







APPLICATION OF DEA IN BENCHMARKING: A SYSTEMATIC LITERATURE REVIEW FROM 2003–2020

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Abstract. Benchmarking is an effective method for organizations to increase their productivity, quality of products, reliability of processes or services. The organization may make a comparison between its performance and that of the peers from benchmarking, and recognize their advantages as well as disadvantages. The main objective of the present systematic literature review has been the study of DEA benchmarking process. Therefore, it examined and gave a summary of various DEA models applied worldwide to improve benchmarking. Accordingly, a list of published academic papers that appeared in high-ranking journals between 2003 and February 2020 was collected for a systematic review of the DEA benchmarking application. Consequently, the papers selected have been classified according to year of publication, purpose of research, outcomes and results. This study has identified eight major applications including: transportation, service sector, product planning, maintenance, hotel industry, education, distribution and environmental factors. They take up a total of 82% of all application-embedded papers. Among all the applications, the highest recent development has been in both the transportation and service sectors. Results showed higher potential of DEA as a suitable evaluation method for the further benchmarking researches, wherein the production feature between outputs and inputs has been practically lacked or very hard to obtain.

Keywords: benchmarking, data envelopment analysis (DEA), systematic literature review (SLR).

JEL Classification: C14, C44, C67, L8, L9, M21.

Introduction

Benchmarking was described as a measure of the quality of the policies, products, services, strategies, etc. of an organization or company, and compared them with the standard measurements or similar measurements of the respective peers. It has been considered as one

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of the common tools that is widely utilized as one of the methods for improving the competitiveness and efficiency of organizations in the business life (Peng Wong & Yew Wong, 2008). Many papers on benchmarking applications have been published such as management education (Yeravdekar & Behl, 2017), banking (Radojicic et al., 2018; Sufian, 2011a), airports (Adler et al., 2013), energy systems (Kilkiş, 2015; Mardani et al., 2017), transportation (Swanson, 2016), hospitals (Portela et al., 2016), productivity (Chodakowska & Nazarko, 2017), labour efficiency (Nazarko & Chodakowska, 2017), supply chain management (Soheilirad et al., 2018; Yazdani et al., 2019), hotels (Chiu & Lin, 2018), innovative companies (Žižka et al., 2016), asset management (Kaganova & Telgarsky, 2018) and others, to name only a few. Cook et al. (2004) pointed out that benchmarking and performance evaluation are prominent continual improvement devices, which make organization to evolve continually and ameliorate for surviving and succeeding at aggressive business competition condition (Wu, 2012). Anand and Kodali (2008) proposed that companies have been constantly pressurized for becoming stronger, quicker and more affordable than that of their peers, which benchmarking must be identified as one of the catalysts for change as well as creativity in this regard, and that it can be used as a prime management method by learning from best practices to achieve organizational performance objectives. Barber (2004) stated that the overall aim of benchmarking as the evaluative method for providing continual learning for project organization and project manager is regarded problems, which should discuss more extensively in the discipline of the project management.

Depending on objectives and benchmarking utilization areas, some models may be specified related to it (Quaresma Dias et al., 2009). Deming plan do check act (PDCA) cycle model in researches of (Aires et al., 2014; Silva et al., 2017) the supply-chain operations reference (SCOR) model in researches of (Li et al., 2011; Sellitto et al., 2015) and the data envelopment analysis (DEA) model in researches of (Lim et al., 2011; W. P. Wong & K. Y. Wong, 2008; Wu et al., 2016). Peng Wong and Yew Wong (2008) claimed that because of (a) robust, (b) standardized, and (c) transparent method of DEA, this can be utilized as one of the benchmarking tools. Second, when multiple performance measures available, it would be one of the important tools for determining comparative efficacy of the peer decision making units (DMUs). Third, this tool assesses efficiency regardless from the definition of the association or interactions between performance indicators before measurement. Forth, it utilizes the definition of an effective frontier as a criterion for performance assessment. In addition, Charnes et al. (1978) introduced DEA as one of the methods to assess efficacy and efficiency of decision making units. DEA was widely known as a modern tool for measuring efficiency (Emrouznejad & Yang, 2018). However, substantial execution of DEA in performance measurement is one of the reasons for DEA employment as one of the tools for multicriteria decision-making (MCDM). In this type of thinking, decision making units need to be replaced with alternatives, for example, the cost criteria should be a substitute for input, and must to reach its maximum, and the cost criteria should be replaced by the output, which must be the lowest possible value (Makui et al., 2008). One of the most fundamental differences between MCDM and DEA is the impact of human judgment on it. Unlike MCDM, the DEA method attempts to extract the same data and avoids judgment (Belton & Vickers, 1993; Doyle & Green, 1993; Papagapiou et al., 1997; Stewart, 1994, 1996). Perhaps it would be better if these two methods work in some cases like each other: the DMUs are carefully

performed because of the standard criteria and that judgment is not involved. On the other hand, measures taken in the MCDM method can be used to make judgments specifically for limiting weight in DEA (Azadeh et al., 2008). In addition to a comparison of the efficiency throughout the DMUs into an entity, DEA was often employed for comparing efficiency into companies. DEA gains a distinctive merit over other efficiency approaches obtained by benchmarking results. Therefore, both forms of data, output level as well as information on benchmarking, would be indivisible. Therefore, distance of the seen DMU with reference DMU that is used as the benchmarking aim, defines the efficiency (Baek & Lee, 2009).

The aim of the present article has been to review application of DEA in benchmarking literature. The aim of this article has been the collection of a sample representative of research work on application of DEA in benchmarking processes, emphasizing the utility and applicability of these methods for future study projects. Hence, it aimed at the illustration of what areas have been investigated in benchmarking using DEA also which area has the highest growth recently? Based on the studied articles, there is no Systematic Literature Review (SLR) article reviewing the application of DEA in Benchmarking in different fields. On the other hand, there are not many articles which have evaluated the application of DEA in Benchmarking. Therefore, the authors attempted to fill the mentioned gap and systematically review papers of DEA utilization in Benchmarking at a wide scale. In this study, through the analysis of published literature, the research was tested and examined. The purpose of our work is not to review all the common practices in benchmarking among the current method, but focus went for DEA in benchmarking instead. Since the benchmarking plays an important role in a competitive advantage, hence, this paper examines existing methods and focuses on issues that are likely to be faced. Finally, a roadmap is presented to solve current problems. This review is based on DEA-benchmarking. The summary of the contributions are as follows; first, to complete a systematic and comprehensive view of the available DEA presented in the benchmarking to identify the advantages and disadvantages of each area. Second, outlining the key areas wherein further studies may improve the application of DEA methods in the benchmarking.

Therefore, Section 1 presents a discussion of the background of concepts. Then, methodology is described in Section 2. Section 3 reviews the chosen publications. Section 4 discusses results and presents an open issue. Eventually, last section concludes the paper.

1. Background

In this section, benchmarking and DEA will be reviewed accordingly.

1.1. Benchmarking

History of benchmarking may be originated from the 1800s in the context of textile mills (Bogan & English, 1994), and it has undergone many developments especially with the emergence of quality management principles. The use of benchmarking as an effective and practical management tools began in the 1980s by Xerox¹ Corporation because of losing its market

¹ Xerox Corporation is a multinational American company that offers paper solutions and services and information technology products in over 160 countries.

shares and a sense of much pressure from its competitors, especially Japanese companies. Successful lessons learned from Xerox motivated many other organizations to adopt this new approach for raising performance level, production efficiency, and consequently, for the sake to get competitive advantage (Camp, 1989). Benchmarking has spread fast and become one of most used competitive technique (Chen, 2002). It is widely used as a tool to improve performance (Yasin, 2002) eliminate the process of trial and error, enhance efficiency of developing new products (Hong et al., 2014), and improve customer satisfaction (Brah et al., 2000).

In relation to that, benchmarking has numerous definitions in literature. Camp and Camp Robert (1989) presented a commonest definition that described it as “a search to achieve the most acceptable industry exercises that would result in the exceptional results by implementing these best practices”. Kumar et al. (2006) emphasized that benchmarking helps to enhance an organization’s efficiency by recognizing, understanding and implementing other organizations’ good practices. Moreover, it is seeking to find best practice and then trying to apply to achieve the organization’s goals. Furthermore, Sarkis (2001) defines benchmarking from a strategic point of view as “a continuous and systematic method for reviewing organization’s products, facilities and processes that are known as best practices for organizational development.” Although in the related literature, the benchmarking has more than 42 definitions (Heib & Daneva, 1995), but it can be clearly stated that there is still no proper and comprehensive definition of it (Fernandez et al., 2001). But Wai Peng Wong and Kuan Yew Wong (2008) stated that, according to most authors, the benchmarking as one of the management tools is a systematic process for finding best practices, innovative ideas and performance on the continuous improvement pathway. In our study, the purpose of the improvement is to find a way to perform similar tasks with more efficiency, identifying and implementation of techniques that increase process performance, and determination of output amount (Pickrell et al., 1997). In this regard, Elmuti and Kathawala (1997) argued that benchmarking, as a strategic tool, aims to increase productivity and performance assessment, tools for continual improvements as well as tool for improving performance. In addition, Mollae and Rahimi (2009) asserted benchmarking aims to achieve continuous improvements through applying five steps:

Step one: Deciding what to benchmark via prioritizing and specifying a specific procedure.

Step two: Analysis of the initial position as well as the objective by determining the measurement devices, which enable to determine the improvement that occurred.

Step three: Choosing an appropriate partner.

Step four: Getting the required insight from the partners.

Step five: Using the lessons learned and activating for improvement.

In line with this vein, benchmarking is an attempt to achieve superior performance by searching for the best practices of others and trying to adopt these practices to suit the conditions of the organization. Asher and Kanji (1996) stated that benchmarking assists organizations to concentrate and be closer to markets and customers. According to (Boxwell Jr, 1994), benchmarking process, in any organization, falls into three approaches namely, training approach, management approach and comprehensive approach. Training approach is often used to enhance competitive awareness in people while management approach is used to fill the

gaps or handle weaknesses besides improving process in grassroots level. The comprehensive approach of benchmarking is focusing on setting up an inclusive benchmarking process in the organization. Regardless of the approach being used in any organization, there are two points in common. The first point is that organizations are not satisfied of the status quo, and the second point is that organizations are looking forward to enhancing their competitiveness. In other words, benchmarking approaches assist organizations to look outside the box and seek best practices to accomplish goals (Alosani et al., 2016).

1.2. Data envelopment analysis modeling

Building on concepts proposed by (Farrell, 1957), Charnes et al. (1978) seminal study “Measuring Efficiency of DMUs” for the first time utilizes the linear programming for estimating an empirical frontier of the production technology. After that, multiple books as well as journal papers have been compiled about the DEA or utilizing the DEA on diverse sets of issues. Assuming that the random error is zero, in the DEA model all the unknown changes are considered as a defect that causes the system to be inefficient. It should be considered that linear programming involves flexible approaches. The DEA technique is a linear and parameter-free programming method. This method is used in cases where the purpose is to compare outputs and inputs of production units or DMUs with each other. This technique is a suitable device to measure and evaluate relative efficiency of manufacturing units or manufacturers. Common and traditional statistical methods serve as one of the crucial tendency approaches and evaluate them by comparing manufacturers’ specifications with respect to the average characteristics of a producer. While DEA is an extreme point approach, which compares and evaluates the characteristics of each manufacturer with only the best manufacturers’ specifications. In fact, the development of the DEA technique began with the measurement of the productivity in its usual way, the output-to-input ratio. Then, for different inputs, the method of measuring relative efficiency was introduced as the ratio of the weighted output to weighted input. Lai et al. (2011) showed the procedure for DEA model as it is in Figure 1. Comparing with traditional approaches of performance evaluation, DEA has many advantages. The following can be noted as part of its advantages:

- In this technique, weights measurement is done with regard to values of the input and output of each unit that are compared, and there is no need to evaluate the weight of input or output variables or prioritize them.
- Because the DEA technique involves multiple inputs and outputs processing, the relative performance can be measured.

