3.3. Research Techniques and Tools

Step 1 - Systematic Review

The research was started with a literature survey to find out the approaches, gaps and applicability of existing available literature related to distribution network optimization on petroleum supply chain. Systematic review of the literature is the first step of the research that was conducted to identify the studies that have been already done related to petroleum supply chain. The commencement is via literature review of the research area that will be conducted to identify the fundamental characteristics in petroleum supply chain. Then results of the literature survey to business context and research questions was formulated. The objective of this phase is to create consensus on data, constraints, requirements, assumptions, and modeling approach for developing the model.

Step 2 - Exploratory Study

An exploratory study was carried out by interviewing an expert on the Sri Lankan petroleum distribution network. That was caused to identify inefficiencies in the petroleum distribution network and how it will help to improve optimize the distribution network. Thorough knowledge can be gained by interviewing the experts on that particular area. Therefore, this questionnaires was created to get inputs in the experts' perspective of the current issues and inefficiencies of Sri Lankan petroleum distribution network.

Step 3 – Analysis Petroleum supply Chain

The objective is to create consensus on data, constraints, requirements and assumptions on which the network design will be based, storage and distribution related data, operational constraints, future trends and business requirements.

Step 4 – Network Optimization

An overall distribution network that is efficient, meeting all requirements, minimizing cost, minimizing structurally cost based issues and supports any other management constraints and satisfying constraints is developed, via an optimization model.

Step 5 – Exact Mathematical Model

Mathematical model is a scientific approach in a decision-making process to find an optimal, or the absolutely most efficient, way to achieve an objective while simultaneously satisfying all constraints associated with achieving the objective. Typically, the objective is maximization or minimization of an analytical mathematical expression with a large amount of variables. Quite often, the objective function is a mathematical expression of the revenue or cost function. The optimization can be simplified in to a mathematic subject, based on causing critical factors in petroleum distribution network. The distribution network problem is one of the most comprehensive strategic decision issues that need to be optimized for the long term efficient operation of whole supply chain. VBA (Visual Basic Application) is used to gain exact mathematical optimization focused on petroleum distribution network.

Step 6 – Testing and Validation

Testing the data using the model will be done, and it will also be validated and verified using appropriate techniques. The final optimization is ensured to be giving an accurate output under a wide variety of conditions.

4. Data Acquisition

An exploratory study was carried out by interviewing an expert on the Sri Lankan petroleum industry. The expert interviews was conducted to acquire the needed data to conduct the research. The use of interviews can help to gather valid and reliable data that are relevant to the research questions and objectives. Interviews were carried out by two stages. The first stage interviews were conducted to explore in depth a general area in which authors are interested by using unstructured in-depth interviews.

It was helpful to understand the general petroleum distribution in Sri Lanka and get clear idea about the aspects that authors want to explore. Unstructured in-depth interviews gave an opportunity to talk freely about the research

purpose. The second stage interview was formalized and structured, using interview questions for each research participant. Interview responses were recorded and written by the author. The nature of the questions and the ensuing discussion that data is recorded by audio-recording the conversation and note taking. The interview questionnaire was used as a data acquisition tool. This is the major method of data acquisition.

Subsequently, identified the full variety of secondary data that are available with Sri Lankan petroleum industry. Data that have already been collected for some other purpose, perhaps processed and subsequently stored, are termed secondary data. Secondary data can provide a useful source from which to answer, or partially to answer the research question mentioned in chapter 1. Secondary data include both raw data and published summaries. Sri Lankan petroleum industry collects and stores a variety of data to support their operations: for example accounts of sales and distributions, accounts of finance and including reports about daily refined products, distributed products, petroleum product demand all over the country etc. These archival records and documents was gathered in order to acquire the required data.

4.1. Data Analysis Methods

Qualitative Analysis

Qualitative data refers to all non-numeric data or data that have not been quantified and can be a product of all research strategies. Qualitative data analysis method is used when there is complex and real data which are extracted from unstructured data acquisition methods. To be useful these data need to be analyzed and the meanings understood. In this research, authors have used the unstructured in-depth interviews in the first stage of exploratory study. Therefore qualitative analysis method was used to analyze the data that are extracted from in-depth interviews with petroleum industry domain experts. There are three main common qualitative analysis approaches, summarizing (condensation) of meanings, categorization (grouping) of meanings and structuring (ordering) of meanings using narrative. All of these can be used on their own, or in combination, to support interpretation of the acquired data. Subsequently, descriptive analysis is used as a qualitative analysis method.

