusion:
The computing world has to gain a lot from the neural network. It is concluded that when the oil and petroleum industries in India have applied the supply chain management along with neural network concept, then their production have been improved. As the neural network learns from training and it has continuous feedback and error detection which makes them very flexible and powerful. So at every point in the network we can find out the expected outcome and the actual outcome. And in this ongoing process of SCM and continuous evaluation of the outcomes, we can improve the productivity. When the ANN is embedded with SCM; there is improvement in the production, planning and control of the Supply Chain of the industries. It maximize profit, maximize safety and minimize the impact on the environment. In the future the importance will be given on the other areas of application and implementation of Neural Network with supply Chain Management with a variety of industrial projects across diverse domains.

REFERENCES
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