A Study on Assessing Circular Economic Practices in the Construction Sector

Mona Noreng and Anandasivakumar Ekambaram
SINTEF, Trondheim, Norway

Mona.Noreng@sintef.no
siva@sintef.no

Abstract: Circular economic practices are encouraged in several sectors, including the construction sector. These practices and related performances are assessed by using indicators. In general, indicators play a significant role in measuring performance / effect of actions and operations, which can then lead to devise plans to improve the performance in the future. This paper looks at small and medium-sized enterprises (SMEs) in the construction sector. In this context, indicators can play a role in supporting a systematic understanding of how circular economy practices are perceived and adopted among SMEs in the construction sector. In this study a set of indicators from an established framework is applied with modifications and evaluated. Since this study is connected to a project, the indicators are categorized to fit the project's context, and their relevance is evaluated based on input from representatives from the SMEs who participated in this study. By ranking a set of indicators, we gain insight into which aspects of circular economy (which indicators) are currently perceived as most important or applicable. This insight can help to prioritize areas for further investigation and practical application within the project. This paper is based on a part of a technology acceptance study for circular economy (CE). It focuses on the development and categorization of indicators to evaluate circularity mechanisms (CM), recycling techniques (RT) and technology knowledge (TK) within the SMEs in the construction sector. Quantitative method was applied in this study. In this regard, a questionnaire was used to obtain data from potential respondents. The findings reveal, among other things, that indicators related to organizational and strategic drivers, particularly handling human resource, social circularity, and policy & regulation adoption, are perceived as the most relevant and/or consistently understood. These results suggest that SMEs demonstrate relatively high maturity or a strong degree of prioritization regarding general / overall organizational awareness, strategic alignment, and stakeholder engagement with CE principles.

Keywords: Circular economy, Indicator, Construction sector, Small and medium sized enterprises (SMEs)

1. Introduction

This paper focuses on the development and categorization of indicators to evaluate circularity mechanisms (CM), recycling techniques (RT) and technology knowledge (TK) within small and medium-sized enterprises (SMEs) in the construction sector.

According to OECD/DAC an indicator is a: “Quantitative or qualitative factor or variable of interest, related to the intervention and its results, or to the context in which an intervention takes place” (OECD, 2022). Indicators play a significant role in measuring performance/effect of actions and operations, which can then lead to devise plans to improve the performance. Karlsen (2023, page 59) mentions that “measurable indicators […] are used to track progress towards achieving a particular goal or objective”. Referring to previous studies, Martin et al. (2024) emphasize the important contribution of robust indicators to circular economy (CE) in assessing circularity of materials, supply chains and organizations. Using indicators is well-suited to measure topics such as CM, RT and TK, as the indicators provide a practical way to identify and structure relevant aspects of the topics. By breaking down complex topics into measurable components, indicators support a systematic understanding of how circular economy practices are perceived and potentially adopted among SMEs in the construction sector. By ranking a set of indicators, we gain insight into which aspects of circular economy (which indicator) are currently perceived as most important or applicable, and also, helping to prioritize areas for further investigation and practical application within the project.

In this study, a set of indicators from an established framework (Jayakodi et al., 2024) is adopted with modifications. The indicators are categorized to fit the project's context, and their relevance is evaluated based on input from the representatives (respondents) from SMEs who participated in this study. The categorization of indicators is further detailed in the next chapter. This paper is connected to a project called “SUM4Re” (https://sum4re.eu/), funded by the European Commission.

2. Categorization of Indicators

Jayakodi et al. (2024) conducted literature review to identify CE assessment indicators specific to main contractor organisations. Their study covered both the construction project and organization level and identified 18 project-level indicators and 20 organisation-level indicators, with 16 indicators overlapping both levels.

The study on which this paper is based, focuses on SMEs in the construction sector and has therefore limited its scope to the indicators identified by Jayakodi et al. (2024) from construction-specific sources. The indicators from the framework (Jayakodi et al., 2024) were reorganized to better align with the context of this study, which focuses on SMEs in the construction sector. Since the participating companies in this research are active construction SMEs, the selected indicators were considered more relevant and accessible for the target respondents in our study.

