Sustainable Production and Consumption 36 (2023) 513–525

Contents lists available at ScienceDirect

Sustainable Production and Consumption

journal homepage: www.elsevier.com/locate/spc

Tools for assessing qualitatively the level of circularity of organisations: Applicability to different sectors

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ARTICLE INFO

Article history:
Received 16 September 2022
Received in revised form 30 January 2023
Accepted 31 January 2023
Available online 10 February 2023

Editor: Prof. Marzena Smol

Keywords:
Circular economy
Software
Organisation
micro level
indicator

ABSTRACT

The transition towards a circular economy (CE) has been identified as one of the biggest challenges for our society in general and for organisations in particular. In this context, organisations have begun to call for methods to measure their level of circularity and therefore, in recent years, various specific CE tools have been developed. The objective of this study is to analyse the applicability, utility and user-friendliness of CE tools that autonomously measure the level of circularity of organisations by using qualitative data. For this purpose, seven qualitative CE tools (CAS2.0, CE-Diagnosis, CircularTRANS, Circulytics, CM-FLAT, INEDIT and MATChE) are selected and applied to four organisations (two belonging to the service sector and two to the production sector). The results show that, due to the absence of uniformity, regularity, and singularity in the CE assessment, the circularity indicators included in each CE tool analysed are different; therefore, the level of circularity calculated for each specific organisation by means of the different CE tools are comparable. Moreover, the CE tools are heterogeneous in terms of content, length and number of questions; and they do not incorporate the specific characteristics of the different sectors of the organisations analysed. Furthermore, after gathering the opinions of managers regarding the applicability of each CE tool to each organisation, it is observed that the existing CE tools can be useful but need further development. For these reasons, further research and development of standardised sectoral CE tools that consider sector specificities and allow organisations to obtain accurate and comparable results is needed.

1. Introduction

In recent years, the concepts of the circular economy (CE) and sustainable development have been recognised by the European Union (EU) as one of its greatest challenges. Given these circumstances, the European Commission has recently embraced the *European Green Deal* (COM 640, 2019) as a guiding framework to bring about the target of climate neutrality by the year 2050, with the *New Circular Economy Action Plan* (COM 098, 2020) forming its backbone, it being founded on the earlier *CE Action Plan* (COM 614, 2015). The aim of this regulatory framework is to ensure that the value of products, materials and resources is retained in the economy for as long as possible, and that waste generation is minimised. It involves implementing actions based on the principle of "closing the loop" of products, services, waste, materials, water and energy. So, the implementation of the circular economy is seen as an instrumental strategy to support the achievement of global resource, energy and climate mitigation goals. Furthermore, Schroeder et al. (2019) and Rossi et al. (2020) stated that CE has the potential to contribute to other dimensions of sustainability beyond de environmental ones, including several Sustainable Development Goals (United Nations, 2015).

The transition from linear to circular models requires focusing efforts on the three fundamental levels of the circular economy: the micro level (organisations), the *meso* level (eco-industrial parks) and the macro level (national) (Geng and Doberstein, 2008; Yuan et al., 2006). Advances at the meso and macro levels have been made recently (Eurostat, 2021); however, the *New Circular Economy Action Plan* (COM 098, 2020) widens the focus to the micro level, encouraging organisations (specifically industry) to move towards a clean and circular economy (action: "*mobilisation of industry for a clean and circular economy*"). Hence, in the context of organisations, implementing actions to promote a transition to the circular economy, along with communicating these actions to the various stakeholders, has come to be a goal of primary concern.

Consequently, organisations are beginning to demand proposals that can ascertain their degree of circularity and verify the contribution of their actions in moving towards a circular economy (Vayona and Demetriou, 2020). To this end, indicators need to be developed to quantify the current status and progress in terms of circularity (Smol et al., 2017). At macro level (city, region, nation) a monitoring framework for the circular economy (COM 029, 2018) composed of a set of 10 key circular

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https://doi.org/10.1016/j.spc.2023.01.023

economy indicators (Eurostat, 2021) was published with the aim of measuring the CE progress at all stages of the life cycle of resources, products and services. However, although the *renewed EU Industrial Policy Strategy* (COM 479, 2017) highlighted the relevance of the circular economy for EU industry and the *New Industrial Strategy for Europe* (COM 102, 2020) identified the necessity of acquiring CE performance indicators to measure organisations' progress towards the CE, these proposed territorial indicators are not directly applicable to organisations and no standardised indicators have been developed at micro level (organisations) either.

For this reason, in recent years, different approaches have been developed to measure the level of implementation of the circular economy in the organisations. For example, indicators have been proposed by different studies such as Rossi et al. (2020) or Ibáñez-Forés et al. (2022); Eurostat CE indicators have been adapted to organisations by Rincón-Moreno et al. (2021); new methods or frameworks have been defined by researchers such as Franco et al. (2021) or Ahmed et al. (2022); and, finally, automatic CE tools such as CircularTRANS (2020) or CTI Tool (2020) have been developed; among others.

In light of this context, the objective of this study is to analyse the applicability and usefulness of tools capable of measuring the level of implementation of circular economy in organisations automatically (CE tools). To do it, this work is organised as follows: Section 2 explores the background related to the CE assessment in organisations; Section 3 presents the five-stages involved in the methodological procedure; the results obtained are presented and analysed in Section 4; these are then discussed in Section 5; and finally, the conclusions are detailed in Section 6.

2. Background

In the last decade, the CE has generated interest from organisations, institutions and academics, making the transition from a linear to a circular economy a trending topic in research. In fact, the number of publications related to the measurement of CE implementation in organisations is growing in recent years, which demonstrates that the determination of the circularity using a criteria and indicator approach has been the subject of research in many branches of science. However, given the lack of standardisation, different approaches for assessing the level of circularity of organisations have emerged.

In this line, standards have been developed for the application of the principles of the CE in organisations, such as BS 8001 (2017), aiming to involve the main economic and social players in the transition towards the CE, or the XP X30-901, 2018, which is a CE project management system, developed with the aim of facilitate dialogues to reflect on modes of production and consumption and provide a management tool to plan, implement, evaluate and improve a circular project. Otherwise, CE guidelines have been developed, which are approaches to identify potential opportunities to ensure progress towards CE business models in order to improve the competitiveness of organisations, such as Circle Economy (2021) and Circulab (2021). However, “what to measure” is still a matter of debate (Moraga et al., 2019).

So, several indicators and metrics have been developed to measure the level of circularity of organisations. Indicators, according to Circle Economy (2020), refer to a single value and its unit, which is used to indicate a specific circular trend or performance. Whereas metrics, as described by Vinante et al. (2021), are measurable quantities for tracking an indicator, where the indicator normally has a broader focus. So, circularity indicators and its metrics are fundamental approaches in the process of measuring the progress towards CE, as they provide crucial information for the design of policies and strategies and allow identifying and evaluating the impacts derived from their implementation. In this sense, companies, governments and academics have formulated various proposals to measure circularity, such as Material Circularity Indicator (MCI) (Ellen MacArthur Foundation & Granta Design, 2019) or the adaptation of Eurostat indicators to organisations (Rincón-Moreno et al., 2021).

In addition, many studies are focused on the assessment methods or frameworks development, which are methodologies that provide guidance on the dimensions and variables that should be taken into account to measure the circularity, as Sala et al. (2013) indicated they are a set of indicators, tools and models. In this line, Sassanelli et al. (2019) analysed the current state of the art on CE assessment methods, while other authors worked on proposing frameworks. Franco et al. (2021) proposed a strategic measurement framework to monitor and evaluate the performance of circularity in organisations from a transition perspective, Ahmed et al. (2022) proposed an assessment framework that enables comparisons between different products and processes with regards to their circularity, Sucozhañay et al. (2022) proposed a circularity framework that includes 81 indicators classified into 11 categories, or Baratsas et al. (2022) proposed a quantitative and holistic framework for evaluating the circular economy and validated it for different sectors (energy & utilities, manufacturing, automotive and services), among others.

At the same time, alternative ways of measuring the level of circularity using information that organisations are currently communicating have been explored. For example, Ibáñez-Forés et al. (2022) analysed the information currently reported by organisations in their Corporate Sustainability Reports and proposed a set of indicators and metrics based on this, or Barón Dorado et al. (2022) analysed the information reported in the EMAS declarations and concluded that it is neither extensive enough nor provided as scalable and comparable quantitative data to be considered as a valid tool to measure the level of adoption of the circular model in companies.

In this context, numerous reviews focused on identifying CE indicators for organisations in general can be found in the literature. de Oliveira et al. (2021) analysed 58 indicators being 20 of them for organisations, Kristensen and Mosgaard (2020) analysed 30 CE assessment indicators for organisations, Moraga et al. (2019) analysed CE assessment indicators for organisations and the Eurostat Indicators for the territorial level and classified them according to reasoning on what (CE strategies) and how (measurement scope), Saidani et al. (2019) analysed 55 CE assessment indicators for organisations, eco-industrial parks and territorial level, Vinante et al. (2021) reviewed CE metrics for organisations, or Kravchenko et al. (2019) investigated CE indicators in connection with implementing CE strategies in organisations, among others.

