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THE DESIGN OF INDICATORS FOR A MODEL MEASURING THE CIRCULARITY OF REUSE ORGANIZATIONS

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ABSTRACT. Reuse organizations play a key role in the circular economy. However, their performance needs to be measured if they are to operate more efficiently, gain wider public support, and contribute to more sustainable management of materials and resources. A comprehensive picture of performance can be provided by a sufficiently robust and flexible model consisting of a range of indicators, i.e. a model that can be applied at different measurement levels. This article aims to propose a methodological framework for possible model configurations to quantify the circularity of reuse organizations and the volume of municipal waste processed by reuse organizations as a main circularity criterion reflecting the ongoing economic cycle dynamics and associated customer behaviors. The research hypotheses are based on the analysis of different studies presenting options for measuring circularity. A decomposition method was used to ascertain the multidimensional impacts of reuse organizations´ activities on individual key elements of circularity. The obtained results were verified by conducting a focus group involving heterogeneous groups of participants. The proposed indicators should, on the one hand, reflect various dimensions and simultaneously, due to their nature, encompass different degrees of complexity in the focus and activities of reuse organizations.

Keywords: circular economy, Czech Republic, waste, reuse centers.

Introduction

Nowadays, when environmental sustainability is one of the key topics on the global agenda, the signicance of waste reduction and optimal use of resources is growing. Reuse centers and reuse points represent one of the ways to achieve these objectives. These facilities (organizations) extend the life cycle of products and materials, which leads to a significant reduction in the amount of waste that would end up in landfills or incinerators. Recycling reduces the demand for new raw materials, thereby conserving non-renewable natural resources and maintaining the balance of natural ecosystems. The production of new products, which is both energy-intensive and contributes to greenhouse gas emissions, is thus avoided. In general, lower extraction of raw materials, lower production volumes, and greater waste reduction result in improved soil, water and air quality. The possibility of reducing costs is a major benefit for consumers, as reused products are usually cheaper than new ones. Thus, families can save money on their budgets and businesses can save on operating costs. The social aspect is also an undeniable benefit, as reuse businesses create employment opportunities in collecting, repairing and selling reused products. These organisations also educate people about waste management and the relationship with the environment, organize repair or creative workshops. In this way, they help both to promote innovation in the design and creation of new business models or the use of new technologies, and to raise awareness of the importance of responsible consumption and the impact of each person's purchasing decisions on the environment.

Reuse organizations therefore play a key role in the circular economy. However, to be able to operate more efficiently, gain wider public support and contribute to more sustainable management of materials and resources, reuse businesses need to be supported. Such support can take a blanket form (applicable to all such organizations) - e.g. in the form of legislation and regulation, but some types of support are and will be linked to the performance of either an individual organization or organizations in a specific geographic area (state, region, etc.). Measuring the benefits of reuse centers and reuse points is therefore essential to ensure their long-term sustainability and effectiveness.

A comprehensive picture of the performance of reuse organizations can be provided by a model consisting of a number of indicators. Given the lack of relevant studies on this topic, discussions on possible model structures for measuring the circularity of reuse organizations that are sufficiently robust and flexible, or applicable at individual levels of measurement, and thus usable to make decisions on the extent of support and development of reuse organizations should be encouraged.

1. Literature review

1.1. Fundamental principles of the circular economy

Measuring the circularity of reuse organizations is based on the frameworks for sustainable development, circular economy and environmental management. From the European policy point of view, the basic principles of circularity, including the prevention and reuse hierarchy, were originally set out in the Waste Framework Directive 2008/98/EC (WFD). The WFD, particularly in Article 4, established the waste hierarchy as a central principle of waste policy within the EU and its Member States. Recent research highlights that the transition to a circular economy is essential for achieving sustainable development in the European Union, especially in new member states where data gaps and policy challenges remain significant (Simionescu, 2023). This hierarchy prioritizes waste prevention, followed by preparation for reuse, recycling and other recovery methods, with waste disposal being the least preferred

option. The Directive lists various waste prevention measures and encourages promoting the reuse and repair of suitable end-of-life (discarded) products or their parts. It suggests educational, economic, logistical and other initiatives to promote or establish accredited repair and reuse centers and chains, particularly in densely populated areas.

The WFD mandated that Member States establish waste prevention programs by 12 December 2013. While the Directive allows flexibility in the nature of these programs, it stipulates that they must include specific objectives and qualitative or quantitative benchmarks. Other frameworks addressing reuse include the Roadmap to a Resource Efficient Europe (EC, 2011) and the EU's Seventh Environment Action Program (EU, 2013), both of which emphasize the importance of waste prevention. Additionally, the updated framework for waste policy and resource efficiency was recently introduced in the Circular Economy Action Plan (EC, 2015). This action plan aims to transform Europe into a more competitive, sustainable, and resource-efficient economy by addressing various economic sectors, including waste. It comprises a detailed program with measures covering the entire lifecycle, from production and consumption to waste management and the market for secondary raw materials.

