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CIRCULAR ECONOMY INDICATORS IN AUTOMOTIVE INDUSTRY

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Abstract: *The concept of the circular economy is increasingly discussed, from its theoretical foundations to its integration with and distinction from related concepts such as environmental protection and sustainability. To enhance its practical applicability, defining circularity indicators is essential. By establishing and measuring a well-defined set of indicators, the level of circularity can be assessed across different industries and at various levels. Building on this, we have identified relevant indicators from the existing literature and selected those applicable to the automotive industry. From the total number of 112 indicators identified, 22 indicators were selected and analyzed considering the life cycle perspective.*

Keywords: *circular economy, automotive industry, indicators, environmental protection, life cycle.*

1. INTRODUCTION

The circular economy can be applied in a wide range of areas, differently adapted to each area. It is important to identify indicators that can be used either for several fields of activity or punctually, for a certain field of activity.
According to the study conducted by 1, the question "How to measure circularity?" was asked. We can practically say that the answers to this question have multiplied the questions in several directions: What do we want to measure? What are Key Performance Indicators (KPIs) for? What level of approach can we have?

2. CIRCULAR ECONOMY INDICATORS

The literature, the indicators and their classification have been approached by several authors, including Saidani et al [1] who managed to classify the indicators into several groups.
According to the study conducted by Saidani and al 2 focused on circularity indicators, they were grouped into several groups according to typology. We note such differentiating criteria as: levels of circular economy (CE) implementation (eg. micro, meso, macro), EC loops (maintenance, reuse, remanufacturing, recycling), performance (intrinsic, impacts), perspective of circularity (current, potential) they take into account, or their degree of transversality (generic, sector-specific). A very clear and useful way to differentiate the circularity indicators proposed by Saidani et al [1] is the one regarding the differentiation on level, namely: micro-level (organization, products, and consumers), meso-level (symbiosis association, industrial parks) and macro-level (city, province, region or country) indicators. Another classification made by 3 group the indicators into 4 classes respectively: nano-level - for products, micro-level for companies, meso - for industrial symbiosis and macro-level for cities and regions (see figure 1). Saidani from many definitions of the circular economy has focused on *"an economic system that replaces the concept of life "with the reduction, alternatively reuse, recycling and recovery of materials in the processes of production / distribution and consumption. It works at the micro level (products, companies, consumers), meso- level (eco-industrial parks) and macro level (city, region, nation and not only), in order to achieve sustainable development, thus creating environmental quality, prosperity and social equity, for the benefit of current and future generations"*. [1] In

other words, the circular economy can be said to be based on the principle of waste ranking.
According to the statement extracted by Saidani [1] taken from Elia et al. (2017) according to which there is not a single global indicator that includes all the requirements of the circular economy, perhaps a model that includes relevant indicators would be comprehensive to fill this gap in the literature.
Given the fact that I want to identify useful indicators in automotive production companies, I think it would be sustainable to address the problem of circularity indicators taking into account the evaluation of the product life cycle.
According to Saidani et al in the study [1] found that some authors argue that it is important to measure the process of transition to the circular economy by evaluating before (ex-ante), during (ex during) and after (ex post). The use of appropriate indicators that have stability targets and used in different stages of the transition, can show the progress through different values that it indicates. It is not necessary to set different indicators for different stages, because the values of a certain indicator assigned to a time scale can highlight progress.
Thus, based on the indicators identified in the literature it is necessary to identify a model that can be applied to identify the degree of circular economy and to indicate the need for continuous improvement of the performance of the analyzed system.

3. RESULTS

The methodology used to search for indicators specific to the automotive industry was based on the analysis of the literature in the Web of Science (WOS) database. Several successive searches were performed based on the essential terms for identifying the relevant ones. The initial starting point was a deep analysis of the literature on the circular economy, followed by the analysis of the text from 1, followed by the search for additional studies in the WOS Core Collection database. It is very important that the representative indicators can be used in practice, not to remain at the declarative stage. The search was performed on WoS Core Collection database based on the keywords "circular economy indicator*" and "industr*". Although the number of search results returned is large in volume, such an analysis is important to cover as large an area of previously identified indicators as possible, so that the most representative ones can be selected. The analysis included 50 reviews regarding circular economy indicators. From them, were excluded the ones relevant only for macro level. Studies referring to performance indicators in line with circular economy strategies and sustainability are excluded. The purpose is to identify the indicators for determining and evaluating the degree of circular economy.

