# Recommendations for designing a circularity assessment framework

Erwan de Bantel, Ghada Bouillass, Marija Jankovic, Bernard Yannou

# RECOMMENDATIONS FOR DESIGNING A CIRCULARITY ASSESSMENT FRAMEWORK

**Erwan de Bantel[1], Ghada Bouillass[1], Marija Jankovic[1], Bernard Yannou[1]**
[1] Laboratoire Genie Industriel, CentraleSupélec, Université Paris-Saclay, France.
Contact: erwan.de-bantel@centralesupelec.fr

***Abstract:***

The uptake of digital solutions can significantly foster the transition towards circular and sustainable value chains and territories. Such solutions can help to effectively assess the circularity performance while ensuring the lowest environmental, economic, and social impacts. Thus, it provides decision-makers of considered organisations, i.e., both industries and territories, with a holistic vision of the actions they are willing to adopt. The newly proposed Circular Digital Cockpit (CDC) intends to enable the development of these types of digital solutions. Indeed, this conceptual framework aims to provide a systematic approach for measuring circularity, facilitating well-informed decision-making, and targeted interventions.

The present paper proposes a comparative analysis of five industrial and territorial organisations to underline variants and invariants in their circular economy (CE) capabilities and the motivations driving such initiatives. Such a comparative study relies on a content analysis of sustainability and CE-related documents or reports, as well as results from four workshops conducted with five organisations.
First, in response to the different types of CE capabilities observed in the organisations, a two-tiered categorisation of CDC beneficiaries is suggested: CE "operators" and "facilitators". This categorisation is likely to influence the design of the CDC framework by highlighting the need to introduce a multi-scale perspective within the design of the CDC. Indeed, both facilitators and operators are interested in micro-level CE indicators for self-implementation of CE strategies within their organisations. However, only facilitators are also interested in meso and macro levels, reflecting their added focus on, amongst others, fostering networks and enabling collaboration between stakeholders (although, in some cases, operators can also be interested in meso-level indicators when they are part of eco-industrial parks).
Second, analysing motivational factors for developing CE practices emphasises the importance of regulatory compliance. However, regulations mainly focus on the end-of-life and waste treatment aspects of CE, especially for public organisations such as local authorities. Two other main motivational factors are described: economic incentives (competitors' pressure, market share, profitability gains, etc.) and environmental objectives (compulsory and voluntary commitments). Therefore, the ambition behind circularity strategies is not solely centred on inherent circularity. There is a need to consider circularity as a means rather than an objective. These considerations advocate adopting a multi-criteria approach in the CDC framework, combining circularity metrics with economic and environmental performances. Moreover, this introduction of the concept of performance assessment raises the question of positioning results on a performance scale. Several options are possible through relative performance assessment (vs. past performance, vs. performance of similar players, etc.) and absolute performance assessment (vs. national, international, scientific framework, etc.). For the latter, it is possible to refer to a framework such as the planetary boundaries, which would also enable setting science-based objectives (cf. absolute environmental sustainability assessment methodology).

To enrich the CDC conceptual framework, the categorisation of organisations needs to be further studied (beyond "operators" and "facilitators"), possibly through a persona-based

design approach. Furthermore, the willingness and ability of the different types of organisations to adopt absolute sustainability approaches will be investigated through an interview campaign.

*Key words: Circular economy; Performance indicators; Sustainability; Planetary Boundaries; Digital platform*

---

# 1 INTRODUCTION

## *1.1.* General context

With the advent of regulatory frameworks and initiatives promoting circular economy strategies at both European and national levels, there is a burgeoning interest in the subject. For example, at the European level the "new Circular Economy Action Plan For a cleaner and more competitive Europe" [1], part of the European Green Deal, recommends several circularity indicators and includes the development of a Digital Product Passport (DPP) to standardise information regarding the lifecycle of products. This regulation aims to achieve a triple objective: (1) contribute to reaching the 2050 neutrality target, (2) create sustainable growth and jobs, and (3) reduce pressure on natural resources as well as biodiversity. Additionally, the European taxonomy incorporates the transition to a circular economy as one of its six criteria for an economic activity to be deemed environmentally sustainable. The first list of circular economy technical criteria has been published for the construction sector [2], with plans for similar specifications in other sectors. Developed methodologies addressing these frameworks, such as the Circular Economy Action Plan [1], should not merely measure circularity but also provide actionable insights and prioritise improvement areas across diverse industries.

