European Journal of Social Impact and Circular Economy

Micro-level measurement of the circularity of organizations: the Italian innovative standardized approach applied to a public sector case study

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Received: 22/11/2022
Accepted for publication: 16/04/2023
Published: 21/04/2023

Abstract

This study analyses the implementation of a circularity measurement methodology at the University of Piemonte Orientale (UPO) in the early stages of the development of the UNI1608856 project "Measuring circularity - Methods and indicators for measuring circular processes in organisations, the first attempt to assess an organisation's circularity under a standardized framework in an Italian University. The single-case study examines the organisation's framework implementation, followed by an in-depth discussion of the phenomenon under study. The circularity measurement metrics applied to the UPO case have been extracted from a draft standard prepared by the Italian standardization body (UNI). The UPO case study considers the draft's general propositions with a focus on the metrics related to the management of human resources, assets, policy, and sustainability. Some useful insights emerge from the critical analysis of the norm proposal, both regarding adopting different types of measures and implementing the circularity measurement in terms of the organisation's readiness to collect data for the metrics. As this study deals with a new framework applied to a public Organisation, several issues come to light. The first implementation of UNI1608856 allows discussion of the effective measurement of circularity at the micro level and how an organisation's managerial processes need to evolve to provide the data required to measure circularity.

Keywords: Circular economy, Circularity measurement, Metrics, Standards, Public organizations, Lifecycle

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1. Introduction

The circular economy (CE) is a system approach that can replace linear industrial operating models with cyclical, closed-loop production systems based on the no-waste principle in nature, thus dissociating economic growth practices from using and exploiting natural resources (UNEP, 2006; EMF a, 2013; BSI, 2017; Ilic *et al*., 2018).

With the CE concept gaining traction in the last decade, companies and policymakers started directing their attention to what is seemingly a promising tool to foster sustainable development (Jia *et al*., 2020), underlining the importance of CE transition. As a result, an increasing number of scholars and practitioners have focused on the progress of CE initiatives, and hence the development of circularity measurement tools. Despite the growing interest in CE assessment methods, the lack of a standardized approach, a commonly agreed scientific basis, and the low applicability of these methods in organizational realities are often cited as fundamental barriers to their uptake (Saidani *et al*., 2019; Franco *et al*., 2021).

CE transition currently concerns only a small fraction of organizations able to explicitly address CE in their business processes. For these reasons, extensive literature reviews on the approaches, methods, and tools to assess CE point to the potential usefulness of a more holistic measurement framework/method (Sassanelli *et al*., 2019; Walzberg *et al*., 2021; Roos Lindgreen, Salomone & Reyes, 2020).

Given these shortcomings in CE assessments, the goal of our study is to analyse the implementation of an innovative approach to standardizing the circularity measurement of organizations that UNI/CT 057 – the technical commission of the Italian body for standardization (UNI) – proposed within the specific context of a public Organisation, the University of Piemonte Orientale. Moreover, the case study aims to identify the potential limitations of the metrics of the standard and the managerial difficulties in applying the standard itself.

In this study, we analyse the implementation of the methodology drafted in the early stages of the development of the UNI1608856 project "Measuring circularity - Methods and indicators for measuring circular processes in organizations" by the University of Piemonte Orientale. This innovative approach is a first attempt to assess an organization's circularity in view of the development of an international standard for measuring the circular economy[1].

The objective of this study is to critically discuss the framework of the methodology formulated within the UNI1608856 project and its implementation in a public Organisation from a managerial perspective. Topics like the relevance of the proposed indicators list and data availability for application to the case study are fundamental for the definition of the methodology and need to be investigated. Specifically, we focus on the micro-level of Organisation circularity, focusing on improving the environmental performance of a particular Organization (through different initiatives such as resources consumption reduction, waste management, etc.).

The remainder of the paper is organized as follows. After this brief introduction, we review the literature to assess the circular economy measurement concept. The third section describes the research design and methodology adopted. Section 4 presents the findings from our case study, Section 5 discusses the results, and the last section offers some conclusions, limitations, and future research avenues.

2. Literature review

Measuring circularity: a debated topic

The EU CE program (EU COM2015) explains that prolonging the value chain of products and services in the economy will generate a sustainable economic system that will benefit organizations, citizens, and the environment.

Due to the importance of achieving sustainability, the CE concept has in recent years garnered the increasing attention of governments, regulatory bodies, organizations, citizens, and scholars.

The CE systemic approach is aimed at expanding the lifecycle of materials, design out waste, increase resource efficiency, and achieve a better balance between different critical issues regarding economic growth, environmental protection, and social wellbeing. A particularly interesting aspect of the circular economy concept is its compatibility and consistency with sustainable development through its three associated pillars. Indeed, CE directly aims for not only economic benefits (e.g., value creation

[1] ISO 59020 "Circular Economy – Measuring and assessing circularity" – CD stage.

and savings by reducing raw materials), but also environmental benefits (e.g., impact reduction), and indirectly, social benefits (e.g., job creation) (MGI, 2015; Accenture Strategy, 2015).

Therefore, under the United Nations 2030 Agenda, a significant number of the Sustainable Development Goals (SDGs) relate to CE practices (Schroeder, Anggraeni & Weber, 2019; Rodriguez-Anton *et al*., 2019; Netherlands Enterprise Agency, 2020). Organizations and collectives are increasingly willing to move towards a more circular and sustainable economic and business model as a means of achieving commercial differentiation, competitive advantage, and potential growth with economic spillovers.

However, the Circularity Gap Report 2020 underlines that the world is only 8.6% circular, meaning that only this small percentage of all minerals, fossil fuels, metals, and biomasses are cycled back (CGRi, 2020).

While there is currently no standard CE definition, the different definitions proposed or established by major organizations and academics have much in common, tending to formalize and converge towards the same paradigm (Carencotte *et al*., 2012).