In other hand, the limitations can be summarized as following:

- Exact relative efficiency cannot measure by DEA where return to scale is inconstant.

DEA is recommended to help traditional activities of benchmarking and to provide guidance to management (Donthu et al., 2005). Different experiences indicate that this technique is a powerful tool for evaluating performance and benchmarking to improve and enhance the company’s performances. It has been employed in different studies successfully (Martín & Román, 2006; Min & Jong Joo, 2006; Seol et al., 2007; Sherman & Zhu, 2006; Horta et al., 2016). Consequently, since DEA is proposed by Charnes et al. (1978), this method has a widespread utilization for benchmarking studies. DEA has also proven that positively influence determining functions and operating efficiency of different companies (Lai et al., 2011).

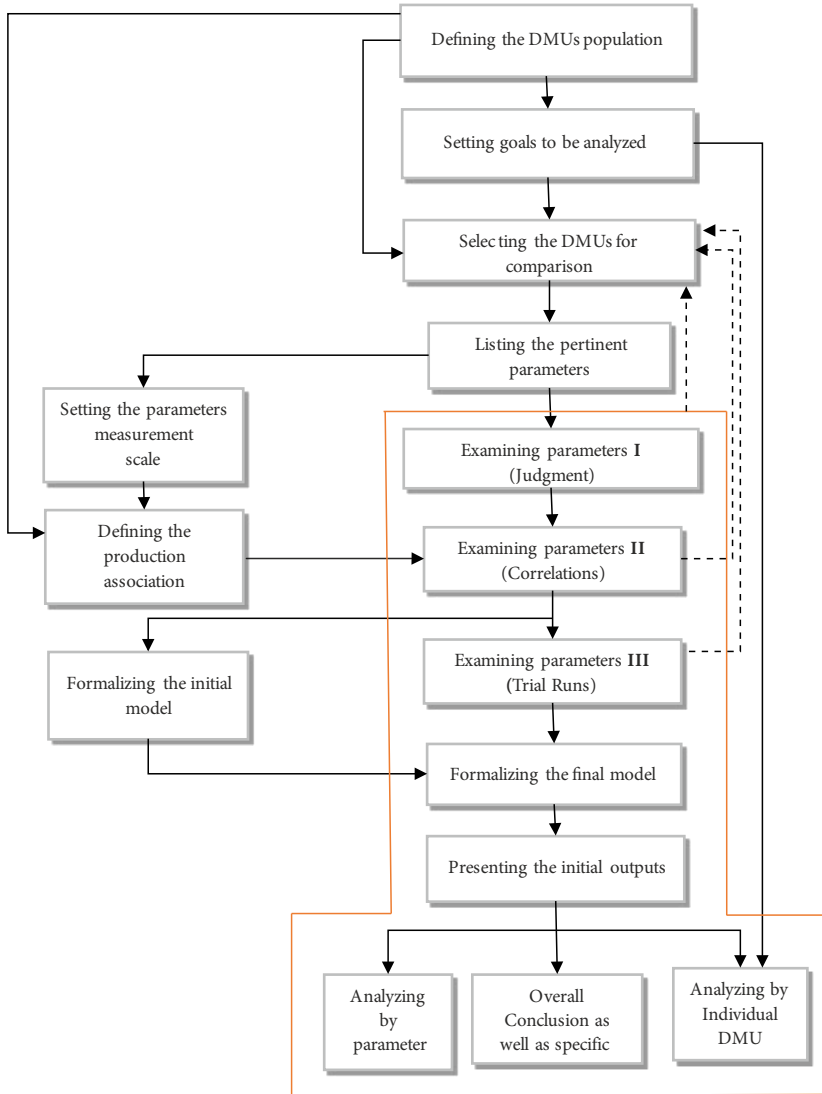


Figure 1. DEA process (Lai et al., 2011)

2. Systematic review

Here, an SLR has been utilized for comprehensively studying benchmarking and the application of DEA in benchmarking from 2003. In the next step, the validity of the selected method in this study was evaluated. The search process, including the formalization of the questions, the selection and the classification steps of the article, are described in the following steps. Therefore, we utilized Web of Science (WoS) and Scopus as the 2 major data bases with numerous other online indices like, Science Citation Index Expanded, Social Sciences Citation Index, Arts & Humanities Citation Index, Conference Proceedings Citation

Index, to provide the systematic review using DEA in benchmarking. In this stage, search was carried out in these databases to find the articles with regard to diverse keywords like “data envelopment analysis” and “DEA”, “benchmarking”. Based on our initial searched (topic, keyword, abstracts) in data bases 1377 records have been discovered. After the first phase of our literature search, papers polished with redundant data in order to prevent duplicate records. Upon the completion of the data collection process, the search results have been screened and investigations with an emphasis on the DEA and data envelopment analysis and benchmarking keywords in English, have been maintained. So, 255 articles were deleted. The second selection hallmark relates to the emphasis of abstract for the reduction of the initial sample and uniquely investigates the articles with the abstracts addressing benchmarking concerns. Therefore, we read the chosen abstracts and then two reviewers examined them comprehensively. Hence, among 1122 articles, 1027 papers have been excluded due to irrelevance with the review objectives. The second selection criterion addresses the emphasis of the entire paper. Thus, 2 reviewers read a sample of 95 articles. Then we separated the articles that were based on the DEA approach from the rest of the articles. Notably, 2 researchers screened all articles in the early search outcomes and determined separately if this paper must be embedded in the resulting data-set. Various comments have been elaborated to reach an agreement. However, the resulting data-set contained 51 journal papers reported till the end of April 2020.

Our initial objective is to investigate the applications of benchmarking with DEA techniques. In order to limit our articles collection, the following conditions defined:

- 1) In order to match the selected articles with the objectives of the study, papers were selected that included their decision-making sciences, computer science, or business-related fields. In reviewing articles, research was conducted at data bases like Scopus, Science Direct, Emerald, Springer-Link, and Google Scholar Journals.
- 2) The keywords for our search were “benchmarking” “data envelopment analysis” “decision making”. The literature that had been published in the last 16 years was considered. Therefore, searching led to the identification of 51 investigations that have been regarded to be relevant to be analyzed. Then, number articles were selected and analyzed according to the publication time.
- 3) In order to be more relevant and more efficient, only articles from international journals were selected. Consequently, the conference papers, unpublished papers, textbooks and notes, and master’s and doctoral dissertations have been not studied in our study. The dataset was retrieved presented in the Figure 2.

The classified articles distribution by the benchmarking and DEA approach is described in this section. Furthermore, the articles distribution by publication year is shown in Figure 3. presents variations of total numbers of the investigations on the DEA utilization in benchmarking. The results indicated a constant gradual rate of increased attraction to the DEA as well as benchmarking from 2003. Moreover, number of the publications from 2011 to 2016 growingly enhanced. Such an unexpected enhancement discussed in the newly published researches. Nevertheless, authors presented 21 articles in 2015 till Feb 2020 as the most leading years. As a result, authors are continuously active on the mentioned titles.

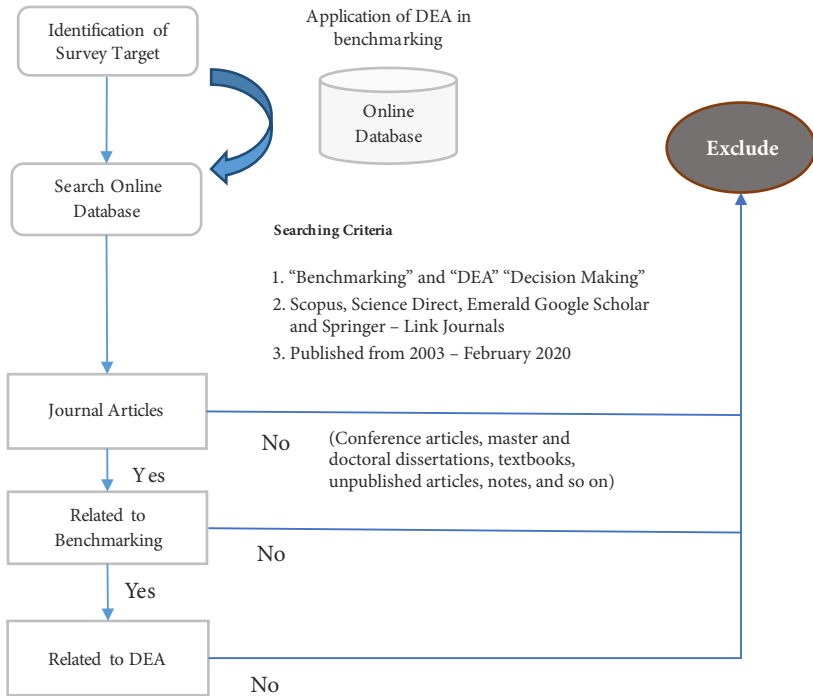


Figure 2. Research methodology of this survey

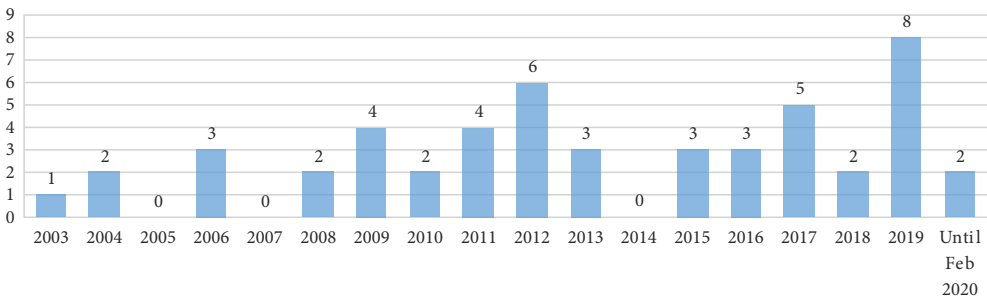


Figure 3. The number of the Benchmarking-DEA articles from 2003 to February 2020

Figure 4 shows different publishers and the articles distribution, where 43.14% of the total journals article belong to Elsevier. To further investigate, 21.57% of the literature is related to the Emerald, 9.80% is related to Taylor and Francis, 9.80% is associated with Springer, and the remained percent deal, Wiley Online Library, MDPI, World Scientific, International Information Institute, Inderscience, The Institute of Electrical Engineers of Japan and Kluwer Academic Publishers.

To provide a systematic review, the VOS viewer Knowledge Mapping Framework (Van Eck & Waltman, 2014) was implemented. In this benchmarking exercise, the software helps carry out three important modifications to previously undertaken actions: (1) Evaluation of the

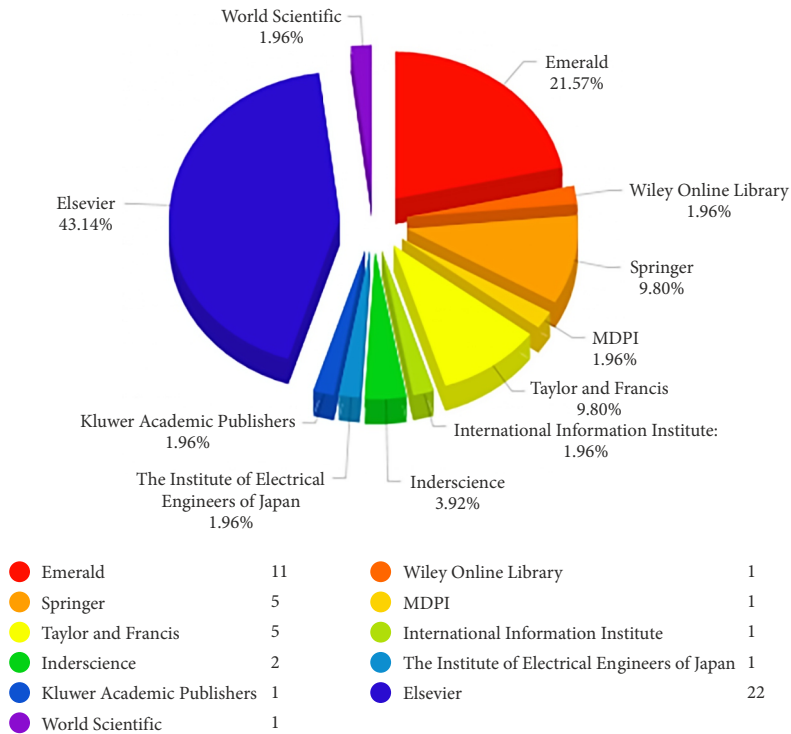


Figure 4. Percent of Benchmarking-DEA articles with regard to various publishers

areas studied become more graphical and the number of analyzed scholarships could increase significantly, (2) systematic identification of content and intellectual structure of the studied areas is possible through the design of a complete set of bibliographic methods, and 3) the content representation of the field’s topic could be in detailed by improving the level. By using VOS viewer, the subject can be arranged so that it can be downloaded and the search for the benchmarking field can be dynamically possible, and so readers can explore the intellectual content and structure of it in more detail. All these advantages made VOS viewer to employ widely in order to outline many literatures across the sciences in the past few years and become a popular tool for reviewing and analyzing scholarship (VOS viewer – Publications, 2015).

