A PRISMA-Compliant Review of DEA Applications in Multimedia

Katerina FOTOVA ČIKOVIĆ*, Damira KEČEK, Joško LOZIĆ

Abstract: The overarching objective of this paper is to survey, identify and present the most relevant papers that have applied the leading non-parametric methodology (namely, the Data Envelopment Analysis, hereafter DEA) in the research field of multimedia. Another goal is to provide a theoretical background to the DEA methodology and the literature on multimedia.This systematic literature review has applied the PRISMA guidelines to include relevant DEA applications in multimedia-related studies. For this purpose, the most relevant and globally renowned scientific databases Clarivate Web of Science and the Scopus database have been explored with the use of the keywords "DATA ENVELOPMENT ANALYSIS" and "MULTIMEDIA". The review and survey have resulted in six published papers regarding multimedia with the application of DEA. Their findings, the used DEA models, and different perspectives of DEA application have been presented and analysed in more detail. All of the six surveyed papers have been published after 2005 (i.e. from 2006 to 2019) and their modest number implies that the DEA methodology, even though very well-known and quite popular in the literature for over three decades, has been neglected by researchers in the multimedia-related research. Hence, this paper represents an incentive and an inspiration to other scholars to implement the DEA methodology more often in their multimedia research and any other research for that matter.

Keywords: data envelopment analysis; DEA; literature review; multimedia; PRISMA guidelines

1 INTRODUCTION

Multimedia has become a fundamental part of people's lives, and this has been achieved in the past two decades through the rapid development of the Internet and technology. Considering the immense impact on societies and economic growth, the question of efficiency in multimedia-related research has been posted. Efficiency in general could be empirically evaluated in three ways: the ratio indicators, the parametric and the nonparametric methods [1]. The Data Envelopment Methodology (DEA) has been one of the most applied non-parametric methodologies in the past few decades due to its simplicity to use and wide application possibilities. It is commonly applied and best-known for efficiency evaluation in different industries. More on the DEA methodology is presented in Subsection 2.1.

In this study, the PRISMA-guided systematic review has been conducted with a survey and exploration into two of the globally most relevant scientific databases, i.e. the Scopus and Clarivate Web of Science, with the use of the keywords "DATA ENVELOPMENT ANALYSIS" and "MULTIMEDIA".

The main objective of this study is to identify all the relevant published studies in multimedia-related research, as well as to present and analyse their findings as a means for the synthesis of the state of knowledge in the field of multimedia.

The rest of this paper is structured as follows. Section 2 introduces and provides a theoretical background to DEA and multimedia literature. Section 3 presents the research design and Section 4 reveals the surveyed papers and their findings. Finally, Section 5 opens up a discussion and provides concluding remarks.

2 THEORETICAL BACKGROUND
2.1 Data Envelopment Analysis (DEA)

Ever since its introduction in the late 1970s, DEA has been widely applied in efficiency measurement in many empirical research studies in various industries. Even though it has been primarily developed for use by

non-profit organizations, its application has surpassed other non-parametric methodologies and is now one of the leading and most popular non-parametric methodologies.

Data Envelopment Analysis (DEA) is a data-oriented approach and a non-parametric method for linear programming used for evaluating the performance (i.e. the relative efficiency) of a set of units called decision-making units (DMUs), which uses multiple input and output variables in the evaluation. DEA is an effective system analysis method commonly used in recent years and a popular analytical tool in the "new field of interdisciplinary research of operations research, management science and mathematical economics" [2]. This methodology is recognized as an excellent and easy-to-apply approach for modelling operational processes for performance evaluation [3]. In fact, it is a mathematical programming technique that allows for a relative comparison of the efficiency of each DMU relative to the other entities included in the analysis [4].

