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GUIDELINE FOR CONSTRUCTING COMPOSITE INDICATORS THAT MEASURE CIRCULAR ECONOMY PERFORMANCE

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Abstract. *Composite indicators are modern tools for evaluating, comparing, and measuring the performance of multidimensional concepts such as sustainable development, environmental protection, or circular economy among countries, regions, or cities. The core of composite indicators includes the mathematical relation of individual indicators pertaining to different dimensions of the observed concept. Importantly, composite indicators are constructed by means of various mathematical models, primarily multiple-criteria decision analysis, which allows the selection of adequate individual indicators within a composite indicator. This is followed by the selection of a suitable aggregation model and a careful selection of a system for assigning individual indicator weights. Subjectivity during decision-making should be avoided as much as possible, as it could lead to an imprecisely formed indicator. In addition, this requires a proper previous definition of indicator robustness, which explains the level of coverage of a specific concept, as well as potential restrictions that need to be listed in indicator notes. This paper discusses the key features of measurement using indicators and the application of composite indicators in circular economy. Guidelines are also provided for proper definitions and construction of composite indicators that measure circular economy performance, all for the purpose of improving the system for circular economy performance measurement.*

Key words: *circular economy, composite indicators, performance, decision-making, aggregation*

1. INTRODUCTION

Circular economy performance can be measured efficiently using composite (combined) indicators, which target different dimensions of circular economy, such as economic, social, or environmental [1], whereby attention should be paid to indicator construction so

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as not to draw simplified and inaccurate conclusions about circular economy. The concept of circular economy is founded on resource reuse and recycling as support for building a new sustainable society, which requires changes in the way of thinking and doing business, and modifications of living habits [2]. The results of previous studies of indicators that measure circular economy performance highlight the need to create proper methodological guidelines, which would significantly improve the construction of composite indicators [3,4]. The ISO 14031 standard provides guidelines for evaluating environmental performance using indicators, while the BS 8001:2017 standard from the British Standards Institute (BSI) can be used to implement circular economy in organizations and companies; however, harmonization requirements are lacking. Methodologically, the construction of composite indicators that simultaneously measure multiple dimensions of circular economy is not defined finitely, although there have been attempts to construct composite indicators or indexes of circular economy [5,6]. These attempts will be discussed below. Circular economy performance measurement lies on the foundations of the science of measurement – metrology. Measurement is a process used to experimentally determine one or more values of a quantity being measured. The measured quantity can be measured directly or indirectly [7]. In a narrow sense, measurement only refers to quantitative or numerical measurement. In a broad sense, in addition to quantitative measurement involving assigning numbers to objects, measurement also refers to a qualitative (categorical) measurement that determines the value of a categorical variable by sorting objects into categories. Measurements scales have four fundamental levels (nominal, ordinal, interval, and ratio), while measurement is also accompanied by measurement error. Essentially, measurement is a set of procedures whose goal is to determine the value of a quantity [8,9].

2. INDICATORS

In multidisciplinary sciences, measurement imperfections often leave true values of a measured quantity unknown; therefore, the measuring technique or manner is essential. To define the manner of determining the values of different objects or the manner of operationalizing variables means to find a way to empirically represent a theoretical variable. As the empirical variable would thus become the indicator of the theoretical variable, it can be defined as an indicating variable or an indicator [10]. Specifically, indicators indirectly and partially measure complex phenomena that would otherwise be difficult to measure directly. Indicators have to be measurable since they are a precise and reliable measure of an object with a specific statistical significance, whose value can be influenced by multiple factors. They serve as tools to represent a specific state or changes in that state. Indexes and indicators are used as tools for minimizing and simplifying large amounts of data while preserving their essence and making them more compact and easier to understand. On the one hand, indicators are statistically steered toward indicating specific questions pertaining to the results and conclusions of a specific phenomenon. On the other hand, indexes represent the relationships pertaining to the variations of one or more time or dynamic series. The terms index and indicator can sometimes be synonymous. Since indexes connect different indicators into a single number, which is advantageous for temporal and spatial comparisons, literature frequently equates composite (combined) indicators with indexes, whereby indicator exclusively refers to individual indicators [11].

3. Application of Composite Indicators in Circular Economy

Considering that multidimensional phenomena cannot be measured by an individual indicator, individual indicators and their weight coefficients are integrated into a single composite indicator. According to some authors, composite indicators originated due to globalization, while the reason for their widespread use is that they make collecting, translating, and interpreting shared trends of various phenomena much easier [12,13]. Composite indicators are nowadays increasingly used to measure complex concepts, such as environmental protection, sustainable development, and circular economy. In 2015, The European Commission developed a Circular Economy Action Plan, which is intended for monitoring and measuring accomplishments in circular economy; however, it lacks proper composite indicators on the national level. That is why the remainder of this section mentions some of the most interesting examples of composite indicators that directly or indirectly measure specific segments of circular economy and that were constructed by different authors or institutions. The Global Resource Indicator (GRI) is a combination of the depletion of resources and recyclability as quantitative values of resource availability and recycling rate, while the geopolitical availability of resources and their equal distribution are combined as a qualitative category [14]. The Sustainable Circular Index (SCI) is based on sustainability reports according to the methodology that includes information weighting and factors that are determined in consultation with experts [15]. The list can also include numerous composite indicators that are based on index methods, such as: Environmental Performance Index (EPI), Environmental Sustainability Index (ESI), Sustainable Process Index (SPI), Embodied Energy Index (EEI), and many more. The European Academies' Science Advisory Council (EASAC) proposed a possible combination for a composite indicator [16]:

