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A Comparative Analysis of Analog and Digital Gantries in Nigeria's Hydrocarbon Depot Management

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Abstract

This study is focused on the comparative study of a Nigerian Independent Petroleum Company (NIPCO) digital depot operation and Consolidated Oil (CONOIL) analog depot operation in petroleum product supply chain. The analytical tools used in this study are; DEA Model and Censored Normal Regression Analysis. Censored Normal Regression Analysis was used to analyse the relationship between depot output (ullage savings) and gantry time. The result of the study suggests the following: Firstly, NIPCO is relatively more efficient than CONOIL. Secondly, the coefficient of gantry time is negatively related to output. This implies that increasing gantry input (time) will reduce the productivity of the depot output and vice versa.

Keywords: *Supply Chain Management, Gantry, Efficiency, Information Technology, Bulk Road Vehicles and Petroleum Product.*

1. Introduction

The petroleum downstream sector is a mature, competitive and complex industry (Roeber 1994; Hackworth, 2004). According to Masseron (1990) and Yergin (1991), the petroleum industry is a significant sector from different points of views. For instance, the industry is as strategic as the basic transportation and other essential activities of the economy of any country. As a result of its strategic nature, it is in the centre of the international geopolitical and macroeconomic panorama. Hence, a majority of governments maintain careful control of the development of the industry or even directly manage the operations in their respective countries (Masseron 1990). The supply chain of the petroleum downstream sector has distribution and marketing as a well differentiated part of the chain where focused planning and scheduling is needed. The distribution echelon of the chain demands the efficient use of the tools of management and the seizure of market opportunities in an increasingly competitive environment. Nowadays, firms are in the era of improving the organizational competitiveness, in order to be able to compete within the global market. This trend is applicable to all international and national competitive businesses. The competitive business environment today has resulted in increasing cooperation amongst individual firms as supply chain networks. The petroleum industry is one of those dynamic and competitive industries that strive to remain competitive against all odds. In 2006 the petroleum industry supply chain faced significant challenge such as the geo-political instability in supply areas and increased focus on terrorism and security threats, coupled with the effect of 2004 hurricane season on the United States of America's Gulf Coast chemical heartland. In Nigeria, the importation and distribution of petroleum products had its peculiar challenges, notably as a result of the chain reaction from pipeline vandalisation, kidnapping of oil expatriates, just to mention a few.

2. Background of the Case Companies

Conoil Plc. is a company involved in the production, distribution and marketing of petroleum products in Nigeria. This company originally started in 1958 as National Oil, which is a subsidiary of Shell Petroleum Trading Company that is in charge of product distribution. Conoil was incorporated as a public company in 1989. Until recently, when the Federal Government divested from the company, the shares of the company were held at 40% each by the NNPC and Shell Petroleum of United Kingdom. The United Kingdom group sold its 40% interest to the government just before the government re-advertised the sale of its interest in the company. This made it possible for the government to make 80% of the company available for the public in the privatization program that resulted in the acquisition of 60% of the company by ConPetro which was later changed to Conoil Plc., in 2000. Conoil Plc. markets petroleum products which includes AGO, PMS, HHK, ATK, LPFO, Chemicals, Base Oil, etc. Nigeria Independent Petroleum Company Plc (NIPCO) is an indigenous private depot that is responsible for selling of products to over 4000 fuel stations of independent petroleum marketers, out of over 10800 service stations nationwide. According to NIPCO boss, Girish Sanadhya in 2006, tankage capacity has increased to a total of about 50 million litres with the refurbishment of 12 tanks inherited from Unilever Plc. They claim to sell 325 million litres of products to marketers yearly and in 2006 they dispensed over 600 million litres of petroleum products which is about 42% capacity utilization of the company's total installed capacity of 1.3 billion litres.

3. Problem Statement

The Supply Chain Management (SCM) system of the downstream sector in Nigeria is subject to further challenges such as the regular attack on oil installation in the Niger Delta by militant groups, the incessant kidnapping of expatriates, and the vandalization of pipelines, illegal bunkering and lack of maintenance, extinct railway and un-dredged problematic waterways of Nigeria. The distribution of refined petroleum products into the hinterland by oil firms has basically rested on the shoulders of the road mode, which is cumbersome in nature, coupled with its attendant problems such as monopoly, congestion, costs, pollution, etc. The NNPC as the government owned overseer of the Nigeria's oil industry, saddled with the responsibility of purchasing petroleum and its products and by-products and treating, processing, mining and marketing petroleum products is backed by certain law which gives it an undue privilege, such the purchase of 445000 barrel per day (bpd) of domestic crude which is exactly how much all the refineries would refine at full capacity. This privilege is irrespective of the actual capacity used by the refineries. NNPC also enjoys the privilege of buying crude at a discounted rate regardless of the international price of crude. Another, privilege is to sell what refineries do not use up at the refineries at prevailing world market price

