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COMPARATIVE ANALYSIS ABOUT THE APPLICATION OF METHODS OF THE DATA ENVELOPMENT ANALYSIS (DEA) IN THE OIL INDUSTRY

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ABSTRACT

This article seeks to contribute with the state of the art related to the Data Envelopment Analysis (DEA) tool and its application in petroleum engineering, which has the purpose of evaluating relative efficiency of productive unities, therefore a methodology that helps on planning and decision making. The aforementioned research quantifies the number of publications along the periods and tries to identify research development areas using DEA in petroleum engineering. One of the objectives is highlight the efficiency or inefficiency assessed from conflicts of variables (inputs/outputs). DEA methodology started in works developed by Charnes, Cooper and Rhodes, in 1978, which had Farrel's work as a ground for their own (1957). DEA's modeling evolution, whether in theoretical aspects or applications, can be proven by its large number of published works. However, in petroleum engineering, academic research deserves to be the most disseminated.

KEYWORDS: data envelopment analysis, state of art, oil industry.

INTRODUCTION

Data Envelopment Analysis (DEA) is a mathematical programming technique that analyses performance, in terms of relative efficiency, of a wide variety of decision making unities (DMUs – Decision Making Units), from a set of inputs and outputs. DMUs located at the "borders" of efficiency will serve as benchmark for the others. DEA origins were first revealed by the authors Forsound and Sarafoglou (2002) and was first developed by Charnes, Cooper and Rhodes (1978), parting from principles derived from Farrell's model (1957).

A productive unit's efficiency is measured through the comparison between the observed values and optimized output and input values. This comparison can be made, in general, by the reason between the minimum amount of resources needed and the products generated.

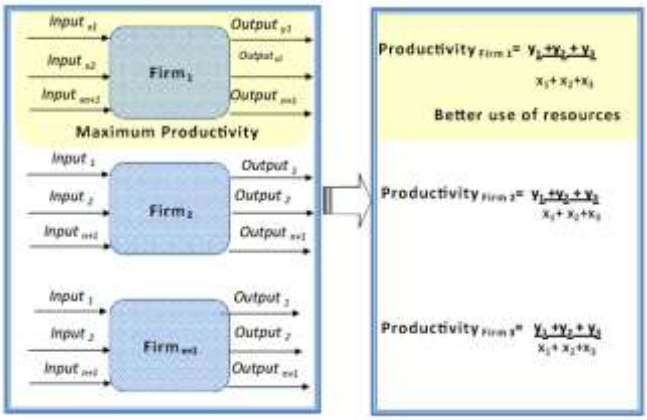

Figure 1 – Efficiency measurement scheme

The main objectives of the DEA, according to Gomes, Soares and Estellita (2004) are:

a) Compare a determined number of DMUs that execute similar activities and differ in inputs and outputs;

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b) Identify efficient DMUs, measure and look for inefficiency and estimate a piece-wise linear production function (also known as piece-wise linear frontier), supplying benchmark values to inefficient DMUs;
c) Determine relative efficiency of DMUs, supplying each one benchmark values, relative to all the others contained in the studied group. Therefore, under certain conditions, DEA can be used in the fixing of organizational issues as a multicriteria decision support tool;
d) Subside strategies of production that maximize efficiency of evaluated DMUs, correcting inefficiencies by working on target units; Establish substitution rates between inputs, between outputs and between inputs and outputs, allowing general decision making;
e) Consider the possibility of the outliers to not only represent deviances in comparison to the "average" behavior, but possible benchmarks to be analyzed by remaining DMUs. Outliers can represent the best practices inside the investigated universe.

OBJECTIVES

Identify the state of art regarding the DEA (Data Envelopment Analysis) methodology and its application in the oil industry.

Specific Objectives

- Quantify the number of publications throughout the periods;
- Identify research development areas using the DEA;
- Track countries with the largest amount of publications;
- Conduct a comparative analysis about the application of methods of the DEA throughout the periods.

RESEARCH METHODS

In this research, target population is constituted by publications related to the theme "DEA in the oil industry" obtained at SCOPUS website (www.scopus.com) in December of 2015, using the following keywords: efficiency, productivity, DEA + Oil, Data Envelopment Analysis + Petroleum.