To structure the data, we have divided the indicators into the following categories:

- Circularity Mechanisms (CM) – Indicators related to practices and processes that enable the reuse, recycling, and efficient management of resources to minimize waste and close material loops within construction projects
- Recycling Techniques (RT) – Indicators related to specific methods and technologies applied to facilitate material recovery, reuse, and reduction of construction and demolition waste.
- Technology Knowledge (TK) – Indicators related to the degree to which organizations adopt, understand, and innovate with digital and technical solutions to support circular economy goals.

In addition to these three categories, a fourth category, Organizational & Strategic Drivers (OSD), was added as a necessary expansion to capture indicators related to framework conditions, human resources, and strategic choices. This aligns with previous findings in the circular economy literature, which point to a significant overlap between project-level and organizational-level indicators (Jayakodi et al., 2024) and emphasize that organizational support, collaboration or regulatory frameworks are often requirements for implementing circular initiatives (Ali et al., 2024; Klein et al., 2020).

- Organizational & Strategic Drivers (OSD) – Indicators related to internal capabilities, policies, stakeholder engagement, and strategic initiatives that guide and support the implementation of circular economy principles at the organizational level.

The indicators are placed in different categories as shown in Table 1. The different categories are colour-coded to visually distinguish between them, making it easier to interpret the distribution and thematic focus of the indicators. Some indicators can represent more than one category. In these cases, the indicators are listed under both, with a notation indicating which category is considered the most relevant ("primary") and which category it also can be relevant for ("secondary"). Each indicator is assigned the colour of its primary category.

Table 1: Categorization of indicators

Circularity Mechanisms	Recycling Techniques	Technology Knowledge	Organizational & Strategic Drivers
Managing Supply Chain (primary)	Circular Economy Driven Building Design (primary)	Adoption of Technologies	Handling Human Resource
Waste Circularity (primary)	Circular economy Driven Building Construction (primary)	Circular economy-driven innovations	Social Circularity
Managing logistics	Waste Circularity (secondary)	Circular Economy Driven Building Design (Secondary)	Circular economy-driven policies and regulations adoption
Land circularity	Material Circularity (secondary)		Circular economy-driven Stakeholder collaboration and management
Material Circularity (primary)	Water Circularity (secondary)		Economic Circularity
Water Circularity (primary)			Circular Economy Services (primary)
Emission Circularity			Managing Supply Chain (secondary)
Energy Circularity			
Circular Economy Services (secondary)			
Circular economy Driven Building Construction (secondary)			

Several indicators could arguably fit within both the CM and OSD categories, as they encompass broad aspects of circularity mechanisms and Organizational & Strategic Drivers. However, the categorization presented here reflects our assessment of the most appropriate and representative placement for each indicator.

A brief description of the 18 indicators from Table 1 are presented in Table 2. Table 2 also contains dimensions that are associated with each of the indicators. The description and the dimensions can be considered to concretize / operationalize the indicators in a given context.

Table 2: Description and dimensions of indicators (Jayakodi et al. 2024)