In order to be able to analyze and subsequently select the indicators useful for the automotive industry, the indicators identified following the analysis of specialized literature were centralized. Macro studies (cities, countries, etc.) were excluded from the analysis, as well as studies referring to a social industry other than the automotive industry (such as the textile industry, construction, tourism, etc.).

3.1Performance and evaluation indicators

According to [2] it was demonstrated that most of the indicators of the circular economy analyzed following a review are more focused on the economic component and less on the environmental or social component. Generally, desirable indicators as a general definition “are those that summarize or otherwise simplify relevant information, makes visible or perceptible phenomena of interest, and quantify, measure, and communicate relevant information.” [3] This definition was one of the factors that contributed to the selection of relevant indicators. Both circular economy and environmental indicators are needed to monitor the transition to the circular economy, and at micro-level LCA (Life Cycle Assessment) is a robust method for use. [4] Measuring the performance of the circular economy considering the complexity of the concept must be done from a multidimensional perspective. Also, the existence of a large number of indicators should lead to a prioritization to allow focusing on the most important ones to measure performance with a limited number of indicators. The study highlighted the fact that in many previous issues, the authors discussed the

need to create an index to measure the degree of circular economy. An index is easy to interpret, understand and communicate. [5] The indicators are useful because through them the performance, the progress of a system or process can be tracked. By extension, circularity indicators allow monitoring and can highlight how much a system is associated with circular economy practices and strategies. [6] Many stakeholders like companies, scholars, governments have proposed various indicators for measuring circularity, but it is considered that they are not designed for the multidisciplinary nature of the circular economy and are based exclusively on measuring the closing of loops. [7]

The purpose of creating an indicator or model is to be easy to use and put into practice to evaluate the performance of the circular economy at a given time. On the other hand, to be used in practice, it must be based on easily obtainable data.

Following the analysis of the literature based on the methodology described above, 112 indicators were identified, those being centralized by others in the selected and analyzed reviews.

3.2 Circular economy indicators challenges

One of the issues refers to the availability of data for the calculation of indicators. Also, according to [8] it was not well highlighted how the indicators can complement each other. At the micro level, 20 indicators have been identified, but some of them are under development and in the pilot phase. The indicators regarding the level of measurement of the application of the implementation of the circular economy strategies, especially at micro level, are in the incipient phase, this also explaining the low implementation in the industrial practices. There is no single global indicator for all the requirements of the circular economy, which is why a common multi-indicator model may be useful. For Elia et al [9]*"focusing on one single dimension of the CE (e.g. resource use) represents a limitation in the assessment of CE models, leaving other important factors, such as emissions and energy use"*. Further research on the relationship between circularity assessment and life cycle assessment indicators is encouraged. How to measure the progress and performance of the circular economy further postpones a basic question on this complex concept as concluded by Saidani. [1]

The main challenges facing stakeholders in terms of circularity indicators are:

- weight in measuring the circular economy in relation to all dimensions of sustainability;
- assessment of the deficit of used materials;
- insufficient representation of the operating cycles and the consequences of material recycling.[7]

Given the multitude of existing indicators in this field, it becomes very difficult and equally and subjective to select the appropriate indicators. [9] It is recommended to standardize the indicators defined in the literature to obtain practical results in their use. [2] The indicators are very varied, and research has shown that there are superficial assessments of circularity due to non-comprehensive indicators. [6] The transition to the circular economy is achieved through the involvement of all stakeholders and through their ability to create appropriate models; the transition is at the beginning. [10] There are many indicators for the circular economy that emerge from their reviews over time, but there are no standardized measurement metrics. [11] A potential cause for the variety of circularity indicators could be a vague understanding of the concept of circularity for which definition and conceptualization is still an issue. [7]

Most of the indicators on the circular economy are very much based on recycling indicators, probably also due to the fact that the practice of recycling already has an older history as part of waste management. Reuse, repair or maintenance, which are also part of the circular economy cycle, have no exclusive indicator. [12]

Further research is needed to demonstrate the relevance and accuracy of the indicators for calculating the circular economy for various applications. [9]

Following the review carried out by 15 it is considered necessary to create a more comprehensive indicator for the circular economy for the construction of which to

involve various stakeholders. It also recommends using Principal Component Analysis (PCA) as a method to create a robust and effective index. As ideas for future research, it is possible to focus on the classification of indicators according to practicability and on the standardization of indicators in various sectors of activity. [6] Improvements are needed in the adoption of circular economy strategies by producers and consumers, due to the fact that they play an important role in European policies. Improvements are needed in the adoption of circular economy strategies by producers and consumers, due to the fact that they play an important role in European policies. [10] A necessary condition for a real transition to the circular economy is to understand the limits of existing indicators and to simplify the current measurement scenarios. In conclusion, it is necessary to simplify the list of indicators and create a common model for evaluating the circular economy. [11]

