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Bi-Objective Multiple Criteria Data Envelopment Analysis combined with the Overall Equipment Effectiveness: An application in an automotive company

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ABSTRACT

The mass production companies need to seek high efficiency in the use of equipment and human resources, as well as in the consumption of their inputs. One of the key methods to address these challenges is the adoption of Overall Equipment Effectiveness, derived from Total Productive Maintenance. This work aims to propose a new efficiency indicator, called Overall Machinery Effectiveness, to be applied in an automotive company in Brazil that adopted Overall Equipment Effectiveness indicator. The studied company made available production data from ten months, associated to two Press machines, generating twenty Decision Making Units for Data Envelopment Analysis and Bi-Objective Multiple Criteria Data Envelopment Analysis models application. As results, Press #2 was identified as being the most critical because, among the first ten DMUs in the efficiency ranking, seven are associated to Press #1. The targets values recommended by the new indicator were considered feasible to be implemented by the company, thus validating in practice the new proposed procedure for the management of machines effectiveness. Moreover, the identification of the relevant variables (input and output) for the Press #1, and Press #2, allowed the decision maker to act in the best way to increase their efficiency.

1. Introduction

According to Eswaramurthi and Mohanram (2013), mass production companies must have high efficiency in equipment use, human resources, and inputs in general. Aktin and Gergin (2011) commented that companies operating in today's challenging market conditions require an effective procurement process to gain competitive advantage. For Schöggl et al. (2017), in automotive industries, sustainable development is of particular importance, and they need to comply with environmental standards and meet societal requirements, but also maintain a competitive edge in a rapidly-changing business (Maxwell and van der Vorst, 2003; Zhu et al., 2007).

For Maclean and Lave (2003); Mayyas et al. (2012) and Jasinski et al. (2015), examples of strategies used by automotive company to mitigate social and environmental effects include investment in clean technologies, design for sustainability and creating value for local and global communities.

One of the main tools to be used in order to face these challenges is the Total Productive Maintenance System (TPM), that aims at adding business value to an organization by maintaining and improving the integrity of production and quality systems involving collaborators, processes, and machines (Eswaramurthi and Mohanram, 2013). The objective of TPM is to improve the Overall Equipment Effectiveness (OEE) of plant machine, which is considered the broadest set of performance measures to analyze the efficiency of a single manufacturing machine or an integrated system (Ferko and Znidarsic, 2007). For Nallusamy (2016), OEE of a machine plays a significant role in the present scenario, where right quality and right delivery at the right time are the major factors influencing a customer.

Abbreviations: TPM, Total Productive Maintenance; OEE, Overall Equipment Effectiveness; DEA, Data Envelopment Analysis; DMUs, Decision Making Units; DEA-CCR, DEA model proposed by Charnes, Cooper and Rhodes; DEA-BCC, DEA model proposed by Banker, Charnes, and Cooper; MCDEA, Multiple Criteria DEA; BiO-MCDEA, Bi-Objective MCDEA; OME, Overall Machinery Effectiveness; SMED, Single-Minute Exchange of Die; WF, Workforce; MSA, Measurement Systems Analysis; VBA, Visual Basic for Application.

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According to the definition of Nakajima (1989), OEE is measured based on the six large losses, considering machine availability, performance and quality rates (Ahire and Relkar, 2012). It does not identify a specific reason why the machine is not as efficient as it should be, but it assists in categorizing areas in order to identify those that are in need of equipment improvement most (Eswaramurthi and Mohanram, 2013).

On the other hand, mathematical models have been developed to quantify performance, quality and flexibility and to justify investments in production systems (Liu, 2008); and in order to manage operational performance, different approaches can be used (Ferko and Znidarsic, 2007).

As pointed by Chen and Jia (2017) and Haghighi et al. (2016), there are two main methods on efficiency evaluation; the first one is stochastic frontier analysis method, which is a parametric approach, and other that is a nonparametric method, known as Data Envelopment Analysis (DEA). In practice, DEA has been regarded as an alternative multiple criteria tool for manufacturing technology assessment (Liu, 2008), and for evaluating performance and decision-making processes (Dotoli et al., 2015).

The DEA CCR model (Charnes et al., 1978), with constant return of scale, and DEA BCC model (Banker et al., 1984), with variable return of scale, can be used to evaluate relative efficiency of a set of homogeneous Decision Making Units (DMUs); moreover, these DEA models do not require a specific form of the production function and they are especially suitable for multi-input and multi-output scenarios (Cook et al., 2014; Ohsato and Takahashi, 2015).