What topics are being published by Benchmarking and DEA? To find the answer to the question, 4257 distinct terms (title and summary of documents) were examined from 51 documents. The documents examined were printed between 2003 and Feb 2020. The purpose of these actions is to create a network and branches that are relevant to our research. The colors used in the text represent the words in the same subject line. In Figure 5, the color of branches is classified according to their abundance. The red branch is used to display phrases related to “implementation” and “education”, blue for the terms related to “criteria”, green for terms related to “production” and “branches”, yellow for phrases related to “plan” and “performance”, sky blue, associated with “customers” and “services”, and pink branches associated with “productivity” and “variables”. Definitely, in order to establish rules for firms’ competitive objectives, intervention and observational investigations like those released by

3. Review of the DEA application area in the benchmarking

Now, we will present and illustrate the latest utilizations in benchmarking DEA into eight groups. Section 3.1. Transportation, section 3.2. Service sector, section 3.3. Product planning, section 3.4. Maintenance, section 3.5. Hotel industry, section 3.6. Education, section 3.7. Distribution, and section 3.8. Factors of environment and 3.9. Other topics and in each part the related works are discussed.

3.1. Transportation

Yoshida and Fujimoto (2004) tried to check the validity of these data by measuring and analyzing the performance of Japanese airports. To do this, the study uses two different methods, namely, DEA as well as endogenous-weight TFP methods. Outputs obtained by the above methods strongly reflect the fact that performance of the regional airports in the mainland Japan is less than other airports. This shows that the airports fabricated in the 1990s have been partially inefficient.

To analyze the relative function of all airports in Spain, the SMOP and DEA ranking methods were used by Martín and Román (2006) this method has also been used to rank all of its efficient and inefficient airports. In previous studies, with regard to relative efficiency, most airports were compared. However, this method does not accurately reflect the overall performance of airports. For this reason, for the full ranking of airports in Spain, six different ratings were used. At the end, they tried to eliminate the deviation between performances gained from the minor productivity indices and performance gained from the proposed ranking methods. To achieve this goal, non-parametric statistical tests were designed to determine correlation between the rankings attained by each method. They proposed the cross-efficiency DEA method as the most acceptable option, which may be utilized in each circumstance for ranking the performance of the airports.

Quaresma Dias et al. (2009) intended for doing benchmarking analyses on the major Iberian Seaports by especial emphasis on the efficiency of their container terminals. They analyzed functions of the Iberian container terminals using the DEA model. To do such an activity, some outputs and inputs associated to this terminal has been gathered and a benchmark analysis has been performed. Variables such as the number of cranes, employees, terminal areas, trailer, yard equipment, and terminal length, the moved TEUs and container movement for one hour via ship were investigated. Hence, it is generally concluded that most of the container terminals have been efficient, although at various levels. Moreover, the Iberian container terminals with the greater performance levels include Alicante, Terminal XXI, Algeciras, and TC Leixões-N. Meanwhile, lowest performance was observed at the Bilbao Container Terminal.

De Koster et al. (2009) contrasted output scores from the benchmarking exercise with the earlier research and addressed reason for conflicting outcomes. This paper uses DEA on primary big container terminal data. The results showed that the greater terminals had higher efficiency and trans-shipment terminals have been considerably more effective in comparison to the terminals for import/export. There are not major difference between ter-

minals in various areas of the world, between terminals of diverse operators and with distinct stacking material handling systems. Wu et al. (2010) described an approach to evaluate the performance and improve the process of 77 world container ports. They employed a combined multi factor efficiency models, clustering methods as well as aggressive cross-efficiency DEA to assess the container port function and in identification of proper benchmarks to ameliorate the ports with poor performance. In the analysis method used in this study, 4 inputs; that is, Number of Berths, Capacity of Cargo Handling Machines, Storage Capacity, and Terminal Area and one output, namely Container Capacity were selected. Outputs from efficiency values have been examined and a specific arrangement has been made with regard to average cross-efficiency of the ports. In addition, for selecting better targets for poor ports, the cluster analysis has been utilized as one of the benchmarking tools.

Lim et al. (2011) proposed effective methods of benchmarking that DMUs that do not perform well can rely on it and, more practically, achieve their goals. In this method, the DMUs are grouped into layers, which are executed based on their performance. Subsequently, a benchmarking method is created along each layer. The next goal of the benchmarking is based on components such as attractiveness, progression and inaccessibility, selected among the most suitable DMUs in the next layer. By application of this method, it may resolve constraints of typical DEA-based benchmarking. By the use of this method, the performance of 26 container terminals situated at Asia was tested and assessed. Selection of benchmarking objectives was done with regard to a combination of 3 criteria of progress, impossibility, and attractiveness. This led to increased effectiveness, efficiency and ease in benchmarking practices.

Park et al. (2012) investigated improvements in the DEA-based port efficiency as well as selection of the step-wise benchmarking target. Research showed the widespread utilization of DEA to evaluate the port terminals efficiency and derive benchmarking methods. However, these studies have not considered the minimization of resources necessary to select benchmarking target and have not provided any clear information regarding which resources should be preferentially improved to increase efficiency. To address these issues, they propose a DEA based step-wise benchmarking procedure, which can gradationally select benchmarking targets via examining a minimization of the inputs and outputs expansion and can prioritize resources for amelioration of the efficiency. To achieve this goal, they suggested a benchmarking distance minimization model and a sensitivity analysis used DEA method. A benchmarking of 30 major international ports conducted to illustrate the effectiveness of our method. An actual industry application showed this new method may be a more feasible and effective benchmarking one for terminal ports.

Egilmez and McAvoy (2013) conducted relative efficiency and road fatalities reduction efficiency in 50 US states using the DEA-based Malmquist index model. A score in the name of road safety came from an outlet, a deadly fall and five entrances. Based on the results, with an average of 2.1% reduction in productivity and 1.8% of technical development, there was some reduction in productivity in minimizing the number of deaths. Thus, although a declining trend has been observed in accident-related deaths, state performance in utilizing social and economic resources is still low for achieving the objective of zeroing mortality.

Therefore, purpose of this study has been to focus on road safety organizations to explain a more effective policy on improving road safety through increased safety belts and better use of financial resources.

Sharma et al. (2016) examined the performance of rail transport services in delivering rail services and providing a comprehensive notion of service delivery. They defined the quality of the service agents based on limitations such as the availability of data and the rules of the DEA. Hence, quality parameters of the service in their study are being on time, level of general complaints (customer satisfaction) and level of consequential train accidents (safety). The DEA method was utilized as one of the benchmarking tools for evaluation of the performance of 16 Indian Railways (IR). This assessment was performed based on the efficiency and identification of sample areas. The results of this study can act as the performance goals in the reward system, control systems, as well as the performance score-card.

Park and Sung (2016) presented a systematic integrated approach for building a benchmarking network. This method has been considered to be a network structure that includes one of the alternative sequences of the benchmark objectives. In this method, cross-efficiency DEA, the K-means clustering as well as the context dependent DEA are merged with regard to the stability of the pattern of resource improvement and selection based on the IBTs of an inefficient DMU. For example, a 34-port container terminal was tested on a benchmarking network. For inefficient ports such as New York, Valencia, Leam Chabang, and Antwerp, a network of benchmarking was created for the assessment of their UBTs such as Hong Kong, Singapore, Keelung, and Cayenne. However, despite the application of the proposed method, the most suitable DMU in each layer was not found to reach UBT. Also, the minimum step-by-step benchmarking objectives for inefficient DMUs were not determined to reach UBT. However, in organizations with inadequate performance, it is possible to consider numbers of the benchmarking stages as one of the prominent factors in the decision-making procedure to improve efficiency of the stage.

Melo et al. (2018) assessed the measurements of corridors and shipping routes using DEA. In their study, the effectiveness of Brazilian and American transport corridors in the field of soybeans from farm to export terminals was measured and compared with the use of DEA. This paper aimed to find the best route from the smallest production area to the extreme part of the export, in particular using Slack-based measurement (SBM) as well as variables, which are in fact essential pillars (economic, social and environmental) of stability and sustainability. One of the global reports presented in both countries on the transportation of soy is consistent with the outputs from the present research. The most important goal of the research is to examine the criteria for assessing corridors and overall effectiveness. Also, the proposed method in this study can be used in various fields of procurement, such as the generalization of the study to other countries. It can also be used to capitalize on underlying assets.

We reviewed eleven articles reviewed related on application of DEA in benchmarking categorized into transportation industry group. After reviewing the main advantages and disadvantages of each article, it is presented briefly in Table 1.

Table 1. Summarize of the advantages and disadvantages of transportation articles

Author	Purpose	Advantage	Disadvantage	Main suggestion for future research
Yoshida and Fujimoto (2004)	Application of the DEA as well as EW-TFP for the measurement of the Japanese airports' efficiency	To get "physical" performance, focusing in particular on the issue of over investment	Does not contain financial data because of difficulties in data collection	The transportation infra-structure projects like the airports would be time-consuming to generate sufficient demands for efficient service. A potential extension of the new researches will be calculating the long-term efficacy by taking this claim into account
Martín and Román (2006)	To examine the relative function of all Spanish airports: * For ranking inefficient and efficient airports in full; To compare 6 distinct strategies of benchmarking with regard to the DEA and SMOP making a comparison between them SMOP- Cross-efficiency; matrix-Super-efficiency-Virtual efficiency (champion performer)	With a specific weight vector, it is possible to get maximum rank of the efficient and inefficient airports that has been determined with regard to the performances of each sample airport. Second, ranking is more reliable in contrast with the rest of the approaches, and ultimately, ranking outcomes would be more accurate than the outliers remain	This method does not accurately reflect the overall performance of airports	Perform at airports in other countries and do compare
Quaresma Dias et al. (2009)	They utilized DEA model for assessment of the function of main Iberian container terminals	Data mining as well as DEA are used to compare operational data of container terminals at seaports	The decreased numbers of the entrance and exits, validity of data and extrapolation of the entrance values. The data available on websites of organizations is not adequate, is not trustworthy and is not presented in a consistent manner	Through an investigation, the approach may be applied to the people responsible for each terminal service, with the goal of validating the data obtained and even considering further years of study