However, the lack of standardised approaches for assessing circularity indicators and prioritising corresponding objectives in industrial value chains and territories [4] poses a significant challenge. The recently published Circular Digital Cockpit (CDC) framework [4], seeks to bridge this gap by establishing a systematic approach to measure circularity. It aims to enable well-informed decision-making and targeted interventions on value chains to improve circularity and sustainability performance. Indeed, the CDC framework methodology ranges "from the diagnosis of the key activities of an industrial company or a territory to the implementation of a digital platform for the management and improvement of circularity by all the actors in the organisation concerned" [4]. This paper aims to provide recommendations for designing this circularity assessment framework, which is still in its early conceptual stages.

## *1.2.* Research clarification

The CDC framework aims to apply to various industrial and territorial contexts to enable an effective transition towards circular and sustainable value chains. Several challenges can arise from the differences between these contexts, such as the nature of stakeholders and their roles, the perimeter of action, and the scale to be addressed (i.e. micro, meso, and macro) [5]. To address these challenges, variants and invariants in current organisational patterns that are put in place to increase circularity must be identified and characterised. Critical inputs for the CDC framework design will then be derived from this analysis to permit adequate categorisation and parametrisation.

Hence, the present paper investigates variants and invariants in circular economy capabilities and motivations across different public and private organisations through a comparative analysis of industrial and territorial use cases. The aim is to contribute to a more precise identification of generic or beneficiary-specific CDC features, allowing an effective framework design. This paper, therefore, delves into the following question: How can the design of the CDC framework be influenced by the variants and invariants observed in the circular economy capabilities and motivations of industrials and territorial organisations?

# 2 MATERIALS AND METHODS

Our comparative analysis includes five use cases representing potential beneficiaries of the CDC framework: two cases focus on industrial challenges with the remanufacturing of heavy-duty and off-

road (HDOR) vehicles by an original equipment manufacturer (OEM) - Manitou Group - and the circularity of a medical systems OEM - GE HealthCare. The three other use cases focus on territorial challenges with the management of bio-waste collection and treatment (SIOM), the reuse of construction site waste at a territorial level (CSTB), and the circular economy strategy of a local authority (Communauté d'Agglomération Paris-Saclay).

To conduct this descriptive study, qualitative data was collected from:

- Documents shared by the different organisations
- Four workshops held with the different entities during the initial development of the CDC framework [4];
- 1-hour semi-structured interviews with three PhD students working specifically on three of the five use cases (Manitou Group, GE HealthCare, CSTB);
- ESG/sustainability reports published by the different organisations involved.

# 3 INITIAL INSIGHTS FROM THE FIVE USE CASES

The five organisations constituting the use cases are compared in terms of variants and invariants in their circular economy capabilities, as well as motivations for implementing such practices. Moreover, the main challenges faced by each organisation in improving circularity performance are also studied.

## *3.1.* Circular economy capabilities

All the studied organisations have already developed activities related to circular economy to a greater or lesser extent. Table 1 summarises the various circular economy capabilities of the five organisations.

Table 1. Circular economy capabilities within the five use cases.

| Use cases | Circular economy capabilities |
|---|---|
| *HDOR vehicles OEM* | • *Component remanufacturing:* Machine users send in their faulty components; the OEM repairs them, stocks them, and exchanges them for remanufactured components.<br>• *Machine trading:* Second-hand machines are bought and resold as is.<br>• *Machine refurbishing:* Machines are refurbished entirely and then sold abroad.<br>• *Machine renting:* Long-term rent, short-term rent or rent to rent and then sale of the machines abroad at the end of the rental period – as is or refurbished. |
| *Medical systems OEM* | • *Machine upgrading:* Changing one or more machine parts installed on a customer's premises to adapt to new requirements rather than changing a complete machine. There is also a possibility of upgrading machines remotely through software updates (automatically or on request).<br>• *Machine refurbishing:* Machines are recovered from customers, reconditioned, and resold at a preferential second-hand price.<br>• *Machine extended life:* Machines at the end of their life cycle have some of their components replaced to extend their lifespan on the customer's premises.<br>• *Component harvesting and reuse:* Collecting parts from recovered machines and reusing them with or without repair on other machines (there is a list of harvestable components depending on the machine types).<br>• *Machine maintenance:* A material-saving preventive maintenance policy with connected machines has started being applied. Spare parts are more systematically repaired, and even old working components are replaced during maintenance operations to improve their health and increase the reliability of the sub-assembly.<br>• *Machine leasing:* Machines are available for leasing, not just for sale. |
| *Waste collection and treatment services provider* | • Industrial and household waste collection and treatment activities.<br>• Development of biowaste collection and treatment activities (currently 10% compost, 90% methanation).<br>• Construction of a waste and resale centre.<br>• Heat production through energy recovery from waste. |