Significant efforts have been also made related to the CE assessment for organisations from some specific sectors, such as those from Marino and Pariso (2021) who analysed and assessed the transition in 13 top performing small and medium-sized enterprises (SME) in Europe. Within the manufacturing sector, Negri et al. (2021) reviewed the literature on measuring the performance of the CE for manufacturing companies, and Trollman et al. (2021) developed a circularity indicator tool for measuring the ecological embeddedness of manufacturing. Regarding the building sector, Khadim et al. (2022) conducted a literature review to analyse the existing nano and macro-level building circularity indicators and frameworks, Abadi et al. (2021) proposed a framework of 12 indicators to measure the circularity of projects in the circular economy of construction, Tokazhanov et al. (2022) developed a circularity assessment tool for construction projects in emerging economies, Dräger et al. (2022) adapted the MCI indicator (Ellen MacArthur Foundation & Granta Design, 2019) to analyse the circularity of construction products available in the German ÖKOBAUDAT (2020) database, and Honarvar et al. (2022) used the MCI indicator (Ellen MacArthur Foundation & Granta Design, 2019) to assess the level of circularity of buildings. Regarding the agricultural sector, Esposito et al. (2020) conducted a systematic literature review to investigate the state of the art of research related to the adoption of CE models and tools along the agri-food supply chain, Rocchi et al. (2021) adapted the MCI indicator (Ellen MacArthur Foundation & Granta Design, 2019) for biological cycles, and Silvestri et al. (2022) proposed a set of indicators for measuring sustainability and the CE in the agri-food sector. Regarding the textile industry, Hanuláková et al. (2021) analysed the Slovakian textile and clothing industry to explain the principles of transition and the potential for change, Mazzoni (2020) analysed which types of eco-innovation could lead to the implementation of the CE in Italian industrial clusters, and Galatti and Baruque-Ramos (2022) proposed 40 indicators to

measure the capacity of the Brazilian textile and fashion industry to promote social innovation in the circular economy. Finally, there are some studies focused on analyzing the circularity of infrastructures, such as Kovačič Lukman et al. (2022) who proposed a conceptual model to measure the circular economy of seaports.

The conclusions of reviewing all these studies stated that there is a lack of homogenisation in assessing circularity in organisations owing to the great number of existing indicators/metrics and that it is necessary to standardise and develop more simple methods that encourages and makes it easier to assess such information in a more concise and useful way. Accordingly, some circular economy assessment tools (CE tools) have been developed in recent years, which automatically calculate CE indicators using qualitative and/or quantitative data from the organisation.

On a qualitative level, CE tools such as CAS 2.0 (CAS2.0, 2021), CircularTRANS (CircularTRANS, 2020), CM-FLAT (Sacco et al., 2021), Inedit (Inedit, 2020), MATChE (MATChE, 2021) or CE-Diagnosis (CE-Diagnosis, 2017) have been developed. On a quantitative level, CE tools such as ACODEA (ACODEA, 2018), CTI-Tool (CTI Tool, 2020) or Material Circularity Indicator (MCI, 2017) have been developed. In addition, there are hybrid CE tools that include both qualitative and quantitative aspects, such as CIRCelligence by BCG (Rubel et al., 2020) or Circulytics (Circulytics, 2020). Valls-Val et al. (2022) reviewed these CE tools capable of measuring the level of circularity of organisations, and concluded that they differ in terms of the type of data used, the level of accuracy, the indicators calculated, the scope of application and the reports generated. Furthermore, they stated that the use of these CE tools by organisations is extremely low, and the information on their practical application is scarce.

On the one hand, regarding the impact in the literature, only three studies are focused on describing CE tools: Sacco et al. (2021), Pigosso and McAloone (2021) and Urain et al. (2022) which described the basis of CM-FLAT, MATChE and CircularTRANS, respectively. Moreover, Vayona and Demetriou (2020) analysed the Circulytics tool with a focus on its social dimension, Hofstetter et al. (2021) and Martinetti and Havas (2021) described and analysed the Circulytics and CTI-Tool, and Verstraeten-Jochemsen et al. (2020) analysed the Circelligence, Circle assessment, Circulytics and CTI-Tool. In addition, Maranesi and De Giovanni (2020) used the Circulytics tool to evaluate the circularity of the Italian company Itelyum, and Schulz-Mönninghoff et al. (2023) used the CTI-Tool to measure the circularity of a vehicle manufacturer seeking to improve the circularity of batteries for electric vehicles. On the other hand, regarding the impact of these tools in organisations, according to the information provided by the CE tools, the most used CE tools are Circulytics and CTI Tool (both have already attracted over 500 organisations), followed by CircularTRANS used by 45 companies, and Inedit which has worked with multinational companies. However, no information has been found on the remaining tools. To date there are no studies that analyse the utility and applicability of CE tools to organisations from different sectors.

In light of this context and the research gap observed related to the analysis of the applicability and utility of the CE tools, the aim of this study is to analyse the applicability, usefulness and user-friendliness when assessing the degree of circularity in organisations, and what the users' (organisations) opinions of them are. Based on the conclusions of Valls-Val et al. (2022), which highlighted the difficulty in comparing qualitative and quantitative tools, this study focuses on qualitative ones. For this purpose, the selected qualitative CE tools were applied to four organisations (production and service organisations), with the aim of comparing the results achieved by each tool for each organisation, observing the convergence between the utilities of the tools and the demands or requirements of organisations, obtaining feedback from CE tool users (organisations) and observing further aspects concerning the implementation of the tools.

To fill these scientific gaps and achieve the goal of this article, three research questions are proposed: RQ1 — Is the level of circularity calculated for a specific organisation with different CE tools comparable? RQ2 — Are the CE tools capable of considering the specificities of organisations belonging to different sectors? RQ3 — What is the opinion of managers regarding the applicability of each CE tool to their organisation?

3. Methods and materials

The methodological procedure adopted in this study was based on the four main stages shown in Fig. 1 and described below.

3.1. Stage I. Selection and description of CE tools

A literature review was performed in the Google Scholar and Scopus databases as well as in internet search engines to identify and then select extant CE tools able to measure the degree of circularity in organisations using qualitative data. To this end, a search was executed that combined the keywords of “circular economy” or “circularity” with those of “calculator”, “tool”, “assessment” or “diagnos*”. The obtained

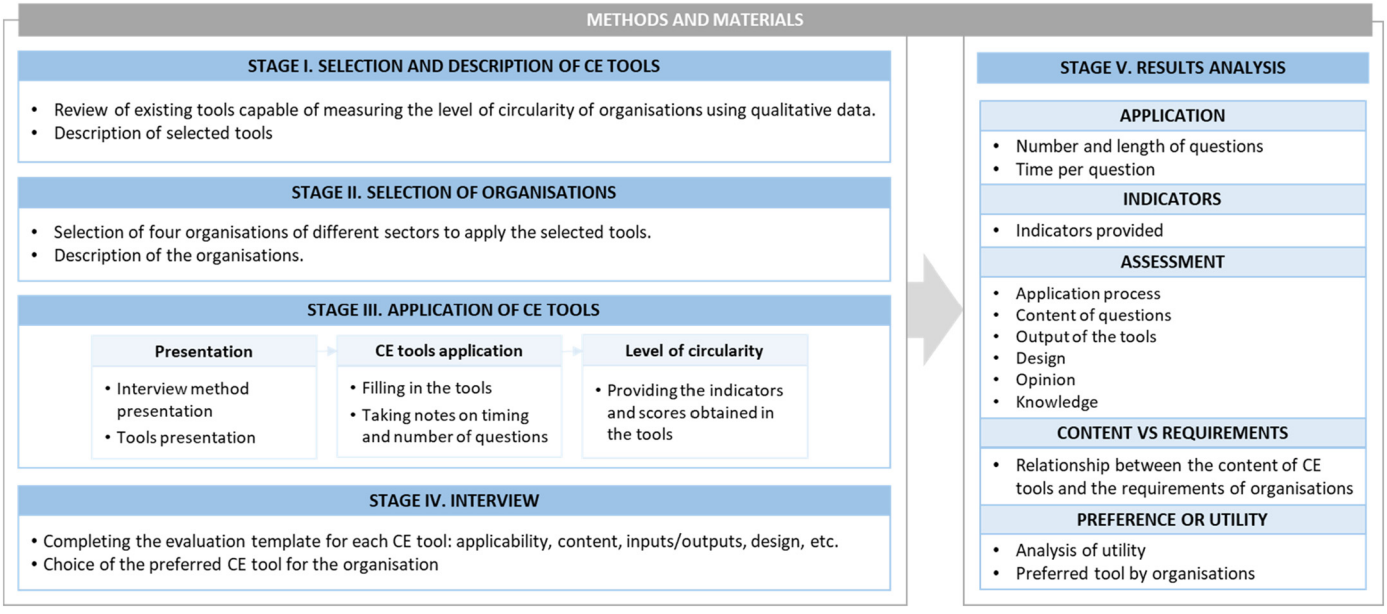

Fig. 1. Methodological approach.

Table 1
Selected CE tools for evaluating the Circular Economy in organisations.

CE tool	Developed by	Year	Format	Nº [1]	Reference
CAS2.0 [2]	Circular Business Academia in cooperation with Interreg Alpine Space Project Circular 4.0	2021	Webpage	29	(CAS2.0, 2021)
CE-Diagnosis	School of Engineering of the University of Navarra (Spain)	2017	Google forms	20–38	(CE-Diagnosis, 2017)
CircularTRANS	Higher Polytechnic School of the University of Mondragon (Spain) and with the collaboration of other organisations	2020	Webpage	132–172	(CircularTRANS, 2020)
Circulytics	Ellen McArthur Foundation in collaboration with 13 Strategic Partners and member companies	2020	Qualtrics platform	40	(Circulytics, 2020)
CM-FLAT [3]	Fraunhofer Italia Research, Innovation Engineering Center and the Faculty of Science and Technology, Free University of Bozen-Bolzano (Italy)	2021	Computer-supported tool [4]	27–45	(Sacco et al., 2021)
INEDIT	Inedit Innova	2020	Webpage	12–22	(Inedit, 2020)
MATChE	Technical University of Denmark.	2021	Webpage	37	(MATChE, 2021)

[1] Number of qualitative questions, [2] Circularity Assessment Score 2.0, [3] Circularity and Maturity Firm-Level Assessment CE tool, [4] CE tool that is currently under development.

outcomes were then filtered in order to select only the CE tools that autonomously measure the degree of circularity in organisations by using qualitative data, excluding guidelines or recommendations and those CE tools focused on product circularity. Nine CE tools were initially identified. Access permission was requested for the CE tools that required it, and for those where access was not obtained, an information request was made to identify how the CE calculation is made. If any of this information was not obtained, the CE tools were removed from the sample. Finally, the seven CE tools presented in Table 1 were selected.