Continue of Table 1

Author	Purpose	Advantage	Disadvantage	Main suggestion for future research
De Koster et al. (2009)	Comparison of the benchmarking results from the exercise with those from previous research	Description of the current state of play by using DEA methodologies to evaluate performances of the container terminals at ports	DEA can be suitable for benchmarking of container terminals, but only if it is possible to obtain higher-quality as well as further output and input data	Analysis on terminal types could be regulated
Jie Wu et al. (2010)	Researchers illustrated the performance assessment and process management approach of 77 world container ports	Cluster analysis methodology has been utilized for selecting the most suitable objectives for using as the benchmarks for the ports with poor performance	Although this research provided one of the random samples of the entire population, certain extension of efficiency and overall competitiveness of the industry should be further assessed	The study as well as evaluation of divers' strategies to clustering, factor analysis and multidimensional scaling may provide the grounds for further studies
Lim et al. (2011)	Created a tool for choosing efficient benchmarking paths on which the inefficient DMUs would more effectively attain their ultimate goals on the competitive frontier	The proposed approach resolves functional problems in reference to several benchmarks, as is frequently the case with traditional benchmarking based on DEA	The container terminal experiment has been not a full-scale implementation; however, a partial scale analysis used only to demonstrate this new approach. Diverse investigations required for a completely justifiable DEA utilization have been facilitated or neglected	Can create a 0–1 integer mathematical programming model for finding optimal overall benchmarking path, which diminishes Skpxkp number
Park et al. (2012)	Propose a DEA-based stepwise benchmarking procedure, which may gradually choose the benchmarking targets	Established stepwise benchmarking targets considering the minimization of the resource improvements for the 30 terminal ports and established resource priorities for improving the inefficient ports efficiency	Their new methodology would not consider numbers of the benchmarking stages for an inefficient port for reaching the final benchmarking target	Controlling the number of benchmarking steps could be a future research issue

Continue of Table 1

Author	Purpose	Advantage	Disadvantage	Main suggestion for future research
Egilmez and McAvoy (2013)	A Malmquist index model based on DEA was devised to evaluate US productivity and relative efficiency	Analysis of DEA findings will be very useful in contrasting the relative quality of road safety success with state highway agencies	Don't find essential aspects of fatal crashes including the presence of alcohol, the type of vehicle (e.g. truck, passenger car)	More successful policy making towards raising the use of safety belt and better use of safeness expenses for improving the road conditions have been extracted from their research as the main topics, which should be focused on for the state high-way safety agencies
Sharma et al. (2016)	Has implemented a new approach to benchmarking and ranking to find the best sustainable suppliers	By implementing these decision makers, we recognized the efficient as well as inefficient suppliers and identified the future suppliers' inefficiency	There has been not constantly feasible that make a comparison every field on precisely the same basis as the work culture and difficulties vary in areas, divisions, states, and regions that restrict the analysis	Similar work can be replicated with fuzzy data for other decision-making topics, like selection of product and technology
Park and Sung (2016)	Proposed a systemic comprehensive approach to develop a benchmarking network	Have specified a new protocol whereby similar DMUs have been categorized into a similar cluster with regard to the benchmarking direction	If there are so many step-by-step benchmark objectives, a major practical challenge may be experienced for the DMU in achieving schedule of benchmarking	The way of picking the most acceptable IBT amongst the number of the DMUs in all layers in such a way that the analyzed DMU may achieve UBT, and the way of application of the numbers of step-by-step benchmarking objectives for more realistic step-wise benchmarking would be challenges, which should be considered in further researches

End of Table 1

Author	Purpose	Advantage	Disadvantage	Main suggestion for future research
Melo et al. (2018)	To generally evaluate and measure efficiency of transport corridors for the American as well as Brazilian soybeans, from the farmers to the export ports, with the use of DEA	It enhances the corridor benchmarking topic, and usually emphasizes the productivity. It suggests a framework that can be implemented in multiple logistics contexts, such as extending the analysis to include specific countries	The routes having more than 3 modes appear to have inefficiency implying a multimodality limit	It is recommended to extend and include variables such as lead time, cost of the maintenance path, trade disparity, kind of the cargo as well as a variable reflecting social values like the operator's life quality. Further studies will concentrate on directing investment in the storage field. Including relation and carryover parameters as well as exploring possibilities of other DEA models, like the structural window analysis, the network and dynamic models, and other tie breaking methods are also suggested

3.2. Service sector

In this regard, Sherman and Zhu (2006) evaluated alternative techniques using quality in the DEA benchmarking. The results indicate that the simple approach to qualitative measures as one of the DEA outputs would not play a role in the diagnose performance. Hence, in the present study, a new DEA-based approach which is quality-balanced (Q-DEA) with a higher sensitivity and quality was presented. The results were implemented in a network of 200 bank branches in the United States. The purpose of this performance measurement was to manage operational costs and service quality. The results of the Q-DEA application, in addition to reducing costs and improving and upgrading operations, was maintaining the quality of service at an appropriate level, which was one of the major goals of the program. Using Q-DEA, new approaches and perspectives have been identified on how for improving operations of the branch with regard to the best practices of high-quality benchmarking (high quality and low cost).

Deville (2009) provided a benchmark analysis of the regional banks and branches from a big French banking group. Therefore, the present analysis aimed at the evaluation of the op-

erational performance. In fact, “network” of diagnosis was created by performing a diagnosis as “individual” at the branch level. This study mainly aimed to: (i) use inefficient privileges to determine and develop operational performance indicators; and (ii) establish a benchmarking instruction, taking into account the structure of the banking network. This banking group has 1611 branches in 16 regional groups. Therefore, branches work in 6 distinct business environments. Therefore, one method would be needed to (a) collect the inefficiencies of each branch in order to assess regional groups and (b) sum up environmental difference in the assessment guidelines. Results indicate that about 30% of the branches have efficiency. The main focus and emphasis is on determining the amount of productivity gains at the level of the regional banks, as well as the implementation of the bank’s benchmarking.

Baek and Lee (2009) DEA was designed to achieve all goals and the strengths of the respective benchmarking methodology gave DEA a specific merit in comparison to other performance analysis methods. Their research suggested utilization of the Least-Distance Method for obtaining the shortest projection from the measured DMU to the highly efficient output frontier, thereby enabling inefficient DMU for finding the simplest way for improving the performance. The data on 14 general hospitals is used to test the proposed method.

Kumar and Vincent (2011) ranked India’s banks, with regard to their performance during the 13 years after the reformation period with a progressive time weighted, using the DEA model. In addition, the relative performance of each bank was evaluated using the DEA method of constant benchmark, compared to the bank that provided the best performance. The results indicate that, when the banks’ productivity is assessed on the basis of a common criterion, none of the government banks has superiority over private banks, and vice versa. However, productivity in public banks is more stable than private banks. Results related to Efficiency on the basis of ownership of banks showed, which public sector banks have more stability and order over the years as well as between banks. The results of the comparison of the commonly used ranking method with a progressive approach regarding to the time, have revealed significant disparities in some of the banks.

The purpose of Lai et al. (2011) was to carry out an effective measurement. To this end, the use of a DEA approach, the creation of a rational knowledge-based system (BKBS) to benchmark, as well as the performance review and procedure modification, created an integrated framework. The present study demonstrates how BKBS has been executed at a medical facility. Such a system allows us to identify specific benchmarking partners for assessing the relative performance and bridge the gap between partners in a health metrology industry. Ultimately, a rational KBS provides a quick way for the implementation of the meta-analysis procedures.

Sufian (2011a) utilized DEA to investigate the inefficiency sources in the Korean banking sector. This research concentrated on 3 specific strategies of intermediation, value added, and operational approach in order to distinguish how performance scores varies with the alterations in the input and output.

Wu (2012) proposed one of the integrated solutions to benchmark with the use of gray entropy, Borda count, as well as DEA. Therefore, the most important component in the process of benchmarking is identifying the best constructor. In order to find the best builder, their suggestion has been the utilization of DEA model with extraordinary efficiency and to apply the gray entropy evaluation method to integrate the ranking list using these two meth-

ods and Borda counting. The results of the study showed that they were able to discover the best constructor for conscious analysis.

Nigam et al. (2012) investigated mobile service providers in India's telecom system to determine relative efficiency. To evaluate the performance of mobile services, they presented a DEA-based approach. In their study, they examined some of the common concepts between qualitative performance and benchmarking. The results of the study included performance and classification based on public service sensitivity. The comparison of the effectiveness of DEA from the basic model with perturbed models showed that it affected performance. Reporting data for a one-year and three-month period reflects different quality parameters. The DEA method was used to perform benchmarking comparisons of 126 services, which include private and public sector operators (PSUs). Results were compared with performance of efficient and inefficient sectors. With regard to the above findings, inefficient units may implement strategic programs for improving their status.

Karbassi Yazdi and Abdi (2017) reviewed the best banks based on the variables introduced. Banks are initially examined for variables like operating expenses, deposits, employees, net profit, loans, and investment. After that, type of these variables is determined by their input or output. To investigate the efficiency or inefficiency of DMUs using the DEA method, the performance of banks was examined based on these variables. The purpose of this study was finding the most acceptable banks with regard to the previous criteria. Hence, division of criteria into input and output groups was done. The present investigation aimed at implementation of the model with the AP Super Efficiency Model for finding effective units for benchmarking. Because some of the inputs and outputs are more important than other variables for banks, so there should be some changes to the category. According to the outcomes, out of 13 banks (10 public banks and 3 private banks), only five public banks were efficient. In fact, five other public banks were the other three inefficient private banks.

Álvarez-Rodríguez et al. (2019) merged the use of DEA and Life Cycle Assessment (LCA) in the retail sector (grocery stores) for organizational and environmental benchmarking. Researchers confirmed the LCA + DEA approach as one of the valuable tools for evaluating and benchmarking grocery's operational and environmental efficiency as one of the illustrative case studies into the tertiary sector. Hence, it concludes that the LCA + DEA framework is particularly applicable to the service sector. With respect to the particular case study, a fairly suitable environmental and operational output of the grocery collection has been found, each of them included the efficiency scores >0.6 and a $1/3$ of which are considered to be efficient. This research also demonstrated the viability of utilizing SBM-Max model in the setting LCA + DEA as one of the beneficial methods for the gradual multidimensional benchmarking of related organizations for improving the quality. Such a condition caused complemented benchmarking of less ambitious reduction targets concerning application of the operational inputs in the assessed grocery stores (3 to 13%). Their outcomes have been additionally enhanced by a super-efficiency analysis, finding two best-performing grocery stores. Overall, the LCA + DEA technique has demonstrated a strong capacity to help decision-makers such as company executives in setting ambitious goals for environmental and operational improvements in the grocery stores in a service industry.

We reviewed 10 articles analyzed and named as service sector. After reviewing the main advantages and disadvantages of each article, it is summarized in Table 2.