- energy productivity (GDP/total primary energy supply [TPES, in tonnes of oil equivalent per capita]): larger values indicate progress;
- GDP per capita (GDP/population): current progress indicator;
- resource recycling rate (%): better recycling means increased indicator;
- division by the amount of CO2 emissions: reduced emissions mean increased indicator;

whereby the following formula applies to calculate the composite indicator developed by EASAC:

$$\frac{\text{GDP}\times\text{GDP}\times\text{recycle rate}}{\text{TPES}\times\text{population}\times\text{CO}_2\ \text{emission}} \quad (1)$$

The Circular Economy Index (CEI), constructed specifically for European countries [4], comprises three sub-indexes: Sustainable Resource Management Index (SRMI), Societal Behaviour Index (SBI), and Business Operations Index (BOI). Each sub-index comprises several indicators within the index measurement scope.

4. Guidelines for Constructing Composite Indicators

In contemporary literature and practice, the results of the analysis of circular economy performance indicators show a superficial consideration of sociological and circulatory measurements, instead of focusing on economic and environmental impacts. The existence of differences in the construction of circular economy performance indicators depends on

values and methodologies and allows rail access to Circular Supply Chains [17]. In view of the current tendency to construct an ever-increasing number of composite indicators, and in order to avoid misunderstanding of indicators by experts, it is necessary to attach metadata to the indicators. The metadata need to include all the relevant documentation about a new indicator: indicator name; subject area; indicator type; description and definition; license/standard; data collection and computation methodology; measurement unit; and reporting period [18]. The same author highlights transparency as a key property of properly constructed composite indicators and lists conceptual definition, sub-groups designation, and individual indicator selection as the most important steps when constructing composite indicators [19]. The authors of the present paper think that the basic data should also include the restrictions (space, time, sample, conditions, stakeholders, etc.) wherever delicate or ambiguous questions arise. This will improve methodological transparency and define a given indicator more accurately.

According to a group of authors, there are ten key steps in the construction of composite indicators [16]: (1) theoretical framework; (2) data selection; (3) imputation of missing data; (4) multivariate analysis; (5) normalization; (6) weighting and aggregation; (7) uncertainty and sensitivity analysis; (8) return to the data; (9) links to other indicators; (10) visualization of the results.

Another group of authors lists the following five steps in the construction of a circular economy index [3]:

1. Theoretical framework of the circular economy indicators and construction of a decision matrix, as shown in a data set (2), where n denotes the number of countries and m the number of indicators:

$$X = x_{i,j} \quad (i = 1 \ldots n;\ j = 1 \ldots m) \tag{2}$$

2. Computation of the normalized decision matrix to ensure comparability, where the normalized value is obtained according to

$$r_{i,j} = \frac{x_{i,j}}{\sqrt{\sum x^2_{i,j}}} \tag{3}$$

3. Definition of the weight system and calculation of the normalized decision ($v_{i,j}$) using equation (4), where $w_{i,j} \in [0,1]$ are the weights associated with each sub-criterion j and obtained according to the weighting system where $\Sigma w_{i,j} = 1$:

$$v_{i,j} = w_{i,j} r_{i,j} \tag{4}$$

4. Determination of the values of an ideal and negative-ideal solution according to the established cost-benefit criteria;
5. Definition of the aggregation methods for the separation measures. This step can profoundly affect the overall ranking within the circular economy index, so it is a key step. To ensure maximum flexibility when aggregating the separation measures of the individual indicators for each dimension to the ideal and negative-ideal, the standard constant-elasticity of substitution (CES) function is used to generate the aggregated distances.

Normalization is one of the most important basic actions in defining and solving multiple attribute decision-making (MADM) models [20]. The model applies whether the composite indicators are constructed by means of life-cycle analysis (LCA) methods, Data Envelopment Analysis (DEA), the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), or other methods. A model guideline for constructing composite indicators that measure circular economy performance is shown in Figure 1.