Table 1 presents the main aspects of each of the tools selected: the year of launch, the developer, the format and the number of questions included. As can be seen, the CE tools for measuring the level of CE implementation are very recent, 85 % were launched in 2020 or later. Moreover, it can be observed that all of them are available online and free of charge — which promotes their use — and 60 % are developed by universities or research centres. Finally, the great variation in the number of questions, ranging from 12 to 172, should be highlighted.

3.2. Stage II. Selection of organisations for the case studies

Managers from organisations belonging to different sectors were contacted in order to apply the selected CE tools to their organisations and gather their opinions on implementing the process. Four organisations were selected, two of them belonging to the service sector (education and wastewater treatment), and two belonging to the production sector (industrial equipment and construction material). All were located in Castellón (Spain).

Table 2 presents some information about these organisations: sector, size (number of employees), position of the person in charge of applying the CE tools and the existence or otherwise of circular economy and/or environmental action plans.

3.3. Stage III. Application of the CE tools

The process of applying the seven CE tools under study to each organisation was supervised by a member of the research team (interviewer) with the aim of conducting the process under the same conditions. Firstly, the researcher briefly introduced each tool to the contact person of each organisation (respondent). Then, the contact person (respondent) filled in the seven CE tools with the data of his or her organisation. Meanwhile, the interviewer observed the process and took notes to record the time required to complete each CE tool and the number of questions answered. Finally, the level of circularity of the organisation was obtained for each CE tool and the reports generated with each tool were provided to the respondents.

3.4. Stage IV. Interview

After the application process, the interviewer asked the respondents to answer an evaluation template (Table 3) for each CE tool, in order to give feedback on how they perceived the characteristics of the application process and assess the functionalities of each tool. This template was designed including aspects related to the application/implementation, the content, the outputs, the design and utility of the CE tools. Responses were rated using a Likert scale of 1–5, where 5 always indicates the most desirable/positive option and 1 the most negative option. It also included a section for additional comments, a question related to previous knowledge of the CE tool and a last question related to the personal choice of preferred tool for their organisation.

Table 2
Description of selected organisations.

	Sector	Description	Size	Position	Action plan
A	Education	Higher Education organisation with ≈15,000 students	>250	Environmental manager	E [1] [2] ; CSRR
B	Wastewater treatment	Urban wastewater treatment with a capacity of ≈100,000 population-eq	10–49	Operations manager	CSRR
D	Industrial equipment	International company with two production plants.	>250	Quality and environment engineer	E [1] ; CE
C	Construction material	International company with 3 factories, with a capacity of ≈10,000,000 m^2/year	>250	Industrial engineer	E [1] [3]

E[1]: Environmental action plan, with environmental management system certified according to ISO 14001; E[2] Carbon footprint calculation, energy saving plan and measures aimed at promoting climate neutrality; E[3] Environmental action plan with Environmental Product Declaration verified by AENOR for each type of product. CSRR: Annual Corporate Social Responsibility Report. CE: Circular economy action plan that includes aspects such as redesign, reduce, reuse, repair and recycle.

Table 3
Evaluation template.

		☆ ☆ ☆ ☆ ☆
APPLICATION	Appropriateness of **time** invested	Low ····· High
	Appropriateness of the **number** of questions	Low ····· High
CONTENT	**Clarity** of question statements	Low ····· High
	Repetitiveness of questions	High ····· Low
	Consideration of the **specificities** of the organisation	Low ····· High
	Difficulty in **answering** the questions	High ····· Low
OUTPUTS	Level of **detail** of the **report**	Low ····· High
	Level of **exploitation/use** of the report	Low ····· High
	Level of **agreement** of the **level of circularity** obtained to the reality	Low ····· High
	Utility of the **suggestions for improvement** offered by the CE tool	Low ····· High
DESIGN	**User-friendliness** of the CE tool	Low ····· High
	CE tool design	Bad ····· Good
GENERAL	**Utility** of the CE tool	Low ····· High
	Did you know about it before?	YES / NO
	Other **comments**	.....
	Which one would you choose to use in your organisation?	.....

3.5. Stage V. Results analysis

After applying the four stages described, the analysis of the results was carried out following the steps presented in Fig. 1. First, the characteristics of the application process of the CE tools (number of questions, the length of questions and the time spent) were analysed. Second, the partial and overall indicators obtained in each CE tool were analysed in order to ascertain whether the results obtained were comparable. Third, the assessment provided through the evaluation templates was analysed. Finally, the convergence between offer and demand was analysed in order to draw conclusions on the applicability and utility of the CE tools.

4. Results

The results of the CE tool application process length, number and time of response per question), the indicators and scores obtained in the CE tools, the respondents' assessment of the CE tools and the relationships between the content of the CE tools and the requirements of the organisations are analysed below.

4.1. Application process of the CE tools

The application process of each tool ranged from 4 to 40 min, with the Inedit CE tool taking the least time and the CircularTRANS CE tool taking the most. The results of the application process of the CE tools were analysed by considering the number of questions (both mandatory and optional), the length of the questions (both statement and answer sentences) and, finally, the time taken to answer each question. This information can be seen in Fig. 2, which analyses the results taking into account the variability between the organisations interviewed (A, B, C & D) in the time taken to complete the process, and can be consulted in more detail in the Supplementary Material (Table S1).

Fig. 2 shows that, in general, the CE tools that employ Likert scale options to input responses (CircularTRANS, MATChE or CE-Diagnosis) were less time consuming, since the user only spends time reading the question, not the answer for each question, thereby accelerating the response time. Therefore, it can be stated that Likert responses make the process faster, although they have the disadvantage that they may be less accurate and precise, and depend to a greater extent on the respondent's experience. The CE tool with the lowest time investment per question was CircularTRANS, probably due to it being that with the most concise questions (lowest number of words per question), and also because it was the tool with the highest number of questions (the user does not pay as much attention to individual answers when he/she becomes aware of the significant length of the process).

4.2. Indicators of the CE tools

After the seven CE tools had been filled in by the respondents from each of the four organisations detailed in Table 2, the indicators provided by each tool for each organisation were obtained in order to ascertain the comparability of the results. Table 4 shows the partial indicators considered by each CE tool with their scale and the weight of each partial indicator in relation to the overall indicator. In addition, the partial indicators and overall indicators as a measure of the level of circularity are presented for each organisation (A, B, C & D) and for each CE tool.

As can be seen in Table 4, on the one hand, each CE tool included different indicators; furthermore, although some of them were similar, their weighted contribution to the overall indicator (level of circularity) were also different. The common indicators among the CE tools were the indicators related to the strategy of the organisation and the business model (included in CAS2.0, CircularTRANS, Circulytics. CM-FLAT and Inedit, with a weight ranging from 15 % to 50 %), followed by the indicators related to end-of-life strategies (included in CE-Diagnosis CircularTRANS, CM-FLAT and MATChE, with a weight ranging from 10 % to 28.5 %), the indicators related to the operational process (included in CE-Diagnosis, CircularTRANS, Circulytics and MATChE, with a weight ranging from 13 to 15 %), and finally the indicators related to resource consumption, symbiosis and cooperation, use/life-cycle stage and innovation (each one included in two CE tools). On the other hand, although all the tools presented an overall indicator to represent the level of circularity (named distinctly in each CE tool), the scales differed for each tool, so they cannot be easily compared. For these reasons, the indicators of the organisation obtained in different CE tools could not be compared on first view.

In order to compare the results, Fig. 3 represents the overall indicator (level of circularity) obtained in each selected tool on scale of 0–100. Additionally, the overall indicators obtained in the CE tools for each organisation were analysed by using box-plot graphs, where the median, upper/lower quartiles and upper/lower whiskers were represented for each case study. The width of each box-plot indicates the variability of the overall indicator for each organisation depending on the CE tool applied.

As can be seen, the overall indicator obtained in the CE tools differed greatly. The range of variation in the level of circularity obtained was 38 %, 26 %, 32 % and 30 % for organisations A, B, C and D, respectively.

Fig. 2. Number, length and time of questions.

Furthermore, no upward or downward trend in the CE tool overall indicator was observed among the CE tools, and the CE tool that scored closest to the average was not the same in all the organisations analysed (the CE tools with similar overall indicators to the average were CM-FLAT and Inedit, CAS2.0 and Inedit, MATChE and CE-Diagnosis, and MATChE for organisations A, B, C and D, respectively). For example, Inedit obtained a level of circularity very similar to the average for organisations A and B, a level of circularity above the average for organisation C and a level of circularity below the average for organisation D. While CAS2.0 obtained an overall indicator very similar to the average for organisation B, an overall indicator above the average for organisation A, and an overall indicator below the average for organisations C and D. Therefore, although Inedit and MATChE were the CE tools with the highest percentage of similar overall indicators to the average, it was not possible to make any conclusions about the indicators, except to emphasise that the results were not comparable.