It should be observed that, according to Banker et al. (1989), DEA (CCR and BCC) models may present problems to discriminate the efficient DMUs adequately if specific conditions are not met, named as DEA Golden Rules, with respect to a minimum amount of involved DMUs. In this sense, in order to avoid such a problem new multiple criteria DEA models have been proposed, such as the MCDEA – Multiple Criteria DEA (Li and Reeves, 1999), and the BiO-MCDEA - Bi-Objective Multiple Criteria DEA (Ghasemi et al., 2014).

A citation report (see Table 1) was done with data from an important database (Web of Science) to characterize the up to date importance of the problem investigated here, as well as to identify the existing gaps (questions) in the theory, and whose solutions (answers) could be of great interest in everyday of companies.

Fig. 1 shows the results of publications and citations obtained by searching the Web of Science by using the keyword "Data Envelopment Analysis", it is noticed that, in the period of 1998–2017, there was more than 9900 publications, and more than 121,900 citations. These results demonstrate that such tool have been widely adopted in solving several problems in different contexts.

Fig. 2 shows the results of publications and citations obtained by searching the Web of Science by using the keywords "Overall Equipment Effectiveness and OEE". It is noticed that, in the period from 1998 to 2017, more than 160 publications, and more than 550 citations, that is, OEE is a technique widely used.

Figs. 1 and 2 show that the OEE and the DEA have been widely applied, but individually. In fact, combining the keywords "Overall Equipment Effectiveness, OEE, and Data Envelopment Analysis"

Table 1
Citation Report from Web of Science database for Period 1998–2017.

Keywords Combinations	Number of Publications	Citations
"Data Envelopment Analysis"	9965	121,947
"Overall Equipment Effectiveness and OEE"	164	599
"Data Envelopment Analysis and Overall Equipment Effectiveness"	4	48
"Overall Equipment Effectiveness and Automotive Industry"	6	48
"Multiple Criteria Data Envelopment Analysis and MCDEA".	10	254
"Total Productive Maintenance and Overall Equipment Effectiveness"	64	321
"Total Productive Maintenance and Data Envelopment Analysis"	3	23
"Overall Equipment Effectiveness; Improving efficiency of machine and Efficiency of productive process"	4	0
"Improving efficiency of machine; Data Envelopment Analysis and machine and Efficiency of productive process"	0	0
"Multiple Criteria Data Envelopment Analysis and Overall Equipment Effectiveness"	0	0
"Bi-Objective Multiple Criteria Data Envelopment Analysis and Overall Equipment Effectiveness"	0	0

Source: Web of Science.

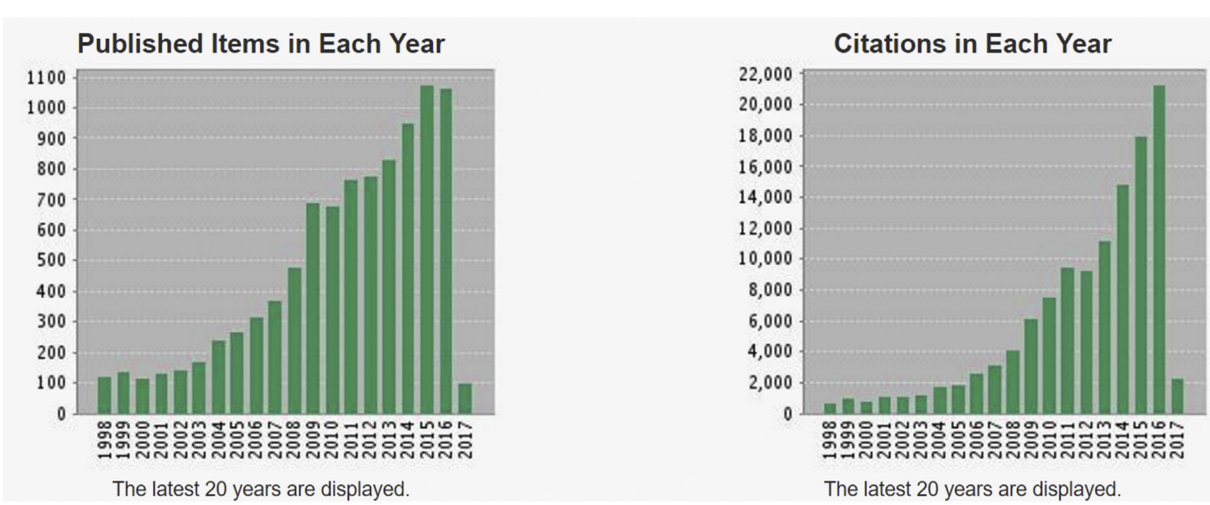

Fig. 1. Publications and citations by searching the keyword "Data Envelopment Analysis". Source: Web of Science.