Table 2. Summarizes the advantages and disadvantages of the service articles

Author	Main Idea	Advantage	Disadvantage	Main suggestion for future research
Sherman and Zhu (2006)	Have presented a novel, more sensitive, quality adjusted DEA (Q-DEA) that efficiently addressed the quality measure in benchmarking	Recent information of the manner of improvement of the branch operation with regard to the most acceptable practice (higher quality and lower costs)	Though information has been induced by Q-DEA analysis, a motive for achieving the cost-saving has been stronger and other procedures may suggest other methods for achieving affordability in the branch network	It is necessary to perform additional researches on the measurement and incorporation of the quality into DEA benchmarking
Deville (2009)	Presenting the benchmarking analyses of the branches as well as regional banks of a big French banking group	Their model determined one efficiency frontier for each kind of environment	Only done in branches and regional banks	One of the benchmarking analyses of the branches as well as the regional banks of a other country and do compare
Baek and Lee (2009)	Using the Least-Distance Measure for obtaining the shortest projection from the assessed DMU to the highly efficient production frontier	Their new model produced reasonable benchmarking outputs and provided the efficiency values, satisfying general requirements that each of the known efficiency measures must satisfy	Do not conducted the meaning of the relative efficiency in the traditional DEA models. Therefore, ranking the DMUs with regard to the relative efficiency may be confusing and unreliable	It is necessary to extend the Least-Distance Measure to the non-convex technology in the real-world problems, convex technology; that is, the production convexity possibility set) cannot be applied. Therefore, extending to the non-convexity technology will ameliorate the utilization potent of the Least-Distance Measure
Kumar and Vincent (2011)	Used diverse DEA models for benchmarking the Indian banks in the course of the post-reform era with regard to the progressive time weighted mean strategy with the use of the overall and ownership-based frontiers	Provided documents of specific convergence in the functions of the public sector banks with the respective counterparts in the course of the post reform interval, which reflected affirmation of the impacts of the reformation process in the Indian banking sector	Increasing number of the production units decreased the efficiency scores	Comparing the efficiency levels among the industries required adjustments for the size of the samples

Continue of Table 2

Author	Main Idea	Advantage	Disadvantage	Main suggestion for future research
Lai et al. (2011)	Devising a knowledge-based system to benchmark with regard to the DEA strategy	It has been found that the medical center administrators may utilize this analysis for helping them determine and handle the benchmarking procedure while adopting the BKBS	Research in the medical industry has been limited	Benchmarking knowledge-based system should integrate RBR, the case based and model-based reasoning to benchmark the implementation, evaluation of the performance and improvements in the process. Hence, it is necessary for the BKBS to integrate the mentioned management devices to benchmark the process
Sufian (2011a)	Essentially examined the source of inefficiency in the Korean banking sector	Focused on 3 distinct strategies of intermediation, value added approach, as well as the operating approach for differentiating how efficiency scores change with the variations in the outputs and inputs	Considering changes in productivity over time can affect the outcome of this research	Examining the productivity experiences some modifications during time. Due to the technical changes, technological advances or regression with the use of the Malmquist productivity index may be one of the other extensions to the article
Wu (2012)	Their study proposed the use of the super efficiency DEA model as well as gray entropy (GE) scoring for conducting the pertinent efficiency assessment and ranking, and utilizing Borda count for incorporating the ranked lists	Undertook the task of demonstration of the utility of a suggested integrated solution to benchmark in order to search the most acceptable performer and involved in extending the feasible uses via incorporation of the GE, Borda count, and DEA	The limitation that though Borda count is greatly easy and understandable, it would not take into account priority for all individual ranked lists	As the ranked lists obtained from the mentioned 2 methods have been not generally equivalent, their recommendation was the use of Borda count for coalescing the ranked lists into a single ranked list

End of Table 2

Author	Main Idea	Advantage	Disadvantage	Main suggestion for future research
Nigam et al. (2012)	The researchers proposed a method to benchmark the performance of the mobile telecom utility on the basis of the DEA	Identified various parameters and consequently procured a model to benchmark the service providers in India	In one country	With regard to the efficiency analysis, benchmark may can be adjusted, and obtaining utility efficiency scores would be feasible on the basis of a set of benchmarks. Therefore, the scores could enable the development of a strategic plan to diminish the parameters involving in the system inefficiency
Karbassi Yazdi and Abdi (2017)	Intended for determining the most acceptable banks with regard to the predefined indices	In a number of cases, the outputs and inputs had higher priority for DMs in comparison to the others; therefore, it would need a series of variations. Moreover, if one of input or output has been greater than the others, DMU became efficient in spite of its low priority. Hence, their study indices have been ranked by Rembrandt method in order to resolve the above problem	Evaluation of bank performance with regard to a limited set of variables	A number of the outputs as well as inputs have been prioritized for banks in comparison to the others; thus, it would need a number of variations in the coming years
Álvarez-Rodriguez et al. (2019)	Combined use DEA and Life Cycle Evaluation for environmental and operational benchmarking in the service sectors	The LCA + DEA method reflected higher potency in advocating the decision-makers like the managers of a company while defining accurate targets for environmental and operational improvements in the grocery stores in the service sector	Only have investigated groceries located in Spain	Nevertheless, national policymakers can take advantage from this kind of methodological solution for setting the threshold values for an efficient utilization and sustainable management of the resources in the service sectors

3.3. Product planning

Braglia et al. (2003) comprehensively examined the performance of five steel factories in a largest private group in Italy. Therefore, the present investigation proposed a new method for determining the efficiency of the plant was proposed, which could help to manage the production strategies based on their performance, usually in industrial environments. In this study, the studies were performed according to the DEA method. In addition, it was enhanced by the use of several modified solutions that were proposed in previous texts. The results were sorted using a suitable cluster analysis. Finally, a technical and economic analysis was proposed for inefficient production units. The proposed model in the industrial unit was used as a reference, which means it can also be used or generalized in other manufacturing areas.

For example, Trappey and Chiang (2008) used DEA framework to develop a management approach and benchmarking planning to maximize activities of new product development (NPD) into a profit center in order to reach the full benefit goal and fulfill the resource constraints. They proposed a new method for NPD's strategic benchmarking, with regard to the business model of the decentralized profit centers, to implement an effective NPD decision making and planning method for profit center managers. The most important component of this approach is the access to NPD activity information, which can easily be found in the industrial companies where NPD projects are fully implemented. Finally, by implementing a realistic model for motorcycle design, this study showed that DEA-based meta-measurements are sufficiently effective for planning NPD projects under the Center model.

Shabanpour et al. (2017) used robust DEA double frontiers and target programming to the further study plans to benchmark and rank the sustainable suppliers. They also proposed a program to improve productivity in order to rank suppliers with a stable and selection criterion. For suppliers, the two levels of the program, which included targets and benchmarks, were presented. To achieve this goal, targets at the first level are determined by target programming (GP) and DEA. Because the inputs and outputs are likely to be unknown at first level targets, the Charnes-Cooper-Rhodes (CCR) boost model was used. After identifying the second level criteria, a modified CCR inefficiency model was used to determine the supplier's rank. Actually, this ranking feature is created by the creation of a dual boundary that includes the inefficient and efficient boundaries of CCR. Accordingly, suppliers were ranked with the use of the first level objectives. According to the new ranking, the targets uncertainties have been determined by the implementation of optimization methods. Their new method provided planning and technical features that have been illustrated by a case study.

We reviewed 3 articles related to product planning analyzed. After reviewing the main advantages and disadvantages of each article, it is summarized in Table 3.

3.4. Maintenance

Gouveia et al. (2015) presented a study on benchmarking analysis related to maintenance activities done by a Portuguese Electricity Distribution Co., EDP Distribution (EDP-D). In this study, relationship between DEA and MCDA was evaluated using a value-based DEA method. Their paper examined impact of applying management priorities on the classification and ranking of the 40 network domains covered by EDP-D. The findings were consistent

with the outputs presented by earlier BCC / DEA model. Therefore, to avoid uncertainty, value-based DEA-based approach to evaluate the performance has been adopted to incorporate the notion “superior performance”. Moreover, researchers, identified the most reasonable practices, inefficient resources, opportunities for improvements, gaps in the most acceptable practices, and supported corrective actions and decision-making on the future objectives and promotion of information of the company.

Table 3. Summarizes the advantages and disadvantages of the product planning articles

Author	Main Idea	Advantage	Disadvantage	Main suggestion for future research
Braglia et al. (2003)	Their proposed method to measure the plant performance could enable managing in the formulation of the manufacturing approaches	This new method has been substantially utilized to the industrial cases of reference and thus it may be readily extended to each manufacturing setting	For a company with poor operation, with the general characteristic of the inefficient plants, DEA analysis may not work. Therefore, each plant should be ameliorated; that is, the plants should have efficiency of 1.	For resolving this limitation, researchers may propose a fictitious series of references described by very good values with regard to the investigated outputs and inputs
Trappey and Chiang (2008)	Employs DEA notion for presenting a benchmarking plan and management procedure for optimizing the NPD activity into a profit center for achieving objectives of the greatest profit and satisfaction of resource restrictions	Using the actual case of electric motor scooter design project, their study demonstrated considerable efficiency of DEA benchmarking for NPD	Don't advocate strategic planning and management of the derivative NPD with regard to the profit-center business model	Applying this research approach to similar industries can be an idea for future research
Shabanpour et al. (2017)	Presented an efficiency improvement program for ranking the sustainable suppliers and selecting the benchmark	By implementing their strategy decision maker identified efficient and inefficient suppliers and recognized the future inefficiency of the suppliers. Therefore, managers may stop additional loss by planning and making the preventing decision	Limited research scope can be one of the limitations of this research	Similar investigations may be iterated for other decision-making issues like selection of technology and product in the presence of fuzzy information

Assaf et al. (2015) measured the relative efficiency of the maintenance unit at a main petro-chemical company in Saudi Arabia. In this study, using an EMS system, an output metric and three input criteria were determined. The DEA method was used in this study. Data from 23 maintenance units were collected and analyzed during 6 months. Using this study, operational units with low efficiency and high efficiency were identified. The most important feature of their research has been the examination of the functions of the multiple inputs and outputs simultaneously. This study provided important and valuable information from the unit’s function to the maintenance department managers and decision makers. The study recommends that rehabilitation work processes be re-evaluated and studied. The study also suggests that scheduling should be started six weeks before the operation is completed to provide all the necessary resources, workforce, as well as spare parts. In addition, all preventive maintenance measures are recommended to ensure accurate human resources estimation and task synchronization, and to be assured of PMR.

We reviewed 2 articles related to maintenance reviewed. After reviewing the main advantages and disadvantages of each article, it is summarized in Table 4.

Table 4. Summarizes the advantages and disadvantages of the maintenance articles

Author	Main Idea	Advantage	Disadvantage	Main suggestion for future research
Gouveia et al. (2015)	Presented a benchmarking investigation for maintenance and outage repair activity performed by a Portuguese electricity distribution Co., EDP Distribuição (EDP-D). The use of Value-Based DEA method linked with Multiple Criteria Decision Analysis (MCDA)	Exploited outcomes of the use of Value-Based DEA for a similar set of information. Allowed for incorporating the managerial priorities for identifying the most acceptable practices	Just one DM has been interviewed during the elicitation procedure of the utility function and introduction of the weight constraints	Besides identification of the most acceptable practices, resources of inefficiency, the gaps relative to the most acceptable practices and chances for improvements, we can support the introduction of the corrective measures and announce decisions of the future objectives, and improve insights into the company
Assaf et al. (2015)	Measured the relative efficiency of the maintenance units into a main petrochemical company in Saudi Arabia	It employed the available indices, which have been put together at all prior to the provision of a detailed study of the unit performance that enabled the efficient benchmarking. Capability of the evaluation of performance of several outputs and inputs at the same time in an objective manner	Does not review work management process	It is recommended to begin the planning and scheduling six weeks ahead of the work implementation for preparing each necessary resource, spare part as well as workforce for avoiding under-utilization of the workforce. Moreover, coordination of each preventive maintenance job would be recommended for assuring the precise approximation of the workforce.

3.5. Hotel industry

Assaf (2012) conducted a benchmarking study of Asia Pacific hotel as well as the tour operator industry. They utilized an innovative approach focused on the combination of stochastic frontier and DEA within a Bayes system. The results showed that Singapore, South Korea, and Australia have been introduced as the most efficient ones in their tour operator and hotel industries.

Wu et al. (2013) presented a benchmarking framework to assess the hotel industry efficiency in several periods, with consideration of depreciable characteristics and transitional activities. In the study, high performance functions have been specified and their business approaches have been illustrated. Dynamic DEA was used to identify stable efficient functions. An excellent DEA method was used for overall ranking of input-output-consumption structure. A further analysis has been also accomplished to facilitate the interpretation of the outcomes of benchmarking. Totally, 9 hotels from 80 international tourist hotels in Taiwan from 2006 to 2010 were recognized as high-efficiency hotels. These hotels offer business strategies for the staff (intensive vs. economical workforces), product (the room vs. F&B services (food & drink), price (very costly and highly cheap prices), guest (e.g., business and tourism guests) and so forth; for example, location supremacy have been divergent.

We reviewed 2 articles identified as hotel industry. After reviewing the main advantages and disadvantages of each article, it is summarized in Table 5.