4. Research Questions

The above problem statement led to the following research questions:

- Does gantry type and Ordering Process affect the Supply Chain process of PMS to final consumers?
- Is value chain transfer observed in supply chain of PMS?
- Amongst the two companies of study, which is most efficient?
- Is there significant relationship between gantry utilization time and depot output (ullage savings in litres)?

5. Objectives

The broad objective of this study is to investigate the influence of ICT integration on the Petroleum downstream supply chain, and to specifically:

- Identify critical node in the supply chain of petroleum products in depots operations.
- Ascertain the main cause of delays in the distribution of petroleum products in the depots.

6. Hypothesis

In order to draw a reliable conclusion from the study a null hypothesis is formulated:

- Ho: There is no significant relationship between gantry (utilization) time and depot output (u llage savings in litres).

7. Literature Review

7.1 Supply Chain Defined

Supply Chain has been defined by so many scholars since its public exposure by a consultant named Keith Olivia in 1984. Supply chain evolution according to Lambert (2001) has been driven by the need to fulfil critical business imperative over the last 20 years. The concept of Supply Chain arose due to the globalization of market economies, rising costs of production /manufacturing and the need to shorten product life cycles. Today, a new concept is added to the above, which is the need for reverse logistics, product recovery for the purpose of recycling, remanufacturing and re-use at the highest level. Lambert (2001) argues that supply chain is not a chain of business with a one-to-one or business- to-business (B2B) relationship, but more than that. Until recently, most practitioners, consultants and academia view supply chain as not as different from the contemporary understanding of logistics as defined by the Council of Logistics Management in 1986 who viewed supply chain as logistics outside the firm to include customer and supplier. Mentzer et al (2001) supported that supply chain is directly involved in the upstream and downstream flow of products, services, finance and/or information from a source to a customer. Considerably, for a firm to be fully effective in a supply chain, its internal logistic operations need to be integrated, which means that the firm must be effective and efficient to span boundaries with customers, vendors and third party services providers. It is also observed that there are 3 degrees of supply chain complexity.

Hence, supply Chain is how organizations are linked together as viewed from particular company. It is the linkages of services or goods, extends from suppliers to the company itself and on to customers. It comprises the interconnected order and delivery processes (including Logistics) up to integrated company processes from product development to cyclical joint planning efforts of all companies participating in the supply chain. This operation is so cumbersome that there is need for a special method of managing the complex activities. The next section will dwell on Supply Chain Management.

7.2 Supply Chain Management (SCM)

Based on the emerging distinction between Supply Chain Management and Logistics, in 2003, Council of Logistics Management modified the definition of logistics as a subset of SCM which includes inbound and out bound transport management, fleet management, warehousing, material handling, order fulfillment, logistic network design, inventory management, supply/demand planning and management of third party logistics service provider. SCM is more of a strategic planning of logistics operation from the supplier's supplier to the consumer's consumer.

LaLonde (1997) proposes that SCM is the process of management of relationships, information and materials that flow across enterprise borders to deliver enhanced customer service and economic value through synchronized management of the flow of physical goods and associated information from sourcing to consumption. The critical difference between the traditional functions and the process approach is that the focus of every process is on meeting the customer's requirements and that the firm is organized around the processes (Cooper et. al. 1997). Davenport (1993) defines process as a structured and measured set of activities designed to produce a specific output for a particular customer or market.

Lambert et al (1998) added that SCM is the integration of key business processes from end user through original supplier that provide products, service and information. Hence, adding value to customers and other stakeholders. A supply chain is the series of activities and organizations that materials both tangible and intangible, move through on their journeys, from initial suppliers to function responsible for moving materials through their supply chains. For the sake of this study we will adopt the following definitions.

SCM is the delivery to customers, goods of economic value through integrated management of the flow of physical goods and associated information, from raw materials sourcing to delivery of finished products to consumers. SCM is the management of the entire value-added chain, from the supplier to the retailer and the final customer. SCM is concerned with improving both efficiency (i.e. cost reduction) and effectiveness (i.e. customer service) in a strategic context (i.e. creating customer value and satisfaction through integrated SCM), to obtain competitive advantage that ultimately brings profitability. Hence, SCM is the implementation of Supply Chain Orientation (SCO) across suppliers and customers.