It was found that a difficulty in implementing the circular economy in companies is, among other things, the fact that there is no common way to measure the level of the circular economy at the micro level. It is useful to create a standardized way of measuring either at the industry level or specific to the circular economy strategy: recycling, remanufacturing, reuse measurement, and other circular economy measures. [12]

As the circular economy is defined as an umbrella concept, it should have defined an evaluation model that includes its criteria such as: resource efficiency, closing loops etc.

The context related to the circular economy is quite broad, it is focused on several sub concepts, but if we look at the macro level, by implementing circular economy strategies we want to improve throughout the life cycle in order to have a waste management much more efficient.

4. DISCUSSION

According to the centralization from the specialized literature, are a multitude of indicators regarding the circular economy (112 indicators). They are many and diverse, but it is very important to be able to evaluate them from a practical point of view. The optimal indicators regarding the circular economy in the car industry were chosen based on an objective method. The identified indicators are applied to a variety of circular economy strategies, it is necessary to identify if they are indicators that evaluate the same thing, which are impossible to put into practice or difficult to manage, which is why the selection of the relevant and optimal ones would ease the work of those who they will want to evaluate the circular economy in the automotive industry.

4.1 Literature selection criteria

In order to identify and select the optimal indicators, it is necessary to identify a set of criteria that will be useful for the selection of indicators.

One set used by [7] adapted by other authors refer to validity, reliability and utility, described as follows:

- validity refers to whether the respective indicator measures the thing for which it was defined;
- reliability if it is consistent, robust and transparent;
- utility if there is a user to implement.

Saidani following searches in specialized literature [1] identified certain barriers regarding the use of indicators in practice, gaps that can identify certain criteria for selecting indicators. It focused on the study conducted by Park and Kremer (2017), highlighting the following criteria:

- usefulness - if an indicator has value and is feasible, being useful and practical
- utilization - current or future of an indicator.

Other criteria identified based on the synthesized gaps made by Saidani include:

- complexity, lack of environmental protection knowledge and the time required for implementation
- the quantity and difficulty of obtaining data for the calculation of some indicators;
- time and costs for obtaining data
- obtaining new data based on digital technologies.

According to [13], for the selection of the most suitable indicators, certain criteria are used such as:

- relevance for the industry or company;

- relevance for the circular economy concept;
- the number of data required to measure the indicator and how big is the uncertainty of data collection;
- costs or time for data collection;
- easy-to-use indicator and easy to understand;
- ease of use of the indicator, not only by experts.

Selecting the final set of indicators is the last step. According to specialized literature, it should be easy to measure and manage, and the optimal number of indicators would be between 10 and 20. [13]

4.2 Systematization process

In order to select the relevant indicators for the circular economy in the automotive sector at the company level, the following steps were established. The indicators applicable at product or company level were selected. From the total number of indicators, 83 indicators are set for nano and micro level. Where excluded the ones applicable for macro level.

From the point of view of the 3 pillars of sustainability - economic, environmental or social, indicators that have at least an environmental component were considered. After refining, 13 indicators were excluded.

The 70 indicators remaining after the refinement were grouped by categories according to the stage of the life cycle for which they are used. In figure 1, it can be seen that the majority refer to End Of Life (EOL) and R strategies followed by full life cycle. At the opposite pole, there are few indicators that emphasize raw materials, production and consumption, life extension and design.