Table 5. Summarizes the advantages and disadvantages of the hotel industry articles

Author	Main Idea	Advantage	Disadvantage	Main suggestion for future research
Assaf (2012)	Measured and compare efficiency of the leading tour operator and hotel companies throughout numerous Asia Pacific countries	Used one of the innovative methodologies on the basis of the combination of the stochastic frontier and DEA in a Bayes framework	A major limitation has been the small size of the sample in a number of countries. Number of years has been limited. Hence, outcomes may be impacted by current directions such the recent financial crisis	As a result of limitations in data, more hotels and tour operators in a number of countries in than other ones may can be obtained. Therefore, efficiency for each sample individually did not estimate and comparison must be done carefully
Wu et al. (2013)	Introduced a benchmarking method to assess efficiency of hotel industries, in a multiperiod setting by examining the perishable features as well as the carry-over activity	Involved in the benchmarking articles and hotel industry in multiple dimensions	Analysis of the variations in the most acceptable hotel practices via comparison of the benchmarking outcomes between 2 distinct multiperiod timetables; for example, from 2006 to 2008 vs. 2009 to 2011	Their suggestion for applying this new multiperiod benchmarking method to other service industries like the transportation system described with perishable and carry-over activities in further investigations

3.6. Education

In this regard, Reichmann and Sommersguter-Reichmann (2006) presented a structure for evaluating technological output in Austria, Australia, Germany, Canada, Switzerland, US of 118 university libraries. The DEA method has been used to investigate and evaluate the difference between those libraries' results. They also looked at how the internal organizational rules influenced the productivity of libraries. Findings of the performance appraisal between countries indicate that nearly 1/3 of the university libraries were efficient. With the use of the particular environmental boundaries, the difference in managerial efficiency versus the difference in environmental productivity was examined, reflecting the major discrepancies in the technical efficiencies of the European as well as non-European academic libraries. Nevertheless, according to environmental laws, non-European libraries with the highest performance are better than their European ones.

In addition, Gourishankar and Sai Lokachari (2012) used the Educational Development Efficiency (EDE) model for benchmarking the country states. In this paper, a conceptual framework for input-process-output was used for identifying educational development aspects. In their investigation, researchers utilized DEA model to compare relative efficacy and benchmarking of 28 states and 7 areas in India. In fact, factor analysis has been used for determining relationship between existing variables. Using multiple regression analysis, effective effectiveness variables were identified. In their study, the benchmarking of the educational development in the Indian states was carried out according to their performance. By examining the results, it was found that the variables that affected state EDE were the ratio of gross participation, students' academic performances and infrastructure investment. Insights into the use of input tools to enhance the quality of education and the later improvements in the state efficiency have been provided. Hence, 4 elements were established to evaluate progress of the educational achievement of the states; that is, financial sufficiency, strength of the school infrastructure, quality of education and access to education.

Cook et al. (2017) proposed a method to study the status of Spanish universities (where the current policies of universities are highly influenced and affiliated with regional governments), and was inspired by studies by Cook and Zhu (2007) to benchmark DMUs that members have same conditions. According to Cook and Zhu (2007), in these cases, a DEA-based strategy, which independently evaluates DMU behaviors is not very effective. The common criteria within the group presented in their study can be considered as a mediator between the common complete benchmarking test and pure DEA for entire DMU set. This approach is on the basis of the Pareto-efficient DEA method, which is determined by a set of DMUs, and supposed to be compared. Such a method has specifically prevented the occurrence of problems in small DMU groups. Empirical observations indicate that the proposed method can produce results that better reflect the conditions of DMUs. Especially when these DMUs are under a same benchmarking.

Ramón et al. (2018) presented a 2-phase benchmarking process in context-dependent DEA model and models that minimize their gap from the efficient DEA model. This method allows us to determine the realistic goals that are achievable, within a short time. In addition, various alternatives may be introduced to plan the progress towards the goals of the effective DEA model, which can be indicative of long-term improvement. Consequently, this

continuous approach provides managers with tools for deciding on ongoing reform strategies based on their operational objectives. This is possible by gaining experience from expertise and efficient systems. The research output of the Spanish public universities was analyzed to demonstrate this approach as an example. Given the respective utility, many ways exist to improve the suggested solution. One of the attractive lines of researches must be aimed at the investigation of expansion of a 2-phase benchmarking method for addressing the targeted DEA models that have been utilized in several practical analytical utilizations. We reviewed 4 articles related to education verified. After reviewing the main advantages and disadvantages of each article, it is summarized in Table 6.

Table 6. Summarizes the merits and caveats of education articles

Author	Main Idea	Advantage	Disadvantage	Main suggestion for future research
Reichmann and Sommersguter-Reichmann (2006)	A DEA framework for international performance evaluation of 118 university libraries consisting of libraries from Austria, Australia, Germany, Canada, US, Switzerland	Providing the initial information of technical efficiency differential at the level of library and at a more aggregate level	Qualities of the DEA outputs depended strongly upon the selection of the output and input measures	Because any information has been not found about in-library use, outputs can be distorted systematically. Measures associated with quality like the satisfaction, user-friendliness and or responsiveness must be considered
Gourishankar and Sai Lokachari (2012)	Develops an EDE model for benchmarking the Indian states	Information of the application of the input resources for enhancing the educational development as well as later improvements in the state efficiencies have been offered	Research in a one geographic area can be a limitation	Offer Indian states a cross-comparison for performance benchmarking purposes with other countries
Cook et al. (2017)	A strategy to benchmark the DMUs, which may be placed within the groups whose members experienced the same situation	The models have been designed for conditions wherein a popular best-practice frontier has been specified for a group of DMUs as a consequence of choosing dimensions, which yielded the closest targets	Due to lack of individual situations of universities into the regions	Evaluation of research performance of university of other countries
Ramón et al. (2018)	Proposing a 2-step benchmarking strategy in the spirit of context-dependent DEA and the models minimizing distance to the DEA efficient frontier	Considering outputs & inputs presented below that related as usual to the physical and human capital and incomes and publications	Only in public Spanish universities	Perform at other universities and educational institutions

3.7. Distribution

Jha et al. (2008) used updated DEA models to test benchmarking of the production and distribution units in Nepal. They studied operating efficiency of the producing stations and Nepal Electricity Authority (NEA) owned distribution centers. These models contain a broad variety of outputs as well as inputs, which reflect the nature of processes in question. DMU rating was provided based on their overall average output score.

Ajodhia (2010) stated that energy regulators, using price-capping system, usually did not use quality in the procedure of benchmarking. Hence, the present investigation aimed at the explanation of a technique for the integrated quality-cost benchmarking in the networks of the electricity distribution. Therefore, 2 fundamental models were used in the study: a technical model that minimizes quality as an input variable and a social cost model that measured quality of an optimal presentation. The two models were used in two Dutch and English companies. The results showed that although the integrated quality-price benchmarking is an important indicator in the regulation of rules, but also its limitations should be identified.

Hung Lau (2012) discussed utilization of DEA model to assess performance of the store with the aim of correcting the distribution network in his study. A DEA model was utilized for examining relative efficiency of the distribution in main stores of a key retailer in Australia. The present investigation was conducted using other methods like spatial distribution of demand and customer segmentation, and showed the DEA method was able to provide a rational and appropriate justification for the distribution network. This method can also be used as an analytical method to facilitate continuous improvement. The result showed that when retail stores are closed down or merged with other stores operating in similar areas, the overall network performance will improve. Such logical actions will result in the integration of demands and modification of the operation of vehicles with minimal impact on customer service.

We reviewed 3 articles related to distribution recognized. After reviewing the main advantages and disadvantages of each article, it is summarized in Table 7.

Table 7. Summarizes the advantages and disadvantages of the distribution articles

Author	Main Idea	Advantage	Disadvantage	Main suggestion for future research
Jha et al. (2008)	To investigate the operational efficiency of the generating stations and the distribution center (DCS) owned by Nepal Electricity Authority (NEA)	The DMUs has been ranked on the basis of their average overall efficiency score	Limited of the variables under study	Select more variable of power plants
Ajodhia (2010)	Developed a method for the integrated cost-quality benchmarking for the electricity distribution network	There is no completely integrated price-quality benchmarking strategy for the electricity distribution networks; therefore, this research filled the mentioned gap	The two models were used only in two Dutch and English companies	Implementation in other companies

End of Table 7

Author	Main Idea	Advantage	Disadvantage	Main suggestion for future research
Hung Lau (2012)	Discussed the use of DEA for benchmarking the store performances in order to rationalizing the retail distribution network	Their strategy may contribute to selection of the most reasonable practice and facilitation of more efficient allocation of the resources through the whole retail network. Moreover, the approach adds further knowledge of how demand management may influence the distribution efficiency of the retail network	The research has been limited to 6 stores in the retail network with a relative function in distributing assessed on a single input and a single output variable	Expanding the scope of research for more stores

3.8. Environment

Liu et al. (2019) developed a range-adjusted measurement (RAM) efficiency metric focused on the farthest target that examined the unwanted production for the calculation of the environmental performance. DEA is used for determining environmental performance of 27 coal-fired power stations in China. Consequently, on the basis of the assumption that information of benchmarking information may provide a crucial path for inefficient DMUs for achieving efficiency, the other RAM environmental performance metric is designed to evaluate the output and provide the closest benchmarking information, with regard to the closest target. Therefore, empirical study showed that the closest goals would be easier to achieve and provided the most important solution for inefficiency reduction.

Didekhani et al. (2019) have suggested the transformation of a non-linear model into a linear one with the correct transformations. In this paper, with the notion artificial DMUs, a practical DEA model has been proposed which considers the environmental and practical constraints. In addition, the model feasibility and bounded efficiency scores could be two merits of the model.

Das and Kundu (2019) determined the crucial parameters of the environment that influenced overall function of Micro Small Medium Enterprises (MSMEs). This research designed an efficiency score for all countries with regard to the interaction variable. As shown by the present study results, each of the countries working at suboptimal scale held the benchmark relationships with an efficient country, which has been operated at the optimized scale. Hence, it is necessary for the macro-economic policy-makers of the inefficient countries to emphasize the benchmark countries while formulating policies.

We reviewed 3 articles related to environment identified. After reviewing the main advantages and disadvantages of each article, it is summarized in Table 8.

Table 8. Summarizes the advantages and disadvantages of the analyzed articles

Author	Main Idea	Advantage	Disadvantage	Main suggestion for future research
Liu et al. (2019)	DEA has been utilized for the evaluation of the environmental efficiency of 27 coal-fired power plants in China	It demonstrates that closest objectives have been more simply achievable and provided the most pertinent solutions for removing inefficiency	Only one country studied	The pollution emission reduction allocation amongst the coal-fired power plants may be one of the directions for further studies
Didekhani et al. (2019)	Their article attempted for extending the basic models to benchmark the efficient units at functional condition	Their model would be constantly practical. Moreover, efficiency scores have been attained at thoroughly feasible condition	Only basic models for benchmarking of efficient units applied	Taking into account vagueness and the environment of functional limitations, unknown strategies like fuzzy, robust as well as stochastic may be utilized to suggest future investigations
Das and Kundu (2019)	Determining essential parameters of the environment that impact overall function of the Micro-Small-Medium Enterprises (MSMEs)	This investigation devised one of the efficiency scores for all countries with regard to the interaction variable	Two area spotlighted	The extended form of the present investigations may be utilized for deeper analyses of the policy associated with MSMEs

3.9. Other topics

Díaz et al. (2004) applied benchmarking and DEA methods for the irrigation districts in Spain. This analysis has been utilized to identify the most representative irrigation areas in Andalusia that have been consequently examined comprehensively via application of the performance metrics chosen by IPTRID to be utilized in international benchmarking programs.