Unlike parametric methodologies, DEA enjoys a few advantages. First, it does not require pre-specification of the model, and it gives feedback on whether the observed DMUs lie below or above the "efficient frontier" instead [5]. Second, there is no need for pre-required "knowledge of the explicit functional form linking input variables and output variables nor a priori determination of the weights for these variables" [6]. Third, it includes simultaneous analysis and the use of multiple input and output variables.

However, this methodology has a few drawbacks as well. For instance, it is only recommended for small samples and its main disadvantage is the assumption "that random errors do not exist", but this leads to "frontier sensitivity to extreme observations and measurement errors" [7].

There are two basic DEA models, namely the CCR and the BCC model. The CCR model has been introduced in the seminal paper of Charnes, Cooper and Rhodes in 1978 and the BCC model has been developed and introduced five years later by Banker, Charnes and Cooper. The key distinction between these models is the assumption regarding the returns to scale. Namely, the CCR model has a constant return to scale, whereas the BCC model variable

return to scale (and therefore, it represents an extension to the CCR model).

2.2 Multimedia

The term "Multimedia" has been thus far "variously and often ambiguously defined" [8]. One of the first attempts to define multimedia occurred in 1992: "A multimedia computer system is one that is capable of input or output of more than one medium. Typically, the term is applied to systems that support more than one physical output medium, such as a computer display, video, and audio" [9]. Even though there have been many definitions that focus primarily on technology, the majority of people would accept the "mix of voice, text and graphics" as a definition [8]. Moreover, multimedia can be defined as an integration of text, graphics, drawings, video, animation, audio, and any other media where information is represented, stored, transmitted and processed digitally [10].

Kennedy (2021) [11] has provided a very tangible definition of multimedia "as a fundamental concept that includes various forms of medium to produce some type of communication". It can actually be pretty simply defined as the use of different and many mediums for information exchange.

Moreover, Abdulrahaman et al. (2020) [12] define multimedia as "a combination of more than one media type such as text (alphabetic or numeric), symbols, images, pictures, audio, video, and animations usually with the aid of technology to enhance understanding or memorization" and "the hardware and software applied for creating and running multimedia applications as multimedia technology". Guan, Song & Li (2018) [13] refer to multimedia as "computer science" that combines two or more than two media and as "a unity of media and a reasonable coordination of media".

There are new emerging definitions of multimedia as a communication tool that "provides consumers with an expanded view of reality, revealing new insights differently and offering added value to the overall communication with consumers" [14].

Rockwell & Mactavish (2004) [15] claim there are two ways to "think through multimedia, to think about multimedia through definitions, histories, examples, and theoretical problems or to use multimedia to think and to communicate thought".

Its definition has transformed during the COVID-19 pandemic when the main focus was on multimedia in the teaching and learning process [12]. However, the definition and relatedness of multimedia with learning have been known for quite some time in the literature [16] and the advantages of Computer Multimedia-aided English Teaching have been known for a fair bit now [13]. There are new studies that claim that ICT (information communication technologies) and multimedia could bring major advantages to other industries such as the tourism industry, which could potentially bring a higher degree of development to the total economy [14].

In the last decade, followed by the growth of multimedia technology, multimedia has entered "all fields of human life with great penetration, such as games,

education, archives, books, entertainment, art, stock bonds, financial transactions, architectural design, family, communications and so on" [2]. Multimedia has been following all the new trends and new human lifestyles and thus, its power nowadays is immense.

