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ORIGINAL ARTICLE

Integration of quality tools and multi-criteria methods: a bibliometric and systemic analysis

Integração das ferramentas da qualidade com métodos multicritério: uma análise bibliométrica e sistêmica

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Abstract: This study aims to identify the integration between quality tools and multi-criteria methods, using a bibliometric and systemic analysis. In order to meet this research objective, the methodology used to select the bibliographic portfolio, perform the bibliometric and systemic analysis was the ProKnow-C (Knowledge Development Process – Constructivist). As result were selected 17 articles that represented the bibliographic portfolio and 351 articles as reference for the bibliographic portfolio. The results highlight the journals: *Expert Systems with Applications* e *Applied Soft Computing Journal.* The most aligned articles with the theme were, "*Supplier selection paradigm: An integrated hierarchical QFD methodology under multiple-criteria environment",* and *"Decision making with the analytic hierarchy process*". In the systemic analysis were considered six lenses, according to the theoretical affiliation MCDA-C, and was concluded that the articles were not totally aligned with this specific affiliation. The AHP and TOPSIS methods stood out as the most used methods in this portfolio. It was verified that the quality tools when used integrated with multi-criteria methods allow the creation of decision making evaluation models for scenarios present in the papers found in this research.

Keywords: Quality; Quality tools; Multi-criteria methods; *ProKnow-C*; Bibliometric analysis; Systemic analysis.

Resumo: O estudo tem por objetivo buscar e identificar informações através da análise bibliométrica e sistêmica sobre a integração das ferramentas da qualidade com abordagem dos métodos multicritério. Para atender ao objetivo da pesquisa, o instrumento de intervenção utilizado para selecionar o portfólio bibliográfico, realizar a análise bibliométrica e sistêmica utiliza-se o processo *ProKnow-C (Knowledge Development Process – Constructivist)*. A partir do uso do instrumento, foram selecionados 17 artigos que compõem o portfólio bibliográfico e 351 artigos que compõem o referencial do portfólio bibliográfico. Destacam-se os periódicos: *Expert Systems with Applications* e *Applied Soft Computing Journal.* Os artigos com maior representatividade são, "*Supplier selection paradigm: An integrated hierarchical QFD methodology under multiple-criteria environment",* e *"Decision making with the analytic hierarchy process*". Quanto aos autores do portfólio e do referencial, destaque para: Bhattacharya, A.; Jusoh A.; Kahraman, C.; Mardani, A.; Marini, C.D.; Zavadskas, E.K; Pramod, V.; Tsai, W.-H.;

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Costa, H.G.; Tzeng, G.-W. e Jagathy Raj, V.P. Na realização da análise sistêmica foram analisadas as seis lentes, de acordo com a afiliação teórica MCDA-C, verificando-se que os artigos não estão alinhados à essa filiação. Destacam-se o AHP e TOPSIS como os métodos multicritério que aparecem com maior frequência nos artigos do portfólio. Verificou-se que a utilização de ferramentas da qualidade com a integração de métodos multicritério possibilitam a criação de modelos de avaliação para tomada de decisão nos diversos cenários presentes nos artigos avaliados do fragmento da literatura em análise.

Palavras-chave: Qualidade; Ferramentas da qualidade; Multicritério; *ProKnow-C*; Análise bibliométrica; Análise sistêmica.

1 Introduction

The quality management systems favor the processes optimization increasing the operation productivity; therefore, these systems can be considered a strategic differential for the companies (Maekawa et al., 2013). Faced with the difficulty of controlling quality levels for satisfying customers' needs, managing scarce resources and preserving results, quality management might be considered a determining factor for organizational management in companies (Mahmoud et al., 2011; Celotto et al., 2015).

The main authors which approach the quality management topics cite the improvements provided by the use of this management system, such as: customer satisfaction, high cost-benefit ratio, quality from process improvement, people training, and production economically, standardization, and increasing of enterprises competitiveness (Feigenbaum, 1994).

In order to meet the established quality concepts, several tools have been used in various contexts; Andrade (2013) utilized in his research, the PDCA cycle (Plan, Do, Check, Act), Six Sigma, Management Excellence Model, 5S, ISO 9001 (International Organization for Standardization). Silva & Sartori (2014) applied a stratification tool; check sheet, Pareto diagram, cause and effect diagram (Ishikawa), histogram and 5W2H. Marques & Monteiro (2014) cited brainstorming as a relevant method of raising hypotheses and favoring the ideas flowing. Paulista et al. (2013) applied Six Sigma methodology in their research.

Thus, also the quality tools have been used for several approaches. As stated by Mahmoud et al. (2011), the correct choice of the quality tool must be closed with the problem to be evaluated, i.e., each quality tool has its own applicability to address a particular problem.

In this context, multi-criteria analysis can integrate methodologies with the quality tools to determine conditions where these themes become more efficient to solve correlated problems. Multi-criteria methods support decision makers from multiple criteria that need to be analyzed together (Vincke, 1992; Roy, 1993).

