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# Recent DEA Applications to Industry: A Literature Review From 2010 To 2014

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***ABSTRACT:*** *Data Envelopment Analysis is an optimization technique widely used in different areas, but one of the most important is in production process (PP) in industry. This paper reports a literature review for DEA with applications to PP, and the methodology followed integrate a review in databases, capturing the author's name, publication year, publication journal, country for first author, university and department filiation for authors and the industrial sector of application. Data was captured in SPSS for posterior analysis. Finds indicate that DEA applications in general areas are having a fast growth and also in PP applications, the countries with more papers are: China, Iran and Taiwan, but the consolidated research groups are in Iranians universities. The journals publishing DEA with PP applications are Expert Systems with Applications, Energy Policy and Energy. Industrial sector been investigated with DEA are energy efficiency, supply chain: supplier selection, transport, logistics, among others.*

***KEYWORDS :*** *DEA, DEA applications, literature review.*

## I. INTRODUCTION

In these globalization times and extensive commercial competence, companies should seek to optimize their resources in the best possible way to survive in the market. However, the word optimization is simple and easy to mention, but very difficult to implement in real industrial cases, because sometimes the variables to be integrated into the models are not generally well-known, there are dynamism in internal and external business conditions, there is a deep mathematical complexity and frequently a lack of understanding by decision makers, among others [1]. Traditionally, optimization is defined as a set of mathematical techniques that can be applied to production systems for design of novel products, its production process, and distribution as a finished product, and nowadays also includes recycling processes after a finished product life [2, 3]. An optimization model features include[4]:

- An objective function, which can be as minimization or maximization, according to the company's needs; for example, profits must be maximized, but the costs should be minimized.
- A set of constraints, which define product's demand for resources and their availability, so these restrictions represent a boundary condition that should not be exceeded.
- A set of constraints characteristics in variables into the model, defining if they can have positive or negative values or can take continuous or discrete values.

Given the components of a model and the characteristics of the variables, some authors classify optimization techniques into parametric and nonparametric, in continuous or discrete [5]. Some of the most common techniques used in optimization are linear programming, dynamic programming, goal programming, data envelopment analysis, compromise programming, among others [6-9]. One of the most widely used in the process of decision-making techniques is the data envelopment analysis (DEA), since it allows generating resource efficiency indices, creating a relationship between inputs and outputs and therefore is defined more widely.

**Data Envelopment Analysis:** Studying DEA, one of the most important words is efficiency, since the technique let's to find a relationship between inputs and outputs in a production process or system in a general way, whatever it is. DEA born from original ideas annunciated by [10]and evolved with the work presented by [11]without the evolution ends today, because there are a lot improvements and combinations with other techniques.

Traditionally DEA is defined as a linear programming methodology [12] that lets to measure the efficiency of multiple decision-making units (DMUs) when the production process presents a structure of multiple inputs and outputs [13, 14], but some other authors include in their definition some characteristics for the technique, for example that is a nonparametric technique [15], which creates a relationship between the inputs required to produce a product [16, 17], which is called as efficiency ratio [18, 19]and using boundary or frontier conditions [20, 21]. However, solving problems that have integrate mathematical programming are difficult to solve, because usually the best or optimal solution should be selected after an iterative process, finding a preliminary solution and moving to another point that is improvement the objective function. Fortunately, today there are many software that have been developed to solve DEA problems and Table 1 presents a list of them, some of which are free and that's way they are divided into two categories: commercial and noncommercial software; also, Table 1 illustrates the websites for contact the supplier or download a free version. DEA concepts of inputs and outputs has make it applied widely in different areas of knowledge and has attracted the attention of academics and researchers, and [22]have conducted a literature review ranging from the first article submitted by [11] to 2010. Several other authors have made more specific literature reviews, such as [23]reviews, who have focused on a review of the combinations between DEA and fuzzy logic.