8. Research Methodology and Approach

In this study both deterministic and behavioral approaches were adopted. The approaches compensate for the lapses resulting from inadequate source of data from the studied companies. The approach shows the depot as the production frontier with variables input and output variables, which when employed in different proportion determine the most efficient depot reordering process between NIPCO and Conoil depots.

9. Analytical Model

The analytical model used in this study is the data envelopment analysis (DEA) Model. DEA Model was used to determine the relative efficiencies of the systems.

10. Data Envelopment Analysis (DEA) Model

DEA literally is Data Envelopment Analysis model. It is a non-parametric (i.e. deterministic (certainty)) model for measuring the efficiency of Decision Making Units (DMU) with multiple inputs and multiple outputs as one of its strong characteristics over linear programming application. DEA is used in this study because of its suitability in analysing efficiency of transit services. This model applies when comparing the efficiency of the depots to know the most efficient amongst the DMUs. DEA as developed by Charnes et al. (1978), who explained that, suppose we have a set of n peers DMUs which produce multiple output vector Y by using observed multiple input vector X respectively. Then the production possibility set will be defined as follows: F= {(Y, X)/X can produce Y }(Po- Kyung and Prabir De 2004)

Where in this study n=Nipco, Conoil, **x**=Gantry Hand Time, Order Process Time, BRV Capacity, etc. **y**=Time savings, Ullage throughput, BRV availability (i.e. number of BRV calls), etc. Therefore a production technology can be represented by a set of DMUs that satisfies Pareto efficiency conditions. DMU is the production units (depots) that transform inputs into outputs. According to Cooper et al (2004), the performance of a DMU is efficient if and only if it is not possible to improve any input or output without worsening any other input or output, while the performance of a DMU is inefficient if and only if it is possible to improve some input or output without worsening some other input and output (Pareto-Koopmans Definition of Efficiency). Charnes et al (1994) developed several formulations as an approach to DEA. In this research the main question is with respect to minimization of inputs that firms are capable of. In this way an approach has been chosen, which is input-oriented model with Constant Return to Scale and Variable Return to Scale analysis. The proposed model involves the following problem of linear programming.

Formulas

Input-oriented Primal (BCCp-I)

$\text{Min } Zo=\Theta\text{-}\epsilon.1^{\mu} s^{+}\text{-}\ \epsilon.1^{\mu} s^{-}$

$\Theta, \lambda, s^{+}, s^{-},$

$\text{s.t. } Y\lambda - s^{+}$

$\Theta X_{o} - X\lambda\text{-}s^{+}$

$1^{\mu}\ \lambda \geq 1$

$\lambda, s^{+}, s^{-} \geq 0$

Input-Oriented BCC Dual (BCCd-I)

$\text{Max } Wo = \mu^{T}Y_{o} + u_{o}$

μ, v

$\text{s.t. } V_{T}Xo = 1$

$\mu^{T}Y - V^{T}X + u_{o}\, 1^{\mu} \leq 0$

$\mu^{T} \leq -\ \epsilon.1^{\mu}$

Where,

X= input vector used in the DMUs.

Y= output vector produced by DMUs.

Є=is a constant non-Archimedean (infinitesimal of the order of 10-6) that insures no input or output is given a zero weight, s+ and s- are the slack vectors for output and input respectively.

ϴ=represents the proportional reduction of the input in relation to the amount of the projected input. The optimal value of λ forms a composite unit outperforming the DMU under analysis and providing targets for this DMU to identify sources of its inefficiency. This model is known as input oriented BCC, the initial being in recognition of its formulators

(Banker, Charnes and Cooper 1984). Banker et al. (1984) observed that it is true that DEA has been applied in analyzing ports but the similarity of ports and depots has led to the choice of this model in comparing ICT integration in SCM with the traditional (analog) system to confirm the most efficient system (Po-Kyung and Prabir De, 2004).

11. Data Collection Methods

In obtaining data, the Supply and Distribution Department of the two firms of study were very encouraging. Cluster Random Sampling design was also used to help in confirmation of some quantitative and qualitative data which were collected through primary and secondary methods. The primary data were obtained through firms Supply and Distribution department and direct observations of the 2 firms. Personal interview and direct observation of operation of the depot operators, fuel station (dealers) and other stakeholders in the supply chain was done. The combination of personal interview and direct observation availed the researcher opportunity for thoroughness in questions and answers section.