According to Generowicz et al. (2011), considering the complexity of decision making, the multi-criteria analysis associates the comparison of alternatives and criteria, constructing a numerical matrix to provide the selection of the best alternative. Thus, the most appropriate alternative is closed to the decision-makers preferences and priorities.

After the contextualisation of the study scenario, the research problem was explored as: “How to search and identify information using bibliometric and systemic analysis in the characterization of the integration between quality tools and multi-criteria methods?” Thus, the objective of this study was to indentify the existent integration

between quality tools and multi-criteria methods using the bibliometric and systemic analysis, and then to meet the gaps in the literature in order to contribute scientifically to the theme.

In order to attend this research objective, the methodology ProKnow-C (Knowledge Development Process – Constructivist) (Ensslin et al., 2010), was used to build the bibliographic portfolio and perform the bibliometrics analysis. The research was carried out by literature analysis, searching in scientific journals and indexed databases, being analyzed impact factor, number of citations, authors and keywords.

This article was structured in five sections, introduction, theoretical reference, and methodological procedures, presentation of the bibliometric results and systemic analysis, and final remarks.

2 Theoretical references

2.1 Quality tools and techniques

The total quality management is an organizational philosophy that allows the training of employees in an organization that is focused at the clear implementation of this culture aiming to promote continuous improvement, whose premises are structured in the concept that the prevention costs are less than the correction costs (Talib et al., 2013; Talib, 2013). Thus, managers can encourage their employees to use quality tools to benefit the entire company (Tari & Sabater, 2004).

Quality tools can be described as techniques that help the focus on the goals and can be used easily. As examples, we can cite; the cause and effect diagram, Pareto analysis, relationship diagram, control charts, histogram, and flowchart. Other techniques have broader application and favor the development of skills such as: SPC (Statistical Process Control), DOE (Design of Experiments), QFD (Quality Function Design), FMEA (Failure Mode and Effects Analysis), Benchmarking (Bamford & Greatbanks, 2005; Fonseca et al., 2015). However, the application of the called “seven basic quality tools” provides the most direct and immediate results for the process improvements (McQuater et al., 1995; Dale, 2003).

The definition of quality tools and techniques was proposed by McQuater et al. (1995) and Dale (2003) but this is not yet a consensus because there are many definitions of quality management and consequent a lack of nomenclature standardization for methods, techniques, practices, and tools that aid the quality management process (Sousa & Voss, 2002; Barbosa et al., 2017).

By combining the use of integrated methods with quality tools, several benefits can be achieved, such as: transforming complex data into simple forms, evaluating the areas with greatest problems, prioritizing processes, analyzing data in a statistical way, and highlighting the causes of variations and errors (Bamford & Greatbanks, 2005). Therefore, the correct selection and use of quality tools becomes essential for the implementation and maintenance of quality management (Jafari & Setak, 2010). However, as there are many tools available, it is important to explore how and when using them for problems solution or processes improvement (Sokovic et al., 2009).

2.2 Multi-criteria methods

Decision making is commonly a complex process because the existing situations involve a large number of factors to be considered and require a choice in favor of one or more options, among various alternatives based on different criteria, and in order to find the best alternative in a presented context. (Lopez et al., 2015).

Multi-criteria decision methods support the manager in solving problems related to decision making process, when are presented multiple alternatives that need to be analyzed together from different points of view. These methods aim to capture the decision maker preferences in a structured way to solve a decision problem (Almeida, 2012).

The first methods to support multi-criteria decision-making have emerged in order to address specific situations in which the decision-maker must solve a problem in which several objectives were to be achieved. According to Roy (1996) the choice of a multi-criteria method involves several factors, such as the problem analyzed, the context, the decision maker's preference structure, and the problem, the role of the other agents that influence the process, the facilitators and the analysts.

To choice the method, the decision maker actuation is fundamental, and this choice will depend on his/her preferences reflected in the criteria that can be: a) Compensatory: where each alternative is evaluated by measuring its performance and establishing a score. It allows trade-offs between criteria, i.e., a criterion with lower performance can be compensated by a higher performance from another one; and, b) Non-compensatory: in which the alternatives are evaluated in pairs by relations of preference, indifference or incomparability. In this situation it does not allow trade-offs (Vincke, 1992).

In addition to the decision-makers role in relation to the criteria, the desired result also influences the selected method, and this result is represented by the “problematics” presented by the theory: a) Choice: aims to reduce the global set of alternatives to a smaller set of alternatives; b) Ordination: seeks to order the alternatives in ascending or descending order; c) Classification: aims to categorize the alternatives into groups by similarity, d) Description: intends to describe the actions and consequences (Roy, 1996; Vincke, 1992).

However, the choice of approach precedes the choice of the method that will be applied to solve the problem in question. Vincke (1992) and Roy (1996) argue that decision support methods specialists divide the approaches in:

a) Multiattribute utility theory or unique criterion of synthesis: It aggregates in a unique utility value measured in an additive form, generating a score being that the alternatives better evaluated represent higher score;
b) Outranking or subordination approach: the alternatives are compared in pairs, being established an outranking relation between them and the best evaluated corresponds one whose score is higher in most of the criteria;
c) Interactive methods: They seek an alternative that is clearly superior in all established objectives.