In short, the CE concept is aimed at systematically maintaining the highest value and use of products and components during their lifecycle through changing the linear loop of material flows (take-make-dispose) to a circular loop (take-make-reuse) (Franco, Almeida & Calili, 2021).

Cui and Zhang (2018) provided an extensive literature review about CE demonstrating the growing interest for the topic.

CIRAIG (2015) performed an extensive literature review and inventory of key circular economy definitions, all of which oppose the linear "make-take-waste" model. In addition, CE implies better resource management throughout the lifecycle of systems, characterized by closed loops, promoting maintenance, reuse, remanufacturing, and recycling.

The most popular definition that the Ellen MacArthur Foundation proposed is that CE includes five fundamental characteristics (design out waste, build resilience through diversity, work towards energy from renewable sources, think in systems, think in cascades), and four building blocks (circular product design, innovative business model, reverse cycles, enablers and system conditions) (EMF a, b, 2013). Moreover, the Ellen MacArthur Foundation butterfly circular economy model is one of the most acknowledged and used in businesses and academic circles (Lieder & Rashid, 2016).

Nevertheless, other studies have defined CE strategies and proposed useful frameworks (e.g., King *et al*., 2006; Jawahir & Dillon, 2007; Allwood *et al*., 2011; EMF, 2013a, 2013b, 2014; Bakker *et al*., 2014a; 2014b; Sihvonen & Ritola, 2015; Willskytt *et al*., 2016; Potting *et al*., 2017; 2018; Reike *et al*., 2018). For instance, the framework of Potting *et al*. (2017) contains a set of R-strategies, grouped around three main circularity strategies: (i) smarter product use and manufacture; (ii) extended lifespan of products and their parts; (iii) the useful application of materials. The ten R-strategies are: (i) refuse (R0); rethink (R1); reduce (R2); re-use (R3); repair (R4); refurbish (R5); remanufacture (R6); repurpose (R7); recycle (R8); and recovery (R9). Furthermore, the priority order indicates that smarter product manufacture and use (R0–R2) are preferable to product lifespan extension (R3–R7). The lowest priorities are material recycling and energy recovery from incineration and anaerobic digestion (R8–R9).

In particular, system thinking is fundamental in the circular economy paradigm. Indeed, according to Balanay and Halog (2016), it is central because designing out waste and closing the loop requires a holistic understanding, wide acceptance, and the success of circularity interventions.

The International Organization for Standardization (ISO) has enriched the international debate on CE by proposing four new norms to promote and accelerate the standardization of the circular economy. Specifically, the aim is to provide a mainframe in which circularity can be measured, intended as the groundwork for future agreements between governments, companies, and society in general. The new ISO standards imply developing indicators that measure the circularity of manufacturing processes, with the goal of reducing their environmental footprint.

According to ISO 59004 (Circular Economy – Framework and Principles for Implementation), a circular economy system uses a systemic approach to maintain a circular flow of resources by regenerating, retaining, or adding to their value while contributing to sustainable development.

In this study, we adopt the ISO framework since it contains a well-defined concept of circularity measurement as the collection, calculation, and compilation of information and/or data to determine circularity performance.

In this context, CE transitions require the ability to measure and evaluate circularity performance progress (Ruggieri *et al*., 2016; Ghisellini, Cialani & Ulgiati, 2016; Kirchherr, Reike & Hekkert, 2017; Potting *et al*., 2017; Saidani *et al*., 2019). The quantification of the circular economy and sustainability is a relevant aspect at different levels of application: (i) companies need to evaluate and improve the environmental, economic, and social impact of their products and processes; (ii) financial bodies must have quantitative information about the potential and risks of the different initiatives to select the optimal opportunity; and (iii) policymakers must be guided toward a coherent definition of strategies at the regional, national, and international level, setting realistic targets, and measuring their effectiveness.

Some authors underlined the need of studies applied to the public sector organizations, in light of the scarcity of research focused on the implementation of CE practices and strategies in this organizational context (Klein, Ramos & Deutz, 2020).

However, the lack of comprehensive and robust approaches to quantify the circular economy makes it challenging to apply quantitative methods and indicators in different contexts and compare the results, with the risk of limiting the practical implementation of circular initiatives due to their unknown and/or unclear potential and contribution.

The CE implementation process can benefit from technology, since it plays as fundamental factor in increasing new practices and leading to more significant environmental development (Massaro et al., 2021). Moreover, the use of technology concerns not only the ability to reduce resources but also the capability to manage information thus increasing the CE's impact.

Circularity metrics description

While there is broad consensus on the need for appropriate methodological approaches to monitor and evaluate the implementation of circularity strategies in business contexts, studies of indicators measuring the adoption of multiple CE strategies are still in the embryonic stage (An, Maarten & Veronique, 2018; Janik & Ryszko, 2019; Saidani *et al*., 2019).

Indeed, measuring and assessing circularity is a complex process comprising several steps and their iteration. ISO illustrates the process in Figure 1.

