# Constructing synthetic indicators using multicriteria methods: A review

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## Abstract

*Synthetic indicators are increasingly recognised as a useful tool in policy analysis and public communication. Their construction has been dealt with from several angles. Some authors claim that MCDM techniques are highly suitable in multidimensional frameworks when aggregating single indicators into a synthetic one, since this process involves making choices when combining criteria of different natures, and it requires a number of steps in which decisions must be made.*

*In this paper, we conduct a literature review of papers published after 2002 in leading international journals indexed in a recognised database (JCR), in order to identify the different MCDM methods used for aggregating single indicators into synthetic ones. They have been classified in five categories: the elementary methods, the value and utility based methods, the outranking relation approach, the data envelopment analysis based methods and the distance functions based methods. In general, our review has shown a clear tendency towards an increasing number of papers that use MCDM methods to construct composite indicators since 2014.*

## 1. Introduction

The number of synthetic indicators in existence around the world is growing year after year, especially due to their aims of summarising, focusing and condensing the complexity of our dynamic environment (Nardo *et al.*, 2008). In practice, they have been applied in relevant dimensions of reality such as country's competitiveness (World Economic Forum (2017a)); the quality of its governance (World Justice Project (2016)); the freedom of its press (Freedom House (2017)); the global, regional and national Human Development (The United Nations Development Programme (UNDP) (2016)); the world's measure of global peacefulness (Institute For Economics & Peace (2017)); the travel and tourism competitiveness (World Economic Forum (2017b)); the country's economy measure (World Development Indicators: The World Bank (2017); the efficiency of its universities (the *Academic Ranking of World Universities*, the *Times Higher Education World University Ranking* or the *QS World University Ranking*), etc.

The construction of synthetic indicators has been dealt with from several angles. Although generally, constructing composite indicators involves three main processes, normalisation, weighting and aggregation.

According to Becker *et al.* (2016), the construction of a synthetic indicator involves making choices when combining criteria of different natures, and it requires a number of steps in which the decision maker must make decisions. In this aspect, some authors claim that MCDM techniques are highly suitable in multidimensional frameworks when aggregating single indicators into a synthetic one (see Nardo *et al.* (2008, 2005); Jacobs *et al.* (2004); Freudenberg (2003); Saisana and Tarantola (2002)).

Therefore, the aim of this study is to carry out a review of the literature in order to identify the different MCDM methods used for aggregating single indicators into composite ones. This has been achieved by conducting a literature review of papers published after 2002 in leading international journals indexed in recognised databases (JCR). To do so, the keywords used are composite/synthetic indicator, multicriteria decision making method, indicator framework and aggregation.

## 2. MCDM methods to construct synthetic indicators

Multicriteria decision making is a set of methods that can be used to support the process of decision making in a flexible manner when more than one criterion are being considered (Cinelli *et al.* (2014)). Within MCDM approaches, one of the most extended classifications differentiates between Multi-Objective Decision-Making (MODM) and Multi-Attribute Decision-Making (MADM). In our case, we have decided to classify MCDM methods used to construct synthetic indicators in five categories:

1. **The elementary methods**. The most common are the Simple Additive Weighting (SAW) and the Weighted Product (WP). The former allows for a total compensation and the latter for a partial compensation. The SAW and WP methods normally require normalising variables before aggregating.
2. **The value and utility based methods** consists of designing a means of associating a real number with each alternative and producing a preference order for the alternatives, based on decision-makers' value judgements (Belton and Stewart (2002); Azapagic and Perdan (2005)). Within this group, some methods allow for a partial compensation, such as the MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique) (Bana-e-Costa and Vansnick, 1994), the Multi-Utility theory (MAUT) and the Multi-Attribute Theory (MAVT) (A key reference for MAUT and MAVT is Keeney and Raiffa (1976)). While, the Utility Theory Additive (UTA) and the Simple Multi-Attribute Rating Technique (SMART) allow for a total compensation.
3. **The outranking relation approach** involves methods based on comparisons between pairs of options to determine whether "alternative a is at least as good as alternative b". Within this family, the two most used methods are ELECTRE (Roy, 1968, 1991) and PROMETHEE (Brans *et al.*, 1986). Both methods allow for a partial compensation among the criteria. These methods do not require a normalisation before aggregating variables, since they use the original data for the comparisons.
4. **The Data Envelopment Analysis based methods (DEA)** (Charnes *et al.*, 1978) and **the Benefit of the Doubt model(BoD)** (Melyn and Moesen, 1991). DEA allows for a full compensation among the criteria. This technique allows the analyst to endogenously determine the weighting of the partial indicators. Interesting links between DEA and MCDM methods can be seen in Stewart (1996); Joro *et al.* (1998); Cooper (2005).
5. **The distance functions based methods**. The use of these methods to construct synthetic indicators requires the assessment of the corresponding reference levels by the decision maker, in addition to the weights. In some cases, a prior normalisation is required, while in others the achievement functions produce normalised values. Within this family we distinguish:
   - The goal programming method (Ijiri, 1965; Ignizio, 1976).
   - The compromise programming method (Yu, 1973; Zeleny, 1974).
   - The reference point method (Wierzbicki, 1980; Ruiz *et al.*, 2011; Cabello *et al.*, 2014) allows for different compensation degrees among the criteria depending on the aggregation scenario.
   - The Technique for Order Preferences by Similarity to Ideal Solutions (TOPSIS) (Hwang and Yoon, 1981) it allows for a full compensation.
   - The principle of the Grey Relational Analysis (GRA) method (Deng, 1989) is similar to TOPSIS.

