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DEVELOPING A CIRCULAR ECONOMY INDEX TO MEASURE THE MACRO LEVEL OF CIRCULAR ECONOMY IMPLEMENTATION IN INDONESIA

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Abstract:
Circular economy (CE) is an interesting approach by many countries to address global environmental problems while gaining economic benefits. The implementation of CE is expected to minimize the use of resources and materials, thus contributing to sustainable development. Much literature has discussed CE assessment indicators and their evaluation, however to date, no single indicator has been proposed that can comprehensively measure the macro level of CE implementation. This study aims to develop a CE index to measure CE implementation at macro levels. In addition, it provides an overview of the impact of CE implementation on the financial, social, and environmental aspects of the economy. To this end, first, an in-depth literature review and descriptive analysis is conducted to identify existing global CE indicators and classify them into financial, social, and environmental categories based on available primary and secondary data. Then, the CE index is constructed using a mathematical equation by considering the CE framework, a single indicator of each aspect as a variable, and the variable's weighting. Finally, the CE index is applied to evaluate the level of CE implementation of CE in Indonesia at macro level. This index is expected to be a valuable tool for measuring CE implementation and therefore improving CE performance.

Key words: *circular economy, CE index, Indonesia, macro level, mathematical equation*

INTRODUCTION

To fulfil their commitment to the Paris Agreement, many countries have adopted the circular economy (CE) approach to address global environmental problems while gaining economic benefits. The Paris Agreement was adopted by 196 parties, including Indonesia, who aims to reduce global warming to below 2ºC through binding international law agreements that highlight the threat of climate change [1].

In general, the CE principle of CE differs from that of linear economy, which uses natural resources to meet consumption needs through production and simultaneously produces waste [2]. In contrast, CE proposes an approach toward sustainable development by understanding the value of handling natural resources to minimize resource and materials consumption, waste generation, and other environmental impacts [3]. Although CE has many different definitions, to date, no concept of CE has been globally agreed upon [4, 5, 6]. The most used definition of CE in literature [7] is "an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models [8], with the aim to accomplish sustainable development [9]. According to [10], implementing CE can minimize the use of resources and energy and reduce waste and pollutants in the automotive industry. In addition, CE can provide more significant benefits for

the industrial sector, such as reducing material costs [11], and can encourage the achievement of sustainable development goals at the global level [10].
Much literature has already discussed CE assessment indicators [12]. Among them are the classification of indicators for the CE monitoring framework in European Union (EU) countries [4] and 55 CE indicators developed to assist industrial practice, especially in the assessment of the quantity and quality of materials [13]. In addition, a CE monitoring framework and indicators have been designed to measure CE progress in EU countries [14]. EU member states adopted and developed these frameworks and indicators to measure their CE implementation [15]. However, to date, no single indicator can comprehensively measure the level of CE implementation.
This study aims to address this gap and proposes a CE index to measure CE implementation at the macro level. Besides that, it also presents an overview of the impact of CE implementation on financial, social, and environmental aspects. The discussion began with a literature review related to global CE indicators, then a descriptive analysis for categorizing CE indicators at the macro level according to CE aspects and proposing indicators for measuring CE in Indonesia with specific criteria. Furthermore, the CE index is constructed using a mathematical equation based on indicators as variables in the hierarchy that has been designed. Finally, the CE index was applied to measure CE implementation at the macro level (Province) in Indonesia.
The paper is structured as follows: Section 1 provides a general background explaining why CE is crucial and the benefits of CE to countries adopting it. In addition, it also presents gaps related to global CE measurements, which are the focus of the objectives of this study. Section 2 reviews the literature on approaches to developing and measuring CE at each level. This section also presents a compilation of existing CE indicators used to assess CE implementation at each aspect and level. Section 3 explains the research methodology conducted, including how we selected indicators at the macro level, designed a CE hierarchy of indicators, and built a CE index with mathematical equations. Section 4 presents a discussion of the results of the CE index measurement in Indonesia at the macro level with case studies in 34 provinces in Indonesia and a discussion of parameters that need to be added to the CE index measurement. In addition, there is also a discussion related to comparing measurement results using the CE index that has been compiled with other references. Finally, Section 5 provides our concluding remarks, discussing the strengths and limitations of this study and suggestions for future research.