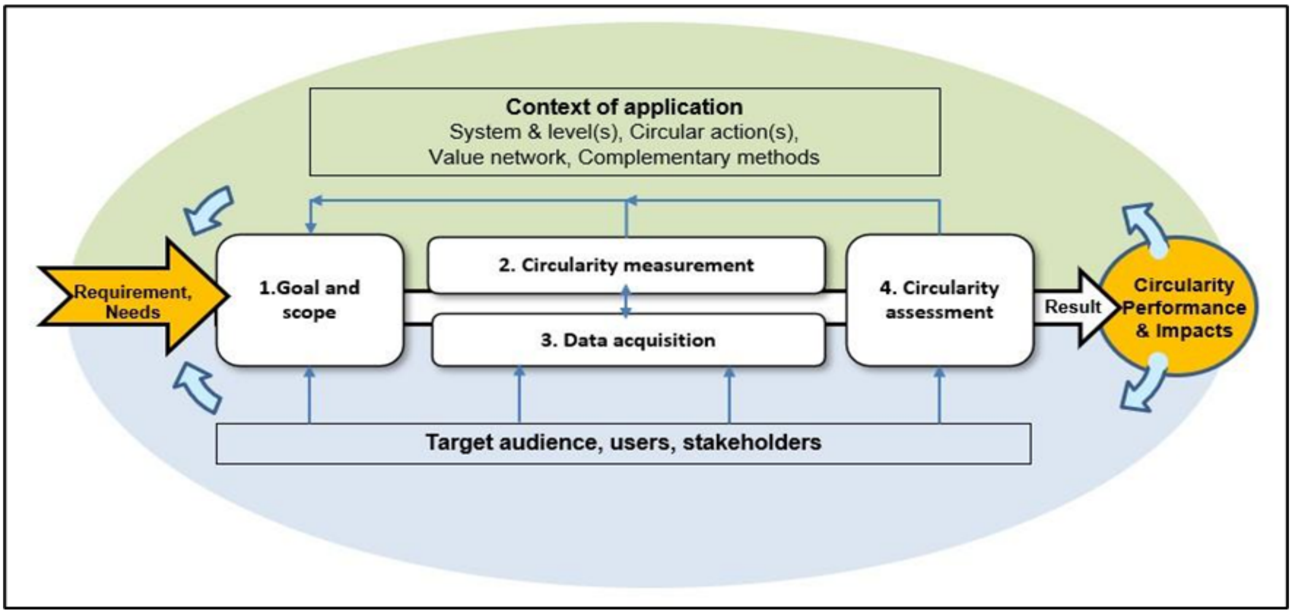

Figure 1. ISO framework for measuring and assessing circularity
(Source: ISO Standard 59020)

The interest in these metrics lies in their ability to summarize and distil the great complexity of environmental dynamics and provide more comprehensive information. Practitioners and scholars (e.g., Balanay & Halog, 2016; Saidani *et al*., 2017; Franco, Almeida & Calili, 2021) have proposed different levels of CE measurement: micro, meso, and macro.

The micro level comprises products, companies, and consumers. The meso level refers to developing an eco-industrial network that benefits regional production systems and the environment. The macro level means circular economy development in global, national, regional, or local contexts. In particular, at the micro level, the CE paradigm introduces a new perspective to look at business ecosystems. In this regard, organizations must prepare for CE transition based on their circularity performance insights, thus needing measurement frameworks to assess their circularity from a transition perspective.

Studies on indicators to measure the adoption of multiple CE strategies in organizations are still in their infancy (An, Maarten & Veronique, 2018; Janik & Ryszko, 2019; Saidani *et al*., 2019). In addition, existing guidelines and standards developed for businesses have been criticized for lacking monitoring C-indicators that link the circular economy with sustainability (Pauliuk, 2018; BSI, 2017). Moreover, a number of studies (e.g., An, Maarten & Veronique, 2018; Saidani *et al*., 2019; Iacovidou *et al*., 2017; Corona *et al*., 2019; Moraga *et al*., 2019; Potting *et al*., 2017, 2018) record the absence of standard indicators to track circularity progress within organizations, leading to misunderstandings and contradictions in implementing CE transition.

Very few indicators capture the effect of strategies concerning smarter product use and manufacture or extending the lifespan of products. Another concern is that, in general, C- indicators focus primarily on physical parameters. Social and environmental indicators are less well-defined and less frequently included in circularity performance measurement frameworks. The same is true for measuring the progress of implementing high-level circularity strategies (An, Maarten & Veronique, 2018; Saidani *et al*., 2019; Moraga *et al*., 2019; Kristensen & Mosgaard, 2020; Rincón-Moreno *et al*., 2021). In the words of Moraga *et al*. (2019, p. 460), "Most indicators focus on the preservation of materials. Strategies focusing on materials, especially recycling, are well-developed, but they are some of the existing options to promote CE recycling even being essential to the economy is not the only aspect of a sustainable CE".

In this regard, Potting *et al*. (2017) also point to the strong focus on recycling. Even so, a more ambitious CE transition towards the significant reduction of resources, material consumption, and waste generation will be based on high-circularity R-strategies.

Ghisellini, Cialani and Ulgiati (2016) underline that the most indicators concern the macro (national) and meso (inter-firm) level, with few metrics at the micro level. Moreover, the circular economy evaluations at the micro level are based on cleaner production and green consumption, which is not a full circular economy approach (Geng *et al*., 2012). As such, this approach could lead to indicators claiming to be of circular economy type at the micro level but without encompassing the overall complexity of the circular economy and all possible end-of-life options to close the loop.

Despite considerable efforts in this regard, gaps are evident in current research concerning C-indicators for monitoring and assessing the progress of organizations towards a CE transition according to their circular strategic choices. Circularity measurement indicators are aimed at providing a value expressing how circular a system is, so that these measures enable assessing the circularity of an organization. These indicators have been developed by defining the main attribute of CE (e.g., recirculated materials in a product) to then assign it a scale ranging from 0 to 100%, representing the degree of circularity.

Our literature review identifies a variety of circularity indicators. For instance, the new product-level circularity metric of Linder, Sarasini and van Loon (2017) defines circularity as "the fraction of a product that comes from a used product" (p. 551). The authors argue that a circularity index should only be focused on the reuse of materials, while other values corresponding to the CE concept (such as environmental quality) should be measured with additional indicators. This argument indicates a divergence between their definition of circularity and the CE concept where circularity relates to only one of the CE goals (material reuse).

Other indicators, such as the Circ(T) and the Global Circularity Metric, are also based on a mono-dimension circularity concept, i.e., merely considering material recirculation, and covering only (and partially) the resource efficient CE goal. For instance, the Global Circularity Metric measures global economy circularity with "the share of cycled materials as part of the total material inputs into the global economy" (De Wit *et al*., 2018, p. 22), using data from input output statistics and projections from a computable general equilibrium model (Hatfield-Dodds *et al*., 2017). In turn, Circ(T) provides a relative measure of the cumulative mass of a material present in a system over a certain time interval in terms of an ideal reference case where the material is kept functional throughout the entire accounting period T (Pauliuk *et al*., 2017). Although the focus is only on material circularity, the developers of these last indicators agree that other goals, such as material saving, value retention, environment conservation, and climate mitigation, should also be considered.