3 RESEARCH APPROACH

The methodology used for this study is a systematic literature review (SLR), which is referred to as an "essential tool for summarizing evidence accurately and reliably" [17]. The main incentive for using this methodology was to summarize past findings and review applications of the Data Envelopment Analysis methodology in multimedia. For this reason, two of the most renowned global scientific bases have been surveyed, as follows: the Scopus and Clarivate Web of Science. The initiated survey has been conducted with the use of "Multimedia" AND "Data Envelopment Analysis" as keywords for the search. The research approach has been presented in Fig. 1. In the first step, the two most relevant scientific databases have been identified. In the second step, only papers written in English and fully downloadable papers have been identified. Thereafter, these papers were screened (i.e. their abstracts have been reviewed in order to establish if they are relevant to this SLR. In this phase, 16 papers have been eliminated from the study and in the next step, the eligibility phase, 3 papers have been eliminated after a full-text eligibility decision has been made. Thus, six papers have made it to the last phase of inclusion (i.e. the quantitative and qualitative analysis). A more detailed presentation of these studies and their findings are shown in the next section.
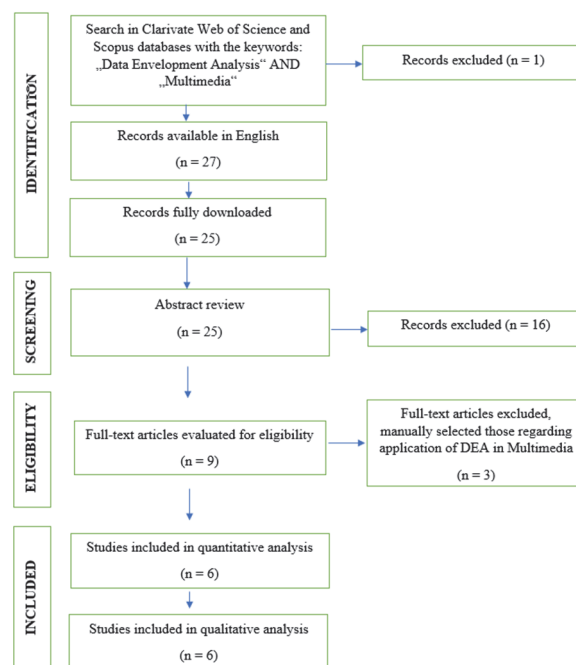

Figure 1 The research design and the selection process of the papers for the literature review (PRISMA-guided)

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, which have been first introduced in 2009 by Moher et al. (2009) [18], have been used in this research. This PRISMA

Statement has been widely used and has become quite popular amongst scholars due to the substantial increase in the number of systematic reviews (SRs) in the past two decades [19]. The PRISMA Statement has a 27-item checklist and a "four-phase flow diagram" and its main objective is to "help authors improve the reporting of systematic reviews and meta-analyses". It can be a useful tool for systematic reviews in different industries and for "critical appraisal of published systematic reviews". However, it should be not considered "a quality assessment instrument to gauge the quality of a systematic review" [18].

4 RESEARCH RESULTS

The main goal of this review was to survey the most relevant scientific databases (i.e. Scopus and Web of Science) in systemizing the previous relevant published work regarding the application of DEA in multimedia-related research. The research design makes it quite evident that the DEA methodology, even though very popular in banking, agriculture, supply chain, transportation, and public policy [20], is insufficiently and very modestly applied to multimedia-related field.

In this section, a tabular overview of the research results has been presented (Tab. 1), and qualitative analysis of each of the surveyed six relevant papers and their findings follows thereafter.

Table 1 Applications of DEA in multimedia-related research

Author/s and year of publication	Title of the paper	DEA methodology
Sahin, Terpenny, Simpson, Shooter & Stone (2006) [21]	A Method to Evaluate Relative Instructional Efficiencies of Design Activities for Product Platform Planning	Data Envelopment Analysis (DEA) model applied to two case studies
Zhao, Fei & Li (2013) [22]	Empirical Analysis on Aerobics Multimedia Teaching Based on Interactive Mode	DEA + the exploratory empirical analysis of the entire teaching system
Wu & Wang (2014) [23]	Simulation Platform Design Based on LabView	Simulation model (English multimedia network teaching platform) based on DEA and LABVIEW
Zuo & Wang (2014) [24]	Research of Network Auxiliary Project on Man–Machine Interaction Under the Multimedia Technology	Data Envelopment Analysis of Multimedia Network Teaching Model
Raayatpanah (2017) [25]	Multicast routing based on data envelopment analysis with multiple Quality of Service parameters	The CCR-efficiency model and the cross efficiency model
Chen (2019) [2]	Application research of data envelopment analysis and multimedia information fusion algorithm in public performance management	Multimedia data envelopment optimization selection model and PCA-DEA