In the multicriteria decision process the interaction occurs between agents and decision factors, following the decision makers identification steps; definition of alternatives; definition of the relevant criteria to the decision problem; and evaluation of alternatives. Basically, the multi-criteria decision analyzes various alternatives under several criteria jointly (Longaray et al., 2014).

3 Methodological procedures

Regarding nature, this study can be classified as exploratory and descriptive. Exploratory because it presents an objective of identifying information about a particular research topic, using the selection and analysis of scientific published papers in periodicals, indexed in databases. Descriptive because it describes the process and characteristics of the bibliographic portfolio selected (Richardson, 2008).

The research process involves data collection and analysis of the problem, and secondary data are collected from scientific publications to configure of the bibliographic portfolio. Also, it is considered that this research addresses the problem qualitatively and quantitatively.

This research has a qualitative characteristic since it seeks to understand a specific phenomenon in depth (Rosa et al., 2011). Its qualitative dimension is caracterized by the bibliographic portfolio selection and identification of highlights in terms of articles, authors and periodicals, lenses, methodologies and indicators. The quantitative approach is characterized when describing the profile of scientific publications on the subject by counting occurrences.

The technical procedure used was the bibliographical research. According to Sá-Silva et al. (2009), the bibliographical research is one based on published material, consisting mainly of books and articles from scientific journals already reviewed. Therefore, this work uses a bibliographical research, since it is carried out based on the analysis of articles already reviewed and indexed in scientific databases.

The intervention instrument used was the process to build knowledge based on the interests and delimitations of the researchers, according to the constructivist view, called *Knowledge Development Process–Constructivist (ProKnow-C),* as shown in the work of Bortoluzzi et al. (2011) and it was carried out in three stages: (i) selection of the literature (bibliographic portfolio) with scientific recognition aligned to the researchers' view on the subject and its delimitations; (ii) bibliometric analysis of selected articles and their respective references; (iii) systemic analysis using the lens approach, methodologies, and indicators. Therefore, it allows researchers to construct the necessary knowledge-base and, secondly, to look for gaps in the literature to contribute scientifically to the theme (Bortoluzzi et al., 2011; Chaves et al., 2012; Ensslin et al., 2013).

As shown in Figure 1, the phases of articles selection and research definition axes were highlighted: Quality Tools and Multi-criteria Methods. For the first research procedure, the following keywords were defined: quality, quality tools, quality techniques, quality methods, quality control, statistical quality control, total quality management and quality management.

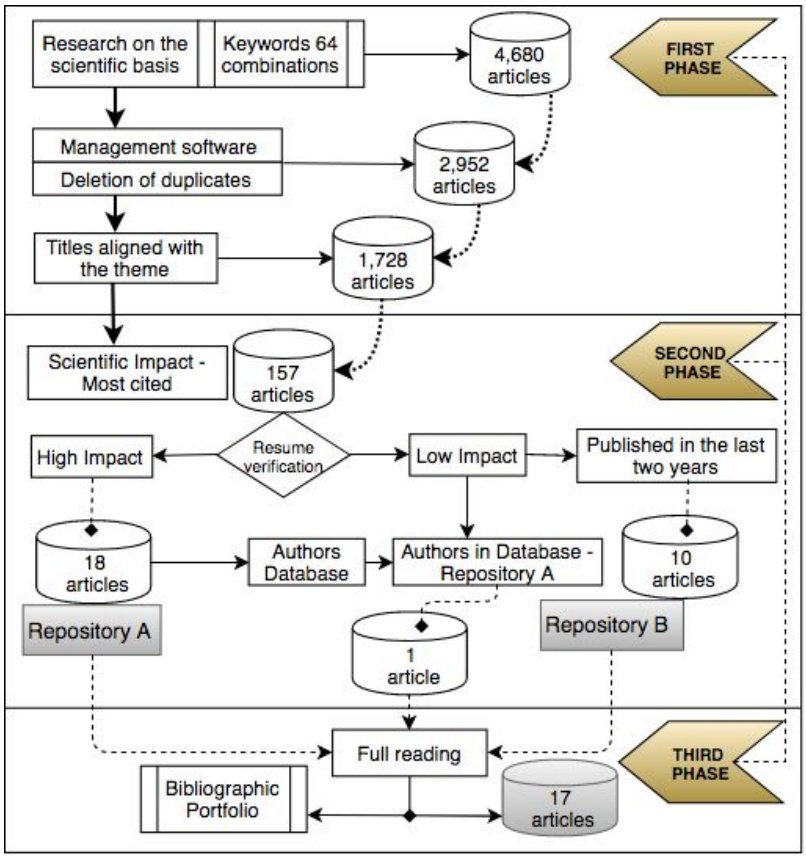

Figure 1. Steps for portfolio selection. Source: Adapted from Ensslin et al. (2010).