The Circularity Index is based on material circulation, but includes the notion of quality in terms of the ratio of energy required for material recovery to energy required for primary production. This approach attempts to avoid the risk of achieving resource circularity by increasing energy use. The Material Circularity Indicator (MCI) that the Ellen MacArthur Foundation (EMF) and Granta Design developed is a micro-level index built on a more complex definition of product circularity expressed as "the extent to which linear flow has been minimized and restorative flow maximized for its component materials, and how long and intensively it is used compared to a similar industry-average product" (EMF, 2015, p. 19). Since this index does not account for the environmental and socioeconomic risks of the analysed systems, additional indicators are proposed to cover the other CE goals.

Circular Economic Value (CEV) and Circular Economy Indicator Prototype (CEIP) both build on the MCI concept. CEV represents the system's circularity by accounting for reduced use of virgin materials, reduced output of waste, increased use of renewable energies, and increased energy output during end-of-life (EoL). The CEIP index is calculated by choosing predefined answers to a series of 15 questions on product design, manufacturing, commercialization, in-use, and EoL (Cayzer, Griffiths & Beghetto, 2017). Then, a final score (in %) is determined by aggregating the obtained scores for each answer.

Our literature review shows that CE measurement has some significant limitations in terms of the scale/level. In particular, the high diversity and fragmentation of approaches and metrics makes it difficult to compare the industrial applications in which such indicators and methods are used. This fragmentation has mainly two reasons. The first is related to the overall CE umbrella concept: hundreds of CE definitions exist, and the paradigm is developing without overall consensus regarding circular actions and aspects. This diversity in the theoretical background is reflected in the industrial adoption of CE, providing very specific case studies. Consequently, these idiosyncrasies also require a tailored assessment framework, challenging replication in other contexts. The second reason that determines CE assessment fragmentation at the same scale/level is the lack of standards.

The issues related to the aforementioned circularity measurement indicators highlight the need for a unique and validated reference (standard). Therefore, in 2020 UNI (the Italian standardization body), proposed a project aimed at developing a standardized approach with the aim of defining a set of metrics that organizations could apply at different micro and meso levels.

In this study, we analyse the implementation of the UNI1608856 project that the University of Piemonte Orientale proposed. This innovative approach is a first attempt to assess an Italian university's circularity under a standardized framework. Moreover, the case study aims to identify the potential limitations of the metrics of the draft standard and the managerial difficulties in applying the standard itself in order to improve the final standard.

3. **Research design and methodology**

Since our aim is to investigate a first adoption of the standard, we employ a single-case study methodology to analyse the organization's implementation process, providing an in-depth discussion of the phenomenon under study (Yin, 2017). This methodology is useful to transcend the local boundaries of the investigated case, capturing new layers of reality, and developing new, testable, and empirically valid theoretical and practical insights (Eisenhardt, 1989; Eisenhardt & Graebner, 2007).

As mentioned, the issues related to above mentioned circularity measurement indicators highlight the need for a unique and validated reference. Therefore, in 2019 the National Standardization Body, UNI, nominated a Technical Committee subdivided in five working groups with the aim to develop a norm for the "Evaluation of Circularity in the Organizations - Micro and Meso level". The Technical Committee was coordinated by the National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) and composed by several experts from academy, industry and national research bodies (e.g. the National Research Council). The goal was elaborating a standardized measurement approach that could be applied to a broad range of organizations (manufacturing companies, service organizations, public entities) at the different micro, meso, and macro levels.

The first draft of this norm is the so-called UNI1608856 project, later published as a technical norm titled UNI/TS 11820. In order to identify hot-spots and potential weakness for the practical application of the developed methodology, accordingly to the implementation of an interventionist approach (Grossi *et al.,* 2021), in 2021 UNI Technical Committee launched a call for volunteers for the preliminary application of the methodology. Considering the relevance to conduct a first attempt to measure the circularity level of a public Organisation at the micro level and the potential relevance of the findings in the improvement of the first draft of the UNI1608856 project norm, authors submitted the application of the case study of the University of Piemonte Orientale (UPO). UPO has locations in three cities (Alessandria, Novara, and Vercelli), around 15.000 students, and 7 (at that time, currently 8) departments that manage the teaching and research activities.

In more detail, UPO is a young university in northern Italy that runs along three cities and eight departments, organized both for logistical ease for students and to take advantage of specific potential of different locations.

More specifically, the departments are as follows: Law and Political, Economic and Social Sciences; Science and Technological Innovation; Pharmaceutical Sciences; Economics and Business Studies; Translational Medicine and Health Sciences; Medicine; Humanities; Sustainable Development and Ecological Transition

UPO has been accepted by the Technical Committee and UPO was enrolled in the list of contributors of the experimental phase of the UNI1608856 project (pilot study).

Methodology: Circularity measurement of organizations under UNI1608856

In response to the need for a unique and validated reference, the UNI Technical Committee CT/057 "Circular Economy" thus drafted a first version of the UNI1608856 project norm. This norm is highly significant as the first standardized framework for organizations to measure and assess circularity, and a reference in the development of a future international ISO 59020 standard[2].

The project defines a set of indicators to evaluate the level of circularity of a single/group of organizations. The measurement approach is based on a rating system that is neither linked to a sectoral benchmark nor a minimum level of circularity but only considers the actual level of circularity reached in respect of the maximum reference of 100 points. It also considers the opportunities to measure the circularity level over time.

The methodological approach is based on the so-called "lifecycle perspective", a holistic approach that aims at maintaining natural flows within systems to generate value for both the ecosystem and future generations. This theory is at the base of LCA (Life-Cycle Assessment), which is a standardized methodology to evaluate the environmental impacts of all the input and output flows of a process over its lifecycle. Specifically, the methodology identifies six main lifecycle stages: design, supply-chain, production, distribution chain and selling activities, use-phase and consumption, end-of-life.