LITERATURE REVIEW

Different countries adopt different approaches in developing CE indicators, although they all fall within the same scope: environmental, economic, and social. Despite these differences, there is a need to measure progress in CE adoption. CE indicators are expected to help measure the implementation of CE and can be developed into a more practical approach starting from the macro to the micro level [16]. The macro level in Indonesia refers to CE implementation policies at the national or regional level (such as provinces). The meso level includes industrial networks between companies in an industrial estate especially those with industrial symbiosis. In contrast, the micro level focuses on single companies, consumers, and products (Figure 1).

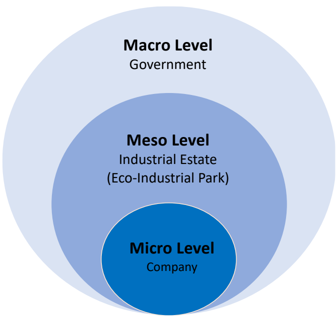

Fig. 1 System-level approach toward CE implementation in Indonesia
Source: modified from [12, 16].

A framework of adaptation [17] was developed to explain CE measurements at each level in detail and determine the impacts of CE on economic, social, and environmental aspects (Figure 2).

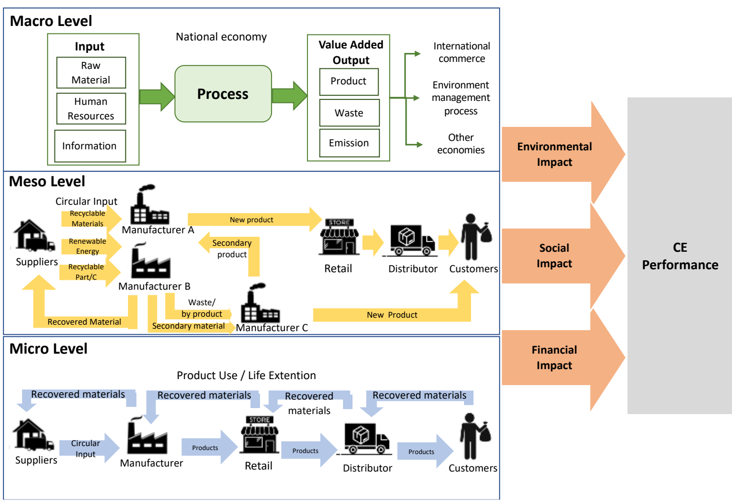

Fig. 2 The conceptual framework of circular economy measurement in Indonesia
Source: concept development from [17].

In this framework, at the macro level, CE is developed with particular attention to the interaction between materials (inputs) and the environment and the economy at the national level [17]. Meanwhile, the meso level is limited to the production side, which involves the Eco-Industrial Park (EIP) connected to the Industrial Symbiosis (IS) network [17, 18]. EIP is an industrial estate concept that has emerged in many countries by sharing materials and resources to optimize economic and environmental performance [19, 20]. With IS, waste from one industrial process can be reused in other industrial processes to optimize material and energy consumption. In addition to minimizing waste and resources, by-products from one company can become inputs for other companies. This process can support sustainable development that considers economic benefits and environmental and social aspects as a circular economy concept [21]. At the micro level, CE implementation measurements are carried out to increase the circularity of its manufacturing company systems and collaboration with other companies through an efficient supply chain [17].

Table 1 lists the summary CE indicators proposed at different levels and covers three aspects compiled from the literature.

The table shows that at the macro level, the CE indicators used to measure CE progress are related to regulations and strategies that could be deployed to enhance the national economy [17], including GDP [15, 22, 23, 24], private investment and value-added [14, 24, 25, 26], number of patents [15], jobs [14, 25, 26], and the recycling rate of municipal waste [14, 22, 25, 26, 27]. Meanwhile, at the meso level, the CE indicator relates to the collaboration of groups of companies with a common goal of increasing economic, environmental, and social efficiency. Finally, at the micro level, the CE indicator has a specific definition and focuses on a single aspect of CE which is intended to assess CE in a company [17].