RESULTS

When setting up marks on a timeline with research related to the theme DEA in the industry of oil it is observed that studies and research developed start in the early 90s until the current year, totalizing forty-three publications, as shown in Picture 2.

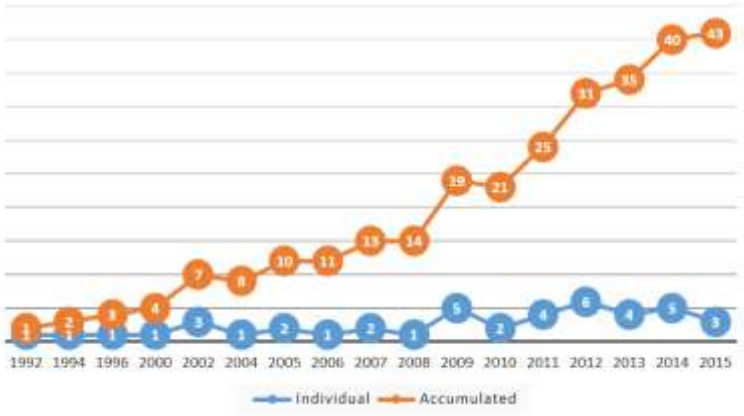

Figure 2 – Number of articles with DEA applications in oil industry

Picture 2 highlights critical marks of the DEA in a chronological order, its first study dating back to 1992, by Thompson, Lee and Thrall in the United States. In 2000, DEA is applied along with other methodologies, using stochastic processes. In 2002 two events marked the evolution of the tool with the application of superefficiency by Rocha and Netto (2002) to classify supplier's orders from Petrobras and the first line of research in oil industry environment (BEVILACQUA e BRAGLIA, 2002).

Kashani (2005) used Malmquist's index to assess to what extent the government create inefficiencies in Norwegian continental platform and to show that inefficiencies can have an influence on contracts. The dynamic

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models are applied to the study developed by Zhang *et al.* (2009), and lastly, Song, Zhang and Wang (2015) used the Network DEA to identify changes in production and environmental efficiency among twenty oil companies in China.

Figure 3 – Critical Marks of DEA applications in oil industry

From works done in the 90s came the research developed by Thompson, Lee and Thrall, originated in America, applying DEA in the economy of the oil industry using CCR and BCC models. In 1992, the economic viability of forty-five oil and gas companies was analyzed in the United States, resulting in a lower technical efficiency, suggesting that the development of the country's energy policy act stimulated dependency on foreign oil.

In 1994 and 1996, the same authors evaluated profitability and efficiency of fourteen oil companies, which resulted in an average inefficiency of 21% throughout the period, suggesting as a measure of improvement that companies lower their prices and obtain a raise of 21% in total profit on conservation of resources.

In 2000, business management was the concern. In the matter, Sueyoshi (2000) applied DEA on strategic planning, having as a goal, the reestablishment of a Japanese oil company. In Brazil, Rocha and Netto (2002) developed a model for classifying supplier's orders and awards from Petrobras. Bevilacqua and Braglia (2002) developed a model to evaluate the environmental efficiency of seven oil refineries along the period of four years contributing to the reaching of environmental goals.

Easton, Murphy and Pearson (2002), in the United States, applied DEA as a useful tool in decision making, adding up to the Supply Chain Management, to improve efficiency in the oil and gas supply chain. Another study involving analysis of efficiency in supply chain was conducted by Ross and Droge (2004).

In the United Kingdom, two articles showed maturity in the use of DEA, using Malmquist's index along with the regression analysis and the stochastic frontier analysis in works developed by Kashini (2005a) and Kashini (2005b). The objectives of these works are to test to what extent the intervention of the Estate create inefficiencies

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in the Norwegian continental platform and understand that inefficiencies generated by governmental institutions cannot be ignored, possibly affecting contracts.

Jiehkun (2006) used DEA to evaluate oil refineries in China, and Vasconcellos, Canen and Lins applied DEA on the process of benchmarking to analyze the best operational practices in a system of productive oil units in Brazil. Liu, Wang and Bai (2007) applied DEA and Markovian models to measure costs of oil company explorations.