The measurement methodology consists of a set of indicators that can be applied at the micro (single Organisation) and meso level (group of organizations, industrial and local clusters, municipalities, cities, districts). The macro level is not considered in the analysis, although a list of indicators currently applied to regions and countries is included in Appendix B[3]. The type of data to be collected and the definition of the so-called "system-boundaries" follow the standardized approach in Figure 2.

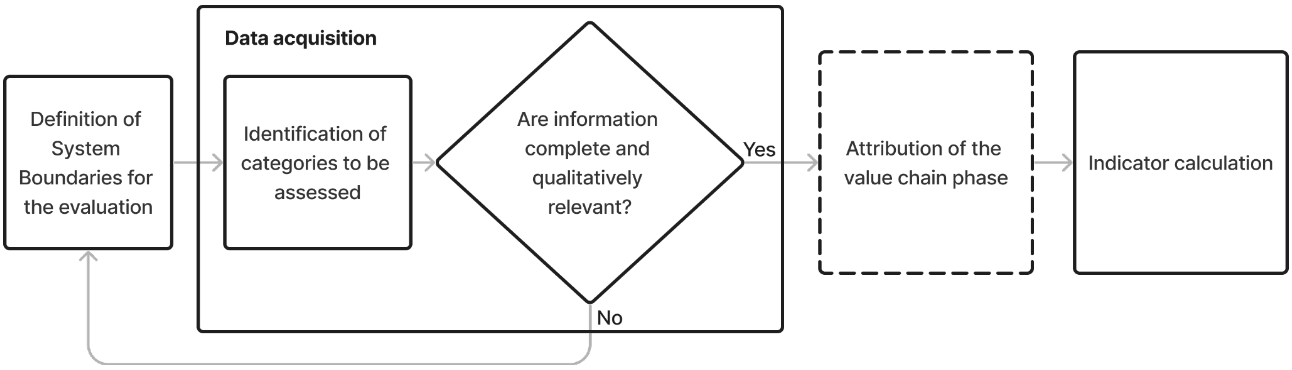

Figure 2. Flow diagram of the process of data acquisition
(Source: project UNI1608856, revision under final public inquiry)

Data acquisition first considers the elementary components needed to identify the primary data (e.g., input and output flows) to be collected using an effective and individual approach. The network of relevant stakeholders and processes involved in the assessment can be represented graphically, such as with a flow-diagram, in agreement with the LCA methodology.

Since the standardized approach to measuring circularity generally considers all private/public services, processes (bioprocesses included), and systems on two levels (micro and meso), it should be compliant with some measurement and

[2] ISO 59020 "Circular Economy – Measuring and Assessing Circularity" – CD stage

[3] UNI1608856 "Measuring Circularity – Methods and Indicators for Measuring Circular Processes in Organizations"

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evaluation criteria. In particular, the nine criteria followed are applicability, coherence, compatibility, transparency, completeness, traceability, data reliability, spatial and temporal coverage, and systemic interdependencies. These criteria are then assessed with data-quality studies that characterize, for instance, data reproducibility, accuracy, precision, availability, representativeness, and so forth.

To evaluate all the different data describing the organization's circularity, three types of indicators are defined:

- Qualitative indicators = non-numerical factors that set the level of progression or positioning in respect of a target, namely qualitative data based on personal opinions.
- Quantitative indicators = numerical factors that determine the level of progression or positioning in respect of a target based on numerical and objective evaluations.
- Semi-quantitative indicators = qualitative evaluation based on a mix of qualitative and quantitative indicators.

These indicators are then grouped into six categories:

1) Management of materials and components
2) Management of energy resources
3) Management of waste and emissions
4) Management of logistics
5) Management of products/services
6) Management of human resources, assets, policy, and sustainability

According to the expected timeline shown in Figure 3, a preliminary set of 103 micro/meso indicators was defined. At the end of 2021, the CT/057 technical committee started a voluntary experimental phase of testing these indicators for applicability and validity, thus calling for volunteers to select a representative set of organizations, including manufacturing companies, service organizations, and public entities.