Wu et al. (2013) focused on Asian Games with more attention to the two main issues, the basis for common comparing for DMU ranking and a reference feasibility between inefficient DMUs and benchmarking goals. In their study, they developed previous studies related to DEA by providing an ameliorated context dependent DEA model. By the use of this model, a proper and specific ranking system has been created for each participating country. Their suggestion was to improve the ranking system in Asian games. As a result, more educational objectives were identified and as a result, participants who had poor performance were able to progressively improve their performance. The results of the study will be effective in improving the strategic management of decision making in sport.

Moreover, Oh and Shin (2015) examined the effects of the performance benchmarking mis-measurement: A Monte-Carlo analysis SFA and DEA with various multiperiod budgeting approaches. In the present article, outputs of the analyses are presented that contain errors in measuring and comparing efficiency of system in different empirical approaches.

In each approach, a production frontier estimation model and a distinct multi-cycle budgeting approach are used. Boundary-estimation models that were used were the DEA model as well as stochastic frontier analysis (SFA). Principal outputs of this investigated included: (1) application of a budgeting approach and a proper benchmarking model may result in a significant increase in the system performance; (2) despite relatively high measurement errors, a “peanut butter” approach works better than a discriminative approach, while in cases where measurement errors are less, a discriminative strategy performs better; (3) frontier estimation models perform better than that of the randomly produced ranks models, even in cases where measurements with the comparatively large errors are faced; (4) in cases where measurement errors are low, the SFA model outperformed the DEA model, while DEA model performs better than SFA when measured with a large error.

Ruiz and Sirvent (2016) presented a DEA based strategy to benchmark and rank the decision makers. In manufacturing processes, many of situations that DMUs are involved in, are similar to each other, so benchmarking these situations leads to finding common problems and, therefore, adopts the most appropriate way to deal with them. Therefore, this method is used when there is no need to examine the DMU conditions individually. In other words, unlike DEA, the value of inputs and outputs must be shared among each unit that are being examined. However, in studies conducted, the DEA model was used to find the CSW for use in performance analysis, which suggests that it can be used to create a benchmarking framework. The approach proposed identifies a common boundary of the most appropriate measures as a form of DEA's efficiency boundary. This common boundary is produced by some DMUs in one of the common reference groups that has high technical capability. This reference group is selected to meet the most (closest) goals, diminishing gaps of the actual performance with the most acceptable procedures. Moreover, the extended model leads to the determination of CSWs that can be used to determine the amount of productivity and DMUs rank.

Mishra and Pal (2017) benchmarked India's SMEs through DEA so that they can predict their performance for effective decision making. For this purpose, there were 41 Indian SMEs that produce automotive parts. Similar groups and weights were identified in ineffective SMEs, which can be beneficial to benchmark ineffective DMUs. SMEs are able to find the factors that are weak and take appropriate measures to improve them. Similar groups in inefficient SMEs represent efficient SMEs that combine their inputs and outputs with many similarities. This tip helps managers to predict DMU performance individually with regard to the input consumption as well as produce “what-if” scenarios.

Wang (2017) examined the use of the DEA model, the measurement of environment-friendly buildings and the identification of its separate advantages. At first, the methods and indicators for assessing the environmental performance standards were reviewed. Then, in order to implement individual and group benchmarking for a certain degree of “star”, a model of benchmarking was performed with regard to the DEA model and identification of separate advantages. Finally, for modeling analysis, 15 specific projects were selected in the same region for determination of benchmarking similar projects. On basis of the creation of the DEA model, this investigation analyzed first validity of the green-building projects that function as a decision-making unit and consequently stated improvement paths for techni-

cally inefficacious or invalid project scales; ultimately finds the learning benchmark provided with the all projects by identification of the individuality benefit. Zhou et al. (2019) investigated the compensation and penalty process based on a DEA benchmarking method for water resource environmental-carrying capacity (WRECC). Therefore, for proving validity of their new method, one of the case studies on WRECC-based PRM of top 10 cities in China's Huaihe River Basin has been chosen. Findings suggested that cities selected would be benchmarked as opposed to Yangzhou, Jining and Zhengzhou in 2016; Zhengzhou, Xuzhou. Yangzhou and Jining will earn reward and the rest of cities that have been assessed will impose penalties. The difference between the actual output and the DEA goals can be established according to the results; how much change those areas may be specified; and areas, which must be punished or rewarded a particular amount of the money expected may be specified.

Samoilenko and Osei-Bryson (2019) presented a modern multimethod method to benchmark, which obviously examined the context-specific parameters influencing the function of the of organizational entities. Such an approach entails creative integration of multiple information systems (IS), artifacts; that is, numerous data mining techniques with DEA. The results showed complexity of the association of the parameters, which show drivers and impacts.

Nasrabadi et al. (2019) presented a benchmarking algorithm to DEA with the interval-scale data. Their strategy has been on the basis of a layering process that classified a series of each unit to various layers based on their efficiency state. Conclude lies on two possible drawbacks. The first probable one is zigzagging; that is, an output or input variable can enhance in one phase and decline in another phase. As a result, the defined path would not experience a monotonic convergence to the final efficient objective. In addition, the amounts of the adjustment between 2 sequential objectives can differ; namely, 2 intermediate objectives can be highly close and include little alterations whereas for 2 other ones, considerable adjustments would be crucial. Hence, we cannot control the amounts of adjustment necessary in each phase in such layering algorithm. Nevertheless, regarding the interval scale data, such a concept would be highly advantageous in discovering the targeted units.

Ashuri et al. (2019) contributed to our information in creating the energy benchmarking using the modern DEA model. This modern DEA model has been utilized for benchmarking the energy efficiency in 108 buildings in a multi-family sector that considered parameters showing the total consumption of energy, building properties as well as local weather condition. It specified ineffective units via examining 3 efficiency scores; that is, pure technical efficiency, scale efficiency, and overall efficiency among the DMUs in a multi-family housing industry. Their outputs reflected that about 20% of the features actually have been activating at the most productive scale sizes as 100% efficient with regard to the pure technical efficiency. The above result indicated management of the features in a more energy-efficient way by the facility managers in those buildings.

Ruiz and Sirvent (2020) argued incorporation of the DEA benchmarking models into their objective criteria in order to choose the proper benchmarks amongst peers and consideration of the definition of pleasant objectives. However, the strategy suggested in the present article intended for developing the DEA benchmarking models, which aimed to set proper objectives and identify the peers after favorable criteria to select the benchmarks. In

particular, these models had two targets of defining the closest objectives and choosing the closest reference sets. Hence, outputs of this empirical utilization showed that the models practically specify the reference sets frequently containing the peers with functions of higher similarity with the unit being evaluated in comparison with the ones offered by the models, which just relate to the definition of the closest objectives.

Ramón et al. (2020) indicated the way of implementation of such a fundamental idea via the notion of cross benchmarking that has been considered to be one of the approaches designed into DEA framework. The outputs obtained from empirical applications illustrated a reality that managers can define their plans to improve via selection amongst the other plans following the consideration of various implications of the reduced input sources and or increased output production as well as reallocation of the resources or substitution of the outputs and inputs.

We reviewed 12 articles with different topic identified. After reviewing the main advantages and disadvantages of each article, it is summarized in Table 9.

Table 9. Summarizes the advantages and disadvantages of different articles

Author	Main Idea	Advantage	Disadvantage	Main suggestion for future research
Díaz et al. (2004)	Application of benchmarking and DEA methods in Spanish irrigation districts	Allowing managers to get a well-defined rating of results. These studies can be very useful for managers who must often choose between reducing labor input or water consumption or substituting current crops for more profitable ones in a given irrigation district	The DEA study imitated for five areas representative irrigation districts of Andalusia	Expand the areas of research
H. Wu et al. (2013)	Extended earlier DEA investigations by incorporating an enhancing context dependent DEA model, wherein the empirical findings for all participants create a specific and equal ranking system	Contributed to the Asian Games through more questions about 2 key problems; that is, general basis to rating DMUs as well as comparison feasibility between ineffective DMUs and their benchmarking targets	It may not be practical to assume that the weight limits on the output items use smoothly throughout each nation and region	Follow-up studies are recommended to perform relevant work in this area of study

Continue of Table 9

Author	Main Idea	Advantage	Disadvantage	Main suggestion for future research
Oh and Shin (2015)	The researchers conducted Monte Carlo analysis for comparing a general system throughput in different experimental scenarios produced by pairing different multi period budgeting approaches with 2 frontier estimation models of output, DEA, & SFA	Every scenario assumes a particular budgeting strategy for multiple periods and the production frontier estimation model	In industry, the expectation of the use of the same measurement error distribution and inefficiency distribution would be feasible during time because it could be conceived that distribution of the measurement error and inefficiency, which dynamically alter as time goes	Future research could extend the scope of such a topic by additionally exploring optimum budget allocation approaches which could increase overall performance of the system more rapid than the peanut butter or potential weighted approaches suggested in the present article. The dynamics behind the time-varying distributions of measurement and inefficiency errors must be taken into account and a novel dynamic SFA model must be developed for capturing dynamics accordingly
Ruiz and Sirvent (2016)	Proposing a DEA-based benchmarking method for utilizing in case of the lack of necessity or unwillingness for allowing for individual DMU situations	Identifies a specific frontier of best practice as the DEA-effective frontier dimension spanned by technically productive DMUs within a shared reference group	Such a strategy would be utilized in case of the lack of necessity or unwillingness for allowing for individual situations of DMUs	To examine a potential extension of such a traditional benchmarking methodology to the case wherein the DMUs could be put in the groups with the members experiencing the same situations along with research in (Cook & Zhu, 2007)
Mishra and Pal (2017)	Their research studied the benchmark of the Indian small and medium enterprises (SMEs) via DEA for predicting SMEs function for effective decisions	It assists managers for predicting functions of the individual DMU with regard to the input used and generating diverse “what-if” scenarios	Only done in one region	Can do it in other country and compare with this research result
(Wang, 2017)	Techniques and assessment indicator of the green building benchmarks is analyzed	Analyzing validity of the green building project that serve as a basis of decision-taking and consequently sets out a course of change for technically invalid or unsuccessful project to scale	Only done in one industry	Can do it in other domain and compare with this research result

Continue of Table 9

Author	Main Idea	Advantage	Disadvantage	Main suggestion for future research
Zhou et al. (2019)	A strategy has been designed to demonstrate how DEA may be applied with the strategy of adapting the benchmarking to the goals to set objectives as the reference point of incentive and penalty plan	Designing the effective Reward and Penalty Mechanism (RPM) for areas in the basin with regard to the function of the Water Resource Environmental Carrying Capacity (WRECC)	Evaluation of a novel DEA benchmarking model with regard to the assessment of the performance limit framework	The proposed method may be devised into a more general framework, in which a nonmonetary compensation and penalty plan would be investigated
Samoi-lenko and Osei-Bryson (2019)	Presenting a novel multimethod benchmarking method which specifically considers context specific parameters that impact organizational entities performance	It involves a new & creative integration of multiple data mining methods (Cluster analysis (CA), decision tree induction (DTI), association rule mining (ARM) with DEA	Not applicable to static business environments, pro- duction process that is context-independent and process improvement approaches	Future could be work developed for the mentioned area as limitation
Nasraba-di et al. (2019)	To suggest an algorithm that leads to a target path for all ineffective devices	The proposed model gives per unit efficiency scores. Proposing an algorithm that results in an inefficient target path for each unit	As a result, the chosen path would not monotonically converge to the ultimate effective target	In this sort of layering algorithms, any control would not be made over the amounts of adjustment needed in all steps. Nevertheless, this concept proved to be highly beneficial in identifying target units in the event of data on the interval scale
Ashuri et al. (2019)	DEA model, which overcomes the shortcomings of current energy benchmarking building models	Involves in detection of low-performance buildings which may be utilized as the investment goals to reduce building's environmental impacts	As a result, the chosen path wouldn't monotonically converge to the ultimate effective targets	It is recommended that the high priority buildings (specified with the use of novel DEA model) should be additionally examined with the energy simulation models to plan the energy efficiency retro-fitting