| | |
|---|---|
| *Research and innovation centre for the construction industry* | • Creation of environmental labels.<br>• Development of prediction material flow databases and models which allow to:<br>- Characterise building components as well as products, equipment, materials and waste generated by their total or partial dismantling.<br>- Quantify and anticipate material flows associated with changes to a building stock based on this estimate of the material stock. |
| *Local authority* | • Set of circular economy actions developed within a Local Climate Plan (LCP, or PCAET in French) - 26 actions with the following objectives:<br>- Implement an industrial eco-industrial park in the territory;<br>- Develop circular economy in the urban planning and construction sector;<br>- Promote solutions for collecting and recovering bio-waste in the territory;<br>- Promote responsible consumption by residents.<br><br>• Set of circular economy actions developed within a circular economy action plan - 38 actions with the following objectives:<br>- *Governance:* create a circular economy dynamic through an exemplary local authority and the mobilisation of local players;<br>- *Food:* organic, local food is accessible to all and generates little waste;<br>- *Urban planning:* a construction sector that uses fewer primary materials and respects natural environments;<br>- *Economic development:* dedicated support for the territory's economic actors to encourage the emergence of innovative circular economy initiatives;<br>- *Reuse and repair:* encourage citizens to consume better and more sparingly to generate less waste;<br>- *Waste:* a territory that generates less waste and where waste management is optimised and more respectful of the environment.<br><br>• Grants are allocated to companies and associations through calls for projects, experts are recruited, and partnerships are formed (with industry or universities, for example) to ensure the success of circular economy actions. |

Based on Table 1's description of circular economy activities in the five considered case studies, the future CDC beneficiaries can be distinguished into two categories: circular economy operators on the one hand (i.e. HDOR vehicles OEM, Medical systems OEM, waste collection and treatment services provider) and circular economy facilitators on the other hand (i.e. research and innovation centre for the construction industry, local authority). Indeed, the first three organisations can be considered as operators as they are directly involved in developing and implementing circular economy strategies, for example, through part remanufacturing, machine refurbishing, machine reuse or biowaste activity development. They possess the decision-making power to develop and implement circularity practices within their activity scope. On their part, the two last case studies support other stakeholders (e.g. companies, associations, citizens, etc.) in increasing their circularity and sustainable performance by developing methodologies and tools (e.g., materials flow prediction model for the construction industry), providing funding and a network of stakeholders (e.g., granting funds to companies to support the establishment of an eco-industrial park) or through specific public procurement conditions, labelling and certifications. Therefore, facilitators' scope of action is twofold. On the one hand, they can increase circularity and sustainability performance within their own organisation, where they have direct decision-making power as they can act as operators. For example, local authorities explain that they need to highlight their exemplarity to play their role as facilitators (e.g., a local authority plans to renovate the buildings it owns to launch a building renovation policy for residents of the territory). On the other hand, as explained above, facilitators support other stakeholders in increasing their circularity and sustainable performance (e.g., all businesses domiciliated in a local authority's territory).