Based on published literature from 2015 to 2022, no publication has comprehensively developed the CE index at macro levels. Although several CE indices have been developed, they do not yet cover all aspects of CE implementation in detail.

Table 1
Circular economy indicators to assess the CE implementation at different level

Aspects \ Levels	Macro	Meso	Micro
Financial	GDP [15, 22, 23, 24]	Resource effectiveness [10]	Cost savings, revenue growth, gross domestic product (GDP) [11]
	Registered unemployed rate [15]	Resource efficiency [28]	Circular Economy Index (CEI) [7, 29]
	Private investment and value added [4, 14, 24, 26]	Annual average growth rate of industrial added value [28]	Value-based Resource Efficiency Indicator (VRE) [7, 29]
	Trade in recyclable material [4, 14, 22]	The proportion of research and development input value in GDP [28]	Product Level Circularity Metric (PLCM) [7, 30]
	Number of patents [15]	The proportion of high-tech output value in gross industrial output value [28]	Remanufacturing Product Profiles (REPRO) [7, 31]
	Number of patents related to recycling and secondary raw materials [14, 26, 32]		Eco-cost/Value Ratio (EVR) [17, 33]
Social	Jobs [4, 14, 26]		Disassembly Effort Index (DEI) [7]
Environment	Recycling rate of municipal waste (RRMW) [4, 14, 22, 26, 32]	System effectiveness [34, 35]	Design method for End-of-use product value recovery (EPVR) [7, 36]
	Circular material use (CMU) rate [4, 14, 22]		Circularity calculator (CC) [7, 37]
			Reuse Potential Indicator (RPI) [7]

METHODOLOGY OF RESEARCH

The methodology adopted in this study has four stages. First is a systematic literature review where literature on CE indicators to measure CE implementation was identified. Second, a descriptive analysis was conducted by classifying the CE indicators on the financial, social, and environmental aspects at the macro level. The proposed CE indicators that have been applied in Indonesia were also analyzed.

Third, a CE index was established by considering the proposed framework to provide a basis for determining a single indicator for each aspect as a variable. Next, the variables were weighted to determine the CE index. Indicators with different scales and units were converted using a deprivation measure based on the maximum and minimum values. Finally, the implementation of CE in Indonesia at macro levels is measured using the available data: secondary data from the government of Indonesia used.

The selection indicators for macro level

The CE indicators suitable for application in Indonesia were selected based on criteria such as general indicator, comprehensive, in line with policies, easy to calculate, and consistent with available data systems. Another criterion used is that the CE indicators are adjusted to the proposed CE indicators for Indonesia in a case study in North Kalimantan conducted by [24]. That study is relevant to the issue of barriers to CE implementation in Indonesia. In addition, it is equipped with various expert perspectives on the acceptance of CE indicators in all aspects. Therefore it can be used for weighting in determining the CE index in this study. In addition, the selected CE indicators are also synchronized with policies related to CE in Indonesia, such as the 2020-2024 National Medium Term Development Plan and the UN Sustainable Development Goals (SDGs). The long list of CE indicators initiated by [38] regarding CE planning documents in other countries is also used to select indicators. The indicators selected as the CE index variables for the macro level in this study are listed in Table 2.

To obtain the quantity (percentage) value as shown in the far right column of Table 2, we utilized the expert data used by [24] as the respondent in the study. These respondents are relevant stakeholders in making city policies in the study area: NGO employees, government officials, company employees, and academics. All respondents were interviewed semi-structured to determine their understanding of CE and its implementation.

After the CE indicators selection, a hierarchy of the CE indicators is designed to construct the CE index (Figure 3). Six CE indicators as variables are used in developing the CE index. The economic indicator (I1) variables consist of two indicators: material productivity and the unemployed rate, which are then averaged and called the value-added economy indicator. The variable of the social indicator (I2) is the human development index which includes three components, namely the health sector (longevity), the education sector (knowledge), and the economic sector (decent living). The variables from environmental indicators consist of 4 indicators, namely: energy consumption per capita (I3), the volume of municipal waste generated per capita to the land (I4), water consumption per capita (I5), and emission per capita (I6).