Quantitative Analysis

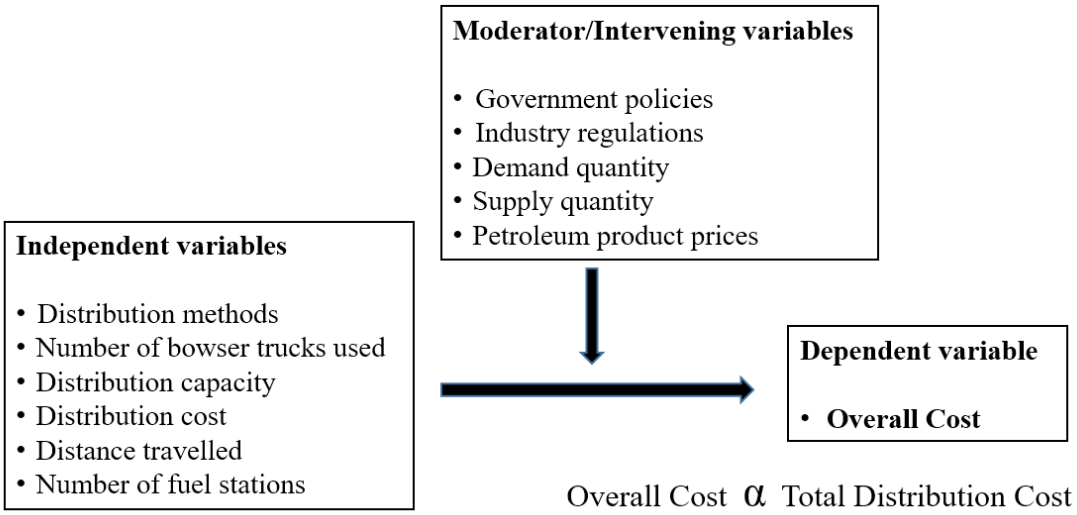
Quantitative data refers to all numeric data or data that have been quantified. Quantitative data in a raw form, that is, before these data have been processed and analyzed, convey very little meaning. These data, therefore, need to be processed to make them useful, that is, to turn them into information. In this research, authors have used the structured interview in the second stage of exploratory study. As structured interviews are used to collect quantifiable data they are also referred to as 'quantitative research interviews'. Therefore quantitative analysis method was used to analyze the data that are extracted from structured interviews with petroleum industry domain experts. Quantitative analysis techniques such as graphs, charts and statistics allow to do this; helping to explore, present, describe and examine relationships and trends within the acquired data.

4.2. Data Reliability and Validity

Reducing the possibility of getting the wrong outcomes means that attention has to be paid to two particular emphases on research design that are reliability and validity. Reliability refers to the extent to which the data collection techniques or analysis procedures will yield consistent findings. Validity is concerned with whether the findings are really about what they appear to be about. The reliability and validity of the acquired data, are functions of the method by which the data were collected and the source. In this research, the proposed model is validated with complex and real data that was collected from Sri Lankan petroleum industry.

5. Findings & Results

A conceptual framework has been developed based on the research findings,



Overall Cost α Total Distribution Cost

Overall Cost = Total distribution Cost via CPSTL trucks, hired trucks and railway + Inventory Cost

A mathematical model has been developed based on the research findings,

$$Z = \sum_{s} P_s \left(\sum_{i,j,k} \left(XT_{i,j,k,s} \times CT_{i,j,k} + XH_{i,j,k,s} \times CH_{i,j,k} + XR_{i,j,k,s} \times CR_{i,j,k} \right) + \sum_{i,k} \left(XI_{i,k,s} \times IC_{i,k} \right) \right)$$

Indices

i , j – Nodes

i - Distribution center

j - Fuel station

t - Distribution type

k - Product

s - Scenarios

Parameters & Variables

- $XT_{i,j,k,s}$ - Volume of product k carrying by truck between nodes in a scenario
- $XH_{i,j,k,s}$ - Volume of product k carrying by hired truck between nodes in a scenario