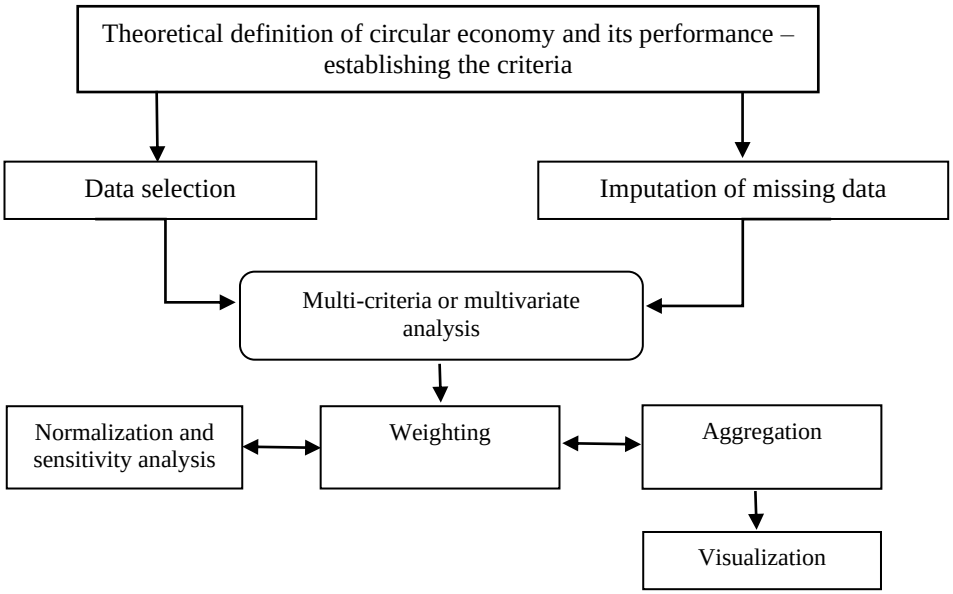

Fig. 1 Guidelines for constructing circular economy composite performance indicators

5. CONCLUSION

This paper provided guidelines for constructing composite indicators that measure circular economy performance. The guidelines were developed based on reviews of previous experience in composite indicator construction by a variety of authors or institutions. They were developed in order to improve the system for circular economy performance measurement, to improve composite indicator construction, and to minimize the possibility of errors and construction of inaccurate indicators. The guidelines emphasize the importance of the theoretical definition of circular economy and its performance. This should be followed by the establishment of criteria and selection of indicators, which is why it is beneficial to involve experts during the first step. The subsequent step would also benefit from expert involvement as they can help determine which indicators best reflect circular economy performance and which can be disregarded or substituted with average values. Multivariate or multi-criteria analysis is essential in constructing composite indicators that measure circular economy performance, because the process requires the analysis from all dimensions as well as the comparison of indicators being evaluated. The influence of an individual on the composite indicator is determined through weighting (subjective or objective) and subsequent aggregation. It is important to note that individual indicators

often have different measurement units, so, in order to achieve indicator comparability, every aggregation is usually accompanied by normalization. The results need to be harmonized with the uncertainty limit and the sensitivity factors. The visualization of the results should be adjusted to suit the stakeholders, as it affects interpretation and understanding. The proposed guidelines for constructing composite indicators that measure circular economy performance can be used by authors who are interested in constructing composite indicators.

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SMERNICA ZA RAZVOJ KOMPOZITNIH INDIKATORA ZA MERENJE PERFORMANSI CIRKULARNE EKONOMIJE

Kompozitni indikatori su savremeni alati za praćenje performansi, vrednovanje i poređenje između zemalja, regiona ili gradova, višedimenzionalnih koncepata kao što su održivi razvoj, zaštita životne sredine, cirkularna ekonomija i dr. Suštinu kompozitnih indikatora čini matematička kombinacija pojedinačnih indikatora koji se odnose na različite dimenzije posmatranog koncepta. Značajno je napomenuti da prilikom razvoja kompozitnih indikatora dolazi do primene različitih matematičkih metoda, najpre je to višekriterijumsko odlučivanje koje omogućava izbor adekvatnih pojedinačnih indikatora unutar kompozitnog. Zatim se mora izabrati odgovarajući model agregacije, kao i veoma oprezno odabrati sistem za dodelu težinskih koeficijenata pojedinačnih indikatora. Pri tome, treba izbeći u što je većoj meri moguće subjektivnost prilikom donošenja odluka, jer može dovesti do neprecizno formiranog pokazatelja. Takođe, prethodno je neophodno dobro definisati robusnost indikatora čime se objašnjava nivo pokrivenosti određenog koncepta, kao i eventualna ograničenja koja je neophodno navesti u napomeni o indikatorima. U okviru rada prikazana je suština merenja putem indikatora, kao i primena kompozitnih indikatora u cirkularnoj ekonomiji. Date su smernice koje se odnose na pravilno definisanje i razvoj kompozitnih indikatora za praćenje performansi cirkularne ekonomije, u cilju unapređenja sistema za merenje performansi cirkularne ekonomije.

Ključne reči: *cirkularna ekonomija, kompozitni indikatori, performanse, odlučivanje, agregacija*