Indicator	Description	Dimensions
Adoption of Technologies	The degree of adoption of digital technologies to achieve circular economy objectives in your projects / organization.	• Smart devices for staff • Integrated web services to improve the business performance • BIM based construction • AR for reuse and recycle practices • Addictive manufacturing • IoT for construction site controlling • Material passport
Energy circularity	The degree of renewable energy produced on-site or nearby, renewable energy consumption and energy-saving mechanisms to total energy consumption in your projects / organization.	• Total energy consumption • On-site energy generation • Energy from local sources • Renewable energy consumption • Energy saving due to active and passive energy saving mechanisms
Social Circularity	The degree of social value creation due to circular economy implementation in your projects / organization.	• Use of local workforce • Community participation to CE activities • Quality of life of the community • Health assurance of the community • Impact on animal and living species • Community consultation on CE
Circular Economy Driven Building Design	The degree of adoption of circular economy-driven building design concepts to your projects / organization.	• Design for disassembly • Design for maintenance • Design for Recovery • Design for product life extension • Design for remanufacturing • Design for conservation
Circular economy Driven Building Construction	The degree of adoption of circular economy-driven building construction methods/techniques in your projects / organization.	• Prefabricated elements • Modular construction
Material Circularity	The degree of material from cyclical sources, locally sourced, and rapidly renewable materials to the total amount of materials used in your projects / organization.	• Total materials • Virgin materials • Reused materials • Recycled materials • Rapidly renewable materials • Locally sourced materials • Bio-based materials • Reusable materials • Recyclable materials • Hazardous materials • Non-hazardous materials
Managing logistics	the degree of adoption of circular economy in the logistics management process in your projects / organization.	• Availability waste treatment infrastructure • Appropriate waste treatment infrastructure • Transportation channels for reverse logistics • Organization own waste treatment infrastructure

Indicator	Description	Dimensions
		• Sustainability mobility initiatives
Economic circularity	the degree of monetary value creation due to circular economy implementation in your projects / organization.	• CE related incomes • CE related expenses • CE project investments
Land circularity	the degree of adaptive re-utilization of land and land conservation to the total area of the land in your projects / organization.	• Adaptive reuse of the land for new purpose • Conservation of the land • Improvement of the land
Emission Circularity	The degree of energy direct and energy indirect greenhouse gas emission reduction to the total emissions in your projects / organization.	• Total greenhouse gases emission • Energy direct greenhouse gases emission • Energy indirect greenhouse gases emission • Emission of ozone depletion substances • Eco friendly fuels
Circular economy-driven innovation	The ability to carry out research and development and innovations to achieve circular economy objectives in your projects / organization.	• Research and development on circular economy • Construction related circular economy innovations
Waste Circularity	The degree of waste goes through the cyclical paths to the total waste generated in your projects / organization.	• Total waste • Waste for landfilling • Waste for incineration • Waste for reuse • Hazardous waste • Non-hazardous waste • Wastewater for reusing • Wastewater for recycling
Handling Human Resource	The ability to strengthen the circular economy skills and knowledge of the workforce in your projects / organization.	• Circular economy related training • Circular economy related skill development programs • Decent work environment • Work satisfaction
Managing Supply Chain	The degree of adoption of circular economy in the supply chain management process in your projects / organization.	• Eco-suppliers Number • Accurate material estimation and procurement • Suppliers to minimize excess packaging • Suppliers to provide small quantity of materials
Circular Economy Services	The degree of providing value-added services for stakeholders engage in your projects / organization.	• Take back products • Sharing economy • Product as a service • Product life extension
Circular economy-driven Stakeholder collaboration and management	the degree of stakeholder collaboration and management to achieve circular economy objectives in your projects / organization.	• Stakeholder meetings • Stakeholder trainings
Water Circularity	The degree of on-site sourced water and cycle-sourced water to the total amount of water consumed in your projects / organization.	• Total water consumption • Reused water • Recycled water • Water saving due to water saving mechanisms • Water efficiency
Circular economy-driven policies and regulations adoption	The extent to which policies and regulations are implemented to promote and support circular economy principles within your projects / organization.	• Environment policies, regulations, and taxation

3. Research Method

The study on which this paper is based, applied a quantitative method: Questionnaire survey. The questionnaire was answered by 66 small and medium-sized construction companies in Europe during the spring of 2025, but not all of the respondents have answered all the questions. The answers per question ranged from 63-66 unique responses. Each question represented one of the indicators, in total 18 questions. The companies were asked to range the indicators on a scale from 1-10 in response to how relevant the indicators are for the company or its projects, 1 corresponds to no alignment within the company/projects and 10 corresponds to the company/projects aligning 100% with the statement.