The first phase was composed by the articles selection procedure for the portfolio delimitation, started with a structured research based on a keywords combination that resulted in a specific number of articles. Of these articles, the titles were read, remaining in the portfolio those aligned to the theme of the research to follow the reading of the summaries. The articles whose summaries were aligned to the theme were selected for full reading and, after that, the articles that remain aligned made up the bibliographic portfolio.

In the second phase, statistical analyzes were carried out on the portfolio in order to identify the most relevant articles, authors, and journals. Finally, in the third phase was performed a systemic analysis, with a content analysis, using lenses that helped the analysis of the articles, allowing literature gaps identification.

The second axis was composed by the keywords: multi-criteria, multi-criteria analysis, MDCM, multi-criteria decision, multi-criteria methods, and multi-objective methods, multiattribute utility and multi-criteria approach.

After the definitions of keywords, they were defined in a set of 64 keywords combinations that were used to search in the Web of Science and Scopus databases considering the period of January 2005 to April 2016. After full reading of the articles, 17 of them were aligned to the research topic, listed in Chart 1, closing the filtering stage of articles, with their respective citation quantity displayed by the Google Scholar site, until in June 2016.

Chart 1. Bibliographic Portfolio contents.

Code	Titles	Quotes
1	A new MCDM method combining QFD with TOPSIS for knowledge management system selection from the user's perspective inintuitionistic fuzzy environment	29
2	A novel hybrid model based on DEMATEL and ANP for selecting cost of quality model development	48
3	Multicriteria decision making in Maintenance Quality Function Deployment through the Analytical Hierarchy Process	32
4	Supplier selection paradigm: An integrated hierarchical QFD methodology under multiple-criteria environment	121
5	Using OWA aggregation technique in QFD: a case study in education in a textile engineering departmen	20
6	A new fuzzy multicriteria decision making approach: An application for European Quality Award assessment	20
7	An Integrated Fuzzy Multi-Criteria Decision-Making Approach for Six Sigma Project	10
8	An Integrated QFD-TOPSIS Methodologyfor Supplier Selection in SMEs	8
9	Probing the innovative quality system structure model for NPD process based on combining DANP with MCDM model	10
10	A hybrid fuzzy MCDM approach to maintenance Quality Function Deployment	0
11	Framework for prioritizing and allocating six sigma projects using fuzzy TOPSIS and fuzzy expert system	1
12	Multicriteria model for evaluation and classification of organizational management: proposal and use case	7
13	Proposing a new hierarchical framework for the evaluation of quality management practices: a new combined fuzzy hybrid MCDM approach	1
14	Selecting Six Sigma projects: MCDM or DEA?	0
15	Application of multiple-criteria decision-making techniques and approaches to evaluating of service quality: a systematic review of the literature	6
16	Product Development using QFD, MCDM and the Combination of these Two Methods	0
17	The multidimensional Shewhart control chart for multicriteria quality management	0

In the next step, the bibliometric analysis was implemented, which sought to verify the relevance of journals, authors, and articles, in order to quantify the characteristics of the portfolio articles and bibliographic portfolio references as oriented in (Ensslin et al., 2010).

And then, the systemic analysis was carried out, characterized by the critical analysis of the bibliographic portfolio from the lenses detailed in Chart 2: approach, singularity, identity process, measurement, integration, and management. As a result of the systemic analysis, the methodologies of the quality tools and multicriteria methods are detailed, as well as the indicators used to measure the object of study of the portfolio articles (Lacerda et al., 2012; Chaves et al., 2012).

Chart 2. Lenses that made up the systemic analysis.

Lenses	Description
Approach	It allows identifying if the construction of the performance evaluation model proposed in the article was: (i) constructed and applied in the same context; (ii) built in one environment, adapted and applied in another; (iii) constructed in one context and applied in another; and (iv) was built in an environment and was not applied.
Singularity (actors and context)	It allows the identification of the decision-makers participation in the decision-support process in articles in the bibliographic portfolio, i.e., if the authors recognize the uniqueness of the problem to those involved in the management process and understand that for each context a model of evaluation of performance.
Identity Process	It analyzes if the authors of the articles recognize the limits of knowledge of the decision maker and their values are taken into account in the formulation of the criteria of what is important to measure.
Measurement	It Identifies if the evaluation models or processes allow the measurement of the criteria.
Integration	It aims to evaluate whether there is integration between the performance criteria, that is, an overall performance evaluation.
Management	It seeks to identify if the model allows the diagnosis of strengths and weaknesses and also if the model allows identifying improvement actions to improve performance.

Source: Defaci & Bortoluzzi (2015).

4 Results

4.1 Bibliometric analysis

The periodicals relevance was verified and those with greatest number of publications were identified. Of the total articles in the portfolio, 2 articles were published in the *Applied Soft Computing Journal* and 2 articles in the *Journal of Business Economics and Management.* The first journal, among other subjects, had its publications focused on the fuzzy logic approach, corresponding to multi-criteria analysis, while the second, focused on business management, which belongs to the quality management topic.