Thus, to develop a CDC for each of these five case studies, a far greater number of common points are expected within operators on the one hand and facilitators on the other, rather than between these two categories of stakeholders, as they perform distinct roles in the development of circular systems. Moreover, this distinction between operators and facilitators is likely to influence the design of the CDC framework in terms of the circular economy scale to be addressed. Indeed, the CDC's operators are expected to concentrate on a circular economy at the micro level, including products, companies, and

consumers [5], aligning with their focus on self-implementation within their organisations (i.e., operators' activities previously described). In contrast, the CDC's facilitators are expected to encompass, in addition to the micro level, circular economy meso (e.g., eco-industrial parks) and/or macro (city, region, nation and beyond) levels [5] reflecting their added focus on fostering networks and enabling collaboration (i.e., facilitators' activities previously described). This mix of micro and macro levels can be particularly tricky when it comes to ensuring multi-level consistency and reflecting at macro level decisions taken at micro level, and vice versa [6]. This difficulty is particularly present in assessing the impact of a local authority's circular economy action plan. Indeed, such an action plan covers multiple perimeters:

- Local authority as an establishment (owner, employer, purchaser, etc.)
- Local authority through the prism of its administrative powers (waste management, urban planning, economic development, etc.)
- Local authority as a territory (activities of citizens, associations and businesses)

Future research will also have to investigate operational measures implemented to increase circularity performance (materials procurement, production processes, logistics including reverse logistics, etc.).

## *3.2.* Circular economy motivations

Multiple motivations explain the willingness of the five studied organisations to develop circular activities. Motivations to integrate circular economy practices can be linked to achieving better circularity performance, such as inherent circularity [7] for regulatory compliance. In contrast, others consider circularity more as a means of improving economic and/or environmental performance, particularly regarding GHG emissions. These motivations are in line with those listed by the European Union to justify the development of the "Circular Economy Action Plan" and its monitoring framework: environmental protection to reduce GHG emissions, pressure on natural resources and biodiversity together with economic performance to creating sustainable growth and jobs [1].

Regarding the motivations, five main categories were identified based on the five case studies:

Table 2. Circular economy motivations within the five use cases.

| **Motivations** | **Use cases illustrations** |
|---|---|
| *Anticipate/Comply with regulations* | • *HDOR vehicles OEM:* possible extension of VHU 2000/53/EC directive to HDOR vehicles and implications of the CSRD and the European taxonomy for reporting on circularity indicators.<br>• *Medical systems OEM:* implications of the CSRD and the European taxonomy for reporting on circularity indicators.<br>• *Waste collection and treatment services provider:* by French law no. 2020-105 [3], from January 1st 2024, all bio-waste must be sorted at source, with the aim of being recovered, regardless of the volumes of waste produced and the type of waste producer.<br>• *Local authority:* French law no. 2020-105 [3].<br>• *Research and innovation centre for the construction industry:* increasing pressure of ADEME to reuse materials in the construction industry. |
| *Match market demand/Competitive pressure* | • *HDOR vehicles OEM:* competitors have developed multiple circular business offerings.<br>• *Medical systems OEM:* in Europe, at the very least, industrial actors perceive the capacity to provide precise circular economy metrics as a competitive advantage (e.g., specific indicators are required by some invitations to tender).<br>• *Local authority:* other local authorities have developed and are developing circular economy action plans. |
| *Develop economic activity and/or profitability* | • *HDOR vehicles OEM*: gain market share by developing circular models, particularly around second-hand machines and parts.<br>• *Medical systems OEM:* gain market share through an aggressive circular economy model and reduce costs through circular material loops (decrease waste and material sources).<br>• *Local authority:* attract organisations and residents on the territory, create employment, and increase the competitiveness of local companies. |

| | |
|---|---|
| *Technology push* | • *Research and innovation centre for the construction industry:* identify application opportunities for the predictive model developed. |
| *Participate in the fulfilment of environmental commitments (mainly reducing GHG emissions)* | • *HDOR vehicles OEM:* help achieve Science Based Targets initiative (SBTi) [8] GHG emissions reduction objective.<br>• *Medical systems OEM:* help achieve SBTi [8] GHG emissions reduction objective.<br>• *Waste collection and treatment services provider:* optimise the operating model to reduce GHG emissions in line with the commitments communicated to the public.<br>• *Local authority:* part of the Territorial Climate-Air-Energy Plan – PCAET – to reduce GHG emissions. |

This analysis of variants and invariants in motivations for implementing circular economy practices does not lead to the same conclusions as the previous one on circular economy capabilities. Indeed, no substantial differences are observed between circular economy operators and facilitators. Instead, the opposite is true, with a homogeneity in the diversity of motivations (regulatory compliance, economic and environmental performance).