- $XR_{i,j,k,s}$ - Volume of product k carrying by railway between nodes in a scenario
- $XI_{i,k,s}$ - The initial volume of product k at a distribution center in a scenario
- $XF_{i,k,s}$ - The final volume of product k at a distribution center in a scenario

- $D_{i,j,t}$ - Distance between nodes for a distribution type
- $IC_{i,k}$ - Inventory cost of product k at distribution center
- $UT_{i,j,k}$ - Unit cost for CPSTL bowser truck distribution
- $UR_{i,j,k}$ - Unit cost for railway distribution
- $CH_{i,j,k}$ - Hiring cost for the hired bowser trucks from private sector
- $CT_{i,j,k}$ - Distribution cost for CPSTL truck

$$CT_{i,j,k} = UT_{i,j,k} * D_{i,j,t}$$

- $CR_{i,j,k}$ - Distribution cost for railway

$$CR_{i,j,k} = UR_{i,j,k} * D_{i,j,t}$$

6. Conclusion

In this research, the proposed model is validated with complex and real data that was collected from Sri Lankan petroleum industry (CPSTL, Kolonnawa). VBA is used to gain exact mathematical optimization. The qualitative and quantitative analysis of data has been done to evaluate the research findings. It is concluded from the study that the overall cost of the petroleum distribution network can be minimized by optimizing the causing critical factors. Thus, this study depicts a distribution network optimization model, with the purpose of minimizing the cost, based on inefficiencies and causing critical factors which are specific for Sri Lankan petroleum industry. As a result, the developed optimization model would enable the Sri Lankan petroleum industry to achieve higher performance leading to competitive advantage.

References

Altiparmak, F., Gen, M., Lin, L. and Paksoy, T., A genetic algorithm approach for multi-objective optimization of supply chain networks, Computers & Industrial Engineering, 51, pp. 196- 215, 2006.

Berman, O. and Wang, Q., Inbound Logistic Planning: Minimizing Transportation and Inventory Cost, Transportation Science, Vol. 40, No. 3, pp. 287–299, 2006.

Chandrasekaran, S.D., and Gabriel, M.K., Optimization of Supply Chain Network Using Genetic Algorithm, Manufacturing and Industrial Engineering, Issue 3,pp. 30-35, 2010.

Cheng-Liang, C. and Wen-Cheng, L., Multi-objective optimization of multi-echelon supply chain networks with uncertain product demands and prices, Computers and Chemical Engineering 28 (2004) 1131–1144, 2004.

Daniela, A. and Maria, G.S., Distribution network design: New problems and related models, 9 European Journal of Operational Research 165, pp. 610–624, 2005.

Ghatee, M. and Hashemi, S.M., Optimal network design and storage management in petroleum distribution network under uncertainty, Engineering Applications of Artificial Intelligence 22 (2009) 796–807, 2009.

Hisain, E., Planning and optimizing of petroleum industry supply chain and logistics under uncertainty, *Sheffield Hallam University Research Archive (SHURA),* at:http://shura.shu.ac.uk/18151, 2017.

Rodrigue, J.P., A Maritime Geostrategy of Petroleum Distribution, Volume 48, n° 135, décembre, 2004.

Sergio, M.S. and Pinto, M., A general modeling framework for the operational planning of petroleum supply chains, *Computers and Chemical Engineering* 28 (2004) 871–896, 2004.

Sha, D.Y. and Che, Z.H., Supply chain network design: partner selection and production/distribution planning using a systematic model, *Journal of the Operational Research Society,* 2005.

Siddharth et al., Evaluating petroleum supply chain performance Application of analytical hierarchy process to balanced scorecard*, Asia Pacific Journal of Marketing and Logistics Vol. 20 Issue: 3, pp.343-356, 2008.*

Truong, T. H. and Azadivar, F., Simulation based optimization for supply chain configuration design, *35th conference on winter simulation: driving innovation*, vol. 2, pp. 1268-1275, 2003.

Verderame, P.M. and Floudas, C.A., Multisite Planning under Demand and Transportation Time Uncertainty: Robust Optimization and Conditional Value-at-Risk, *Frameworks Industrial Engineering Chemistry Research*, Vol. 50, pp. 4959–4982, 2011.

Yasaman, K. and Joshep, S., Modeling downstream petroleum supply chain: The importance of multi-mode transportation to strategic Planning, *Transportation Research*, Part E 83 (2015) 111–125, 2015.

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