The survey represents an analysis which gives a snapshot of the current perspective of the SMEs in the construction sector. It gives a picture of how the different indicators in relation to Circularity Mechanisms, Recycling Techniques, Technology Knowledge and Organizational Strategic Drivers are perceived and prioritized at a given point in time and offers an insight into the construction sector's readiness and attitude to CE practices.

4. Results

The results show an average score for the different indicators ranging from 5,67 to 6.54. The indicators with average scores are listed in Table 3. For each indicator, the average score was calculated based on the number of valid responses received. The indicators are colour-coded as described in Chapter 2.

To support the analysis of response variation, boxplots were created for each indicator. A boxplot provides a visual summary of the distribution of responses. The boxplot which can be seen in Figure 1 helps identify indicators with high consistency, those with narrow boxes, short whiskers, and few outliers, and those with greater variation, which may reflect differing levels of understanding or relevance among respondents. The central line within each box represents the median, while the triangle indicates the average score.

An analysis of all the results per indicator shows that there is a response variation between indicators both in terms of average score and how consistent respondents have been.

The average scores of the indicators ranged from 5.67 to 6.54, allowing for a ranking of the indicators based on perceived relevance among the participating SMEs. The three indicators with the highest average scores, Handling Human Resource (6.54), Social Circularity (6.52), and Circular Economy–Driven Policies and Regulations Adoption (6.51), are all categorized under Organizational & Strategic Drivers (OSD). Indicators within the Technology Knowledge (TK) category, such as Adoption of Technologies (6.37) and Circular Economy Driven Innovations (6.32), are positioned in the upper-middle range. Indicators from the Circularity Mechanisms (CM) category are more widely distributed, with Managing Supply Chain (6.49) among the higher scores, while Energy Circularity (5.67) and Emission Circularity (5.89) are among the lowest. Recycling Techniques (RT) indicators, such as Circular Economy Driven Building Design (6.03) Circular Economy Driven Building Construction (5.98), are generally found in the lower half of the ranking. This distribution illustrates how average scores can be used to rank indicators across categories and identify which indicators are currently perceived as more or less relevant by the respondents.

Table 3: The indicators ranged from highest to lowest average score

Average Score	Indicator
6,54	Handling Human Resource
6,52	Social Circularity
6,51	Circular Economy Driven Policies and Regulations Adoption
6,49	Managing Supply Chain
6,37	Adoption of Technologies
6,32	Circular Economy Driven Innovations

6,31	Circular Economy Driven Stakeholder Collaboration and Management
6,26	Waste Circularity
6,14	Managing Logistics
6,13	Land Circularity
6,03	Circular Economy Driven Building Design
6,00	Material Circularity
5,98	Circular Economy Driven Building Construction
5,98	Circular Economy Services
5,92	Water Circularity
5,89	Emission Circularity
5,83	Economic Circularity
5,67	Energy Circularity