Regulatory factors partly motivate all the studied organisations in their circular economy strategy. Consequently, the CDC framework should contribute to compliance with regulations. Depending on the specific sector of the organisations, these regulatory considerations can involve reporting circular economy indicators, occasionally with performance thresholds (e.g., European CSRD and taxonomy) or even developing new mandatory activities (e.g., bio-waste collection law in France). In some cases, organisations develop their circular economy activities as they anticipate potential future regulations (e.g., the HDOR vehicles industry and the possible extension of the VHU directive). Therefore, a diverse range of sector-specific regulatory modalities can pose a challenge in designing a generic CDC framework.

Economic incentives for implementing circular economy strategies are evident across all the studied organisations. These motivations include defending or gaining market share, especially against competitors already involved in circular economy practices, depending on the industry's maturity. Additionally, organisations can be requested to provide circularity indicators to their clients, investors, or lenders. Furthermore, incentives can also revolve around reducing costs, thereby increasing profit margins. Territorial actors aim to enhance their attractiveness to companies and residents. Thus, the CDC framework should incorporate economic-based indicators to assist beneficiaries in exploring various opportunities for circular business models.

The environmental dimension also plays a significant role in leading motivations of both industrial and territorial organisations. Specifically, circular economy is identified by the organisations studied as a means of achieving GHG emissions reduction targets, aligning with broader climate commitments and plans (e.g., SBTi, PCAET). Two noteworthy points emerge here. The first is that for other environmental impacts (e.g., biodiversity, water, land-use change, etc.), the predominant vision in the case studies appears to be that of the European taxonomy: the “Do No Significant Harm” (DNSH) principle, i.e., making a substantial contribution to at least one environmental objective while doing no significant harm to any other environmental objective [9]. The second critical remark is that, as repeatedly stated in the scientific literature, “a circular system is not always a sustainable system” [10]. Hence, the CDC framework designers will have to look further for this correlation between circularity and sustainability indicators, as recommended by Saidani & al., 2019 [11].

The descriptive analysis of all these motivations indicates a shared interest among both circular economy operators and facilitators in addressing circular, economic and environmental performance (mainly GHG emissions). This triple objective approach mirrors the enhanced “Green Profit Model”, which has been developed in an industrial context and at the circular economy micro level [11]. Indeed, the model aims to provide Pareto optimal solutions to the multi-objective challenge of determining optimal circularity for a given product or set of products to achieve greater economic profit and environmental savings while complying with end-of-life regulations. Therefore, the CDC framework designers should explore the potential of such a model to support decision-making in a multi-criteria context and consider its extension from micro to macro level, especially for facilitator-type beneficiaries.