Sahin, Terpenny, Simpson, Shooter & Stone (2006) [21] have developed a model for evaluation of the relative instructional efficiencies of design activities for product platform planning in the field of engineering design. They have employed the DEA methodology in two case studies, with assignment technical complexity as input and three outputs (assignment appropriateness, clarity, and effectiveness). Their findings reveal that "decision-making appeared to be instructionally more intuitive and cognitively more complete for the students". This study provides a great scientific contribution due to the presentation of the concepts of function-based family design, component sharing, and modularity along with customer needs-driven approaches and due to the insights it provides which improve the "understanding of the relative appropriateness, clarity, and effectiveness of the two design activities for product platform planning".

Zhao, Fei & Li (2013) [22] have applied the DEA to experiment with the exploratory empirical analysis of the entire teaching system. Their main goal was to "provide scientific support for modern education and teaching with positive feedback". They claim that modern teaching methods enjoy many advantages over traditional methods, and multimedia teaching could help in the achievement of a better and more solid teaching effect. The implementation of multimedia technology (graphic images, audio and video digital information) in a reformed and modernized education can improve and enrich the teaching content, and thus, the teaching experience. With their model, they are hoping to reform the development of teaching and scientifically prove the importance and great convenience of multimedia applications in modern education.

Wu & Wang (2014) [23] have developed and established an "English multimedia network teaching platform", based on the information and Internet technology. They have applied the data envelopment analysis to simulate audio data in their model. Their main goal was "to formulate long-term incentive mechanism, to implement scientific and reliable teaching strategy, to encourage teachers and students to actively use the English multimedia teaching platform, and to explore the new mode of English education with information technology". The simulation model is presented in their work, which could contribute to the easier further application and dissemination of their model.

Zuo & Wang (2014) [24] have focused on the "advantages of the integration of multimedia technology and modern education, constructing man-machine interactive network auxiliary teaching theory model under the multimedia technology" with the use of DEA to do the empirical analysis of the teaching theory model. The DEA model analyses five investment projects with Registered authentication, Teaching resource, Courseware management, Interactive platform and Teaching system as input and output indexes of the investment projects. Their paper revolves around modern teaching techniques and the application of multimedia technology in the teaching field produces. Their findings reveal that "the man-machine interaction network auxiliary project under the multimedia technology can support scientific teaching, with the teaching advantages of positive feedback". Moreover, they claim that the application of "multimedia technology can

change the learning environment of traditional teaching, improve the teaching management path, and promote the transformation of the current English teaching means, the expansion of teaching topic, richness of teaching content, the innovation of teaching mode, the ascension of teaching ideas, the improvement of teaching system, the systematization of teaching management". Their paper has been gaining popularity during the COVID-19 pandemic when multimedia teaching was the only choice left for teaching staff.

Raayatpanah (2017) [25] has established a new method for developing multicast trees with multiple QoS parameters, which is based primarily on the DEA methodology. In his study, he focuses on multicasting as the "process of concurrently sending the same data from a source to a group of destinations in a computer network" and as a vital requirement in the transmission of multimedia information. Moreover, the main focus is multicast routing, which is referred to as "an integral part of multimedia application support". In the first step of the study, he employed the DEA to assess the relative efficiency of arcs in the presence of QoS parameters. In the second step, he proposed "an integer linear programming model based on the relative efficiency of arcs to obtain multicast trees for transmitting data from a source to each destination". This study has major practical implications since it provides illustrations and an evaluation of the proposed method through numerical examples.