12. Data Presentation, Analysis of Results and Discussion

12.1 Data Presentation

Data presentation is classified in two phases. To ascertain the result of the analysis, secondary data as regards the performance of these variables from the companies of study further proved the authenticity of the survey responses as shown in Table 4.1 below which is the average secondary data from the firm for 12months.

Table 1: Respondents Statistical Data on Input and Output Variables Classification

	Input variables		Output variables			
Variables	Gantry Hand Time	Ordering Pro Time	BRV Capacity	Ullage Throughput	BRV Availability	Time Savings
Percentages	100	85	90	90	90	70

Source: Field Survey.

Data (Average Values) of Firms' Operational Input and Output Variables before analysis using DEA Model

	Input variables		Output variables			
	Gantry Hand Time (min.)	Ordering Pro Time (min.)	BRV Capacity	Ullage Thruput(ltrs)	BRV Availability	Time Saving(min.)
Nipco	122,960	5	300	229,703,101	2,685	53,700
Konoil	291,156	5,940	300	155,420,101	434	19,920

Source: Konoil and Nipco plc. (Units in minutes and litres)

13. Presentation of DEA Model Results

Table 2: Efficiency Result using DEA-CCR Model-CRS (Input –Oriented)

Efficiency scores	
digiNipco	1.0000
anaConoil	0.6766

Efficiency Result using DEA-BCC Model-VRS (Input –Oriented)

	Efficiency scores	Scale efficiencies	Returns-to-scale	CCR score	NIRS score
digiNipco	1.0000	1.0000	constant	1.0000	1.0000
anaConoil	1.0000	0.6766	increasing	0.6766	0.6766

Inputs – Outputs Slack result using the DEA Model

Input/ output slacks

	GantryHandT	OrderingPT	BRV Capacity	UllageThruP	BRV Availblty	TimeSavings
digiNipco	0.00	0.00	0.00	0.00	0.00	0.00
anaConoil	113,803.59	4,015.70	0.00	0.00	1,382.71	16,414.12

13.1 Presentation of Regression Analysis Results

Table 3: Regression Analysis Result

```
Censored-normal regression                         Number of obs   =         24
                                                   LR chi2(1)      =      47.67
                                                   Prob > chi2     =     0.0000
Log likelihood = -227.86612                        Pseudo R2       =     0.0947

------------------------------------------------------------------------------
  ullage_sav |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
 gantry_time |  -1489.765   183.1213    -8.14   0.000    -1868.581    -1110.95
       _cons |   1.85e+07    1592319    11.63   0.000     1.52e+07    2.18e+07
-------------+----------------------------------------------------------------
      /sigma |    2739066   514200.1                       1675362     3802770
------------------------------------------------------------------------------
  Observation summary:        10  left-censored observations
                              14     uncensored observations
                               0 right-censored observations
```

Table 3 shows the result from the censored-normal regression application in the analysis of the relationship between ullage savings (output) and gantry time (input).

Table 4: T Test Results

```
. ttest gantry_time, by(Gantry_typ)

Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
Analog_G |      12       24263    5027.863    17417.03    13196.75    35329.25
Digital_ |      12    10246.67     2142.01    7420.141    5532.134     14961.2
---------+--------------------------------------------------------------------
combined |      24    17254.83    3045.926    14921.93    10953.86    23555.81
---------+--------------------------------------------------------------------
    diff |            14016.33    5465.127                2682.354    25350.31
------------------------------------------------------------------------------
    diff = mean(Analog_G) - mean(Digital_)                        t =   2.5647
Ho: diff = 0                                     degrees of freedom =       22

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9912         Pr(|T| > |t|) = 0.0177          Pr(T > t) = 0.0088
```

Table 4 shows the result from the two-sample t test gantry time by gantry type.

14. Results Interpretation

14.1 DEA Model Result Interpretation

Table 2 shows the efficiency score result of the CCR model (i.e Charnes, Cooper, Rhodes), also called Constant Return to Scale for Nipco and Conoil depots. The efficiency score shows that the Nipco has 1.000 while conoil has 0.6766.

Table 2 above shows a more detailed efficiency score result using the BCC model, which is Variable Return to Scale for Nipco and Conoil depots. It shows the decomposition of the “global” efficiency (i.e. CCR efficiency) into a “local” pure technical efficiency. The efficiency score in the first column shows 1.000 for both depots, with Nipco row having blue background while Conoil row has cyan background. But the scale efficiency column of the same table 2 shows Nipco having 1.000 while Conoil has 0.6766. The Return to Scale column of table 2 shows that Nipco has Constant Return to Scale while Conoil has Increasing Return to Scale. The CCR score column shows Nipco having 1.000 while Conoil shows 0.6766. The last column “NIRS Score” on table 2 shows Nipco having 1.000 while Conoil has 0.6766.