### *3.3.* First recommendations for the design of the CDC framework regarding its beneficiaries

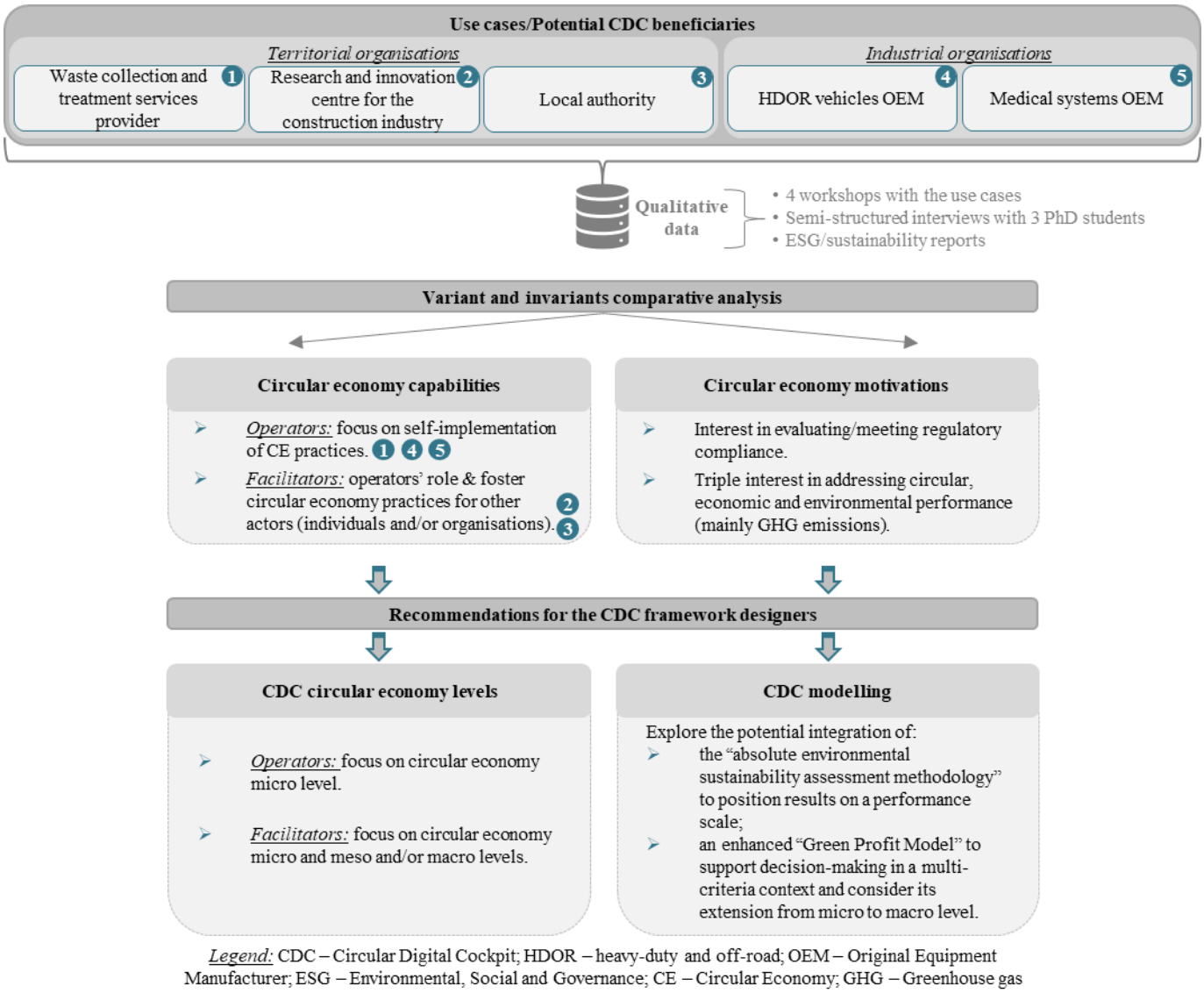


Figure 1. Comparative analysis of five industrial and territorial use cases and first recommendations for the Circular Digital Cockpit framework designers.

To design a generic CDC framework adaptable to the specific needs of different organisations, it is imperative to identify the factors influencing circularity implementation and performance. This paper delves into two key determinants factors of an organisation's circular economy performance: its circular economy capabilities and motivations for adopting such practices.

As depicted in Fig. 1, the comparative analysis of the five use cases identifies distinctive categories of CDC beneficiaries, namely circular economy operators and facilitators, concentrating respectively on the circular economy micro level and, in addition to the micro level, meso and/or macro levels. Therefore, the CDC framework designers need to consider different modelling scales depending on which category the beneficiary is perceived to fall into. Depending on the beneficiaries' type, circular economy micro, meso and/or macro level indicators will have to be calculated. It will have consequences on data collection, processing and visualisation. The scientific literature provides a broad list of circularity indicators, together with their implementation methodologies, classified according to their level (micro, meso, macro) [7]. The simultaneous consideration of several levels of circularity (micro, meso, macro) also raises questions regarding multi-level coherence (e.g., reflecting at a macro level the impact of changes at the micro level and vice versa). Few scientific articles propose solutions to bridge this gap between the different levels [6].

Moreover, further research on the circular economy context of potential CDC beneficiaries is crucial to specify criteria for distinguishing between operators and facilitators. Specifically, there is a need for research on the role that stakeholders can play within a value chain in promoting circular economy practices (scope of action, power, accountability, etc.). The stakeholder value network [12] could be a relevant approach as it has previously been used in a circular economy context with a case study on an eco-industrial park (i.e., circular economy meso level) [13].