For the bibliographic portfolio reference analysis, the papers were published in 218 journals, highlighting, *Expert Systems with Applications* (45 articles), *Total Quality Management and Business Excellence* (9 articles), *International Journal of Production Research,* (8 articles), *Applied Soft Computing Journal,* (7 articles), and *Computers & Industrial Engineering, International Journal of Production Economics e Journal of Operations Management* (6 articles each journal). These journals contained publications related to information system areas, computational methods and models application, management, research and business economics. According to the carried out analyzes, the journal *Expert Systems with Applications,* had a greater number of papers published in the bibliographic portfolio, while the highlight of the portfolio corresponds to the *Applied Soft Computing Journal.*

In order to measure the scientific recognition of each article in the portfolio, the *Google Scholar* was used to check the number of times that article was quoted. The paper "*Supplier selection paradigm: An integrated hierarchical QFD methodology under multiple-criteria environment",* written by Bhattacharya et al. (2010), it was most

cited article in the portfolio, with 121 citations, addressing the integration between a multicriteria analysis method and a quality tool, AHP and QFD, respectively, to perform supplier selection. For identification of the scientific recognition of articles, the number of citations was also verified in the *Google Scholar*. In particular, the article written by Saaty (2008), "*Decision making with the analytic hierarchy process*", had 2,766 quotes, and was published in *International Journal of Services Sciences*, and Ho et al. (2010), "*Multi-criteria decision making approaches for supplier evaluation and selection: A literature review*", had 1,014 quotes, published in *European Journal of Operational Research.* With 840 quotes, the article "*Intuitionistic fuzzy aggregation operators*" (2007) was published in *IEEE Transactions on Fuzzy Systems* and the paper "*Some geometric aggregation operators based on intuitionistic fuzzy set*" (2006) published in *International Journal of General Systems* had 787 quotes.

In the research stage for the authors in the bibliographic portfolio, in a total of 54 authors, seven authors were standed out: Bhattacharya, A. (2 articles), Jusoh A. (2 articles) Kahraman, C. (2 articles), Mardani, A., Marini, C.D., Zavadskas, E.K. (2 articles) and Pramod, V.R. (2 articles). Featured authors in the portfolio Mardani A., Jusoh A. and Zavadskas E.K., published two articles together, whose themes were the evaluation of quality practices using the multicriteria approach and decision making. In relation to the authors of the articles that make up the bibliographic references, 7 authors represent 62% of the articles related to the reference: Tsai, W.-H. (13 articles), Costa, H.G. (10 articles); Kahraman, C. and Tzeng, G.-W. (7 articles). The authors Jagathy Raj, V.P.; Devadasan, S.R. and Pramod, V.R., with 5 published articles. Of these authors, Kahraman, C. had the published works more aligned to the research topic that were highlighted in the bibliographic portfolio and the portfolio reference.

4.2 Systemic analysis

In order to perform the systemic analysis, the 17 articles according to the lenses were studied and classified according to the bibliographic portfolio, as shown in Chart 3.

Chart 3. Classification of articles according to lenses.

Lenses	**Article Code**																
Articles in the Bibliographic Portfolio	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Approaches																	
Model constructed and applied in the same context (environment that gave rise to it);																	
Model built in one environment, adapted and applied in another one.																	
Model built in one context and applied in another one.	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√
Model built in an environment and has not been applied															√	√	

Chart 3. Continued…

Lenses	Article Code															
Singularity (actors)																
Articles that identify the decision maker at work and take it into account for the model construction.																
Articles that identify the decision maker at work, but do not take it into account for the model construction.	√	√	√		√		√				√	√		√		√	
Articles that do not identify the decision maker at work.				√		√		√	√	√			√		√		√
Singularity (context)																
Articles that develop models for a physical context and recognize that it is valid only for this physical context.																
Articles that develop models for a physical context and use it also in other contexts.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Limit of decision-maker knowledge																
Articles that recognize the decision maker knowledge limitations;																
Articles that do not recognize the decision maker knowledge limitations.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Considers the decision maker preferences																
Articles in which the process used to identify the objectives is fully based on the decision maker preferences;																
Articles in which the process used to identify objectives is partly based on the decision maker preferences;					√											

Chart 3. Continued…

Lenses	Article Code															
Articles in which the process used to identify objectives DOES NOT consider the decision maker preferences.	√	√	√	√		√	√	√	√	√	√	√	√	√	√	√
Criteria measurement																
Performs measurement	√	√	√	√	√	√	√	√	√	√	√	√	√			
Does not perform measurement														√	√	√
Criteria Integration																
Performs integration		√				√	√	√			√	√				
Does not perform integration	√		√	√	√				√	√			√	√	√	√
Management - diagnosis																
Articles that allow to diagnose the current situation	√		√		√				√					√		
Articles that do not allow to diagnose the current situation		√		√		√	√	√	√		√	√	√	√		
Management - improvement																
Articles that use process to generate improvement actions																
Articles that do not use the process to generate improvement actions	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

4.3 Lens analysis

Regarding lenses analysis, from the 17 articles analyzed, 14 articles recognize that the model was constructed in one context and applied in another (Li et al., 2014; Tsai & Hsu, 2010; Pramod et al., 2007; Bhattacharya et al., 2010; Okur et al., 2009; Aydin et al., 2012; Percin & Kahraman, 2010; Kumaraswamy et al., 2011; Kuan et al., 2012; Valavi & Pramod, 2015; Jafarian et al., 2014; Costa et al., 2014; Marini et al., 2016; Yousefi & Hadi-Vencheh, 2016. From the total of articles analyzed, in 2 of them the model was built in an environment and not applied (Marini et al., 2016); Mardani et al., 2016).