**Table 1.** DEA Commercial and non-commercial Software

| | **Software** | **Developed by** | **Page to download** |
|---|---|---|---|
| **Non-Commercial Software** | OSDEA 0.287 | Hubert Virtos, Cihan Cetin, Ian Cliffe and Richard Harrop. | http://www.opensourcedea.org/index.php?title=Downloads |
| | DEAP 2.1 | Tim Coelli | www.uq.edu.au/economics/cepa/software.htm |
| | DEA Excel Software | JoeZhu | http://www.deafrontier.net/frontierfree.html |
| | EMS: EfficiencyMeasurementSystem | HolgerScheel | http://www.holger-scheel.de/ems/ |
| | Pioneer: DEA Software | Thomas McLoud and Richard Barr | *http://faculty.smu.edu/barr/pioneer/ |
| **Commercial Software** | DEA Solver Pro 11.0 | SAITECH, Inc | http://www.saitech-inc.com/products/prod-dsp.asp |
| | FrontierAnalyst® Version 4 | Banxia Software Ltd | http://www.banxia.com/downloads/ |
| | ONFront | Rolf Färe and Shawna Grosskopf | www.emq.com |
| | Warwick DEA | Emmanuel Thanassoulis, Keith Halstead, Mike Stelliaros, Robert Dyson, A. Athanassopoulos, A. Emrouznejad | http://deazone.com/en/software |

**Research problems and objective :** DEA applications are numerous and today [22] have conducted a literature review until 2010 and sometimes have specific reviews, such as those in [23], but little literature review of DEA in production systems is known. Thus, the aim of this paper is to report a literature review comprising 2010 to July 2014, but also focus on applications into production system, since this technique is widely used, as demonstrated in Figure 1, where the number of published articles publishing DEA applications in all areas and is being increased from 2005 to July 2014 (information was obtained from Web of Science database). Here is important to note that if publications rate is maintained during 2014, surely there will be more publications that in 2013.

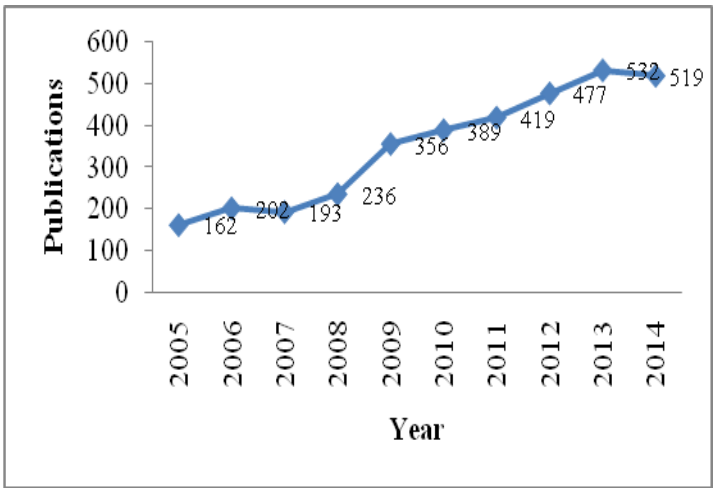


**Figure 1.** Publications using DEA

## II. METHODOLOGY

For the development of this article the following steps were followed:

**Step 1. Finding information :** A search was performed in electronic databases for papers that applied as main tool Data Envelopment Analysis in industry. Major databases were Web of Science, Sciencedirect, Springer, IEEE publications, among others; where the keywords were DEA and Data Envelopment Analysis. The articles were downloaded for later analysis and research is done until May 28, 2014. All references were downloaded using EndNote6 for posterior analysis.

**Step 2. Capture information :** To capture the information, a database is designed in SPSS 21® and the main variables analyzed authors, year of publication of the paper, the country for the authors, and university affiliation of the authors, the department and industrial area the application according to the best fit into nine categories: Energy efficiency, Manufacturing process, Energy, Environmental efficiency, Environmental performance, Logistics, Supplier selection, Supply chain and Transport

**Step 3. Generating the report :** With the database created for references in EndNote6 and SPSS 21® for variables to be analyzed, the next step is to generate the report, for which contingency tables and bar graphs were used. Results are as follows.

## III. RESULTS

158 articles were identified in which the main tool used to solve a problem in a production system was DEA. In the same way as was done in Figure 1, in Figure 2 is illustrated the articles per year.

**DEA Publications by year in PP :** In the same way, as in Figure 1, there is a continuous growth in DEA applications to a productive sector. The highest number of publications was observed in 2013 with 51 publications, but if the rate of publications is maintained for 2014, sure that will be around 70 publications at end of year, surpassing the previous year 2013.