Table 2 also shows slack input/output results. First column- *GantryHandTime* shows Nipco having 0.00 while Conoil has 113,803.59. Second column-*OrderProcessTime* shows Nipco having 0.00 while Conoil has 4,015.70. Third column-*BRV Capacity* shows Nipco having 0.00 while Conoil has also 0.00. Fourth column-*Ullage Throughput* shows both Nipco and Conoil having 0.00. Fifth column-*BRV Availability* shows Nipco having 0.00 while Conoil has 1,382.71

and the last column –*Time Savings* shows Nipco having 0.00 while Conoil has 16,414.12. This outcome implies that Conoil has slacks while Nipco does not have slacks.

The table 1 shows virtual inputs/outputs result which show in its first column- *GantryHandTime* with Nipco having 122,960.00 with 0.00%, while Conoil has 122,960.00 with 57.77%. The Second Column –*OrderProcessTime* shows Nipco having 5 with 0.00% while Conoil has 5 with 99.92%. The Third column-*UllageThroughput* shows Nipco having 300 with 0.00% while Conoil has 300 with 47.79%. The fourth column –*BRV Availability* shows Nipco having 2,685.00 with 0.00% while Conoil has 2,685.00 with 518.66%. The final column–*TimeSavings* show Nipco as having 53,700.00 with 0.00% while Conoil has 53,700.00 with 169.58%. This result shows that Nipco having 0.00% has no need for improvement while Conoil has much need for improvement.

15. Discussion of Results

Table 2 shows that Nipco is shown to be Pareto-Koopmans efficient which means fully efficient (1.0000) while Conoil is less efficient (0.6766) which means Farrel efficient. Table 2 also shows a more detailed efficiency result which is based on Variable Return to Scale, which represents a more strict “local” definition of efficiency devoid of scale effect. The efficiency Scores on table 2 shows both Nipco and Conoil as having 1.000 which means that they are both technically efficient. However, the colour difference with Nipco having blue background while Conoil has a cyan background is another indication that Nipco efficiency is stronger than that of Conoil. The cyan colour of the Conoil result means that it can still accept some improvements by altering its input mix. The Return to Scale column that shows that Nipco has a constant return to scale means that the input mix is perfect and gives a corresponding perfect output mix under the same condition, while Conoil has increasing return to scale which indicates that a unit input mix produces a more than a unit output mix. These indicators show that the companies’ efficiency is different. Nipco is shown again to be Pareto-Koopmans efficient while Conoil is Farrel efficient.

In addition, the table shows the Input /Output Slacks which are very important in this analysis, because it further shows and confirms the authenticity of Nipco as fully efficient as there are no slacks while Conoil has slacks, meaning that it needs improvement by altering the input mix to achieving the efficient output.

Table 1 is Virtual Inputs-Outputs result, which shows the observable potential improvement for the variables. This table shows all Nipco variables as having 0.00%, which is fully efficient (Pareto-Koopmans efficient), while Conoil has been proffered with quantitative solutions to achieve Pareto-Koopmans efficiency.

Table 3 is the regression analysis result which shows that the coefficient of gantry time is negatively related to output (-1489.765). This implies that increasing gantry input (time) will reduce the productivity of Depot output and vice versa.

16. Conclusion

The study has shown that Gantry Hand Time (storage management), Order Processing method and BRV availability (distribution management) are critical nodes in the Supply Chain of petroleum product. The study has addressed the research question by showing that gantry type and order processing system is critical nodes in the petroleum downstream supply chain. The study has also addressed the research questions by showing that value has been added in the form of time savings, sales maximization (turnover), cost reduction and customer satisfaction to the supply chain partners of Nipco than that of Conoil. The BRV Managers of Nipco have more time to lease their BRVs to more clients than Conoil BRV Managers. The depot manager of Nipco also has more time and ullage space to lease to more clients than Conoil. Ultimately, Nipco fuel stations will not experience Out of Stock but Conoil fuel stations will always experience out of stock syndrome. The time savings also buttresses the above point by showing that there is shorter lead time for Nipco serviced partners (customers) than the Conoil serviced partners (customers) along the supply chain. This means that ICT integration of Nipco has enhanced product supply and availability at the fuel stations. It has given the consumers benefits in time savings, product supply, availability and inventory costs reduction.

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