It was identified the use of several multi-criteria methods: TOPSIS (*Technique for Order Preference by Similarity to Ideal Solution*), ANP (*Analytic Network Process*), AHP *fuzzy*, VIKOR *(Visekriterijumska Optimizacija I Kompromisno Resenje)* and ELECTRE TRI (*Elimination et Choix. Traduisant la Réalité),* were applied in conjunction with quality tools to evaluate several contexts, and the authors do not belong to any concept

of performance evaluation and the vast majority of articles were constructed in a different context of application.

In the lens analysis of the singularity for the actors, 6 of the 17 portfolio articles (Bhattacharya et al., 2010; Aydin et al., 2012; Kumaraswamy et al., 2011; Kuan et al., 2012; Valavi & Pramod, 2015; Mardani et al., 2016, do not consider the decision-maker. The remaining 9 articles identify the decision maker, but do not take it into account for constructing the model (Li et al., 2014; Tsai & Hsu, 2010; Pramod et al., 2007; Okur et al., 2009; Percin & Kahraman, 2010; Jafarian et al., 2014; Costa et al., 2014; Marini et al., 2016; Yousefi & Hadi-Vencheh, 2016).

In the bibliographic portfolio, the articles that regard the decision maker, describe him/her as an analyst (Li et al., 2014), specialists (Tsai & Hsu, 2010; Jafarian et al., 2014), managers (Yousefi & Hadi-Vencheh, 2016; Percin & Kahraman, 2010).

In the lens of singularity in relation to the context, in all 17 articles, the models were developed for one physical context, were also used in another one, since the methods of performance evaluation were constructed to serve several purposes.

In the lens of decision-makers knowledge identification, it was verified that the 17 articles in the portfolio do not recognize the decision maker knowledge limits and the process used to identify the objectives does not take into account the decision maker preferences, and his participation in the construction of the model, except for the study by Okur et al., 2009, that the construction of the objectives is partially based on the decision maker preferences. The analysis in the measurement lens indicates that 13 articles measured the criteria (Bhattacharya et al., 2010; Aydin et al., 2012; Kumaraswamy et al., 2011; Kuan et al., 2012; Valavi & Pramod, 2015; Li et al., 2014; Tsai & Hsu, 2010; Pramod et al., 2007; Okur et al., 2009; Percin & Kahraman, 2010; Jafarian et al., 2014; Costa et al., 2014; Yousefi & Hadi-Vencheh, 2016), while 2 of them did not perform the measurement (Mardani et al., 2016; Marini et al., 2016).

Were identified the measurement of criteria in the articles and in a significant number, being analyzed by performance evaluation methodologies. In AHP and TOPSIS methods the criteria measurement was performed by several ways, scales, matrices and numerical methods. In the studies where the measurement was not performed, the literature review and some proposals for criteria measurement models were presented.

Regarding integration lens analysis, it was verified that 6 articles integrate the criteria (Tsai & Hsu, 2010; Aydin et al., 2012; Percin & Kahraman, 2010; Kumaraswamy et al., 2011; Jafarian et al., 2014; Costa et al., 2014) while 9 articles do not integrate the criteria measured (Li et al., 2014; Pramod et al., 2007; Bhattacharya et al., 2010; Okur et al., 2009; Kuan et al., 2012; Valavi & Pramod, 2015; Marini et al., 2016 ; Yousefi & Hadi-Vencheh, 2016; Mardani et al., 2016).

Regarding the management lens, in relation to the diagnosis, only 5 articles allowed to identify the strengths and weaknesses (Li et al., 2014; Pramod et al., 2007; Okur et al., 2009; Valavi & Pramod, 2015; Costa et al., 2014), the remaining 10 articles did not identify the strengths and weaknesses (Bhattacharya et al., 2010; Aydin et al., 2012; Kumaraswamy et al., 2011; Kuan et al., 2012; Marini et al., 2016; Tsai & Hsu, 2010; Percin & Kahraman, 2010; Jafarian et al., 2014; Yousefi & Hadi-Vencheh, 2016; Mardani et al., 2016).

The strengths and weaknesses analysis points out to the result of methodology applications in the scenarios studied in the articles of the portfolio. In the Costa et al. (2014), it was reported the use of the ELECTRE TRI method to classify the companies by performance according to the excellence in management factors (EGF). The authors

were able to classify the organizations in 5 levels (A, B, C, D, E) pointing the EGFs with higher or lower scores, and showing the strengths and weaknesses in this analysis. Still under the lens of management, regarding identification of improvement points, none of the 17 articles present what should be done to improve the weaknesses identified.