Analysing variants and invariants in the motivations for developing a circular economy strategy emphasises the importance of regulatory compliance. These considerations can be sector-specific, so they pose a significant challenge in designing a generic CDC framework. Furthermore, as shown in Fig. 1, the motivations of industrial and territorial organisations to implement circular economy practices involve both a keen interest in inherent circularity and its utilisation as a means of improving economic and environmental performance. Thus, exploring the potential integration of a multi-criteria modelling approach such as the one of the enhanced "Green Profit Model" [11] is a direction that the CDC framework designers could consider. Incorporating such a multi-objective approach will require managing the resultant trade-offs as environmental, circular, and economic perspectives are often not aligned but rather contradictory [10, 14]. Considering circularity as an objective, including in a multi-criteria approach alongside environmental and economic performance, should be questioned. Indeed, as most definitions of circular economy consider that sustainable development is its principal aim [15], why should circularity be regarded as an objective alongside economic, environmental and social performance rather than a means [16]?

# 4 CONCLUSION AND PERSPECTIVES

## *4.1.* Conclusion

This comparative analysis of five industrial and territorial use cases aimed to provide recommendations for designing an effective circularity assessment framework - the Circular Digital Cockpit (CDC) [4]. By studying variants and invariants in circular economy capabilities and motivations across these organizations, several key insights were gained.

First, a distinction was made between circular economy operators who directly implement circularity strategies within their organizations (e.g. component remanufacturing, machine refurbishing), and circular economy facilitators who also support other stakeholders in improving their circularity performance (e.g. developing tools, providing funding, raising awareness). This categorisation highlights the need for the CDC framework to consider different modelling scales [5] - micro level for operators, and micro/meso/macro levels for facilitators to reflect their broader scope of action.

Secondly, while motivations for adopting circular economy practices were diverse (regulatory compliance, economic incentives, environmental objectives), there was a common interest from all organizations in leveraging circularity to improve their economic and environmental performance. This corresponds to the common definitions of circular economy in the scientific literature [15]. This suggests the CDC should incorporate a multi-criteria approach combining circularity metrics with economic and environmental indicators. Circularity could even be considered merely as a means rather than an end-goal [16].

However, aggregating these different performance dimensions raises challenges in terms of methods for multi-criteria modelling and managing potential trade-offs between objectives. The Pareto optimal solutions approach appears as one of the possible available solutions [11].

Overall, this analysis emphasises that to be effectively implemented across sectors, the CDC framework must allow for customisation based on the beneficiaries' role (operator vs facilitator) and priorities, while providing a robust multi-criteria assessment methodology rooted in the latest scientific knowledge on circularity and sustainability evaluation.

## *4.2.* Future research

The analysis of circular economy capabilities and motivations within the five case studies should be further explored. Challenges encountered during the development of circular economy strategies in industrial or territorial value chains (such as data collection and availability, operational deployment of strategies, or economic profitability) should be investigated through interviews with multiple actors involved within the studied organisations.

Several challenges lie ahead regarding implementing multi-criteria (circularity, environmental and economic indicators) modelling within the CDC framework. The potential interest of the different studied organisations in adopting such a multi-criteria modelling approach should be confirmed. It is also necessary to identify the typologies of indicators recommended and feasible for each dimension (circularity, economic profit, environmental savings) from the perspectives of the studied organisations and the scientific literature.

Moreover, introducing the concept of performance assessment raises the question of positioning results on a performance scale. Several options are possible through relative performance assessment (vs. past performance, vs. performance of similar players, etc.) and absolute performance assessment (vs. national, international, scientific framework, etc.). For the latter, it is possible to refer to a framework such as the planetary boundaries (cf. absolute environmental sustainability assessment methodology [17]. This would enable setting science-based objectives and tracking the progress of circular economy strategies towards limited environmental impact. This is in line with the definition of circular economy in French law [18]: "The transition to a circular economy aims to achieve a neutral ecological footprint within the framework of compliance with planetary boundaries and to go beyond the linear economic model […]". The willingness and ability of the different types of organisations to adopt absolute sustainability approaches will be investigated through an interview campaign.

As for multi-level modelling (micro, meso and macro), it is necessary to understand the links between changes at different levels to measure coherent indicators that do not contradict each other. This appears challenging, as shown in the few studies linking the different circularity levels [6].

