Multicriteria applied to Defence: a panorama of the scientific literature.

Pessôa LAM¹, Costa HG²

Abstract Defence and military decisions require taking into account multiple viewpoints, some of them subjective, which leads to the development of MCDM/A models. The advances already reached in this domain are spread throughout the literature, which makes difficult to have a global understanding of the subject. To fill this gap, this paper provides an overview of multicriteria applied to defence through a structured review of the literature published in journals indexed in the Scopus database. As a result, this paper presents the overall behaviour of the academic research over time, indicates the main countries of origin (China and USA), and clusters the findings into different categories for a deeper understanding of the contributions’ context. The paper also highlights the main multicriteria methodologies used in the defence domain and its development tendencies. The taxonomy produced (including “Emergency Management” and “Military” fields), and the gaps identified may be useful for future research and helps to clearly establish future contributions to the existent academic literature.

Keywords: Defence; Multicriteria; Decision.

1 Introduction

In a broad sense, defence may relate to military and non-military contexts. In the latter, there is an emergency response to adversity events. This is because, in this interpretation, defence may relate to protection from natural or non-natural catastrophic events. On the other hand, defence also encompasses a hard power parcel, helping a country to defend its own interests in the International System.

Both military and non-military contexts are inserted in a complex environment, where it is necessary to make complex decisions, most of them taking into account multiple aspects or criteria, and some of them based on subjective evaluations. Such kind of decision situations are eligible to be approached by Multicriteria Decision Aid (MCDA) methods, which have been proposed to support human decisions in complex environments to deal with multiple and subjective aspects.

This paper presents the use of MCDA to the defence field, striving to build a panorama of its approaches regarding the defence domain, based on a bibliography review of the Scopus database.

To provide a methodological structure, the following section presents the theoretical background, discussing elements of multicriteria decisions, and presenting the methodology for this study. Section 3 presents the results, focused on the articles retrieved, showing a crescent academic interest on the subject, especially by China and United States, and a major use of the AHP method in the selected papers. Following, Section 4 presents a brief discussion of the findings and concludes with the future perspectives for the use of multicriteria for defence approaches.

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2 Material and Methods

2.1 Multicriteria Fundamentals

Some classical decision texts, such as one by Arrow (1963), Roy(1968), Fishburn(1970), Saaty(1980), Zeleny (1982), and Roy and Boyssou(1985), consider that decisions are made in a complex environment. One point that attests the establishment of MCDA as a discipline is a growth in the number of multicriteria-based methods and models that have been applied to a wide range of decision problems, mainly: ranking, choice, and sorting problems.

Table 1, extends the works of Rodriguez et al. (2013), Figueira et al. (2010), and Nepomuceno and Costa (2015), by showing a non-exhaustive list of MCDA methods and their references.

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<thead>
<tr>
<th>Method</th>
<th>Reference</th>
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<td>Condorcet</td>
<td>Condorcet (1788)</td>
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<td>Multiattribute Utility Theory (MAUT)</td>
<td>Fishburn (1970), Keeney and Raiffa (1976)</td>
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<td>Elimination EtChoix Traduisant la Réalité (ELECTRE)</td>
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<td>Vikor</td>
<td>Duckstein and Opricovic (1980)</td>
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<td>Simple Multi Attribute Rating Technique (SMART)</td>
<td>Edwards and Barron (1994)</td>
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<td>Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)</td>
<td>Hwang and Yoon(1981)</td>
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<td>CPP TRI</td>
<td>Sant’Anna et al(2015)</td>
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<td>PROMSORT</td>
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<td>REGIME</td>
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<td>ZAPROS</td>
<td>Saaty(1996)</td>
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<td>Verbal Decision Analysis (VDA)</td>
<td>Hansen and Ombler.(2009)</td>
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<td>Potentially all pairwise rankings of all possible alternatives (PAPRIKA)</td>
<td>De Almeida et al. (2016)</td>
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2.2 Method

The method for building the review consists of the following sequence of steps:
1. Research the Scopus database using words designating the most common approaches in the multicriteria field and the keywords ‘defense’ and ‘defence’.
2. Analysis of the documents’ metadata regarding: Time; Most relevant origins; Subjects and Types.
3. Mapping the keyword relevance. Using VOSviewer software (Van Eck & Waltman, 2010), the extracted information regarding the title and keywords are represented in a visual map.
4. Filtering the documents. Selecting only the articles presented in accessible languages. This process is necessary to narrow the documents to the most important sources that can be understood by the authors.
5. Pre-processing the keywords, to unify different terms under the same terminology (such as AHP and Analytic Hierarchic Process), and exclude unrelated keywords, producing significant clusters.
6. Mapping the keywords’ relevance, using the VOSviewer software, the extracted information regarding title and keywords are represented as a visual map.
7. Mapping the abstract words using the VOSviewer software, the extracted information’s abstract words are represented as a visual map.
8. To provide a taxonomy for a better understanding of the subject, by classifying the selected articles based on their use domain.