Several articles allowed the situation diagnosis in each context, however, did not suggest alternatives of improvement for the situation. According with this, in the article of Costa et al. (2014), despite identifying the weaknesses, the authors did not expose actions for the companies that were in the lower level (E) to reach the high level (A).

4.4 Methodologies and indicators analysis

After lenses analysis the methods were the next object of analysis, and it was verified that the most used methods were the AHP and TOPSIS multi-criteria methods, with nine and five applications, as shown in the Chart 4. We highlight the fuzzy, fuzzy AHP and VIKOR methods, with each method being used in more than one work. The Data Envelopment Analysis (DEA), DEMATEL (Decision Making Trial and Evaluation Laboratory) ELECTRE TRI and TOPSIS fuzzy methods were presented with an application in each study.

Chart 4. Methods used in bibliographic portfolio articles.

Methods	Number of articles	Authors / year
AHP	9	Pramod et al. (2007); Okur et al. (2009); Bhattacharya et al. (2010); Percin & Kahraman (2010); Kumaraswamy et al. (2011); Aydin et al. (2012); Valavi & Pramod (2015); Marini et al. (2016); Yousefi & Hadi-Vencheh (2016)
TOPSIS	5	Kumaraswamy et al. (2011); Li et al. (2014); Jafarian et al. (2014); Mardani et al. (2016); Yousefi & Hadi-Vencheh (2016)
ANP	3	Tsai & Hsu (2010); Kuan et al. (2012); Marini et al.(2016)
Fuzzy	2	Aydin et al. (2012); Li et al. (2014)
Fuzzy AHP	2	Aydin et al. (2012); Mardani et al. (2016)
VIKOR	2	Kuan et al. (2012); Mardani et al. (2016)
DEA	1	Yousefi & Hadi-Vencheh (2016)
DEMATEL	1	Tsai & Hsu (2010)
ELECTRE TRI	1	Costa et al. (2014)
Fuzzy TOPSIS	1	Aydin et al. (2012)

Some articles in the portfolio presented a comparative study between two or more multi-criteria methods in the same scenario, such as Tsai & Hsu (2010) (AHP and DEMATEL); Kumaraswamy et al. (2011) (AHP e TOPSIS); Kuan et al. (2012) (ANP and VIKOR); Aydin et al. (2012) (AHP, *fuzzy, fuzzy* AHP e *fuzzy* TOPSIS); Li et al. (2014) (*fuzzy* and TOPSIS); Yousefi & Hadi-Vencheh (2016) (AHP, DEA and TOPSIS).

The AHP was the most used method in the articles of the bibliographic portfolio, and it was applied to several contexts: maintenance quality function deployment (MQFD) analysis, selection of suppliers, determination of priorities of education

policies, evaluation of companies, selection of Six Sigma projects, obtaining criteria weights, selecting quality criteria and evaluating management practices.

The TOPSIS method was the second one with the greatest use in the bibliographic portfolio, and it was applied in the knowledge management systems selection, selection of Six Sigma projects, definition of criteria weights and evaluation of quality management practices.

With this, it is noticed that the multi-criteria methods were applied jointly with the quality tools evaluating, selecting, and defining several contexts. Among the quality tools used in the studies, combined with the multicriteria methods, we highlight QFD, CoQ (Costs of Quality), MQFD, Six Sigma and Shewhart Chart. Regarding the indicators used to measure the criteria and alternatives, given the diversity of the scenarios in which they were applied in the articles of the portfolio, totaling 336 indicators. They were grouped into categories defined by application context for quality tools and multi-criteria methods, i.e., the indicators were grouped according to the study objective that the authors proposed in their work as summarized in Chart 5.

Chart 5. Number of indicators used in bibliographic portfolio articles.

Grouping Indicators	N°	Authors / Year
Business valuation	150	Aydin et al. (2012); Costa et al. (2014); Mardani et al. (2016)
Criteria selection	80	Valavi & Pramod (2015)
Management systems selection	35	Okur et al. (2009); Li et al. (2014)
Suppliers selection	22	Bhattacharya et al. (2010); Kumaraswamy et al. (2011)
Project Selection	22	Percin & Kahraman (2010); Jafarian et al. (2014); Yousefi & Hadi-Vencheh (2016)
Product Development	16	Kuan et al. (2012)
Selection of CoQ models	6	Tsai & Hsu (2010)
Study of viability	5	Pramod et al. (2007)

The groups were divided according to the context of the application, i.e., company evaluation, product development, feasibility study, selection of criteria, selection of suppliers, selection of CoQ models, selection of projects and selection of management systems.

In this scenario, it was verified that the indicators within the proposed classification were those grouped in company evaluation and selection of criteria. In the first group 150 indicators were identified and in the second 80 indicators. The criteria grouped for “business valuation” measured various aspects involving organizational issues, such as leadership, clients, processes, products, strategy, people and security, among others. The groupings by “selection of criteria” were the indicators aimed at the application of a quality tool, MQFD, in a maintenance scenario.