End of Table 9

Author	Main Idea	Advantage	Disadvantage	Main suggestion for future research
Ruiz and Sirvent (2020)	Develops DEA benchmarking models aimed at defining suitable objectives and at defining peers according to appropriate benchmark selection criteria	Through the specification of parameter α , the proposed models will produce some goals and peers, which provide numerous options with the managers for considering in the future planning as well as performance evaluation	Cross-sectional survey with heterogeneous members	Potent lines of the future work may involve, expanding the models suggested for addressing the units, which would be divided into classes of similar circumstances faced by members
Ramón et al. (2020)	Identifying the most reasonable practices for planning the learning and developing improvements. This study showed how this core concept could be applied via cross-benchmarking concept that has been considered as one of the methods formed into DEA context	Extending popular benchmarking method put forward in Ruiz and Sirvent (2016) to a benchmarking strategy for DMUs against multiple reference sets	There's always a major difference between real results and targets in action	Cross-benchmarking needs to be generalized to set more realistically attainable goals

4. Open issue and discussion

This study has identified eight major applications including: transportation, service sector, product planning, maintenance, hotel industry, education and distribution and factors environment. They take up a total of 88% of all application-embedded papers. Among all the applications, the highest growth recently has been in transportation as well as other sectors. The transportation industry and the expansion of its production and service activities are among the issues that are of particular importance in the socio-economic aspects of societies, and any efforts to improve civic and the productivity of this industry has tremendous effects on the economic activity of other sectors. Transportation activities included in multiple way (sea, air and land), multi- ownership (public, private and cooperative), multidimensional (engineering, economic, political and environmental) multinational and regional (inland, provincial and national). The result of these activities is the creation of a spatial relationship between supply and demand with production and consumption centers, so that by shifting

or transporting goods and passengers or transporting and moving people and goods from point to point, creates new value added. Therefore, the main issue of the research here is how it can be deployed for achieving highest level of efficacy in the transportation sector. For this purpose, DEA method could be used to measure the technical, managerial and rail-passenger transportation scale in fixed output conditions as well as variable returns relative to the scale of production in different parts during the years.

The transportation sector includes activities that have a strategic nature in the general process of the economy of the countries. Special attention is paid to domestic trade, foreign trade and tourism activities, so that any failure and crisis in the provision of service activities by it will reduce the economic well-being of the general population. Further, the statistics showed that the transportation sector is one of major consumers of petroleum products among other sectors of the economy. Therefore, the introduction of alternative methods to save energy can have a significant effect in preventing the loss of energy. The multidimensional nature of public transportation and the different perspectives and its expression of performance have transformed the issue of transport performance assessment into a complex issue that involves many factors. A method for evaluating this problem is suitable to cover the various dimensions of the problem. The method of DEA has been carried out in recent years due to the flexibility and expansion of the equipment according to the conditions and coordination with the nature of the issue of transport performance assessment. Although studies in this field have contributed to the advancements in the aforementioned methods, it is still questionable to resolve the issues of transport assessment by a DEA method that can take different mode, aspects and perspectives simultaneously. In other hand, service activities due to their intangible nature, the provision of statistics from their performance are more complex and difficult. For this reason, economists call the service sector an undefined part of the economy.

In sectors like agricultural and industrial, the final product, due to its specific characteristics and the possibility of offering it on the market, easily reaches the consumer through the supply and demand system, and the sales process is easy and transparent. While none of these is true for the service. In the case of many services, the buyer or the consumer will be able to purchase the service without being able to get the right information from what it costs. Performance will be in full swing, but there will be more difficulties in creating competitive conditions in service markets. The lack of facilities for standardizing services and problems in this area, resulting in heterogeneous delivery of services, is one of the main issues limiting competition in the service sector. Quality aspects of service are so high that makes the definition and presentation of specific standards impossible. To overcome this issue there are two solutions. First, using productivity ratio or indicators where data gathering and information are available for all the time as long as organization continues its activity. This method is highly flexible and researchers could adopt any ratio to justify their organizations missions. The second technique is DEA. Comparing to the previous approach, it is providing better theoretical foundation. The total productivity of the production factors is calculated and estimated by the production factors and the Malmquist index, through its components, namely, technological efficiency, management efficiency and scale efficiency. This method from the set of DMUs introduces a number as efficient and, with the help of

them, forms the efficiency boundary. Then, this boundary becomes the criterion for assessing other units. Therefore, the criteria for assessing the decision-making units are in the same situation. Another important feature of this analysis is the combination of a set of factors and therefore it evaluates all the input and output factors together. Another feature is being offset of its models. In other word, this feature allows each decision maker to cover and compensate their deficits or weaknesses in any output or input with the help of other outputs or inputs. Given that DEA models are solved by linear programming, the linear programming method is not sensitive to the measurement unit, and therefore inputs and outputs can be used from different measurement units. Even though there are some limitations, but it is still acceptable and desirable technique to measure the efficiency of the organization in different sectors.

In Table 10, some of the factors investigated in the reviewed articles. By being practical it means show functional the articles are. By used articles diversity the abundance of the articles prospected which have been used at each item. Efficiency and productivity items have investigated each article’s effectiveness and output. The remained two items refer to the inventiveness and self-efficacy of each article. Studies show that in the transport sector, the being practical index is more important and less one belongs to self-efficacy. Also, in the service sector and maintenance being the practical and efficiency index obtained as more important and less important belongs to self-efficacy. In the distribution section, being the practical index, productivity and efficiency are more important and the personal innovation index took less important. Efficiency took first place in the hotel industry and being practical and productivity placed in the last. In product planning, the indicators of being practical and efficiency are of relative importance. While in education section the area of being practical is more important than other sections. In other sections all have relative importance, while the self-efficacy is of low importance. Finally, among the environmental factors, the efficiency section obtained more importance, and self-efficacy got lower place.

Table 10. The summarized of previous literature

Author	Being Practical	Articles Diversity	Efficiency	Productivity	Personal Innovation	Self-Efficacy
Transportation						
Yoshida and Fujimoto (2004)	×	×	✓	×	×	×
Martín and Román (2006)	×	✓	✓	×	✓	×
Quaresma Dias et al. (2009)	✓	✓	×	×	×	×
De Koster et al. (2009)	✓	×	×	✓	×	×
Jie Wu et al. (2010)	×	×	✓	×	✓	×
Lim et al. (2011)	✓	×	✓	×	×	×
Park et al. (2012)	✓	✓	×	×	×	×
Egilmez and McAvoy (2013)	✓	×	×	✓	✓	×
Sharma et al. (2016)	×	×	✓	×	×	×
Park and Sung (2016)	✓	×	✓	×	×	×
Melo et al. (2018)	✓	×	✓	✓	×	×

Continue of Table 10

Author	Being Practical	Articles Diversity	Efficiency	Productivity	Personal Innovation	Self-Efficacy
Service						
Sherman and Zhu (2006)	×	✓	×	×	✓	×
Deville (2009)	✓	×	×	×	✓	×
Baek and Lee (2009)	×	×	✓	×	×	×
Kumar and Vincent (2011)	×	✓	✓	✓	×	×
Lai et al. (2011)	✓	×	×	×	×	×
Sufian (2011a)	×	×	✓	×	×	×
Wu (2012)	✓	×	×	×	✓	×
Nigam et al. (2012)	✓	✓	✓	×	✓	×
Karbassi Yazdi and Abdi (2017)	×	✓	✓	×	×	×
Álvarez-Rodríguez et al. (2019)	✓	×	×	×	×	×
Maintenance						
Gouveia et al. (2015)	✓	×	✓	×	×	×
Assaf et al. (2015)	✓	×	×	✓	×	×
Distribution						
Jha et al. (2008)	×	×	✓	×	×	×
Ajodhia (2010)	✓	×	×	✓	×	✓
Hung Lau (2012)	✓	×	✓	✓	×	×
Hotel Industry						
Assaf (2012)	×	×	✓	×	✓	×
Wu et al. (2013)	×	✓	✓	×	×	×
Product Planning						
Braglia et al. (2003)	✓	×	✓	×	×	×
Trappey and Chiang (2008)	×	×	✓	×	×	×
Shabanpour et al. (2017)	✓	✓	×	×	×	×
Education						
Reichmann and Sommersguter-Reichmann (2006)	×	✓	✓	✓	×	×
Gourishankar and Sai Lokachari (2012)	✓	×	×	✓	×	×
Cook et al. (2017)	✓	×	×	×	✓	×
Ramón et al. (2018)	✓	×	✓	×	×	×
Environment						
Liu et al. (2019)	×	×	✓	×	✓	×
Didekhani et al. (2019)	✓	×	✓	×	×	×
Das & Kundu (2019)	✓	×	✓	✓	×	×

End of Table 10

Author	Being Practical	Articles Diversity	Efficiency	Productivity	Personal Innovation	Self-Efficacy
Other Topics						
Díaz et al. (2004)	×	✓	×	×	×	×
Wu et al. (2013)	✓	×	✓	×	✓	×
Oh and Shin (2015)	✓	×	×	×	✓	×
Ruiz and Sirvent (2016)	✓	×	×	✓	×	×
Mishra and Pal (2017)	×	✓	✓	×	×	×
Wang (2017)	✓	×	×	×	✓	×
Zhou et al. (2019)	✓	×	×	×	×	×
Samoilenko and Osei-Bryson (2019)	×	×	✓	×	✓	×
Nasrabadi et al. (2019)	×	×	×	×	✓	×
Ashuri et al. (2019)	✓	×	×	✓	✓	✓
Ruiz and Sirvent (2020)	✓	×	×	×	×	×
Ramón et al. (2020)	×	×	✓	×	×	×

Conclusions

In companies, managers use benchmarking tools to evaluate their processes and compare them with best practices in a similar group in an industry. By measuring the effectiveness of measures, identification of the most successful companies leads to the setting of goals and enables these organizations to be able to improve their performance by learning from others. Companies’ rating based on assessments that offer beneficial data to decide. In general, the higher-rank refers to the more acceptable performances. The literature of applications of DEA methods in benchmarking Systematically reviewed. The DEA model is a useful and efficient tool for evaluating DMU activities. Identifying weak functions based on general information about activities is a main benefit of the DEA utilization in benchmarking. Since access to this information is often easy and cost-effective, the cost of DEA is often low. In addition, because the DEA model can be implemented based on non-financial valuations, it is also appropriate to compare DMUs with different financial conditions. However, since the evaluation of the DMU is attributable to virtual DMUs, the relationship between the results is due to the appropriateness of the assumed criteria and available information. Finally, results showed that DEA model cannot provide sufficient advice on the improvement of conditions, based on general information, but can only identify the potential of DMUs for improving conditions and facilitate decision making on how to analyze activities. Hence, the DEA model should be considered as an additional tool in activity-based management.

Hence, in this paper, the past articles of DEA in benchmarking systematically surveyed. 51 selected papers classified in eight classes that 11 of them are about transportation, 10 about service sector, education 4, and 13 of them are about factor of environment, product planning, hotel industry, distribution, maintenance and 12 of them about other sectors. These

articles reviewed and compared, and the results were collected. The results have shown that most of the papers tried to improve transportation process. The present paper has some restrictions. One issue is only exploring in popular Search Engine. There might be other scientific magazines offering a better illustration of the pertinent investigations. In addition, the papers excluded written in languages other than English. But, there might be many other related papers written in other languages. Lastly, researchers can perform more studies using other tools like interviews.

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Author contributions

Omid Akbarian wrote the first draft of the article with supervisory of the Reza Rostamzadeh. Reza Rostamzadeh and Audrius Banaitis provided extensive advice throughout the study regarding the abstract, introduction, literature review, research methodology, data analysis, results and discussion, and conclusions of the manuscript. The discussion was a team task. Omid Akbarian and Zeyanb Soltani conducted data analysis. All authors have read and approved the final manuscript.

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