It is important to note that MATChE CE tool considered all the questions when calculating the indicators, including those selected as "not relevant to my company" by the user; that is to say, those not applicable to the organisation. For this reason, the level of circularity (overall indicator) was lower than the average in some of the organisations analysed (organisations A and B). If the overall indicator of the MATChE CE tool were calculated considering only the applicable questions, the level of circularity would be 41 %, 70 % and 76 % for organisations A, B and D, respectively.

Finally, it should be noted that the results of the CircularTRANS, Inedit and MATChE CE tools were obtained instantaneously after the

Table 4
Partial and overall indicators of the organisations A, B, C & D for each CE tool.

CE tool	Indicator	Scale	Weight	Organisations			
				A	B	C	D
CAS 2.0	**Overall (Total CAS2.0 score)**	**0–100**		**62.7**	**59.4**	**44.5**	**48.0**
	Circular Business Model Potential [1]	0–50	50 %	31.3	20.8	18.8	20.8
	Commitment to the Circular Transformation	0–50	50 %	31.4	38.6	25.7	27.2
CE-Diagnosis	**Overall**	**1–7**		**3.71**	**4.77**	**4.09**	**4.52**
	Purchase	1–7	14.3 %	4.75	4.25	4.00	5.00
	Transform [3]	1–7	14.3 %	–	5.00	3.67	6.00
	Distribute	1–7	14.3 %	–	–	–	–
	Use/Consume [6]	1–7	14.3 %	–	–	4.60	–
	Reintroduce [2]	1–7	28.5 %	–	5.80	4.80	3.80
	Symbiosis [5]	1–7	14.3 %	2.67	3.00	2.67	4.00
CircularTRANS	**Overall (Maturity level)**	**0–5**		**1.6**	**3.4**	**3.4**	**3.4**
	Strategic Processes [1]	0–5	n/a	2.0	4.2	3.4	3.7
	Operational Processes [3]	0–5	n/a	0.9	2.2	3.5	2.9
	Support Processes	0–5	n/a	2.9	4.3	3.3	4.3
	Rethink	0–5	n/a	1.2	3.4	2.7	2.6
	Extend Useful Life	0–5	n/a.	3.2	1.7	3.6	1.9
	Optimise Resources [4]	0–5	n/a	3.8	4.1	4.3	4.4
	Cycle Closure/end of life [2]	0–5	n/a	1.6	2.0	3.1	2.6
Circulytics	**Overall (Enablers)**	**A–E**		**D**	**B**	**C-**	**C-**
	Strategy and Planning [1]	A–E	30 %	D-	A-	C	C
	Innovation [7]	A–E	20 %	C-	A	C	C
	People and Skills	A–E	15 %	C-	A-	C-	C
	Operations [3]	A–E	15 %	C-	C-	D	D
	External Engagement	A–E	20 %	C-	C	D-	D-
CM-FLAT	**Overall**	**0–100**		**42**	**52**	**41**	**41**
	Circularity Performance	0–100	61 %	49	48	37	36
	Business Model [1]	0–100	10 %	–	60.00	12.00	–
	Eco-design	0–100	23 %	72.73	76.19	37.70	50.00
	Direct logistics	0–100	2 %	–	–	0.00	0.00
	Resource consumption [4]	0–100	6 %	46.67	46.67	46.67	33.33
	Waste management [2]	0–100	6 %	30.00	26.67	60.00	33.33
	Resource recovery [2]	0–100	13 %	46.67	37.78	43.33	29.63
	Post sales services	0–100	2 %	–	–	80.00	–
	Maturity Performance	0–100	39 %	37	57	47	47
	Strategy & vision [1]	0–100	5 %	25.00	76.92	55.56	44.44
	Environmental management	0–100	7 %	88.24	70.59	94.12	76.47
	Cooperation & industrial symbiosis [5]	0–100	6 %	0.00	53.33	33.33	33.33
	Training	0–100	2 %	0.00	80.00	0.00	40.00
	Employee satisfaction & participation	0–100	2 %	20.00	40.00	20.00	60.00
	Eco-design	0–100	2 %	0.00	25.00	50.00	50.00
	Supplier selection & auditing	0–100	5 %	21.43	21.43	28.57	21.43
	Direct logistics	0–100	0 %	–	–	–	–
	Reverse logistics	0–100	4 %	0.00	0.00	30.00	0.00
	Resource consumption [4]	0–100	3 %	87.50	62.50	50.00	75.00
	Waste management [2]	0–100	2 %	75.00	100.00	75.00	75.00
	Marketing & communication	0–100	2 %	40.00	100.00	40.00	40.00
Inedit	**Overall (Circularity index)**	**0–100**		**42**	**58**	**69**	**40**
MATChE	**Overall (Total readiness score)**	**0–150**		**37**	**70**	**88**	**84**
	Organisation	0–20	13 %	11	16	11	15
	Strategy & Business Model Innovation [1]	0–25	17 %	7	23	15	17
	Product & Service Innovation [7]	0–20	13 %	0	5	12	5
	Manufacturing & Value Chain [3]	0–20	13 %	8	7	7	14
	Technology & Data	0–10	7 %	0	5	7	9
	Use, Support & Maintenance [6]	0–15	10 %	0	5	12	5
	Takeback & End-of-life strategies [2]	0–15	10 %	0	0	12	8
	Policy & Market	0–25	17 %	11	9	12	11

[1]Indicator related to the strategy of the organisation and the business model, [2]Indicator related to end-of-life strategies and waste management, [3]Indicator related to operational process, [4]Indicator related to resource consumption, [5]Indicator related to symbiosis and cooperation, [6]Indicator related to use/consumption life-cycle stage, [7]Indicator related to innovation, n/a: not available.

application process. In contrast, the results of the CAS 2.0 and CE-Diagnosis CE tools required the feedback of the people in charge of the management of each tool, who are responsible for sending the partial and overall indicators by email. For the Circulytics and CM-FLAT CE tools, indicators were calculated by the authors of the article following the instructions given by EMF (2022) and Sacco et al. (2021), respectively.

4.3. Assessment of the CE tools

After completing the CE tool assessment, the respondents from each organisation (A, B, C & D) filled in the evaluation template (see Table 3) to collect their feedback on the main characteristics of the application processes of the tools (application, content, outputs, CE tool design and general comments). The evaluation template responses are detailed

Fig. 3. Level of circularity (overall indicator) obtained for the organisations A, B, C & D for each CE tool.

in the Supplementary Material (Table S2, Table S4, Table S6 and Table S8). Fig. 4 presents both the assessment of the characteristics for each organisation and the average, showing the assessment score obtained. In the case of CE tools that lack some of the functionalities being evaluated, a score of 0 was given for that item.

As can be seen in Fig. 4, not only were differences found between CE tools, but also between organisations A, B, C & D.

On an overall level, taking into account the assessment scores obtained in all the aspects analysed, the CE tools with the highest scores were CE-Diagnosis, CircularTRANS and Inedit. However, it should be considered that CM-FLAT is not yet implemented in any software and therefore it is not possible to score the detail and use of the report, the suggestions for improvement or the design of the CE tool. Therefore, as this CE tool could not be simply compared with the others, it was considered appropriate to calculate the percentage that it achieved with respect to its maximum score. Having calculated this percentage, the highest-rated CE tools were CE-Diagnosis, CircularTRANS, Inedit, MATChE, CM-FLAT, CAS2.0, and Circulytics, with percentages of 80.8 %, 75.0 %, 74.2, 73.1 %, 69.4 %, 66.5 % and 58.1 %, respectively.

Regarding the organisations, in each case there was a top-rated CE tool. In organisation A, the top-rated CE tool was CE-Diagnosis, followed by CAS2.0, and with Circulytics in last place. In organisation B, the top-rated CE tool was CircularTRANS followed by CE-Diagnosis, and with Circulytics and CAS2.0 in last place. In organisation C, the top-rated CE tool was Inedit, followed by MATChE and CE-Diagnosis, and the worst-rated tool was Circulytics. In organisation D, the top-rated CE tool was CE-Diagnosis, followed by Inedit, and with CM-FLAT in the last place. In addition, it was observed that the dispersion in the assessment scores with respect to their maximum score in percentage also varied from one case to another, with more dispersed scores in organisations A and D and scores with less variation in organisations B and C.

Below, the results related to each assessment aspect are presented:

- **Application process**. In terms of the use of the CE tools, there were no major differences between them, with CE-Diagnosis being the top-rated tool, followed by MATChE, Inedit, CAS2.0, Circulytics, CM-FLAT and, lastly, CircularTRANS. On the one hand, the best-rated CE tool in terms of the total time needed to complete it was Inedit, as the organisations considered it useful to obtain an initial overview of the level of circularity of the organisation with minimal time investment. However, this CE tool scored very low on the number of questions as the organisations considered it too short to properly assess circularity. On the other hand, the best-rated CE tool in terms of the number of questions included was CE-Diagnosis, as it included an intermediate number of questions considering all stages of the life cycle. Finally, the worst-rated tool was CircularTRANS, both in terms of the time required and the number of questions included, as the organisations considered that the total time taken was excessive (around 30 min) and the number of questions was too high compared to the other CE tools.
- **Content of the CE tools**. With regard to content, there were greater differences between the CE tools, with Inedit being the best rated, followed by CE-Diagnosis, CAS2.0, CircularTRANS, CM-FLAT, MATChE and, lastly, Circulytics. In this field, the CE tools received positive evaluations in terms of the clarity of the statements, the repetitiveness of the questions and the difficulty in completing the assessment, as the organisations considered the tools to be clear and simple. However, the CE tools were given negative evaluations with respect to the consideration of the specific characteristics of the organisation. This may result either from the differences between organisations or from the wide variety in the content of the CE tools and the clear differences in terms of the scope of their application and adaptability to each organisation, as demonstrated by Valls-Val et al. (2022).
- **Output of the CE tools**. Regarding the output of the CE tools, this category had the greatest variation in scores. This is due to the fact that some tools (CAS 2.0 and Circulytics) did not offer suggestions for improvement; therefore, in relation to this aspect they were awarded a score of 0. Moreover, the CM-FLAT CE tool is not implemented in any software; thus, the organisations only assessed the match of the score with respect to the reality of the organisation, with all other aspects in this category for this tool scoring 0.
The best-rated CE tool in terms of the level of detail of the report was CircularTRANS, as it offered the most extensive results report. This includes a theoretical introduction, the result of the diagnosis (with the various indicators and a comparison with the sector average), a list of