Table 2
Selected CE indicators as the variable of the CE index for the macro level

Aspect	**Selected indicators**	**Description**	**Quantity (percentage by utilizing [24] experts)**
Economic	Material productivity	Percentage of value added in price level	46.2
	Unemployed rate	The percentage of the number of unemployed to the total labor force	
Social	Human development index	The human development index covers: (i) the health sector: longevity, (ii) the education sector: knowledge, and (iii) the economic sector: (decent living)	82
Energy (environment)	Energy consumption per capita	Energy consumption per population in an area (electricity from PLN and non-PLN)	53.6
Land (environment)	The volume of municipal waste generated per capita to the land	The volume of municipal waste generated per population in an area	71.4
Water (environment)	Water consumption per capita	Water consumption per population in an area	57.1
Pollutant (environment)	Emission per capita	The volume of emission per population in an area (CO_2)	67.8

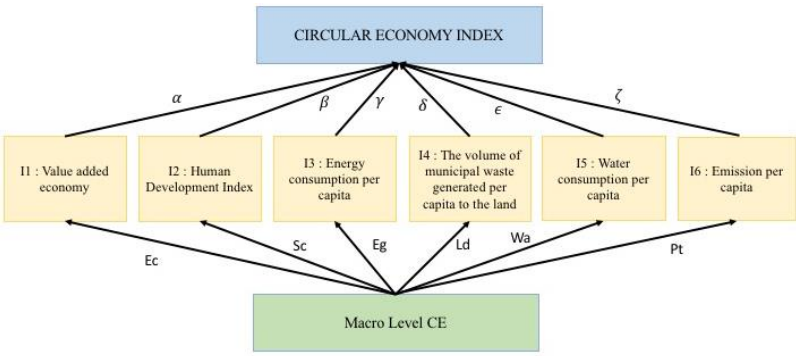

Fig. 3 The hierarchy of CE index for macro level
Source: concept development from [12].

Designing CE index for macro level

The six indicators have different units; deprivation measures are determined for this purpose. Each variable is determined by the maximum and minimum values given the actual value. We obtain a range from zero to one using the deprivation measure, defined by the difference between the maximum and minimum values [39].

Next, the CE index is designed according to the following mathematical equation:

$$Circular\ Economic\ Index\ (CEI)\ = \alpha.Ec + \beta.Sc + \gamma.Eg + \delta.Ld + \epsilon.Wa + \zeta.Pt \quad (1)$$

where:

$\alpha, \beta, \gamma, \delta, \epsilon$, and ζ are the weights of 6 indicators,

Ec is the average deprivation value from the economic indicator,

Sc is the deprivation value from social indicators,

Eg the deprivation value from energy indicators,

Ld is the deprivation value from land indicators,

Pt is the deprivation value from pollutant indicators.

The weight of the variable is based on the expert's perceived quantity (in the far right column of Table 2). The weights are then proportioned to obtain a range of numbers from 0 to 1 (Table 3). For example, an energy indicator (energy consumption per capita) has a perceived quantity of 53.6%. Therefore, a weight of 0.142 is obtained on the energy indicator in proportion to the total perceived quantity.

Table 3

Weights of the indicators

Notation	Weight values
α	0.122
β	0.217
γ	0.142
δ	0.189
ϵ	0.151
ζ	0.179

The weighting values of the indicators were added to Equation (1) to calculate the CE index as presented in Equation (2):

$$Circular\ Economic\ Index\ (CEI)\ = 0{,}122\ x\ Ec + 0{,}217\ x\ Sc + 0{,}142\ x\ Eg + 0{,}189\ x\ Ld + 0{,}151\ x\ Wa + 0{,}179\ x\ Pt \quad (2)$$

RESULTS AND DISCUSSION

Measuring circular economy index in Indonesia at the macro level (case study: Provinces in Indonesia)

In this section, we apply the methodology developed above using available data to measure the CE index at the macro level in provinces in Indonesia. Official sources [40, 41, 42, 43] are used to obtain the required data. Using Equation (2), a CE index score of 34 provinces is obtained from the six indicators representing the three aspects of CE and given ratings are given (Table 4 and Figure 4).