## 3. The weighting and the compensation issues

According to Nardo *et al.* (2005) weighting and aggregation are key steps in constructing synthetic indicators. Weighting methods can be categorized into three main categories: **equal weighting**, **data-based methods** and **participatory based methods**.

In our literature review, we found that data-based methods and participatory based methods are the most frequently used approaches.

Within data-based methods, a weighting technique based on DEA is the most widely used approach. Also, the entropy method, the principal component analysis, the distance principal component and programming model are used.

Concerning participatory based methods, weighting based on expert's opinions and decisions makers are widely used. Also, AHP/ANP, the Delphi technique, SMARTER and MACBETH are adopted.

Finally, the equal weighting approach is also used.

On the other hand, when constructing synthetic indicators, an important aspect to emphasize is the compensation degree among the different criteria. In general, the most applied techniques in the literature of composite indicators are compensatory and non-compensatory techniques (Asadzadeh *et al.*, 2017).

Within MCDM methods, some techniques allow for full compensation among the criteria, such as the SAW, UTA, SMART, DEA and TOPSIS methods, while others limit the compensation degree, such as MAUT, MAVT or the WP method. In the case of the outranking methods (ELECTRE and PROMETHEE), they limit or completely prevent compensation (Attardi *et al.*, 2018),

Moreover, some techniques allow for different compensation degrees depending on the aggregation scenario chosen. A clear example of this is the double reference point method proposed by Ruiz *et al.* (2011) and Cabello *et al.* (2014).

## 4. Categories of MCDM methods and time-based evolution

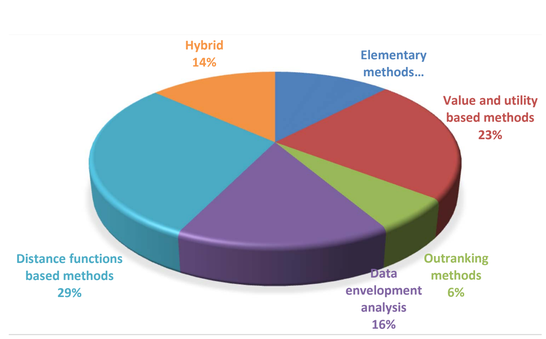


**Figure 1:** *Categories of MCDM methods used to construct composite indicators.*

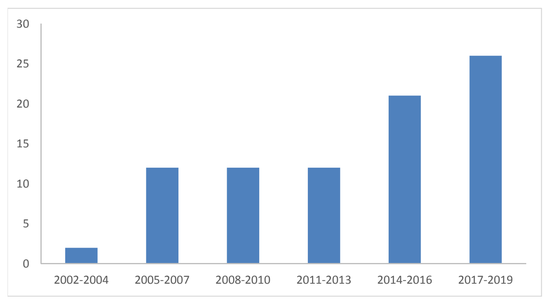


**Figure 2:** *Time-based evolution of published papers using MCDM methods to construct composite indicators.*

## 5. Scopes of application and journals' categories

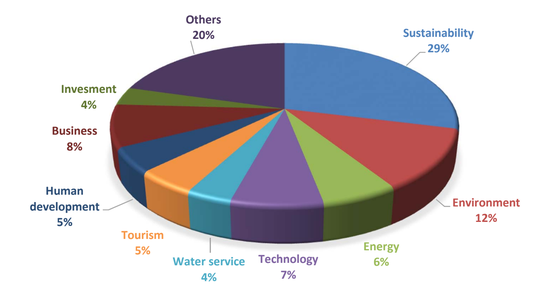


**Figure 3:** *Scopes of application of MCDM methods used to construct composite indicators.*

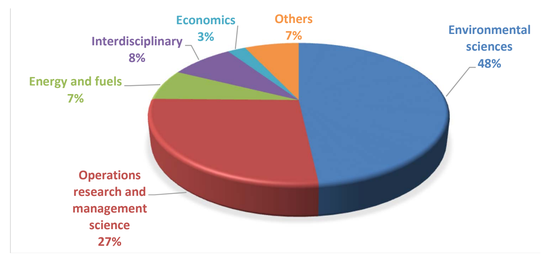


**Figure 4:** *Journals' categories of published papers using MCDM methods to construct composite indicators.*

## 6. Conclusions

MCDM methods have been widely used to construct synthetic indicators. In this paper, we found that most of the papers published adopt the distance functions based methods to construct synthetic indicators, noticing an increasing tendency since 2012. Furthermore, some papers tend to use MCDM methods from different categories simultaneously (hybrid approaches). Concerning this category, our review confirms the tendency towards an increasing number of papers in the last years, especially from 2014.

In general, our review has shown a clear tendency towards an increasing number of papers that use MCDM methods to construct synthetic indicators since 2014. Furthermore, we found that MCDM methods to construct synthetic indicators have been applied in a wide variety of fields, especially in sustainability and environment. Papers have been published in many different journals indexed in JCR since 2002, most of them on the category of "Environmental Sciences".

## Acknowledgements

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