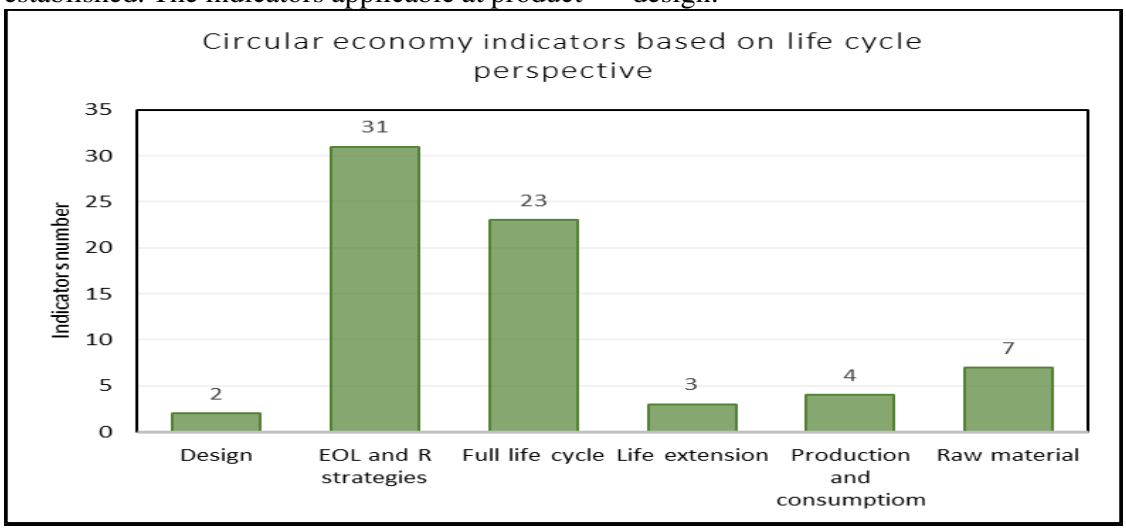

Fig. 1. Distribution of the circular economy indicators based on life cycle phases

Most of the indicators are applicable at the micro level (at the company level), 13 indicators at the nano level and 2 indicators for both levels. The 70 indicators remaining after the initial refinement were analyzed according to the frequency of appearance in the sources from the specialized literature analyzed and cited. This frequency is shown in the table 1.

Table 1

Frequency analysis on the indicators

Frequency (No. of sources)	KPIs number (No.)	KPIs (%)	Cumulate KPIs (%)	Cumulate frequency (%)
1	48	68.57%	68.57%	17%
	11	15.71%	84.29%	33%
3	6	8.57%	92.86%	50%
4	3	4.29%	97.14%	67%
5	1	1.43%	98.57%	83%
6	1	1.43%	100.00 %	100%

According to the data in table 1, it can be easily observed that in a proportion greater than 50% (68.57%) the indicators are mentioned in a single source from those cited. In a significantly smaller proportion, the indications are cited in 2 sources and only a percentage less than 20% are cited in 3 or more sources.

Applying the Pareto analysis it is seen that 48 indicators (69% of the total number of indicators) were considered in fewer than 20%

of the analyzed literature sources. Considering figure 2 and table 1, further will be considered the indicators appearing in at least 2 bibliographic sources, meaning a total number of 22 indicators. Those indicators are centralized in table 2.

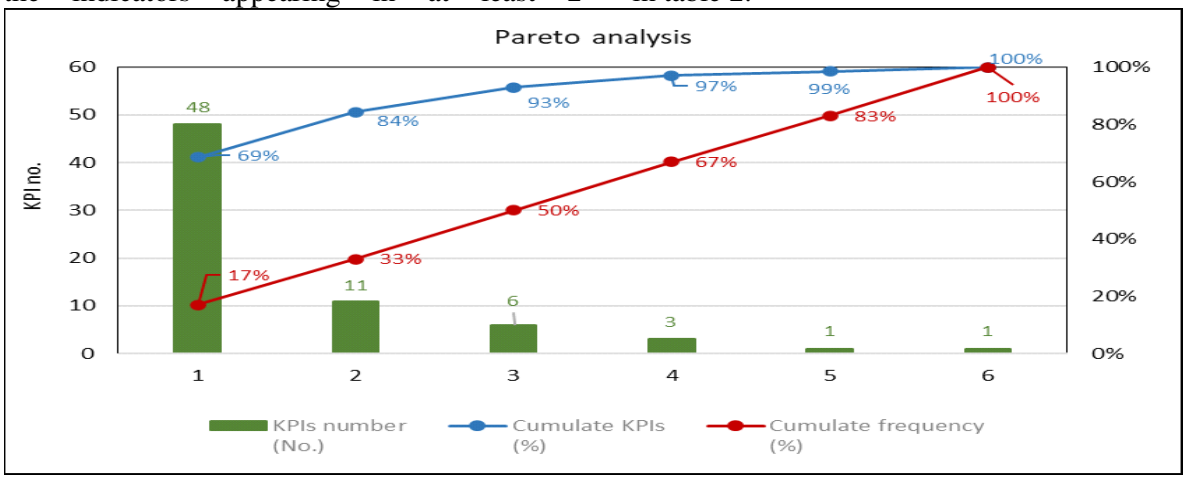

Fig. 2. Pareto analysis for KPI frequency

Table 2.