As no concentration was perceived in the authorship of the documents, we do not explore this matter in this paper.

3 Results

The results of the survey led to the retrieval of the articles metadata concerning multicriteria and the defence domain.

3.1 Metadata analysis - Defence and Multicriteria

This study consulted the Scopus and the search was based in the following query terms: “MCDA or MCDM or multicriteria or ‘multiple criteria’ or AHP or ‘Analytic Hierarchy Process’ or electre or topsis or macbeth or dematel or promethee or ‘Analytic Network Process’”

Figure 1 shows the time series regarding the publication indexed in the database. It shows a marked rise of related documents since 2007. Moreover, despite the number of documents decreasing since 2010, there are still substantially more than in the early 2000s.
As shown in Figure 2, this behaviour is reinforced when we only take articles published in journals into consideration.

The second important aspect is related to the documents’ country of origin, as presented in Figure 3. Figure 4 shows the results if we only take in account the “articles” type of document. As one can see from these figures, there is a greater research interest in China and in the United States.
The subjects covered in the sample are presented in Figure 5. Analysing such figure we conclude that, Engineering, Computer Sciences, Business Management, Decision Sciences and Mathematics are the major related fields.

Focusing our analyses only in “articles” (Figure 6), we achieve that Engineering and Computer Science subjects are still the most related areas; however, Mathematics also has a large importance, when compared with all documents.
Despite some spikes, this figure represents the overall growth of the articles, showing the changing interest in the thematic research.

### 3.2 Analysis of the documents

One-hundred and eighty articles were selected to deeper analysis, excluding papers non-related to the study objective, such as those related to chemical processes, biology, or, for instance, referencing ANP as ‘Atrial natrudpetic’. It is also clear that some results are not linked directly to this study’s focus. Such results were classified as partially related, as they refer to defence only collaterally, presenting a possible use on a defence issue, or using defense with another meaning, such as in football, and were also filtered. In the remaining papers, Analytic Hierarchy Process, and its acronym AHP appear as major items. So, these terms were merged into AHP. VOSviewer displays items with more occurrences more prominently. As shown in Figure 7 ‘emergency management’ is an important concept for those documents. Therefore, it was necessary to separate the articles into two different subsets to be individually explored: Emergency Management and Defence and Military Capability.

![Figure 7 - keywords — filtered articles — consolidated AHP terms](image)

Figure 7 illustrates that ‘emergency management’ is an important concept for those documents. Therefore, it was necessary to separate the articles into two different subsets to be individually explored: Emergency Management and Defence and Military Capability.

In fact, during the classification process, it was found useful to perform a sub-classification that produced a taxonomy to clearly present the results from such explorative study. This classification is not based on previous literature but is derived from the articles found. The references cited on each sub-classification are the more recent examples, but the complete list of related articles is presented on Pessôa & Costa (2020) as a supplementary material.

### 3.3 Emergency Management

Figure 8 presents a plot of the abstracts of emergency management articles.
In this figure, there are three main clusters, with the following terms presenting highlighted importance: Cluster 1 — Factor, area, and risk; Cluster 2 — Emergency management, effectiveness, and resource; Cluster 3 — Decision making, criterion, and problem.

It is also noteworthy that AHP does not appear as a major concept in this depiction, despite the appearance of other multicriteria methods (e.g. dematel).

Figure 9 presents the same representation but indicates the concepts and their publication year.

This figure shows that the appearance of the terms: fire, order, variety, critical success factor, and dematel are more recent than the other selected terms, suggesting a newer approach.

The 'emergency management' group refers to a response to an emergency event. So, the papers in this category could refer to conceptual models for emergency management (Han & Deng, 2018; McCarter et al., 2018; Qi et al., 2017; Qi et al., 2018; Zhou et al., 2017), or could fall into two separate categories: Natural Events; and Risk Management.