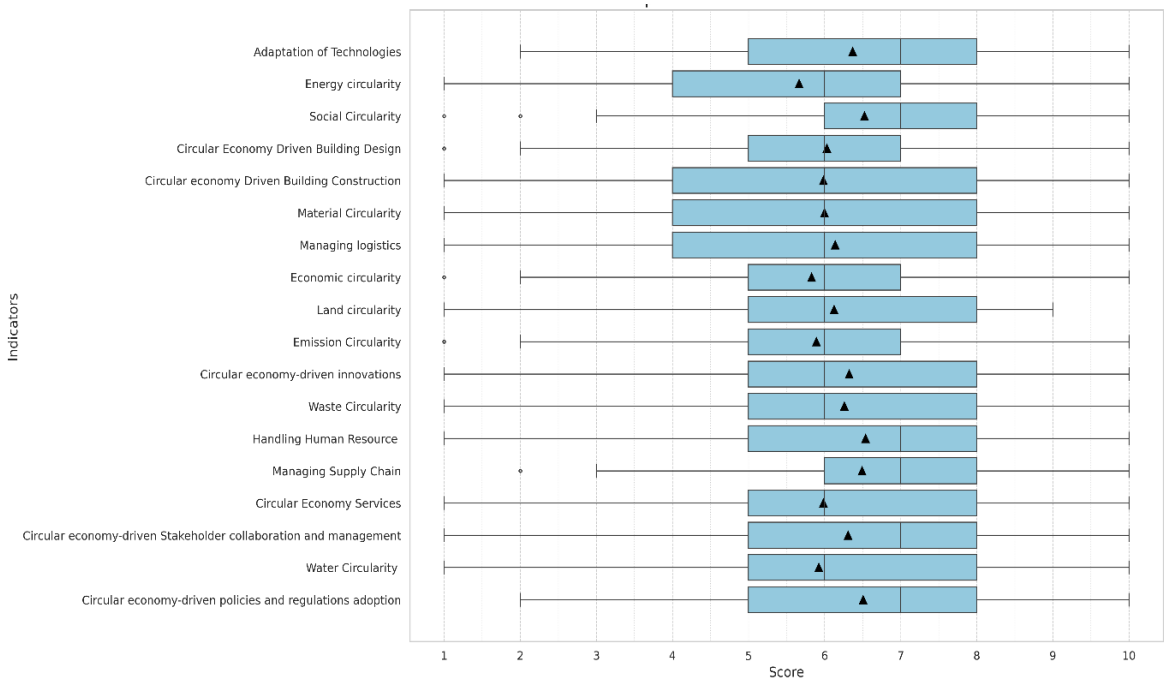

Figure 1: Boxplot of indicator scores

If we look at the boxplot indicators such as Social Circularity, Circular Economy Driven Building Design, Economic Circularity, Emission Circularity, and Managing Supply Chain show relatively tight distributions, suggesting a shared understanding and consistent prioritization among respondents. In contrast, indicators like Circular Economy Driven Building Construction, Material Circularity, and Managing Logistics show wider distributions, indicating greater variation in how these topics are perceived or implemented.

The plot helps identify indicators with high consistency, those with narrow boxes, short whiskers, and few outliers, and those with greater variation, which may reflect differing levels of understanding or relevance among respondents. The central line within each box represents the median, while the triangle indicates the average score.

5. Discussion

Several researchers (Jayakodi et al., 2024; Norell & Sehn, 2024; Demirkesen & Ozorhon, 2017) point out that the construction sector is highly unorganised and fragmented. For that reason, it is important to include a broad range of indicators to gain a good understanding of the CE performance across the sector. A wide set of indicators was therefore included in the survey to get a comprehensive understanding of how different drivers

of circular economy relate to circularity mechanisms, recycling techniques, technology knowledge and organizational strategic drivers.

To establish robust and relevant indicators for these topics, it is necessary to consider multiple factors simultaneously, not just, for example, circularity mechanisms in isolation. It is important to understand why or how a company prioritizes these aspects, as they are closely linked to strategic choices, value chains, and organizational culture. To analyse the results, we examined which indicators the companies said were suitable for their company and projects, and how much agreement there was across the companies for each indicator.

The analysis of each response per indicator shows that there is a variation between indicators both in terms of average score and how consistent respondents have been. If we look at the boxplot (Figure 1), we can see the distribution of responses for each indicator. This boxplot visualization helps identify indicators with high consistency and those with greater variation, which may reflect different levels of understanding or relevance among respondents. As previously mentioned, indicators such as Social Circularity, Circular Economy Driven Building Design, Economic Circularity, Emission Circularity, and Managing Supply Chain show relatively tight distributions, suggesting a shared understanding and consistent prioritization among respondents. In contrast, indicators like Circular Economy Driven Building Construction, Material Circularity, and Managing Logistics show wider, indicating greater variation in how these topics are perceived or implemented.

This variation may reflect differences in experience, maturity, prioritization or relevance across companies. When an indicator shows both high consistency and a high average score, it may suggest that the topic is both well understood and widely prioritized. Conversely, indicators with low average scores and high variation may point to uncertainty, lack of familiarity, or lower perceived relevance.