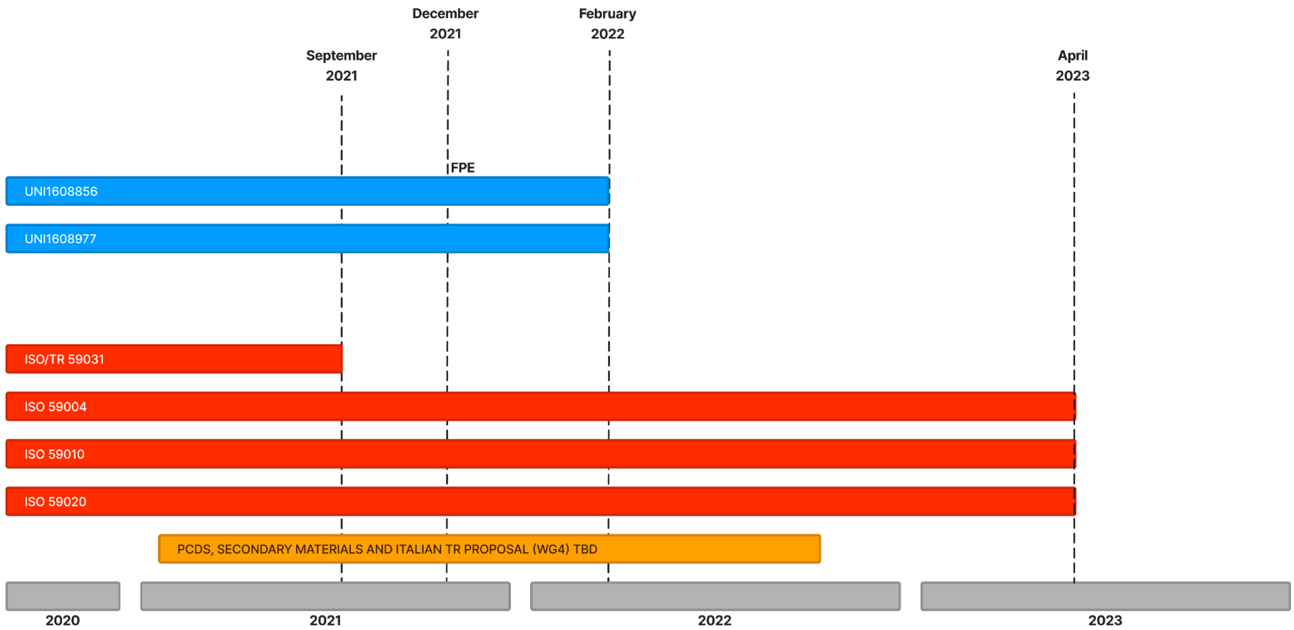

Figure 3. Timeline
(Source: UNI, Italian standardization body)

The findings allowed drafting a summary report for stakeholders and improve the methodology. The number of indicators utilized was then reduced to a set of 81, further classified as:

- Core indicators = indicators that are compulsory

- Specific indicators, if at least 50% are to be assessed
- Rewarding indicators = facultative indicators that if evaluated and different from zero lead to a higher final score[4].

These indicators are further described using additional information: progressive number, description, type of measurement (qualitative/quantitative/semi-quantitative), data-measurement unit (mass, energy, economy, ad hoc), datatype (input, output, internal), numerator and denominator for its evaluation (if present), further definitions, type of evaluation (related to a product and/or service), type of indicator (core/specific/rewarding). All these data are organized in the format of a table (as an example, see Table I).

Table I. Example of indicators for the "Human Resources, Assets, Policy, and Sustainability" category

	Description	**Type of measure**	**U.M.**	**Data type**	**Indicator calculation**		**Related definitions**	**Eval. type**	**Indicator type**
					Numerator	Denominator			
06. Indicators related to Human Resources, Assets, Policy and Sustainability									
65	Index of average energy efficiency of the organisation's buildings for civil use in (n) year Limits: Class A (100%) Class B-C (50%) Class D-F (25%) Class G (0%)	Semi-quantitative	Limits	Internal	Index of average energetic efficiency of the building for civil use in (n) year	-	Index of energy efficiency	P/S	1
68	Does the organisation disclose its sustainability and circularity performance (with a sustainability report, non-monetary declarations, etc.)?	Qualitative	Binary (Y/N)	Output	-	-	-	P/S	2
74	Investments in sustainable reconversion of assets in years (n), (n-1), (n-2) in respect of investments in sustainable reconversion of assets in years (n), (n-1), (n-2), and building new assets in years (n), (n-1), (n-2)	Quantitative	Economic	Internal	Investments in sustainable reconversion of assets in years (n), (n-1), (n-2)	(Investments in sustainable reconversion of assets in years (n), (n-1), (n-2)) + (Investments in building new assets in years (n), (n-1), (n-2))	Assets Reconversion of assets	P/S	2
Legend: Datatype: input, output, or internal Evaluation type: (S) Service, (P) Product, (P/S) Product/Service Indicator type: (1) Core, (2) Specific, (3) Rewarding									

Source: UNI1608856, revision under final public inquiry

Based on these indicators, the evaluation of products and services – separately or jointly – follows. Since this is a differential approach based on experimental data, organizations must define the expected focus *before* the actual data-analysis and

[4] UNI1608856, revision under public final inquiry

measurement phases. In fact, the three different calculation schemas to evaluate are manufacturing companies and service organizations, only manufacturing companies, and only service organizations, as reported in Table II.

Table II. Calculation schema for the evaluation of a service industry, as applied in the UPO case study.

Indicators	Type
04, 12, 17, 19, 20, 21, 22, 24, 65	Core
01, 02, 03, 05, 06, 09, 10, 11, 13, 14, 15, 16, 18, 26, 29, 30, 31, 33, 36, 38, 40, 41, 47, 48, 49, 50, 51, 52, 53, 58, 59, 60, 61, 62, 63, 64, 67, 68, 71, 72, 73, 74, 75, 76, 77, 81	Specific
42, 44, 66, 69, 70, 78, 79, 80	Rewarding

Source: UNI1608856, revision under final public inquiry

For each, the core, specific, and rewarding indicators are summed up separately and then divided by the relative number of indicators employed. This allows calculating the *general* level of circularity, while a further evaluation of each of the six categories of indicators enables assessing the *hotspots*. The mathematical model consists in a standardized procedure structured in the following steps:

-Be: c number of core indicators
s number of specific indicators
p number of rewarding indicators
-Be: $A \subset \mathrm{N}$ ordered set A: $\{1, 2, ..., c\text{-}1, c\}$
$B \subset \mathrm{N}$ ordered set B: $\{1, 2, ..., s\text{-}1, s\}$
$C \subset \mathrm{N}$ ordered set C: $\{1, 2, ..., p\text{-}1, p\}$
-Be: $D \subseteq B \subset \mathrm{N}$ the subset of B of specific indicators used, which must include at least 50% of elements of B set in ascending order.
D: $\{s_1, s_2, ..., s_t\}$
-Be: $E \subseteq C \subset \mathrm{N}$ the subset of C of rewarding indicators used, which could be void or corresponds to C, then set in ascending order.
E: $\{p_1, p_2, ..., p_f\}$
-Be: a_i with $i \in A$ the core indicators $a_1, a_2, \dots a_c$
b_j with $j \in D$ the specific indicators used $b_{s1}, b_{s2}, \dots b_{st}$
c_k with $k \in E$ the rewarding indicators used $c_{p1}, c_{p2}, \dots c_{pt}$

The level of circularity (LC) of an Organisation is defined as:

$$LC = \frac{\sum_{i=1}^{c} a_i + \sum_{j=s_1}^{s_t} b_j + \sum_{k=s_1}^{p_f} c_k}{c+t} \qquad if\ LC \leq 1 \text{ otherwise, } LC = 1$$

The result obtained consists in a numerical value (%) that assesses the organization's circularity level.
Thereafter, the Organisation can assess the conformity of the achieved level with respect to the level set by the norm. This assessment could be made by the Organisation itself (self-evaluation), by a second party as an interested client (consultant), or

by a third-party, thus an independent institution that works in compliance with UNI CEI EN ISO/IEC 17029. The requirements for this conformity evaluation are listed in detail in Appendix A[5].