In the response to natural events category, the retrieved papers deal with the use of multicriteria relating to: climate or meteorological extreme events (Chen et al., 2018; Connelly et al., 2016; Floods Ball et al., 2012; Penning-Rossell et al., 2013) Earthquakes (Wang et al., 2014) and Fires (de Oliveira et al., 2017; Stefanovic et al., 2016).

On the other hand, the non-natural events are the concern of the papers included in the Risks Management category. These papers deal with: Installation and Infrastructure Security (Xie et al., 2017; Farahani et al., 2018); Terrorism (Kang & Lee, 2014; Li et al., 2016); Area Management (André et al., 2016; Serio et al., 2018); and Nuclear and Chemical issues (Argyris & French, 2017; Khakzad & Reniers, 2016).
3.4 Military and Defence Capability

In the Military and Defence Capabilities category, the main terms found are represented in figure 10.

![Figure 10-Military Category](image1)

In this figure, there are three main clusters, with the following terms presenting highlighted importance: Cluster 1 — Analytic Hierarchy Process (or AHP), study and selection; Cluster 2 — technique, theory and similarity; and Cluster 3 — evaluation, multiple criterium and difficulty.

Figure 11 reveals the methodology other than AHP (TOPSIS) present in Cluster 2. When these terms are represented according to the year of publication, it highlights that the TOPSIS method appeared recently.

![Figure 11- keywords](image2)

First, it is important to highlight a previous review on the AHP method for military applications Hyde & Davis (2012). Analysing the other papers in this group, it is possible to separate them into the following subcategories: Strategic Issues; Operations/Military Actions; and Resources.

In the strategic issues category, the articles present broad aspects to be dealt with through the multicriteria methodology. The topics comprise: Finances & Contracts: (Bakirli et al., 2014; Can & Arikan, 2014; Georgiadis et al.,2013); Infrastructure (Mikulik, 2013; Seager et al.,2017; Suharyo et al.,2017); and Doctrine & Decision aspects (Rai & Bolia, 2014; Wan et al.,2018).

The Operations subcategory includes papers more dedicated to the operational employ of military units and tactics, and were subdivided into the following topics: Tactical Decisions: logistics (Han et al.,2016), combat effectiveness (Jia et al.,2017), battlefield assessment (Lei et al.,2006); Unit employment: force planning (Wang et al.,2011; Yang, 2012), weapon selection (Dagdeviren et al., 2009), unit allocation (Goztepe et al.,2016); and Target, Threat, and damage assessment (Frini et al.,2017; Xu et al.,2017).

Regarding Resource Category, the following topics were clustered: Personnel: (Bastian et al.,2016); Computer Based resources (Alnafjan et al., 2013; Alghamdi et al.,2010); and Military equipment: obsolescence (Adetunji et al., 2018), evaluation (Alomair et al., 2016; Fan et al., 2015; Peng et al.,2015), procurement (Nikou & Moschuris, 2016; Nikou et al., 2017); justification (Israeli et al.,1998), selection (Gazibey et al.,2015), composition (Gong et al., 2015), and improvement (Liu et al., 2006).
4 Conclusion

It is interesting to note that among the multicriteria methods, AHP generally has more relevance, but recently other methods have been highlighted. The use of hybrid approaches in both groups (military and non-military domains) is also noticeable.

However, the methods used by the groups are quite different. Each group diversely used new methods, with TOPSIS highlighted by the military, and Dematel by emergency response. This paper provides a brief consultation on the most important terms of each selected reference, striving to depict the motivation, methods, and purposes mentioned in each abstract.

As its contribution, this study suggests a taxonomy to classify results. Such taxonomy was not previously conceived but was drawn from the documents retrieved. The first category comes from the often-used term ‘Emergency Management’ in opposition to ‘Military/Defence department capability’. Such division makes sense for a broader definition of defence, as discussed in the Introduction.

The Emergency Management category contains papers that fall into risk management or natural events subcategories, while the second category relates to strategic issues, operations, personnel, and material resources.

Finally, figure 12 presents a conceptual map made using C-map tools, that represents the taxonomy used to group the articles. Such a map is useful in positioning previous research, presenting a relational context for a more specific bibliography consult, and locating future contributions on the theme.

5 References


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