**Publications by country :** In order to identify the research groups that are focus on DEA application in production systems, then the first step was identify the countries of origin for the first author and here is important to note that many of the published articles are collaborative works with authors from two or more countries. In Figure 3 countries and the number of first authors are shown, however here is important to note that only those countries that have at least three publications are plotted. Also there are countries with two publications, such as Australia, India and Greece, and countries that have only one publication, such as Canada, Czech Republic, France, Iran, Italy, Malaysia, Peru, Republic of Serbia and The Netherlands.According to Figure 3, China is the country with more authors, followed by Iran and Taiwan in second and third place, respectively. So, China alone produces 27.84% of scientific production in DEA area with industrial applications, more than a quarter of publications worldwide. It is also important to note that the academic production of China, Iran and Taiwan summarized represent 54.43%, more than half worldwide papers.

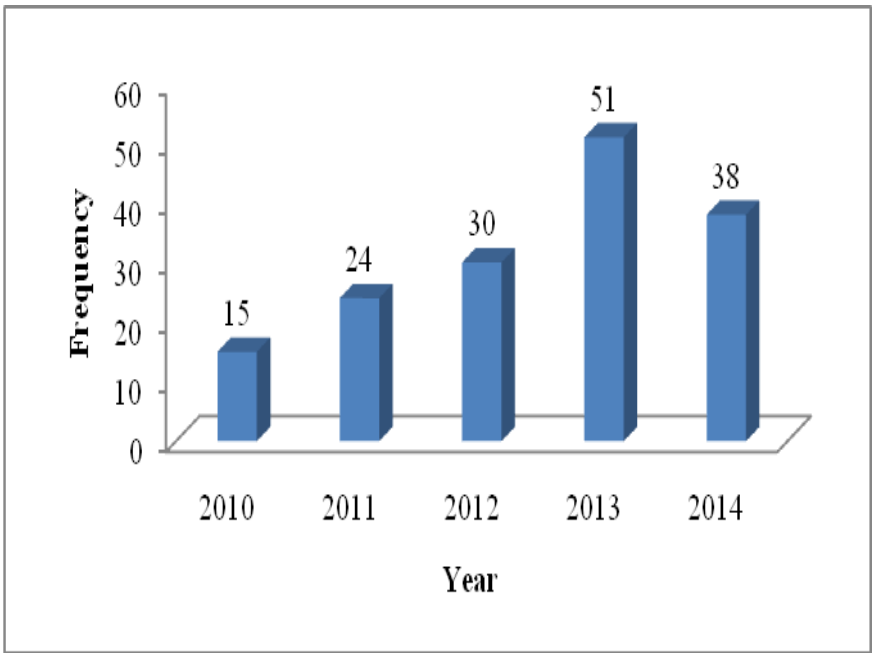


**Figure 2.**Publicationsbyyear

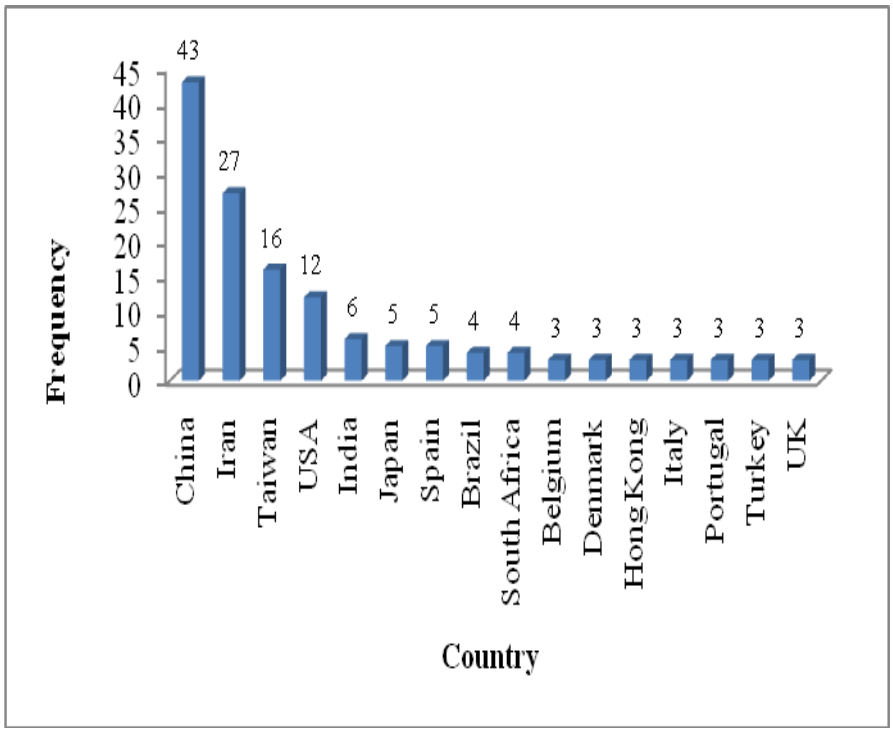


**Figure 3.** DEA publications with PP application by country

**Universities publishing DEA in PP :** However, in order to identify the best research groups that have been focused on DEA applications to production systems, then the universities, academic departments or faculties for authors' affiliation were identified. Table 2 shows the countries, the number of articles published by the research group and the name of the university, which clearly shows that Iran is the country with more established research groups in this area. Here must be mentioned that categorized a research group as consolidated it was considered that the articles were published by the same authors in each university.

**Table 2.** DEA publicationsbyuniversities

| Country | Publications | University |