Mekaroonreung (2007) and Mekaroonreung (2010) compared various methods to estimate the technical efficiency of one hundred and thirteen oil refineries in the United States in operations between the years of 2006 and 2007. Results indicate that the domestic refineries improved efficiency and the environmental regulations reduced the amount of potentially desirable outputs.

Along the same lines, Liu and Wang (2007) applied DEA along with Markovian models to assess the costs of Petro China's Huabei Oil Company and measure costs of goals to be achieved. Furthermore, Ali and Zahra (2008) measured the efficiency and productivity of oil refineries in Iran.

In 2009, there was a meaningful evolution in the use of DEA with applications in the business management area, using new methods such as the logistical regression and cluster analysis along with the DEA, defining a plan of investment for oil exploration and practicing the correct and coordinated use of oil and gas resources (YURUA; DONGKUN, 2009).

Barros and Assaf (2009) analyzed the technical efficiency of oil blocks in Angola between the years of 2002 and 2007, applying DEA and the Bootstrap method. Hamid and Esmaeil (2009) applied DEA to evaluate the efficiency of oil exportations and foreign investment in companies in Iran, and Song (2009) applied GM-DEA in planning the energy use in oil companies with the purpose of establishing a GM-DEA system for the planning and use of energy and perfected the expected results.

In a study developed by Zhang, Huang, Lin and Yu (2009), proposals were presented to address the support to hybrid decisions using DEA with dynamic models to determine alternate Design solutions more suitable for phreatic water systems. On the same matter, Rejin and Jiatao (2011) selected twenty-two oil refineries and evaluated the operational results given by the companies. It was observed that the technical scales from eleven of the twenty-two refineries were validated and its production capacity was not totally or efficiently used.

Halkos and Tzeremos (2011) investigated the relationship between economic efficiency and oil consumption in forty-two countries in the period of 1986 to 2006. In conclusion, the consumption of oil is the main engine behind industrial progress and urbanization. Ye and Tao (2011) analyzed the efficiency of the Shangai Petrochemical Company from 2000 to 2009 applying methods of superefficiency.

Stochastic processes and DEA were applied in seventy-eight businesses, having empirical evidences of the efficiency related to the income of national oil companies and private international oil companies (ELLER; HARTLEY; MEDLOCK III, 2011). This work compared the efficiency of business groups and, as a result, identified that national oil companies are less efficient than private international oil companies.

Al-Naijar and Al-Jaybajv (2012) implemented the DEA approach to measure relative efficiency in a sample of oil refineries in Iraq from 2009 to 2010. Francisco, Almeida e Silva (2012) studied the efficiency of oil refineries in public sectors, emphasizing outputs generated and consumption of water in the production process.

Sueyoshi (2012a) discussed DEA applications in the environment, comparing performances of national and international oil companies. All oil companies need to decrease their operational dimensions to improve environmental performance in CO_2 emissions, suggesting they need to introduce a technological innovation in commercial operations.

In another research, Sueyoshi (2012b) applied DEA for an environmental evaluation using DEA models instead of radial. Xu and Quenniche (2012) applied DEA to evaluate future volatility in oil prices. Azedeh *et al.* (2012) applied the BCC model integrated in the fuzzy model to estimate oil consumption in Canada, United States, Japan and Australia.

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Zhang, Pan and Dong (2013) evaluated the efficiency in fourteen oil refinery operational databases in mass production from 2002 to 2010. It was concluded that total factor productivity decreases in the international oil products industry, input dissipation rates are of 28.4% and, furthermore, the low scale efficiency and low technical efficiency reduce total efficiency.

Esmaeil *et al.* (2013) evolved in methods and applied the CCR model, ecoefficiency indicators, Pearson and Spearman's correlation in the analysis of the environmental performance and economic efficiency of global business operations selected from the oil industry. As a result, it was observed that there was a positive relationship between ecoefficiency and technical efficiency.

For Wang, Lin and Murugesan (2013), the elevated economic and industrial growth along with the population growth generated concerns to the energy situation in India. The study assessed the performance of the industry under a vast number of inputs and outputs. The results showed that Gas of India Limited (GAIL), Chennai Petroleum Corporation Limited (CPCL) and Oil India Limited (OIL) are at the top of the influential ranks.