Table 4

Rank and circular economy index score for 34 provinces in Indonesia

Rank	Province	CEI score
1	Papua	0.921
2	East Nusa Tenggara	0.908
3	West Nusa Tenggara	0.816
4	West Kalimantan	0.791
5	Lampung	0.790
6	South Sumatera	0.788
7	Central Sulawesi	0.778
8	Nanggroe Aceh Darussalam	0.758
9	Riau	0.742
10	Southeast Sulawesi	0.737
11	East Java	0.734
12	Maluku	0.733
13	Jambi	0.729
14	South Sulawesi	0.728
15	North Sumatera	0.725
16	Banten	0.712
17	Central Kalimantan	0.710
18	West Sumatera	0.705
19	South Kalimantan	0.702
20	Bengkulu	0.692
21	Central Java	0.688
22	West Java	0.669
23	North Maluku	0.663
24	West Sulawesi	0.661
25	Gorontalo	0.636
26	Riau Islands	0.627
27	North Sulawesi	0.615
28	Bali	0.601
29	Bangka Belitung Islands	0.596
30	East Kalimantan	0.595
31	West Papua	0.515
32	DI Yogyakarta	0.491
33	North Kalimantan	0.406
34	DKI Jakarta	0.383

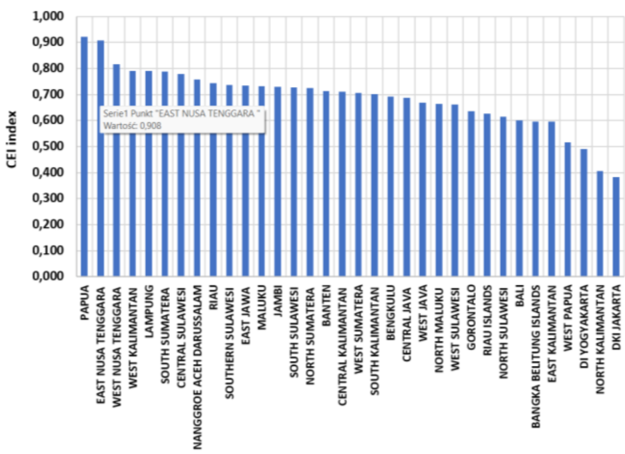

Fig. 4 Circular economy index of provinces in Indonesia

Figure 5 lists ten provinces by CE index score.

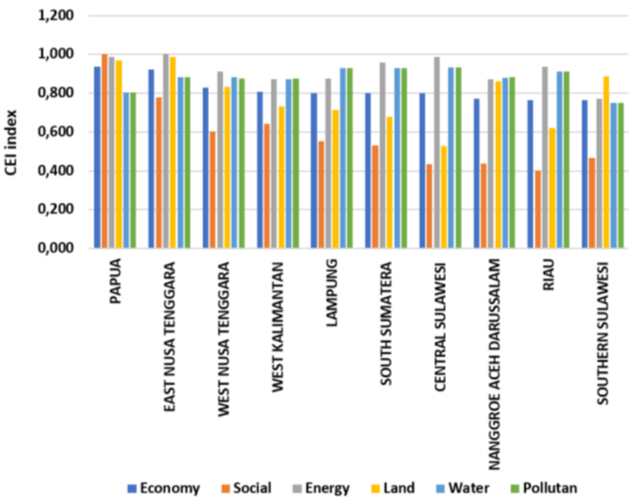

Fig. 5 Top 10 Provinces CE index for six indicators

This score can provide recommendations to policymakers on issues that need further action. For example, the Province of Southern Sulawesi, in 10th place, can improve CE performance by implementing policies that aim to improve the social aspect. This analysis not only shows the weaknesses but also the strengths of each province. Papua Province achieved the highest score on the social aspect (human development index). East Nusa Tenggara received the highest score on the environmental (land) aspect related to the volume of waste generation per capita and excelled in the environmental (energy) aspect.

If we take a closer look at the results of the CEI score in 34 provinces in Indonesia, the province with a smaller population has a high CEI score. Even though a high CEI value indicates a high degree of circularity of the three aspects of CE. Each region seeks to take CE implementation measures, including 9R (Rethink, Refuse, Reduce, Reuse, Refurbish, Redesign, Recycle, Recover, and Rot). These efforts are expected to have a positive correlation with increasing CEI values.