|---|---|---|
| Iran | 10 | University of Tehran |
| Iran | 9 | IslamicAzadUniversity |
| China | 4 | Anhui University of Finance & Economics |
| India | 4 | IndianInstitute of Technology |
| Iran | 4 | Iran University of Science and Technology |
| China | 4 | Tianjin University |
| Taiwan | 3 | SoochowUniversity |
| South Africa | 3 | TshwaneUniversity of Technology |
| China | 3 | University of Science and Technology of China |
| Denmark | 2 | Aalborg University |
| China | 2 | Beijing Institute of Technology |
| Belgium | 2 | HasseltUniversity |
| China | 2 | Nanjing University of Aeronautics and Astronautics |
| Taiwan | 2 | NationalCheng Kung University |
| Taiwan | 2 | NationalChiaoTungUniversity |
| Taiwan | 2 | National Taipei University of Technology |
| USA | 2 | New Mexico Institute of Mining & Technology |
| China | 2 | North China Electric Power University |
| China | 2 | PekingUniversity |
| China | 2 | RenminUniversity of China |
| India | 2 | T.A. Pai Management Institute (TAPMI) |
| Portugal | 2 | TechnicalUniversity of Lisbon |
| China | 2 | The Hong Kong Polytechnic University, |
| USA | 2 | Worcester PolytechnicInstitute |

**Journals publishing DEA with applications to PP :** In Figure 4 the journals that have published at least two articles with DEA and application to a production process are illustrated. Clearly shows that Experts Systems with Applications ranks as first journal because it has 20 publications, representing 12.65% of total and second place is Energy Policy with 18 publications, representing the 11.39% of total. If first six journals are summarized, they represent 82 publications, equivalent to 51.89% of academic production in that area.