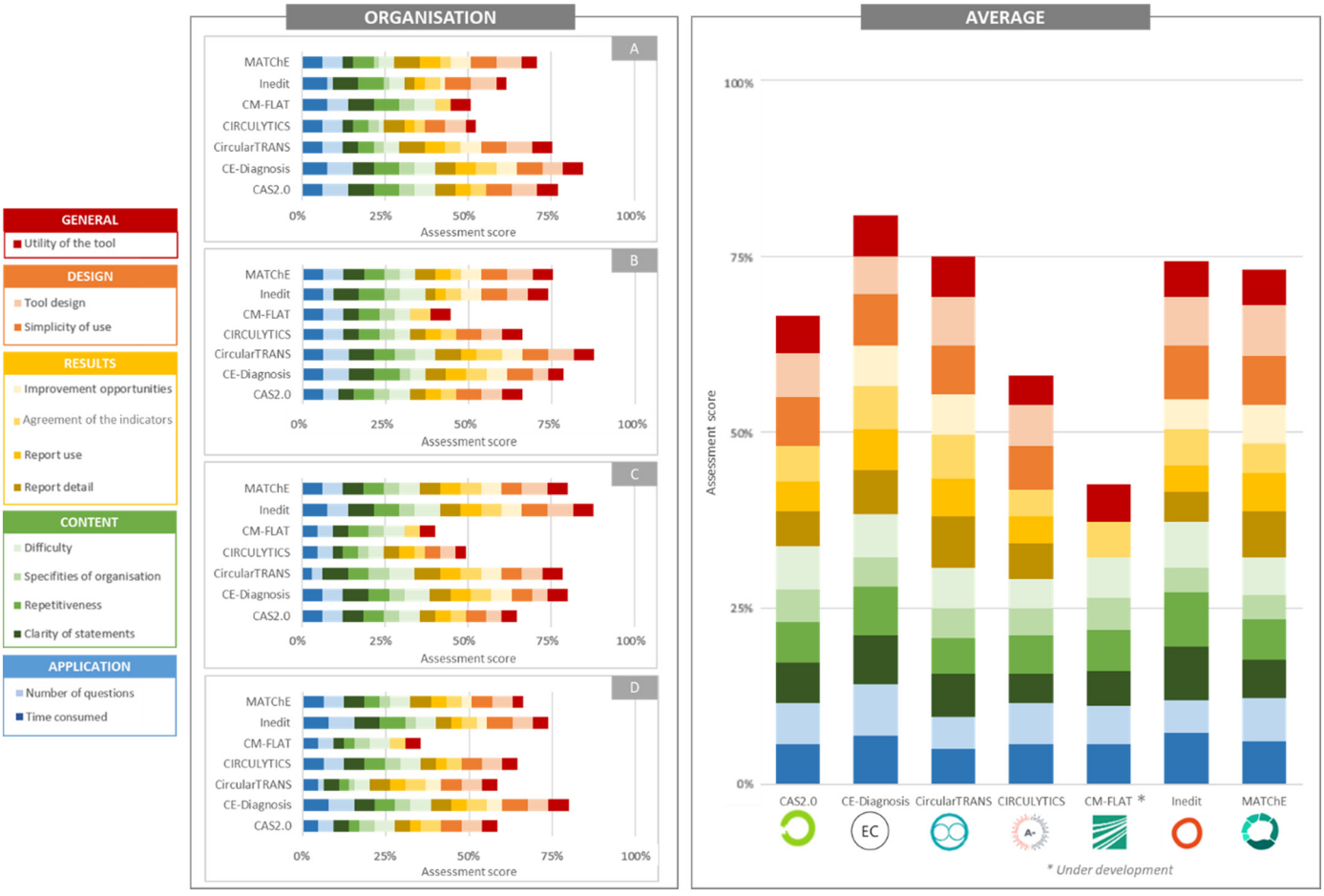

Fig. 4. Users' score assessment of the CE tools.

suggestions for improvement (classified into strategic process, operational processes, support processes and external context), along with a roadmap and an action plan. It should be noted that it is also customisable, so the organisation can modify it by adding its own information or by filling in the roadmap to assess the suggestions for improvement proposed by the tool. The worst-evaluated CE tool in this aspect was Inedit, as it only provided an overall circularity indicator and a very generic set of suggestions for improvement.

Secondly, regarding the use of the report, the CE tools with the highest scores were CE-Diagnosis and CircularTRANS. On the one hand, CE-Diagnosis provided a concise report with information that organisations consider important (indicators linked to life-cycle stages and comparison of the score obtained in each case with the average score for its sector). On the other hand, CircularTRANS, as mentioned above, presented a very detailed report from which the action plan and roadmap could be used. The worst-evaluated CE tools in this respect were Circulytics and Inedit because their reports only provided the indicator scores, and although Inedit included suggestions for improvement, they were very generic.

In addition, the CE tools with the highest scores when it came to matching the CE tool score with the reality of the organisation were CircularTRANS and CE-Diagnosis, with Circulytics receiving the lowest score.

Finally, in terms of the utility of the suggestions for improvement offered by the CE tools, CircularTRANS, MATChE and CE-Diagnosis had similar scores because they offered suggestions for improvement that were more customised and adaptable to the organisations under study. The worst-rated CE tool was Inedit, as the respondents considered that the suggestions for improvement offered were very generic and not applicable to their organisations.

- **Design of the CE tools**. In terms of the user-friendliness of the CE tool, all the tools were positively rated because they did not present any difficulty for the user, as nowadays people are very familiar with online evaluation CE tools. Regarding the design of the tools, CircularTRANS, Inedit and MATChE received better scores, as they have a more attractive design. However, Circulytics and CE-Diagnosis had the lowest scores because they use Qualtrics and Google Forms questionnaires, respectively, along with CAS 2.0, because its design is very simple.
- **General opinion or commentaries on the CE tools**. Regarding the open-response comments made by the respondents, which can be consulted in the Supplementary Material (Table S3, Table S5, Table S7 and Table S9), most focused on the fact that in the case of the CAS2.0, Circulytics and MATChE CE tools, all the questions need to be answered, even when they are not applicable to the organisation, leading to the results distorting the reality. In addition, the respondents appreciated that the CE tools were available in their native language, since this allowed them to understand and interpret the questions better. In fact, all the CE tools selected as favourites were in Spanish, the native language of the respondents. Additionally, respondents were appreciative of reports being generated instantly.
- **Prior knowledge of the CE tools**. It was noteworthy that none of the organisations were aware of these CE tools beforehand, which suggests that the tools should invest a little more in their promotion and publicity in order to encourage their use in organisations.

4.4. Relationship between the content of the CE tools and the requirements of organisations

Fig. 5 classifies the content/topics considered by the CE tools into different categories based on those from Valls-Val et al. (2022) and shown in Fig. 5a. Firstly, the questions in the CE tools were classified into the selected categories using the keywords detailed in the Supplementary Material (Table S10). They were then plotted in Fig. 5b, with the weight of each question in the calculation of the overall indicator being considered and indicating the categories not included in each tool. Secondly, the organisations were analysed to identify which categories applied to them. Fig. 5c presents the aspects applicable to each organisation and the percentage of each of these addressed by each of the tools (displayed in the box for each organisation).

Regarding the content of the CE tools, Fig. 5b reveals that none of the CE tools included all the analysed aspects, and although all the tools placed importance on involvement in CE, there was a great difference in the content included in each of them. On the one hand, some tools focused only on some categories; for example, Circulytics on management involvement in CE, MATChE on circular economy strategies, and Inedit on environmental management, inflows and outflows. On the other hand, other CE tools focused on all categories except outputs (such as CAS2.0 and CircularTRANS), whereas other, more balanced tools, such as CM-FLAT and CE-Diagnosis, considered practically all the categories equally.

In terms of the organisations, it could be seen that the CE tools that include the highest percentage of categories of the organisations in all four cases were CircularTRANS followed by CM-FLAT. The rest of the tools considered <50 % of the organisations' characteristics. Therefore, it can be concluded that these generic CE tools make it very difficult to address the characteristics of all organisations.

4.5. Preference and utility of CE tools by organisation

On the one hand, the preference of the CE tools was assessed in three ways: first, using the assessment score given by the organisations in the evaluation template for the utility category; second, using the total assessment score given by the organisations in the evaluation template; and third, directly from the CE tool chosen by the organisations as that preferred to be implemented in their organisation.