Using DEA and the multicriteria analysis, Lee, Mogi and Hui (2013) evaluated energy technologies against elevated oil prices. Relative score of energy technology efficiency against the elevated oil prices can be fundamental information for decision makers to know how to allocate resources efficiently.

Barros and Antunes (2014) analyzed efficiency and productivity in a sample of oil blocks in Angola from 2002 to 2008. The results show that the Angolan oil blocks experience some growth in productivity during the analyzed period and the technological evolution incidence was positive. In Asayesh and Raad's (2014) proposal, DEA evaluated relative efficiency of oil derived gas stations in Iran and pointed out their relative efficiency through the BCC method. The superefficiency method was used to determine the most efficient unit as well as the performance ranking for the most efficient decision making units. Ike and Lee (2014) measured relative efficiency and productivity of thirty-eight oil companies around the world from 2003 to 2010 applying DEA and random effect regression models.

Arroyo, Yago and Nassir (2014) studied the economic and political effects of a strategic alliance between main oil companies, such as Petrobras and Galp, investigating whether private and public companies affect their country's economy. It has been determined that oil and gas exploration and exportation don't have a significant role in domestic growth and that exploration activities were inflationary, unbalancing and a threat to actual growth. Sueyoshi and Wang (2014) emphasized that the evaluation and protection of the environment are major concerns in the business world. The study proposed use of the DEA to measure business sustainability of oil companies in the United States.

Song, Zhang and Wang (2015) applied the Network DEA model to divide efficiency scores into two subcategories, thus feeding back more accurate results. In China, changes in production and environmental efficiency were evaluated in twenty local oil companies. Sueyoshi and Goto (2014) incorporated Malmquist's index in environmental evaluation studies. Azedeh, Mokhtari, Sharabi and Zarrin (2015) demonstrated the usability of DEA in studies related to health, safety and environment in an oil refinery, improving ergonomic features in the business.

Picture 4 illustrates countries analyzed in the research applying DEA in oil industry. At the top, with the most frequent use of DEA is the United States (24.0%), followed by China (20.0%), Japan (12.0%), Iran (10.0%) and the United Kingdom (8.0%), amounting to 74% of all research.

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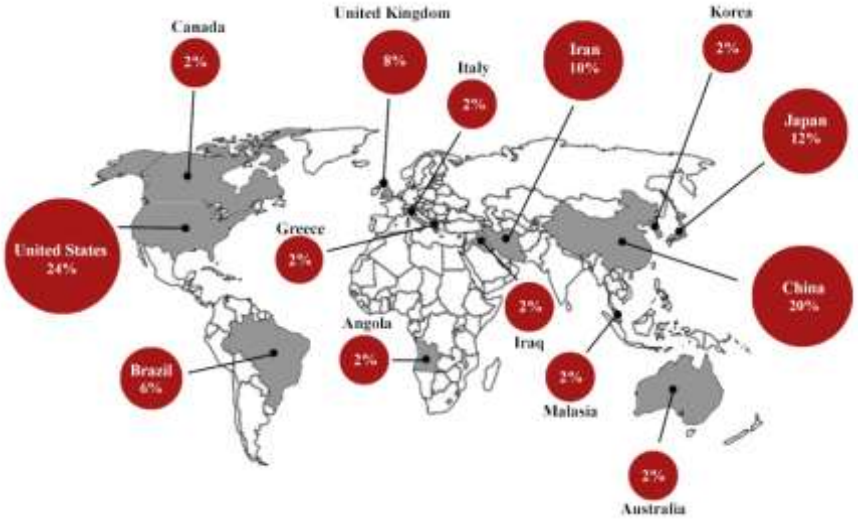

Figure 4 – Research origin countries applying DEA on the oil industry

In Brazil, the application of this technique in oil industries is insipient, making the study of the theme strictly necessary, representing only 6% of developed research. The first work was developed by Rocha and Netto in 2002 in operational research using the superefficiency model.

According to Bezerra, Almeida and Vieira (2015), the main DEA application sectors in the oil industry are economy, environmental management and strategic management, as seen in Picture 5.