The results obtained with the feasibility studies led to the final draft project proposal UNI 1608856 published online as a public inquiry.

4. Results: Project UNI1608856 implementation in UPO

As discussed, UNI1608856 enables overcoming the lack of precise metrics hindering the measurement of circularity of organizations at the micro level. The University of Piemonte Orientale (UPO) was among the organizations that participated in the experimental phase to test the norm's applicability. The university's participation is a first attempt to measure circularity in the public sector at the micro level. As such, the feasibility study conducted at UPO is an original case study aimed at implementing the innovative approach of UNI/TS 11820 in the public sector.

Among the six categories listed, the "Management of Human Resources, Assets, Policy, and Sustainability" was further investigated due to the general academic structure under public management. The set of indicators assessed for this category comprise 30 questions. As an example, Figure 4 shows the original indicators 81, 91, 105 and 106, as measured in the UPO case study.

[5] UNI1608856, revision under public final inquiry

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081. Indicate: The Value Phase(s) and the Percentage, in the Other field, % Ratio of energy consumption, connected to energy efficiency: year n. -1, / analogous value of the year n. (%) *01 Design* *02 Procurement* *03 Production* *04 Distribution and Sale* *05 Usage / Consumption* *06 End of life management* *Other*
091. Indicate: The Phase(s) of the Value and the Percentage, in the Other field, of Investments in asset conversion activities in year no. / Investments in asset conversion activities in year n + investments in new asset construction activities in year no. (This indicator aims to measure the ability to extend the useful life of assets - such as plants or buildings - instead of build new ones) (%) *01 Design* *02 Procurement* *03 Production* *04 Distribution and Sale* *05 Usage / Consumption* *06 End of life management* *Other*
105. Indicate: The Phase(s) of the Value and with YES or NO in the Other field - The organization has drawn up and published the Report of Sustainability? [Based on internationally recognized certification schemes] *01 Design* *02 Procurement* *03 Production* *04 Distribution and Sale* *05 Usage / Consumption* *06 End of life management* *Other*
106. Indicate: The Phase(s) of the Value and with YES or NO in the Other field - The organization has prepared and published the Balance of non-financial information? [ref. directive on non-financial information "NFRD" its amendments and additions and transposition into IT) *01 Design* *02 Procurement* *03 Production* *04 Distribution and Sale* *05 Usage / Consumption* *06 End of life management* *Other*

Figure 4. Example of indicators for the "Management of Human Resources, Assets, Policy, and Sustainability" category (Source: Questionnaire for UNI1608856 early-stage revision)

In detail, 21/30 indicators are explicitly related to a specific lifecycle stage, namely use-phase and consumption (9/21), and 4/21 for other phases, such as design, supply-chain, and end-of-life, as shown in Figure 5.

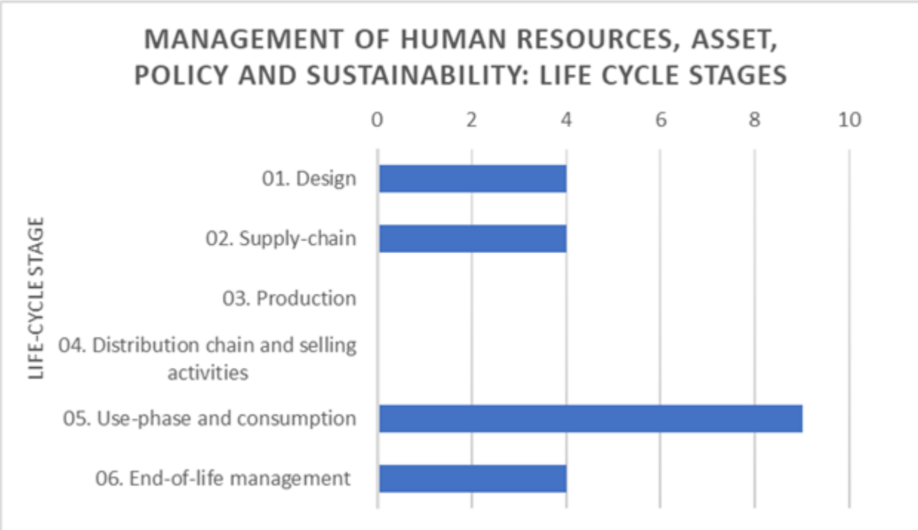

Figure 5. Lifecycle stages of the "Management of Human Resources, Assets, Policy and Sustainability" category (Source: Own elaboration)

Figure 6 shows that data were recorded for half the answers in this category.