Based on this interpretation of the data, it can be said that the industry appears to be more mature or have a stronger degree on prioritization regarding Handling Human Resources and Social Circularity, as they have a higher average score, in relation to Economic Circularity and Energy Circularity, with a low average score.

Interestingly, although Circular Economy Driven Building Design and Circular Economy Driven Building Construction are thematically related, they show different patterns in the data. The design indicator shows higher consistency and a higher average score, while the construction indicator is among those with the most variation. This may reflect the fact that design-related circular practices, such as material selection or design for disassembly, are more familiar and easier to conceptualize, whereas construction practices require more complex implementation, coordination, and resources. It may also indicate that respondents are more involved in planning and design phases than in on-site construction activities.

By collecting information from SMEs and using indicators derived from construction-specific literature, this study provides insights into which indicators are directly relevant for evaluating current practices, barriers, and technology acceptance in construction companies that operate close to projects where CE solutions are implemented in practice.

In this study, a 1–10 scale was used to assess the perceived relevance of each indicator for the participating SMEs. This approach allows for a more nuanced understanding of how circular economy practices are perceived and prioritized across different companies and contexts. Compared to binary or ternary systems (e.g., yes/no or yes/partly/no), which are often used in CE assessment tools, the 1–10 scale provides a spectrum of responses. While binary and ternary systems can indicate whether a practice is present or partially implemented, they do not capture the degree or maturity or prioritization of implementation. In contrast, a 1–10 scale enables respondents to express gradations in relevance and implementation, allowing for the definition of a CE level rather than a simple presence or absence. This also facilitates statistical analysis of variation, which can be essential for understanding CE practices and readiness.

The three indicators with the highest scores suggests that small and medium-sized construction companies are aware of the importance of strengthening the circular economy skills and knowledge of the workforce (Handling Human Resource), acknowledge the social value creation due to circular economy implementation in their projects and organisation (Social Circularity), and believe it is important to implement policies and regulations to promote and support circular economy principles (Policy & Regulation Adoption). This result can be seen in connection with other studies: The importance of focusing on policies and regulations is also pointed out by other researchers. Bilal et al. (2020) present several barriers to CE and say that “lack of environmental regulations and laws is driving the rest of the barriers to the circular economy” (page 1). It is interesting to note that one of those rest of the barriers is lack of proper training and development programs for the members of supply chain. The study conducted by Martin et al. (2024) also mention that inefficient / lack of policies and

regulations is one of the major barriers to promoting CE principles. When it comes to lack of knowledge as a barrier, the authors, by referring to AlJaber et al. (2023), say "When knowledge is limited, stakeholders may fail to see the possible economic and environmental benefits, thus missing the opportunity to create more circular and lucrative results" (page 474). Martin et al. (2024) then point out the importance of ensuring proper strategies that support creating awareness, reflection, learning and development of new knowledge. Ayaz & Tatoglu (2024) highlight the role of social value creation in operational and strategic landscape of SMEs within the context of CE. According to the authors, the insight obtained from their study "provides a departure from conventional notions, signaling that SMEs can concurrently pursue economic prosperity, social responsibility, and environmental stewardship" (page 13). Le et al. (2024) mention the importance as well as the process of integrating CE into corporate strategies of SMEs to deal with environmental and social issues effectively.

The fact that several indicators categorized as Organizational & Strategic Drivers have a higher average score than many of the other indicators suggests that the organisations prioritize or are more mature in terms of internal awareness, strategic alignment, and stakeholder engagement than in the practical implementation of technical and practical circular economy solutions. This is also supported by the score of the indicators in the category Recycling Techniques, which are the category with the lowest acquired average score across the categories, and by the results from the lowest scoring indicator over all, Energy circularity, that suggest that companies make limited use of renewable energy sources and implement energy-saving measures to only a limited extent in their operations.