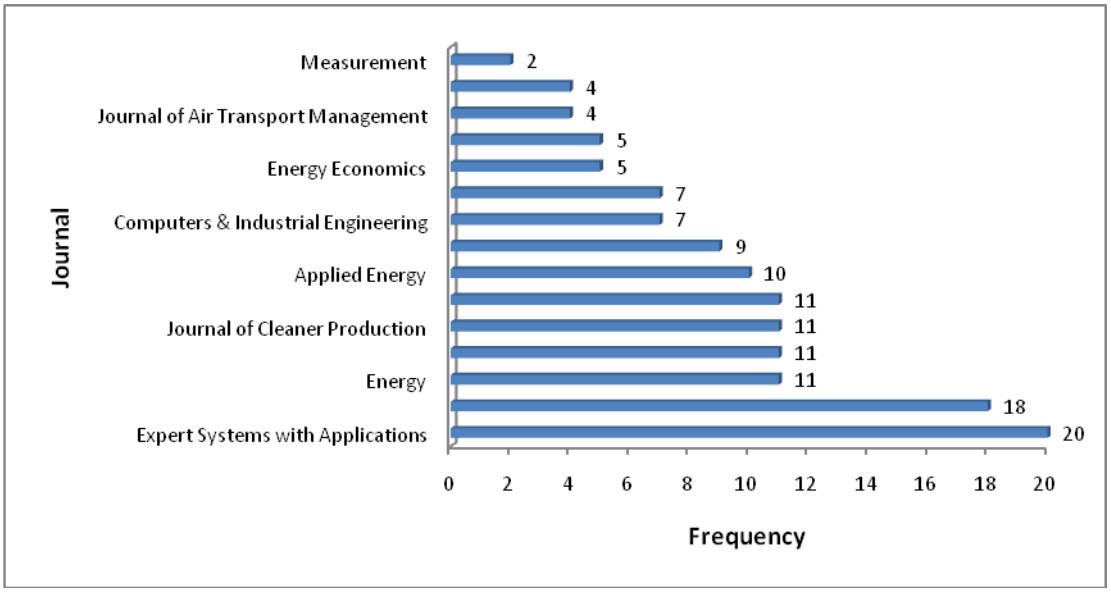


**Figure 4.** Journals publishing DEA with applications to PP

However, there are other journals that have published only one article, such as Accident Analysis and Prevention, Applied Mathematical Modelling, Applied Thermal Engineering, Bioresource Technology, Computers & Operations Research, Economic Modelling, Electrical Engineering in Japan, Electrical Power and Energy Systems, International Journal of Advanced Manufacturing Technology, International Journal of Refrigeration, Journal of Industrial and Management Optimization, Journal of Industrial Ecology, Journal of Manufacturing Systems, Marine Structures, Materials and Design, Process Safety and Environmental Protection, Resources, Conservation and Recycling, South African Journal of Industrial Engineering, Transportation Research Part E and Water Resource Manage.

**The main DEA applications to PP :** As mentioned in methodology section, DEA applications in industry with applications to a production process have been divided into nine categories, which are illustrated in Table 2, together with the authors that represent them, which show the versatility of the technique to be applied to different environments. The *energy efficiency* has a total of 58 references and it appears that DEA has found its niche applications in this productive sector, where the issue of energy costs has been very important nowadays, because the most common energy sources are the hydrocarbons, having lot pollutants consequences (J. Yu, Zhang, & Qian, 2011). Notes that authors are affiliated with research institutions from several countries, demonstrating its relevance and generality for resource optimization problem, and in some cases, also the barriers to adopt energy efficiency measures are reported (A. Trianni&Cagno, 2012; Andrea Trianni, Cagno, Worrell, & Pugliese, 2013). This category has been separated from the simply named *energy* because it refers only to the sector in which it is applying the DEA technique and does not integrate the concept of efficiency.

**Table 2.** DEA applications to industrial sectors

| **Sector** | **Authors** |
|---|---|
| Energyefficiency | [12, 24-78] |
| Manufacturingprocess | [13, 17, 79-97] |
| Energy | [13, 45, 75, 98-108] |
| Environmentalefficiency | [109-112] |
| Environmental performance | [15, 113-120] |
| Logistics | [104, 121-130] |
| Supplierselection | [79, 131-140] |
| Supplychain | [21, 84, 141-153] |
| Transport | [44, 130, 154-167] |

Second category refers to *manufacturing process*, where efficiency is studied and refers to production processes and components, such as efficiency in machinery and equipment, production lines, manufacturing cells and even personnel. Another sector in which it has been applied DEA is the *supply chain* and that category was divided separated from other categories, because research here categorized refer just to supply chain, without reporting a specific area; *suppliers selection* at the beginning of the supply chain, *logistics* policies followed and methods of *transportation* for goods, whether raw materials entering the production process or finished products. Another group of categories are observed regarding environmental systems is that DEA is slowly coming traditional for application in areas like this niche. Here we have seen basically two categories, which refer to the *environmental efficiency* policies, equipment and machinery monitoring and finally, the *environmental performance*.

## IV. CONCLUSIONS

After reviewing 158 articles related to DEA and its applications in any production process in industry, it can be concluded that:

[1] Though DEA has more than three decades being used in decision-making process, its implementation and application is still increasing and specifically DEA with applications in industry, looking always to optimize resources in competitive industries.

[2] Countries with most prolific authors publishing DEA application in industry are found in China, Iran and Taiwan.

[3] When and analysis is performed by universities, then is observed that the consolidated research groups are in Iran, especially in the Tehran University and Islamic Azad University. However, also were detected research groups in China at Anhui University of Finance & Economics, in India at the Indian Institute of

Technology, and again in Iran and again at University of Science and Technology, and as can see, three research groups are from Iranian universities.

[4] Given that DEA with applications in industry have been investigated, no wonder that Expert Systems with Applications is the journal publishing more this area, closely followed by Energy Policy and Energy journals.

[5] Regarding the application areas, it appears that DEA found a great niche in the area of energy efficiency, since that area have most of the applications reported, followed by applications to processes manufacturing and supply chain issues such as logistics and transport.

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