In terms of the score obtained in the utility question, CE-Diagnosis and CircularTRANS were the best-rated CE tools. Moreover, regarding the total score obtained, CE-Diagnosis and CircularTRANS were also the best rated. In addition, regarding the preferred CE tool to be used in their organisation, CircularTRANS was selected by organisations B, C

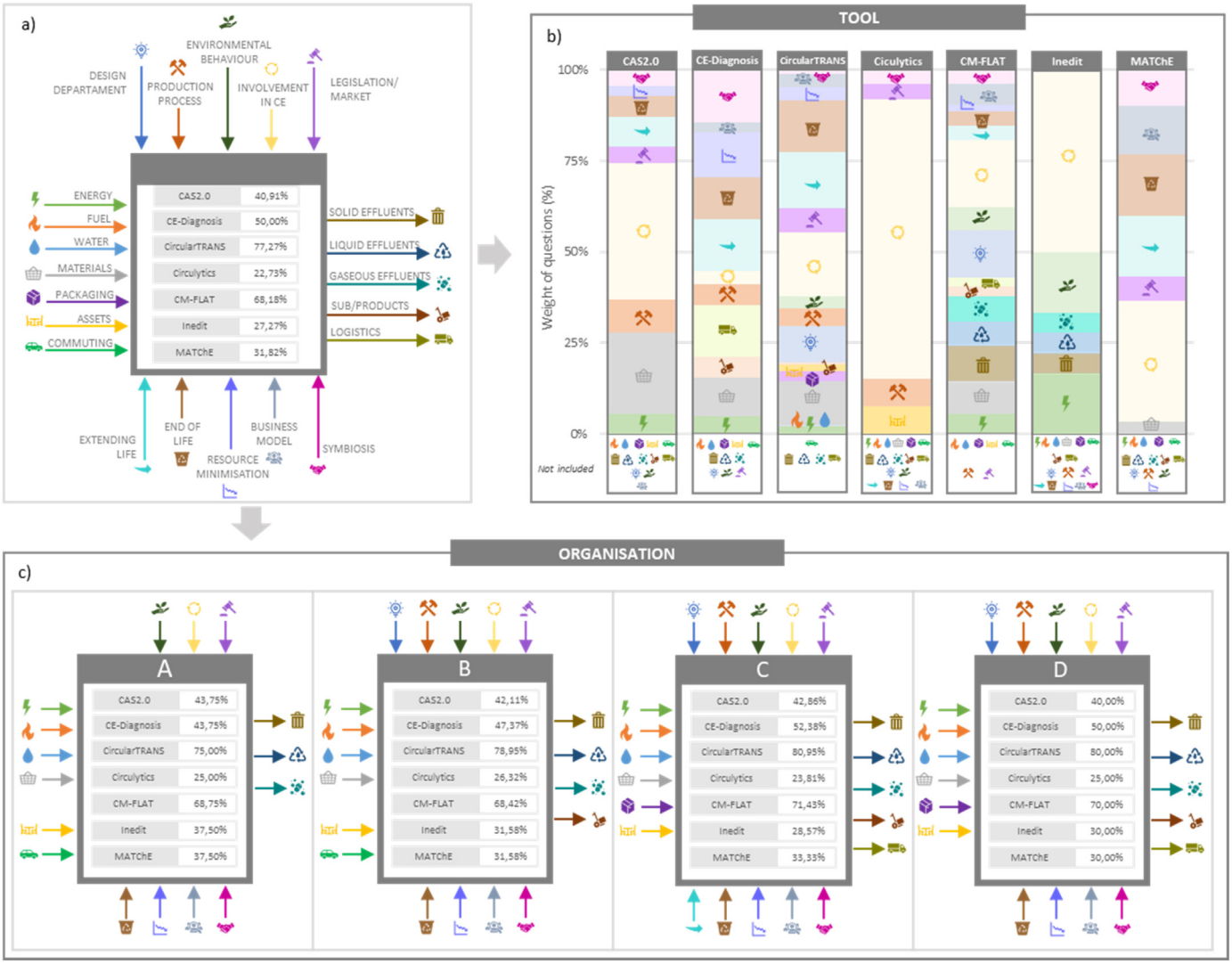

Fig. 5. Relationship between the topic of the questions included in each CE tool and the organisations A, B, C & D.

Table 5
Relationship between CE tool ranking and preferred CE tool for organisations A, B, C & D.

	Ranking	Preferred CE tool
A	CE-Diagnosis > CAS2.0 > CM-FLAT* > CircularTRANS > MATChE > Inedit > Circulytics	CE-Diagnosis/CM-FLAT*
B	CircularTRANS > CE-Diagnosis > MATChE > Inedit > CM-FLAT* > CAS2.0 = Circulytics	CircularTRANS/CE-Diagnosis
C	Inedit > CE-Diagnosis = MATChE > CircularTRANS > CAS2.0 > CM-FLAT* > Circulytics	CircularTRANS/Inedit
D	CE-Diagnosis > Inedit > Circulytics > MATChE > CAS2.0 > CircularTRANS > CM-FLAT*	CircularTRANS/CE-Diagnosis

* Under development.

and D, and CE-Diagnosis by organisation A. So, it could be concluded that the organisations considered CircularTRANS and CE-Diagnosis to be the most useful CE tools.

Table 5 establishes the relationship between the CE tool selected as that preferred by the organisations and the score ranking that the organisations assigned to each tool. As can be seen, in organisations A and B, the CE tool selected as preferred was, in fact, also that with the highest score. Meanwhile, in organisations C and D, the CE tool rated in second position regarding preference received the highest score. In organisation C, Inedit was not selected as the preferred CE tool because it was considered too short and simple; and in organisation D, CircularTRANS was selected as the preferred CE tool because it was the most comprehensive.

5. Discussion

Having applied and analysed the existent CE tools used to ascertain the degree of circularity in organisations, the research questions stated in the introduction were addressed as follows.

Regarding **RQ1** (Is the level of circularity calculated with different CE tools comparable?), it was concluded that the results obtained with different qualitative CE tools are not comparable, as the fact the CE tools differ in numerous aspects produces mismatches. This concords with Valls-Val et al. (2022) statements, who highlighted the lack of standardisation among qualitative and quantitative CE tools. This is also in line with the conclusions of Vinante et al. (2021), in the sense that the results for the same organisation obtained from different CE tools cannot be compared on the face of it, as each CE tool includes different indicators, and even though all of the tools provide an overall indicator (level of circularity), they are on different scales, so they cannot be easily compared. Moreover, according to the results presented in Section 4.2 (see Fig. 3), when calculating the overall indicator for all the CE tools on the same scale, it can be seen that they differ to a great extent. Specifically, the average range of variation of the level of circularity obtained with the different CE tools analysed exceeded 30 %. This may be because each CE tool considers distinct areas and elements, and none includes all the possible aspects — as Corona et al. (2019) and De Pascale et al. (2021) concluded in relation to the CE indicators analysed. This implies that it would be impossible to achieve the same results. The considerable differences observed in the CE tools studied reveals the discrepancies in perceptions regarding what should be contemplated when it comes to assessing CE, along with the varying interpretations of the CE concept. This finding is in accordance with the conclusions presented by Saidani et al. (2019), De Pascale et al. (2021) and Corona et al. (2019), among others, and highlights the difficulty of obtaining comparable results in CE assessments. Therefore, depending on the case of application, the choice of one CE tool or another will benefit or disadvantage the organisation.

Regarding **RQ2** (Are the CE tools capable of considering the specificities of organisations belonging to different sectors?) it was observed that the organisations under study believed that the analysed CE tools did not consider the specificities of their particular sector: none of the organisations were convinced that their characteristics were included in the CE tools. The organisations also considered that some of the mandatory questions were not applicable to them, which had a negative effect on the level of circularity obtained in the CE tool, and that some important characteristics of their activity were left outside the scope of the tool.

According to the results presented in Sections 4.3 and 4.4, it was observed that organisations A and B (service organisations) had more difficulty in completing the data, and considered that their specifications were less well covered by the CE tools than in organisations C and D (production organisations). This is in line with studies published to date related to CE assessment in some specific sectors, which, as seen in the background, are mainly focused on production organisations, such as manufacturing (Negri et al., 2021; Trollman et al., 2021), building sector (Negri et al., 2021; Trollman et al., 2021), textile industry (Galatti and Baruque-Ramos, 2022; Hanuláková et al., 2021; Mazzoni, 2020), among others. This may be due to the fact that the New Circular Economy Action Plan (COM 098, 2020) includes the mobilisation of industry for a clean and circular economy as a line of action, so current efforts are focused on industrial and production sectors. Moreover, among the production organisations, the organisation involved in the production of technological material (organisation C) had a stronger relationship with the questions included in the CE tools (since its product is more related to the CE strategies such as modularity, repair, etc.), whereas an organisation involved in the production of a ceramic tile (organisation D) considered that many of the questions did not apply to its product since many of the CE strategies considered were not applicable (for example, shared use, product as a service, etc.).

As each organisation under study had different specificities, each valued different aspects of the CE tools positively; therefore, the selection of the preferred CE tool to be applied in the organisation was influenced by its sector of activity. In other words, the significant differences that exist between organisations and the peculiar characteristics of each sector, require individual approaches and careful analysis. Therefore, it can be affirmed that generic CE tools make it very difficult to consider the characteristics of all organisations, so the development of sectorial CE tools could be an interesting possibility. This is in line with Koszewska and Bielecki (2020), who affirmed that each branch of industry must have its specific challenges regarding the circular economy and its own methods of solving them; and with Lindgreen et al. (2020), who stated that, depending on their characteristics, different organisations may require distinct CE tools.

Regarding **RQ3** (What are the opinions of managers regarding the applicability of each CE tool to their organisation?) and according to the results of 4.3 section, the organisations analysed considered that selected CE tools could be useful, but they need further development to include the characteristics of different sector activities and greater standardisation to provide comparable results. Respondents value the fact that the CE tools use ranges or concrete data instead of Likert scales because they are more objective, well explained statements to avoid confusion in the answers, availability in the native language and the option does not apply in those questions that are not relevant for the organisation. Studies into methodologies, metrics and indicators to determine the implementation of CE are currently in ongoing development. This aspect permits a degree of freedom when it comes to constructing CE tools; nevertheless, the absence of uniformity and agreement is a limitation to the understanding and measurement of CE (De Pascale et al., 2021) and to organisations' acceptance of results from CE assessment approaches (Lindgreen et al., 2020). As a consequence, the organisations did not consider any of the CE tools to be optimal or suitable.