Chen (2019) [2] has implemented the DEA methodology in public performance management and has developed a public performance management framework. Namely, in his paper, he has combined the multimedia data envelopment optimization selection model and PCA-DEA, solved the algorithm and combined different methodologies in the development of his mixed model (such as the fuzzy c-means clustering, principal component analysis and multimedia data envelopment analysis). The results indicate that the developed model contains characteristics of both data mining technology and multimedia data envelopment analysis method and could be used for "complex performance evaluation and analysis requirements". This study provides a great scientific contribution, considering that research on multimedia data envelopment analysis (MDEA) is "scientific and innovative", and could be used as an analytical tool and support system for complex performance evaluation and analysis.

5   DISCUSSION AND CONCLUSION

Most of the surveyed papers offer new insights into the multimedia research field. Considering the amount of research done in multimedia altogether (128.905 papers with the keyword "MULTIMEDIA" in Clarivate Web of Science and 150.919 papers in the Scopus database), and the amount of total research on the DEA methodology and its global popularity, it becomes clear that the Data Envelopment Analysis is rarely applied in multimedia related research. Namely, when exploring both Scopus and Clarivate Web of Science databases with the keyword "Data Envelopment Analysis", a total of 40.768 papers appear. This number decreases dramatically when applied with the keyword "MULTIMEDIA". This calls for

additional efforts to incorporate the DEA methodology and all of its models in the field of multimedia related research.

Most of the surveyed papers offer a great scientific and practical contribution. Namely, Raayatpanah (2017) [25] has developed and introduced a new method for developing multicast trees with multiple QoS parameters, based on the DEA methodology; Chen (2019) [2] has developed a new MDEA (multimedia data envelopment analysis) method; Wu & Wang (2014) [23] have established an "English multimedia network teaching platform" based on the information and Internet technology; Zhao, Fei & Li (2013) [22] have empirically assessed the entire teaching system and promoted the importance of reform in the teaching process; Sahin et al. (2006) [21] have explored the area of engineering design, examining the Product Platform Planning, offering new insights while solving two case studies. Moreover, all of these six surveyed papers revolve around different aspects of multimedia. For instance, Zuo & Wang (2014) [24] have examined and proposed even greater use of modern multimedia technology in education, as an opportunity to modernize and reform teaching research and the whole education sector. They have furthermore stated that the application of multimedia technology can transform the learning environment of traditional teaching and improve the overall education system and teaching management. The teaching and education field has been the main focus of the work of Wu & Wang (2014) [23], as well.

All of the six surveyed papers have been published after 2005 (from 2006 to 2019). Even though the DEA methodology is well known and quite popular for over three decades, it is slowly becoming visible to its audience in multimedia-related research, but still in a very modest manner.

This paper aims to present the DEA methodology and the possible application possibilities and thus inspire other scholars to implement this methodology more often, especially in the research of the multimedia industry. This way, other scholars and practitioners could grasp the advantages and the potential applications of the DEA methodology in efficiency evaluation in multimedia related research.

This paper, however, is not without limitations. Namely, this review has taken into consideration only two of the globally largest and most relevant scientific databases in the world nowadays (the Scopus and the Clarivate Web of Science). Therefore, there is a possibility that not all relevant studies regarding the application of DEA in multimedia-related research have been surveyed and identified.

In future work, the authors will focus on implementing the proposed DEA models in a multimedia-related case study in Croatia.

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Contact information:

Katerina FOTOVA ČIKOVIĆ, PhD, Ass. Professor
(Corresponding author)
University North,
Trg dr.Žarka Dolinara 1, 48000 Koprivnica
E-mail: kcikovic@unin.hr

Damira KEČEK, PhD, Ass. Professor
University North,
Trg dr .Žarka Dolinara 1, 48000 Koprivnica
E-mail: dkecek@unin.hr

Joško LOZIĆ, PhD, Ass. Professor
University North,
Trg dr. Žarka Dolinara 1, 48000 Koprivnica
E-mail: jlozic@unin.hr