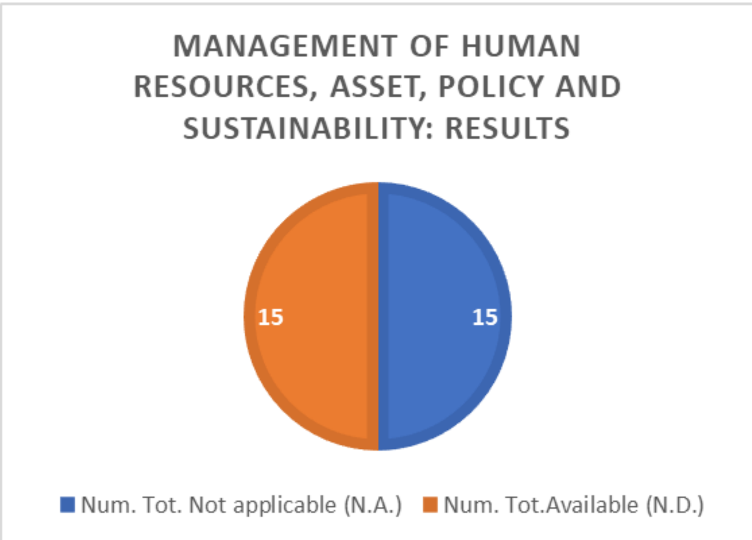

Figure 6. Results of the "Management of Human Resources, Assets, Policy, and Sustainability" category (Source: Own elaboration)

5. Discussion

The UNI1608856 project is a first proposal aimed at bridging several circularity measurement gaps outlined by scholars. Importantly, it provides a framework to measure the circularity of organizations, considering that scholars, such Ghisellini, Cialani and Ulgiati (2016), amongst others, lament the lack of circularity indicators at the micro level. Moreover, the framework is in line with initiatives dedicated to measuring circularity progress in organizations. Indeed, the methodology is based on metrics assessed at the organizational level with no reference to minimum scores but seeking desirable increases over time. This perspective is consistent with calls for indicators to measure progress in circularity (e.g., An, Maarten & Veronique, 2018; Saidani *et al*., 2019; Iacovidou *et al*., 2017; Corona *et al*., 2019; Moraga *et al*., 2019; Potting *et al*., 2017, 2018).

Moreover, the norm distinguishes the metrics proposed according to the type of activity conducted by organizations. Therefore, three different circularity calculation schemas are defined, respectively for manufacturing companies, service organizations, and manufacturing-service organizations.

This distinctive feature of the norm allows properly measuring circularity, since the determinants can vary greatly depending on the type of business.

Important to note is that for this case study, only half of the indicators proposed for the category under investigation were applicable (15 out of 30), indicating the need to discuss the metrics concerning the specific industry in which the organization operates.

Considering the applicable indicators, the results show that the data collected mostly concern the processing phases (out of the six main phases recommended). Specifically, most answers were recorded for the use-phase and the consumption lifecycle stage, and only a few for other phases.

Since UPO declared that data were unavailable ("N.D.") for many of the indicators analysed, it was impossible to obtain precise information. Indeed, the answers recorded referred to different measurement units (binary, limits, economic).

An obvious difficulty emerges: finding useful records that could be linked to the internal Organisation of information within UPO. In fact, data are not easy to access because they are gathered in many different archives. To overcome this issue, the data should be internally reorganized and better integrated with the related management activities. For example, data digitization could be enabled by the adoption of facility management systems.

Moreover, the answers related to the management of building stocks and assets highlighted a general lack of traceability concerning energy or organizational/functional interventions, likely because the collection of some data for traceability purposes is optional at the public level.

These considerations draw attention to the need to assess and evaluate the overall information system of the entire organization to find the right solutions to satisfy divergent needs, from accounting to procurement, to facility management. Some difficulties are also highlighted about human resources management. The results indicate a general need for knowledge of the circular economy principles at many levels, from education and the assignment of specific tasks to employees, to communication between stakeholders and students.

The results also show a general need for knowledge of international certification schemes for energy and environmental management (e.g., ISO 50001), as well as for sustainability reports and non-financial statements.

Therefore, a main recommendation is to include circular economy issues within the management of human resources, assets, policy, and sustainability at UPO. To ensure successful circular economy transitions, organizations require qualified staff with specific skills. In addition, education and training systems focused on circularity are critical in the human resource management.

6. Conclusions, limitations, and further research

Moving from the ISO Framework mentioned in the literature review, the UPO case study highlights some critical points with regard to the methodology proposed to measure circularity according to the UNI1608856 project. In view of similar problems emerging in other experimentations, some revisions were made to the first project of the norm. First, further categorizing the indicators as core/specific/rewarding, second, downgrading some from "core" to "rewarding", thus facultative, which allows slightly mitigating the problem of the consistent number of "not applicable" (N.A.) answers, as highlighted by the UPO case study.

Moreover, since the total number of indicators seemed ineffective, their number was reduced to a set of 81, further categorized with respect to "evaluation type", namely service, product, or product/service (see Table I). The distinction between evaluation type should be made *before* the actual data-analysis and measurement phase. In fact, when based on precise indicators, the description of products and/or services would be more detailed. For instance, in the revised norm, the number of indicators for the "Management of Human Resources, Assets, Policy, and Sustainability" category was reduced to 18, and further classified as core/specific/rewarding. Therefore, the original indicators reported in Figure 4 were re-elaborated as those in Table I, so the number 81 became 65 in the final revision, number 105 and 106 were merged in number 68, and the 91 was renamed as number 74.

However, the procedure described in the UNI1608856 project to measure the level of circularity of organizations is expected to be applied on a voluntary basis. The analysis of manufacturing companies and service organizations at the micro and meso level is likely to be up-scaled if some criteria are to be assessed on a mandatory basis. For instance, this would help identify benchmarks and hotspots in respect of different life stages and categories, thus gaining meaningful data to improve the circular economy also at the national level. Moreover, any activity of third-party evaluations of the conformity of results is highly recommended. This would set a proper basis to improve communications between stakeholders at the general level, as in the case of Type III environmental declarations (UNI EN ISO 14025:2010), for example. In fact, these provide objective and comparable data related to the environmental performance of products and services, without setting minimum levels, similarly to the scope of the UNI1608856 project with respect to the circular economy.

As concerns the research limitations, this study is based on a single case of the implementation of a working draft of a standard.

The results would benefit from measuring the circularity level of UPO once the UNI/TS 11820 norm is published. Furthermore, the application of the standard to other public organizations could highlight relevant hotspots useful for future revisions of the standard, as well as considerations derived from the implementation of the norm by different types of organizations. In this respect, in fact, UNI1608856 is applicable to all organizations and the case of UPO could, in general, foster useful insights.

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