Moreover, the organisations considered that more resources should be invested in promoting these CE tools since they were not well known.

In accordance with the results presented by Saidani et al. (2019), Sassanelli et al. (2019) or Elia et al. (2017), it can be stated that there is a lack of standardisation, uniqueness and uniformity in the circularity assessment in organisations, although there is an appreciable increase in interest. The circularity assessment is still under development, which allows the use of tailor-made approaches, and there is a low acceptance of the results of CE assessment methods on the part of organisations (Lindgreen et al., 2020). Therefore, more research and development are needed to produce a standardised CE assessment CE tool that includes the best characteristics of each CE tool and meets the requirements or demands of the organisations.

6. Conclusion

After applying existing CE tools to ascertain the degree of circularity in organisations by using qualitative data, it can be concluded that there are clear differences in their applicability, utility and user-friendliness. They differ in terms of adaptability to the case study, appropriateness of content, application and design aspects. Moreover, the results obtained differ considerably from one CE tool to another, which can lead to advantages or disadvantages for organisations depending on which one they use in their analysis.

Organisations consider that the CE tools could be useful, but they need further development as they are too general, heterogeneous and do not allow the specificities of the different sectors to be modelled. Respondents generally preferred to use CircularTRANS as it was the most complete; however, this CE tool obtained results that were quite distant from the average. It could be said that the most suitable CE tool for a detailed analysis would be CircularTRANS, that Inedit would be the optimal CE tool to obtain an initial overview of the organisation's level of circularity, and that CAS2.0, CM-FLAT MATChE or CE-Diagnosis would be in an intermediate position, with Circulytics being the CE tool worst ranked by the organisations.

Therefore, the work carried out is essential to help organisations select the CE tool best suited to their needs. Moreover, as none of the CE tools can be classified as optimal, it can be concluded that further research is needed to develop standardised sectoral CE tools that consider sector specificities and allow organisations to obtain accurate and comparable results; and the research conducted in this paper is key to establish the basis for the development of these new standardised CE tools.

This study has the limitation that it was focused on CE tools that use qualitative data as input information, are developed in English or Spanish language, are currently accessible online or can be downloaded. In addition, the selected CE tools were applied to four organisations belonging to different economic sector. So, for future developments, it is proposed to extend the number of CE tools and to extend the sample of organisations at different levels (more organisations, more sectors, more countries, more years, etc.) or, on the contrary, to focus only on a specific sector.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors are grateful to the Ministerio de Ciencia, Innovación y Universidades (Spain) (DPI2017-89451-R and FPU18/02816) for the financial support and to the respondents from the organisations for their participation in this study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.spc.2023.01.023.

References

Abadi, M., Moore, D.R., Sammuneh, M.A., 2021. A framework of indicators to measure project circularity in construction circular economy. Manag. Procure. Law 175, 54–66. https://doi.org/10.1680/jmapl.21.00020.

ACODEA, 2018. Circularity calculator for organisations. [WWW Document]. Solidforest URL https://acodea.solidforest.com/.

Ahmed, A.A., Nazzal, M.A., Darras, B.M., Deiab, I.M., 2022. A comprehensive multi-level circular economy assessment framework. Sustain. Prod. Consum. 32, 700–717. https://doi.org/10.1016/j.spc.2022.05.025.

Baratsas, S.G., Pistikopoulos, E.N., Avraamidou, S., 2022. A quantitative and holistic circular economy assessment framework at the micro level. Comput. Chem. Eng. 160, 107697. https://doi.org/10.1016/j.compchemeng.2022.107697.

Barón Dorado, A., Giménez Leal, G., de Castro Vila, R., 2022. EMAS environmental statements as a measuring tool in the transition of industry towards a circular economy. J. Clean. Prod. 369, 133213. https://doi.org/10.1016/j.jclepro.2022.133213.

BS 8001, 2017. Framework for Implementing the Principles of the Circular Economy in Organizations. Br. Stantards Inst.

CAS2.0, 2021. Circularity Assessment Score 2.0. [WWW Document]. Circular Business Academy URL https://www.circularbusiness.academy/circularity-assessment-score/.

CE-Diagnosis, 2017. Circular economy diagnostic questionnaire. TECNUN. Escuela de Ingeniería. Universidad de Navarra. URL https://economiacircular.wixsite.com/economiacircular/cuestionario.

Circle Economy, 2021. Circular Economy Briefing for Business.

Circulab, 2021. Toolbox. [WWW Document]. URL https://circulab.com/toolbox-circular-economy/.

CircularTRANS, 2020. Mondragón University. [WWW Document]. URL https://www.mondragon.edu/circulartrans.

Circulytics, 2020. Measuring circularity. [WWW Document]. Ellen MacArthur Foundation URL https://ellenmacarthurfoundation.org/resources/circulytics/overview.

COM 029, 2018. On a monitoring framework for the circular economy new Circular Economy. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions.

COM 098, 2020. A new Circular Economy Action Plan For a cleaner and more competitive Europe. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions.

COM 102, 2020. A new industrial strategy for Europe. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, European Commission.

COM 479, 2017. Investing in a smart, innovative and sustainable Industry. A renewed EU Industrial Policy Strategy. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committ.

COM 614, 2015. Closing the loop - an EU action plan for the Circular Economy. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions.

COM 640, 2019. The European Green Deal. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions.

Corona, B., Shen, L., Reike, D., Rosales Carreón, J., Worrell, E., 2019. Towards sustainable development through the circular economy—a review and critical assessment on current circularity metrics. Resour. Conserv. Recycl. 151, 104498. https://doi.org/10.1016/j.resconrec.2019.104498.

CTI Tool, 2020. WBSCD Circular-IQ [WWW Document]. URL https://ctitool.com/.

de Oliveira, C.T., Dantas, T.E.T., Soares, S.R., 2021. Nano and micro level circular economy indicators: assisting decision-makers in circularity assessments. Sustain. Prod. Consum. 26, 455–468. https://doi.org/10.1016/j.spc.2020.11.024.

De Pascale, A., Arbolino, R., Szopik-Depczyńska, K., Limosani, M., Ioppolo, G., 2021. A systematic review for measuring circular economy: the 61 indicators. J. Clean. Prod. 281. https://doi.org/10.1016/j.jclepro.2020.124942.

Dräger, P., Letmathe, P., Reinhart, L., Robineck, F., 2022. Measuring circularity: evaluation of the circularity of construction products using the ÖKOBAUDAT database. Environ. Sci. Eur. 34. https://doi.org/10.1186/s12302-022-00589-0.

Elia, V., Gnoni, M.G., Tornese, F., 2017. Measuring circular economy strategies through index methods: a critical analysis. J. Clean. Prod. 142, 2741–2751. https://doi.org/10.1016/j.jclepro.2016.10.196.

EMF, 2022. Circulytics. Method introduction. Circulytics. Ellen MacArthur Foundation, pp. 1–23.

Ellen MacArthur Foundation & Granta Design, 2019. Circularity indicators. An approach to measuring circularity. Methodology.

Esposito, B., Sessa, M.R., Sica, D., Malandrino, O., 2020. Towards circular economy in the agri-food sector. A systematic literature review. Sustainability 12, 7401. https://doi.org/10.3390/SU12187401.

Eurostat, 2021. Circular economy indicators, monitoring framework. [WWW Document]. European Commission. URL https://ec.europa.eu/eurostat/web/circular-economy/indicators.