The indicators for “selection of management systems”, with 35 indicators, were focused on the application of these systems in educational institutions. Indicators grouped by “supplier selection”, with 22 indicators, were applied to the suppliers’ selection process in the organizational context and of small companies. The “project selection” grouping, with 22 indicators, was applied to the selection of Six Sigma projects. Finally, product development, feasibility study and selection of CoQ projects,

with 16, 5 and 6 indicators, respectively, were applied with less representativeness in the other articles.

5 Final remarks

The integration of multicriteria methods and quality tools allows benefits for companies such as planning of products and processes development, reducing losses, whether of material or time, as well as giving managers a clearer view of the organization process. In this context, the multi-criteria approach presents advantages for the organization, contributing to the decision-making process, since it is efficient when the problem presents multiple criteria in its evaluation.

From this study, we tried to answer the research problem: How to identify information using bibliometric and systemic analysis on the integration between quality tools and multi-criteria methods? In order to meet this purpose, was used the intervention instrument ProKnow-C (Ensslin et al., 2010), and three phases were used to fulfill this purpose: the bibliographic portfolio selection process, bibliometric analysis, and systemic analysis.

At the end of the research process, 17 articles were explored in consonance with the theme, and they composed the bibliographic portfolio to perform the bibliometric analysis, in which the main journals where the published works appeared were: *Expert Systems with Applications*, with the highest number of published works in the bibliographic portfolio reference and the *Applied Soft Computing Journal*, a prominent journal of the bibliographic portfolio. The most referenced articles in the portfolio were respectively "*Supplier selection paradigm: An integrated hierarchical QFD methodology under multiple-criteria environment*", written by Bhattacharya et al. (2010) with 121 citations and "*Decision making with the analytic hierarchy process*", written by Saaty (2008) with 2,766 citations. We highlight 7 authors who composed the bibliographic portfolio: Bhattacharya, A. (2 articles), Jusoh A. (2 articles) Kahraman, C. (2 articles), Mardani, A., Marini, C.D., Zavadskas, E.K. (2 articles) and Pramod, V.R. (2 articles). The authors that stood out in the portfolio were: Tsai, W.-H. (13 articles), Costa, H.G. (10 articles); Kahraman, C. e Tzeng, G.-W. (7 articles); Jagathy Raj, V.P., Devadasan, S.R. e Pramod, V.R., (5 articles to each author).

In the systemic analysis, six lenses were analyzed as suggest by Schnorrenberger (2005), and according to the theoretical affiliation of the Multi-criteria Methodology to Support the Constructivist Decision - MCDA-C, it was verified that the articles were not aligned with this theoretical affiliation, since the multi-criteria methods derive from the Classic Operational Research, whose focus is on the structuring and model validations, different from the traditional methodology of structuring processes to solve the problems.

In the lenses analysis, 15 articles used a model constructed in one context and applied in another and 2 of them did not apply the developed model. All papers present models that were developed in one context and applied in another and it was verified that the decision maker importance was null. Although the measurement was carried out in 14 articles, only 6 presented criteria integrated, 5 pointed out the strengths and weaknesses of the scenario and none of them indicated improvement actions.

The AHP and TOPSIS methods stood out as the multi-criteria methods that appeared most frequently in the articles of the portfolio, being applied in several contexts: MQFD application analysis, supplier selection, education policy prioritization, selection of Six Sigma projects, obtaining criteria weights, selection of quality criteria,

evaluation of management practices and selection of knowledge management systems.

The indicators were grouped by categories according to the application context: company evaluation, product development, feasibility study, criteria selection, and suppliers' selection, selection of CoQ models, projects selection and management systems selection. They were the most numerous indicators present in the "enterprise evaluation" and "criteria selection" clusters.

Finally, it was verified that the integrated use of multicriteria methods and quality tools provides diversity in the scenarios analysis and meets the proposed objectives in the evaluated articles. The fact that the articles in the bibliographic portfolio were restricted to scientific journals available in the Web of Science and Scopus databases, from January 2005 to April 2016 and following the assumptions established by the intervention instrument Proknow-C are the limitations of the research.

Despite the limitations, we can evidentiate that the results can contribute to the scientific development due to the presentation of a structured process to identify and select relevant articles aligned with the theme. Through the fragment of the literature obtained by the methodological rigor proposed by the Proknow-C instrument, the studies were found allowing verifying the contributions of the quality tools and multi-criteria methods integration, in the evaluation models applicable to different decision-making scenarios.

Considering the great number of quality tools, as well as a considerable number of multi-criteria methods available, the studies found in the literature present the use of one or two multicriteria methods jointly with few quality tools to construct evaluation models. It has a difficult conclusion due to a greater number of elements at the same work and diversity of existing methodologies. However, no similar studies were found in the literature relating the integration of quality tools and multi-criteria methods.

For future studies we suggest the research replication enlarging the temporal cut-off to identify a larger range of papers related to the topic and, with this, to identify more gaps in the literature and different scientific opportunities for the theme.

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