## REFERENCES


[1] 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 : A new Circular Economy Action Plan For a cleaner and more competitive Europe, no COM/2020/98, 2020. Consulted on January 29th 2024. [Available online] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2020:98:FIN

[2] Commission Delegated Regulation (EU) 2023/2486 of 27 June 2023 supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to the sustainable use and protection of water and marine resources, to the transition to a circular economy, to pollution prevention and control, or to the protection and restoration of biodiversity and ecosystems and for determining whether that economic activity causes no significant harm to any of the other environmental objectives and amending Commission Delegated Regulation (EU) 2021/2178 as regards specific public disclosures for those economic activities, no C/2023/3851, 2023. Consulted on January 29th 2024. [Available online] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32023R2486

[3] Law (France) n° 2020-105 of 10 February 2020 relating to the fight against wasting and the circular economy, 2020-105, 2020. Consulted on December 15th 2023. [Available online] https://www.legifrance.gouv.fr/loda/id/JORFTEXT000041553759/2023-12-15/

[4] B. Yannou, G. Bouillass, M. Saidani, M. Jankovic, *The Circular Digital Cockpit: Towards an actionable framework for life cycle circularity assessment and decision*, Life Cycle Engineering, p467-472, Torino, Italy, 2024.

[5] J. Kirchherr, D. Reike, M. Hekkert, *Conceptualizing the circular economy: An analysis of 114 definitions*, Resources, Conservation and Recycling, Vol. 127, p221–232, 2017.

[6] S. Harris, M. Martin, D. Diener, *Circularity for circularity's sake? Scoping review of assessment methods for environmental performance in the circular economy*, Sustainable Production and Consumption, Vol. 26,

p172–186, 2021.
[7] M. Saidani, B. Yannou, Y. Leroy, F. Cluzel, A. Kendall, *A taxonomy of circular economy indicators*, Journal of Cleaner Production, Vol. 207, p542-559, 2019.
[8] Science Based Targets initiative. Consulted on February 19th 2023. [Available online] https://sciencebasedtargets.org/about-us
[9] Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088, 2020. Consulted on January 2nd 2023. [Available online] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32020R0852
[10] T. Schaubroeck, T. Gibon, E. Igos, E. Benetto, *Sustainability assessment of circular economy over time: Modelling of finite and variable loops & impact distribution among related products*, Resources, Conservation and Recycling, Vol. 168, N°105319, 2021.
[11] M. Saidani, H. Kim, B. Yannou, Y. Leroy, F. Cluzel, *Framing product circularity performance for optimized green profit*, International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Anaheim, United States, 2019.
[12] W. Feng, Strategic management for large engineering projects: the stakeholder value network approach, Massachusetts Institute of Technology, Engineering Systems Division, 2013. Consulted on January 2nd 2024. [Available online] https://dspace.mit.edu/handle/1721.1/80983
[13] A. Hein, M. Jankovic, W. Feng, R. Farel, J. Yune, B. Yannou, *Stakeholder power in industrial symbioses: A stakeholder value network approach*, Journal of Cleaner Production, Vol. 148, p923–933, 2017.
[14] T. Schaubroeck, *Circular economy practices may not always lead to lower criticality or more sustainability; analysis and guidance is needed per case*, Resources, Conservation and Recycling, Vol. 162, N°104977, p1-3, 2020.
[15] J. Kirchherr, N. N. Yang, F. Schulze-Spüntrup, M. J. Heerink, K. Hartley, *Conceptualizing the Circular Economy (Revisited): An Analysis of 221 Definitions*, Resources, Conservation and Recycling, Vol. 194, N°107001, 2023.
[16] T. B. J. Coenen, k. Visscher, L. Volker, *Circularity in the Built Environment: A Goal or a Means?*, Nordic Conference on Construction Economics and Organisation, p253-267, Copenhagen, Denmark, 2022.
[17] A. Bjørn, C. Chandrakumar, A-M. Boulay, G. Doka, K. Fang, N. Gondran, M. Z. Hauschild, A. Kerkhof, H. King, M. Margni, S. J. McLaren, C. Mueller, M. Owsianiak, G. Peters, S. Roos, S. Sala, G. Sandin, S. Sim, M. Vargas-Gonzalez, M. Ryberg, *Review of life-cycle based methods for absolute environmental sustainability assessment and their applications*, Environmental Research Letters, Vol. 15, N°8, 2020.
[18] French environmental code, article L110-1-1, 2020. Consulted on June 6th 2024. [Available online] https://www.legifrance.gouv.fr/codes/article_lc/LEGIARTI000041598662/2024-06-03/