However, if we compare the best and worst rankings from CEI, the Province of DKI Jakarta, which received the lowest CEI score (0.383), has a population of 10,576,400 people. In comparison, the Province of Papua, with the highest CEI score (0.921), has a population of 3,393,100 people. In addition, the condition of Papua has a nature that is still preserved so that efforts to do CE are minimal to get a high CEI score. Contrary to the condition of DKI Jakarta as the nation's capital and a major city in Indonesia with a dense population, it requires more extraordinary efforts to implement CE (municipal waste recycling) to get a high CEI score. This is unfair in measuring CEI in Indonesia.

For this reason, it is necessary to have one additional dimension as a consideration parameter in measuring CEI. This parameter is the gross regional domestic product (GRDP), the total added value of goods and services produced by various regional production units within a certain period. The GRDP of the Province of DKI Jakarta and the Province of Papua (in rupiah units) is normalized so that the ratio to the CEI score is then carried out. The results are shown in Figure 6, which shows that one additional GRDP parameter in the CEI measurement can represent the CEI score in certain areas for the CE implementation efforts made to increase the CEI score.

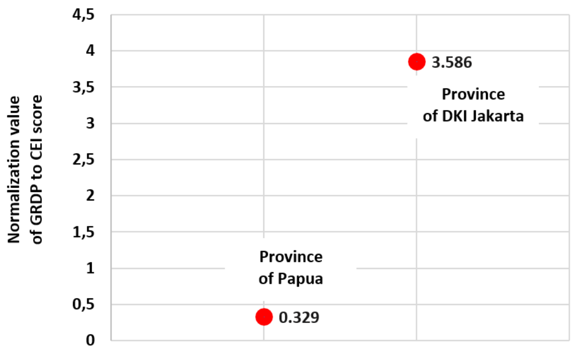

Fig. 6 Results of normalization of gross regional domestic product (GRDP) on the CEI score

Compared with research conducted by [26] who has measured CE composite indicators in 28 EU countries, this study provides more information by considering the addition of dimensions (GRDP) to reduce unfairness in assessing the CE index with the measurement model that has been built. The high and low results of measuring the implementation of CE in an area without paying attention to the factors that affect the value of the CE index will be prone to getting unfair values and can impact future CE policymaking. In addition, this research complements the results of a study conducted by [24] who proposed CE indicators for cities in Indonesia, where our study presents CE implementation measurements at a more macro level in provinces in Indonesia.

CONCLUSIONS

The CE is an exciting approach for many countries to review. However, until now, no single indicator has been proposed that can comprehensively measure the level of implementation of CE that has been done. Appropriate measurement of CE performance is needed to provide recommendations for making well-targeted policies. This study provides proposed solutions that can address these problems and opportunities to provide benefits from an economic, social, and environmental standpoint at all levels. This CE index was built through the stages of the research method, including constructing a mathematical equation that can be used to measure CE implementation in Indonesia.

In addition, the CE index that has been developed comprehensively can be a valuable tool for policymakers to identify the strengths and weaknesses of CE performance at the macro level. The advantage of this study is that the scoreboard of the CE performance of provinces in Indonesia is provided for the first time. Of the 34 provinces in Indonesia that are measured using the CE index, the top 10 provinces with the highest CE scores can be identified, complemented by the strength of each assessment aspect. The CE index provides a macro-scale measure of how EC is performing in one region compared to another, presenting EC best practices that can be adopted for other regions. It shows the strengths of each province's aspects and its weaknesses. This weakness aspect can be known, which requires more attention to improve. By adding one parameter in the form of gross regional domestic product, a CEI value representation is obtained, which reflects efforts to implement CE in a region.

For future studies, the CE index can be developed and formulated at the meso and micro levels to complete the entire system level in CE implementation. The meso level, which includes CE implementation in industrial networks, such as eco-industrial parks, is recommended to be supplemented with a CE index calculation that describes the symbiotic relationship between industries within it.

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