Circular economy selected indicators

Circular economy indicator	Circular economy strategies considering life cycle	Indicator description	Literature source
Recycling rate	EOL and R strategies	Indicators for the circulating behavior of materials, are often used as measure or the degree of circularity of an economy. Recycling rates (RRs) are splitted into closed- and open-loop collection rate (CR). Whereas CR refers to collected material that enters the recycling process, RRs measure the available secondary resources produced from recycling processes.	[1], [9]
Remanufacturing Product Profiles (RPP)	Raw material	To use the RPP, the approach consists of identifying the profile closest to the new product. If a profile is a candidate, it means that envisaging a remanufacturing strategy is relevant to the new product case. If no profile feels suitable, it means that remanufacturing is not known to be a good idea for this product development. This is based using different criteria and it is used a method of descriptive statistical analysis. Identify if a product is suitable for remanufacturing.	[11] , [12]
Circular Economy Toolkit	EOL and R strategies	An online question kit based on questions that fall into several categories based on R strategies (repair, reuse, remanufacture, recycle) which has the role of helping companies to identify the potential for improvement. The CET is a 'five-minute assessment tool' which analyses the products and services sold by a company and gives guidance on potential improvement areas, using trinary questionnaire covering whole life cycle steps.	[1], [6], [11], [12]
End-of-life Index	EOL and R strategies	Product performance at EoL in relation to disposal, disassembly and recovery.	[6], [11], [12]
Material Circularity Indicator (MCI)	EOL and R strategies	The recycled content in a product along with waste (linear flow) and utility of a product. The MCI, combines aspects of lifetime and intensity of use with the proportion of recycled material and the share of	[1], [6], [7], [11], [12], [14]

		materials in a product that can be recycled in a single indicator, applicable at the product or company level. It considers material rates of recycling and reuse, measures how restorative flows are maximized and linear flows are minimized, and also the length and intensity of the product's use.	
Eco-cost/Value Ratio	Raw material	Ratio between eco-costs and the value of a product.	[11], [12]
Longevity Indicator (resource duration)	Life extension	Length of time for which a material is retained in a product system.	[7], [11], [12]
Material Reutilization Score	Life extension	Fraction of recycled or rapidly renewable content in a product with the fraction of material in a product that is recyclable, biodegradable or compostable. The C2C framework performs impact assessments of products and services based on five key principles. These include: material selection and reutilization; the use of renewable energy in the production system; water stewardship; and social fairness.	[1], [11], [12]
Recycling Indices	EOL and R strategies	Contains Product-Ri and material-RI Product-RI refers to the total recycling and recovery rate of a product, while Material-RI expresses the recycling rate of the individual materials of a specific product. The Material-RI expresses the recycling rate of individual elements for the processing flow sheet of a specific product or redesign. The RIs were presented as a tool to visualize the quantified calculation of the recycling rate of a product or recycling route.	[1] , [6], [11], [12]
Circular Economy Indicator Prototype	EOL and R strategies	Circularity assessment of products, in which CE strategies are prioritized. The indicator, using a points-based questionnaire (15 questions), is initially intended to be used by manufacturing and/or retail companies of tangible goods with access to bill of materials. They would use the indicator to measure and evaluate the performance of their products.	[1],[6],[7], [11],[12]
Eco-efficient Value Creation	EOL and R strategies	Sustainable business strategy matrix to analyze the short- and long-term market prospects of products and/or services. The model of the EVR is developed to analyses the required delinking of the economy and the ecology on a product level as well as on a system level: the EVR is a single indicator for sustainability.	[1] , [7], [12]
End-of-life Indices; Reuse index; Remanufacturing Index, Recycling Index, Incineration index.	EOL and R strategies	Design methodology for improving product. EOL performance that applies a cost/revenue.	[11],[12]
Recycling Desirability Index	EOL and R strategies	Mass of the total product, its components and materials in combination with a material security index, technology readiness level and a simplicity index.	[6], [11], [12]
Circularity Design Guidelines	EOL and R strategies	Guidelines within five categories that represent key CE principles of extending life span, disassembly, product reuse, components reuse, and material recycling.	[11],[12]
Combination Matrix	EOL and R strategies	Recycling as the contribution of material recycling to the overall circularity of a product/material.	[11],[12]
Product Recovery Multi-criteria Decision Tool	EOL and R strategies	EOL strategies are assessed according to relevant economic, environmental and social indicators.	[6],[12]
Circular Economy Performance Indicator (CEPI) also known as	EOL and R strategies	Formula: the ratio of the actual obtained environmental benefit (i.e. of the currently applied waste treatment option) over the ideal environmental benefit according to quality, assuming option I (closed-loop recycling) is better and option	[1],[6], [11],[14]