Franco, N.G., Almeida, M.F.L., Calili, R.F., 2021. A strategic measurement framework to monitor and evaluate circularity performance in organizations from a transition perspective. Sustain. Prod. Consum. 27, 1165–1182. https://doi.org/10.1016/j.spc.2021.02.017.
Galatti, L.G., Baruque-Ramos, J., 2022. Circular economy indicators for measuring social innovation in the Brazilian textile and fashion industry. J. Clean. Prod. 363, 132485. https://doi.org/10.1016/j.jclepro.2022.132485.
Geng, Y., Doberstein, B., 2008. Developing the circular economy in China: challenges and opportunities for achieving "leapfrog development". Int. J. Sustain. Dev. World Ecol. 15, 231–239. https://doi.org/10.3843/SusDev.15.3:6.
Hanuláková, E., Daňo, F., Kukura, M., 2021. Transition of business companies to circular economy in Slovakia. Entrep. Sustain. Issues 9, 204–220. https://doi.org/10.9770/jesi.2021.9.1(12).
Hofstetter, J.S., De Marchi, V., Sarkis, J., Govindan, K., Klassen, R., Ometto, A.R., Spraul, K.S., Bocken, N., Ashton, W.S., Sharma, S., Jaeger-Erben, M., Jensen, C., Dewick, P., Schröder, P., Sinkovics, N., Ibrahim, S.E., Fiske, L., Goerzen, A., Vazquez-Brust, D., 2021. From sustainable global value chains to circular economy—different silos, different perspectives, but many opportunities to build bridges. Circ. Econ. Sustain. https://doi.org/10.1007/s43615-021-00015-2.
Honarvar, S.M.H., Golabchi, M., Ledari, M.B., 2022. Building circularity as a measure of sustainability in the old and modern architecture: a case study of architecture development in the hot and dry climate. Energy Build. 275, 112469. https://doi.org/10.1016/j.enbuild.2022.112469.
Ibáñez-Forés, V., Martínez-Sánchez, V., Valls-Val, K., Bovea, M.D., 2022. Sustainability reports as a tool for measuring and monitoring the transition towards the circular economy of organisations: proposal of indicators and metrics. J. Environ. Manag. 320. https://doi.org/10.1016/j.jenvman.2022.115784.
Inedit, 2020. Self-assess. [WWW Document]. Inedit Innova. URL https://circular.ineditinnova.com/index/es.
Khadim, N., Agliata, R., Marino, A., Thaheem, M.J., Mollo, L., 2022. Critical review of nano and micro-level building circularity indicators and frameworks. J. Clean. Prod. 357, 131859. https://doi.org/10.1016/j.jclepro.2022.131859.
Koszewska, M., Bielecki, M., 2020. How to make furniture industry more circular? The role of component standardisation in ready-to-assemble furniture. Entrep. Sustain. Issues 7, 1688–1707. https://doi.org/10.9770/jesi.2020.7.3(17).
Kovačič Lukman, R., Brglez, K., Krajnc, D., 2022. A conceptual model for measuring a circular economy of seaports: a case study on Antwerp and Koper ports. Sustainability 14, 3467. https://doi.org/10.3390/su14063467.
Kravchenko, M., Pigosso, D.C., McAloone, T.C., 2019. Towards the ex-ante sustainability screening of circular economy initiatives in manufacturing companies: consolidation of leading sustainability-related performance indicators. J. Clean. Prod. 241, 118318. https://doi.org/10.1016/j.jclepro.2019.118318.
Kristensen, H.S., Mosgaard, M.A., 2020. A review of micro level indicators for a circular economy – moving away from the three dimensions of sustainability? J. Clean. Prod. 243, 118531. https://doi.org/10.1016/j.jclepro.2019.118531.
Lindgreen, E.R., Salomone, R., Reyes, T., 2020. A critical review of academic approaches, methods and tools to assess circular economy at the micro level. Sustainability 12, 4973. https://doi.org/10.3390/su12124973.
Maranesi, C., De Giovanni, P., 2020. Modern circular economy: corporate strategy, supply chain, and industrial symbiosis. Sustainability 12, 1–25. https://doi.org/10.3390/su12229383.
Marino, A., Pariso, P., 2021. The transition towards to the circular economy: European SMEs' trajectories. Entrep. Sustain. Issues 8, 431–455. https://doi.org/10.9770/jesi.2021.8.4(26).
Martinetti, I., Havas, J., 2021. Measuring circularity at the corporate level. Field Actions Sci. Rep., 62–67. https://journals.openedition.org/factsreports/6645.
MATChE, 2021. Making the transition to Circular Economy. [WWW Document]. Technical University of Denmark. URL https://www.matche.dk/.
Mazzoni, F., 2020. Circular economy and eco-innovation in Italian industrial clusters. Best practices from Prato textile cluster. Insights Reg. Dev. 2, 661–676. https://doi.org/10.9770/ird.2020.2.3(4).
MCI, 2017. Material Circularity Indicator. [WWW Document]. Ellen MacArthur Foundation. URL https://www.ellenmacarthurfoundation.org/resources/apply/material-circularity-indicator.
Moraga, G., Huysveld, S., Mathieux, F., Blengini, G.A., Alaerts, L., Van Acker, K., de Meester, S., Dewulf, J., 2019. Circular economy indicators: what do they measure? Resour. Conserv. Recycl. 146, 452–461. https://doi.org/10.1016/j.resconrec.2019.03.045.
Negri, M., Neri, A., Cagno, E., Monfardini, G., 2021. Circular economy performance measurement in manufacturing firms: a systematic literature review with insights for small and medium enterprises and new adopters. Sustainability 13, 9049. https://doi.org/10.3390/su13169049.
ÖKOBAUDAT, 2020. Informationsportal Nachhaltiges Bauen. [WWW Document]. Bundesministerium für Wohnen, Stadtentwicklung and Bauwesen. URL https://www.oekobaudat.de/.
Pigosso, D.C.A., McAloone, T.C., 2021. Making the transition to a circular economy within manufacturing companies: the development and implementation of a self-assessment readiness tool. Sustain. Prod. Consum. https://doi.org/10.1016/j.spc.2021.05.011.
Rincón-Moreno, J., Ormazábal, M., Álvarez, M.J., Jaca, C., 2021. Advancing circular economy performance indicators and their application in Spanish companies. J. Clean. Prod. 279, 123605. https://doi.org/10.1016/j.jclepro.2020.123605.
Rocchi, L., Paolotti, L., Cortina, C., Fagioli, F.F., Boggia, A., 2021. Measuring circularity: an application of modified Material Circularity Indicator to agricultural systems. Agric. Food Econ. 9, 1–13. https://doi.org/10.1186/s40100-021-00182-8.
Rossi, E., Bertassini, A.C., Ferreira, C.dos S., Neves do Amaral, W.A., Ometto, A.R., 2020. Circular economy indicators for organizations considering sustainability and business models: plastic, textile and electro-electronic cases. J. Clean. Prod. 247, 119137. https://doi.org/10.1016/j.jclepro.2019.119137.
Rubel, H., zum Felde, A.M., Oltmanns, J., Lanfer, C., Bayer, L., 2020. Circelligence by Boston Consulting Group (BCG). [WWW Document]. URL https://www.bcg.com/capabilities/social-impact-sustainability/circular-economy-circelligence.
Sacco, P., Vinante, C., Borgianni, Y., Orzes, G., 2021. Circular economy at the firm level: a new tool for assessing maturity and circularity. Sustainability 13, 5288. https://doi.org/10.3390/su13095288.
Saidani, M., Yannou, B., Leroy, Y., Cluzel, F., Kendall, A., 2019. A taxonomy of circular economy indicators. J. Clean. Prod. 207, 542–559. https://doi.org/10.1016/j.jclepro.2018.10.014.
Sala, S., Farioli, F., Zamagni, A., 2013. Progress in sustainability science: lessons learnt from current methodologies for sustainability assessment: part 1. Int. J. Life Cycle Assess. 18, 1653–1672. https://doi.org/10.1007/s11367-012-0508-6.
Sassanelli, C., Rosa, P., Rocca, R., Terzi, S., 2019. Circular economy performance assessment methods: a systematic literature review. J. Clean. Prod. 229, 440–453. https://doi.org/10.1016/j.jclepro.2019.05.019.
Schroeder, P., Anggraeni, K., Weber, U., 2019. The relevance of circular economy practices to the Sustainable Development Goals. J. Ind. Ecol. 23, 77–95. https://doi.org/10.1111/jiec.12732.
Schulz-Mönninghoff, M., Neidhardt, M., Niero, M., 2023. What is the contribution of different business processes to material circularity at company-level? A case study for electric vehicle batteries. J. Clean. Prod. 382, 135232. https://doi.org/10.1016/j.jclepro.2022.135232.
Silvestri, C., Silvestri, L., Piccarozzi, M., Ruggieri, A., 2022. Toward a framework for selecting indicators of measuring sustainability and circular economy in the agri-food sector: a systematic literature review. [WWW Document]. International Journal of Life Cycle Assessment. Springer, Berlin Heidelberg. URL https://doi.org/10.1007/s11367-022-02032-1.
Smol, M., Kulczycka, J., Avdiushchenko, A., 2017. Circular economy indicators in relation to eco-innovation in European regions. Clean Techn. Environ. Policy 19, 669–678. https://doi.org/10.1007/s10098-016-1323-8.
Sucozhañay, G., Vidal, I., Vanegas, P., 2022. Towards a model for analyzing the circular economy in Ecuadorian companies: a conceptual framework. Sustainability 14. https://doi.org/10.3390/su14074016.
Tokazhanov, G., Galiyev, O., Lukyanenko, A., Nauyryzbay, A., Ismagulov, R., Durdyev, S., Turkyilmaz, A., Karaca, F., 2022. Circularity assessment tool development for construction projects in emerging economies. J. Clean. Prod. 362, 132293. https://doi.org/10.1016/j.jclepro.2022.132293.
Trollman, H., Colwill, J., Jagtap, S., 2021. A circularity indicator tool for measuring the ecological embeddedness of manufacturing. Sustainability 13, 8773. https://doi.org/10.3390/su13168773.
United Nations, 2015. Transforming Our World: The 2030 Agenda for Sustainable Development.
Urain, I., Eguren, J.A., Justel, D., 2022. Development and validation of a tool for the integration of the circular economy in industrial companies: case study of 30 companies. J. Clean. Prod. 370, 133318. https://doi.org/10.1016/j.jclepro.2022.133318.
Valls-Val, K., Ibáñez-Forés, V., Bovea, M.D., 2022. How can organisations measure their level of circularity? A review of available tools. J. Clean. Prod. 354, 131679. https://doi.org/10.1016/j.jclepro.2022.131679.
Vayona, A., Demetriou, G., 2020. Towards an operating model for attribution in circular economy. Proc. - 16th Annu. Int. Conf. Distrib. Comput. Sens. Syst. DCOSS 2020, pp. 490–495 https://doi.org/10.1109/DCOSS49796.2020.00082.
Verstraeten-Jochemsen, J., Baars, N., von Daniels, C., 2020. Circular Metrics for Business. Finding Opportunities in the Circular Economy.
Vinante, C., Sacco, P., Orzes, G., Borgianni, Y., 2021. Circular economy metrics: literature review and company-level classification framework. J. Clean. Prod. 288, 125090. https://doi.org/10.1016/j.jclepro.2020.125090.
XP X30-901, 2018. XP X30-901. Circular Economy - Circular Economy Project Management System - Requirements And Guidelines. AFNOR.
Yuan, Z., Bi, J., Moriguichi, Y., 2006. The circular economy: a new development strategy in China. J. Ind. Ecol. 10, 4–8. https://doi.org/10.1162/108819806775545321.