The relatively high average score for the indicators relevant to Technology Knowledge suggests that the organisations have adopted digital technologies to achieve circular economy objectives and have, to some extent, the ability to carry out research, development and innovations to achieve circular economy objectives. The results indicate that while technology is not yet fully embedded (average scores of 6.32 and 6.37 out of 10), there appears to be an interest and a perceived relevance based on the survey responses, which may serve as a positive indicator for future implementation.

The low score in the category of Recycling Techniques, as mentioned above, might suggest that CE driven building design concepts and building construction methods and techniques are not that well implemented in the SMEs. These findings highlight a potential gap between strategic intent and operational execution, possibly indicating a barrier to technology and circularity adoption. It may also reflect a lack of access to knowledge, tools, or incentives to implement such techniques in practice.

The category Circularity Mechanisms covers a broader range of the CE related practices and includes both some of the lowest scoring indicators but also some high scoring indicators. This variation is expected, given the diversity of topics within the category. The highest scoring indicator in this category, Managing Supply Chain, suggests that CE in the supply chain is perceived as both relevant and actionable. The lowest scoring indicator in the survey was Energy circularity, that suggest that companies make limited use of renewable energy sources and implement energy-saving measures to only a limited extent in their operations. This may reflect structural limitations, lack of incentives, or a perception that energy-related decisions are outside their immediate control.

Even though the average score of the 18 indicators only ranges from 5.67 to 6,54 it does not necessary mean that it is a lack of meaningful variation. It might suggest a general agreement amongst the respondents, and that the indicators are from moderately to highly relevant or are only partially implemented in the companies and their projects. To extract more information from the survey response, it may also be useful to consider several factors, for instance, boxplots that show the variation and spread in the data. For example, indicators with both high average scores and low variation (e.g., Social Circularity) suggest strong consensus and perceived importance, while indicators with similar averages but high variation (e.g., Material Circularity) may indicate uncertainty or differing levels of understanding. The median values, which mostly fall between 6 and 7, further support the interpretation that the typical assessment aligns closely with the average, reinforcing the reliability of the findings.

The indicators analysed in this study also provided a foundation for the development of future tools for assessing and managing circular economy practices in the construction sector. The most relevant indicators, based on both average scores and response consistency, can serve as core elements in CE assessment tools tailored to SMEs. Such tools could support companies in conducting self-assessments, identifying areas for improvement, and tracking progress over time. Additionally, the indicators can be used as a framework for training, maturity assessments, and as a basis for policy development and support schemes, particularly in relation to technology implementation and capacity building.

6. Concluding Remarks

This study identified and evaluated 18 circular economy indicators relevant to small and medium-sized enterprises in the construction sector, based on an established framework and survey data. The findings reveal that indicators related to organizational and strategic drivers, particularly Handling Human Resource, Social Circularity, and Policy & Regulation Adoption, are perceived as the most relevant and/or consistently understood. These results suggest that SMEs demonstrate relatively high maturity or a strong degree of prioritization regarding general/overall organizational awareness, strategic alignment, and stakeholder engagement with CE principles.

Indicators within the Technology Knowledge category, such as Adoption of Technologies and CE-driven Innovations, also scored relatively high, indicating a certain degree of interest and partial implementation of digital tools and innovation to support CE goals.

In contrast, indicators related to Recycling Techniques, such as CE Driven Building Construction, and indicators related to Circularity Mechanisms, such as Energy Circularity, Emission Circularity and Water Circularity received lower average scores and a some of them also showed a greater variation in responses. These findings highlight a potential gap between strategic intent and operational execution. This may also point to areas where companies lack the tools, knowledge, or incentives to implement CE practices effectively.

Therefore, while the high-scoring indicators can serve as a foundation for CE maturity models and assessment tools, the lower-scoring indicators represent critical areas for future focus. Targeted support, such as training, policy incentives, and practical tools, should be directed toward these areas to help bridge the gap between strategic intent and implementation. Doing so will strengthen the sector's overall capacity to adopt circular economy practices in a meaningful and scalable way.

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Ethics declaration: No need for ethical clearance.

AI declaration: An AI tool was used to finetune the language to ensure a better reading experience.

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