Recyclability Benefit Rate (RBR) indicator		IV (incineration) is less preferable. It is defined as the ratio of the environmental benefits that can be obtained from recycling a product, over the environmental burdens related to production from virgin resources followed by disposal. These benefits are expressed in terms of environmental impacts, calculated through LCA.	
Circularity Potential Indicator (CPI)	Full life cycle	Through a questionnaire of twenty attributes desired for a circular economy, that are based on and grouped within the four building blocks (BB#) of circular economy defined by Ellen MacArthur Foundation, the CPI aims at evaluating the circularity potential of industrial products (during design, re-design or benchmarking phases) as well as providing keys for improvement and monitoring the circularity of products and businesses practices.	[1],[11]
Closed Loop Calculator (CLC)	Full life cycle	Kingfisher Circularity Calculator to establish how 'closed' particular products could be.	[1], [6]
Circular Pathfinder (CP)	Full life cycle	Identify the most suitable circular pathways for the product one company design and manufacture, in just a few minutes (Strategy ideation tool, Project definition phase, No preparation required, Approximately 15 minutes needed to complete).	[1], [6]
Resource Duration Indicator (RDI)	Life extension	A new performance metric, the longevity indicator, which measures contribution to material retention based on the amount of time a resource is kept in use. The measure is composed of three generic components: initial lifetime, earned refurbished lifetime and earned recycled lifetime. Circular Economy: "where the value of products, materials and resources is maintained in the economy for as long as possible" according to European Commission 2015 Action Plan.	[1], [6]
Global resource indicator	Raw material	It integrates different aspects to characterize the resources such as recyclability and geopolitical availability of the resource GRI = X/Y x Z X(Scarcity), Y(recyclability), Z(geopolitical availability).	[6], [7], [11]

5. CONCLUSION

The advantages of using the above systematization process, are the following:
- considering the complexity of the circular economy concept, each indicator is correlated with the stages of the life cycle, as well as with certain circular economy strategies (eg life extension);
- are applicable in the automotive industry.

A limitation regarding the selection of the relevant indicators is represented by the selection of the databases that were the basis of the bibliographic study on the indicators on the circular economy. On the other hand, another limitation is represented by the own selection method of the relevant indicators. The indicators that are used at the macro level without evaluating the potential to be applied at the nano, respectively micro level were excluded. Also, the selection keys for the relevant indicators can be considered subjective, with this method there is a risk of excluding other relevant indicators.

The advantage of analyzing the reviews, which in turn analyzed the circularity indicators, allows the more accurate centralization of the indicators in an attempt not to lose sight of certain previous articles that aimed to present an indicator. In addition to these indicators, it should be borne in mind that there are also macroeconomic circular indicators that were not evaluated in this study. The large number of identified and centralized indicators indicates that the circular economy has attracted attention as a concept and more. The authors have tried to find solutions to quantify the degree of

implementation of circular economy strategies, but both subjectivity and inaccuracy emerge through the large number of defined indicators. It is necessary to find a model based on the most appropriate indicators that is sufficiently comprehensive to assess the circular economy. If there is a limitation of indicators that assess only one stage such as resource efficiency or the process of recycling, remanufacturing, or any other process, then we can note that we are dealing with the evaluation of other concepts other than the circular economy, such as natural resource management, waste management, etc. Only a simple, correct and complete integration could be helpful in the future.

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INDICATORI PRIVIND ECONOMIA CIRCULARA IN INDUSTRIA AUTOMOTIVE

Abstract: Conceptul de economie circulară este din ce în ce mai discutat, de la fundamentele sale teoretice până la integrarea și distincția de concepte conexe precum protecția mediului și sustenabilitatea. Pentru a spori aplicabilitatea practică, definirea indicatorilor de circularitate este esențială. Prin stabilirea și măsurarea unui set bine definit de indicatori, nivelul de circularitate poate fi evaluat în diferite industrii și la diferite niveluri. Pe baza acestui fapt, au fost identificaţi indicatori relevanți din literatura existentă aplicabili industriei auto. Din numărul total de 112 indicatori identificaţi, au fost selectaţi și analizaţi 22 indicatori ţinand cont de perspectiva ciclului de viaţă.

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