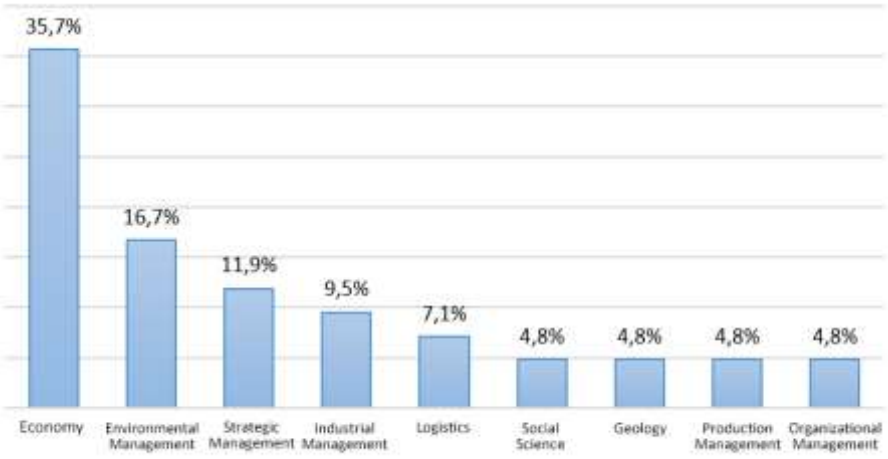

Figure 5 – DEA application sectors in the oil industry

Eight methods involving DEA methodology can be identified in Picture 6. The most commonly used methods for the development of the studies are the CCR (45.32%) and BCC (31.25%), adding up to 76.57% of applied techniques. Table 1 shows other methods used along with DEA.

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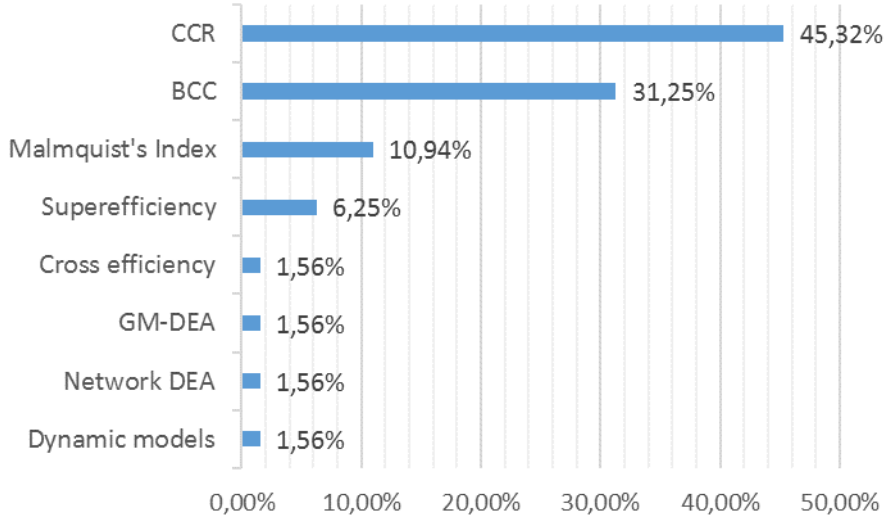

Figure 6 – DEA models applied in the research

CONCLUSION

DEA is a mathematical technique that analyzes performance, in the lines of relative efficiency from a set of inputs and outputs. It is a methodology that assists in planning and decision making. However, it has been poorly and scarcely used in the oil industry. Researched information shows that in 25 years only 43 publications were release with application of DEA in the oil industry.

United States, China and Japan were the first three in the research rank. In the worldwide picture Brazil fills the 6th place, with studies related to efficiency in oil refineries, gas stations and improvement in business management. The restrict use of DEA might be the issue for specific software and methodology complexity.

DEA's main application sectors are the studies of oil refinery efficiency, environmental efficiency and efficiency in environmental management practices. Later works on the oil economy sector date back to the 90s. Brazil deserves the development of lines of research with application of DEA in engineering and reservoir geology studies, exploration and exploitation of oil, automation in the oil industry and environment in the oil industry.

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