1.2. Municipal waste management - The Czech Republic status quo

It appears that, due to the economic and political system shift in 1989, the Czech Republic is emulating developed countries in their consumer consumption habits and its resulting solid waste generation, albeit with a certain delay. As scholars like Strasser et al. (1998) have noted, consumption became a battleground in the ideological conflict between capitalism and communism, driving economic growth but also leading to hyper-consumer societies marked by significant depletion of natural resources and waste production. Consequently, most developed societies, including the Czech Republic, are attempting to adopt integrated waste management systems to recycle and recover materials from waste.

Each region in the Czech Republic, including its capital city, Prague, was required to develop its individual Waste Management Plan. With a focus on supporting reuse and service centers as well as charitable organizations involved in the repair and reuse of products and materials, the aim is to target specific waste streams (such as construction and electrical and electronic equipment). This approach addresses waste prevention indicators rather than establishing quantitative waste prevention targets.

This requirement, prescribed by Act No. 185/2021 Coll., Section 43, and related legislation, integrates the execution of Government Regulation No. 352/2014, dated December 22, 2014. This regulation pertains to the Waste Management Plan of the Czech Republic for the 2015-2024 period. Additionally, Government Resolution No. 1080 concerning the Waste Management Plan regulation adheres to valid European Union directives and considers the European Commission’s methodology for drafting a Waste Management Plan.

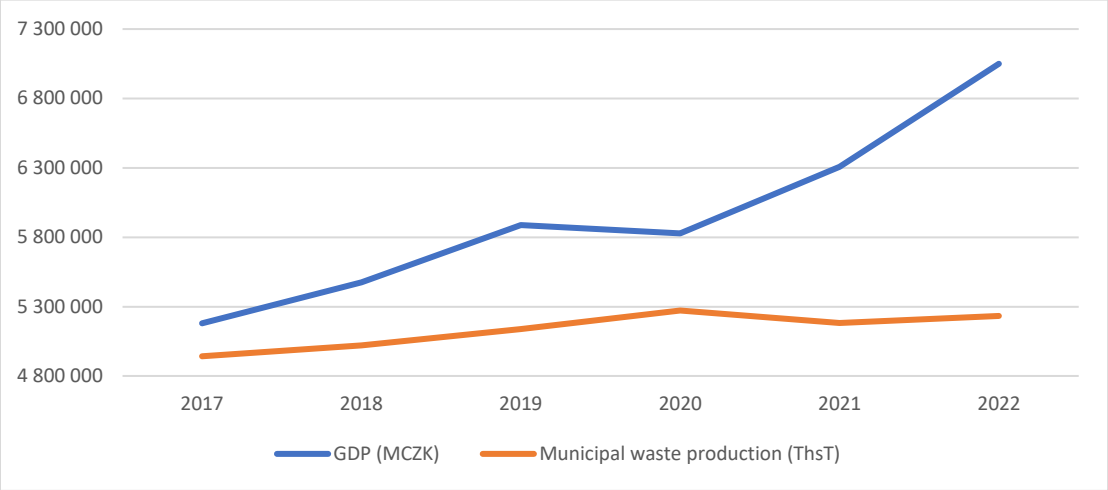
A crucial component of the aforementioned regional Waste Management Plan is a mandatory segment that sets the foundation for processing municipal waste management plans, decision-making, and activities of associated administration offices, regions, and municipalities within the waste management sector. This compulsory segment illustrates the future strategy and outlines priorities for waste management development. It comprises goals, principles, and actions that consider the environmental policy of the Czech Republic, the country’s European obligations, and the current needs of its waste management system.

The strategic goals of waste management in the Czech Republic of period 2015-2024 are:

1) The prevention and decrease of specific waste generation.

2) The mitigation of harmful impacts of waste production and handling on human health and the environment.
3) The attainment of sustainable societal growth and a progression towards a European "recycling society".
4) The maximization of waste utilization as an alternative to primary resources and a shift towards a circular economy.

In the context of a historical comparison of the economic cycle development of the Czech Republic (represented by the Gross Domestic Product characteristic) and consumer behavior (represented by the variable of municipal waste production), and without any sophisticated quantitative analysis regarding their potential mutual interdependency, it can be stated that a similar common direction of development can be observed. In other words, an increase in GDP leads to an increase in municipal waste production, as shown in Graph 1.

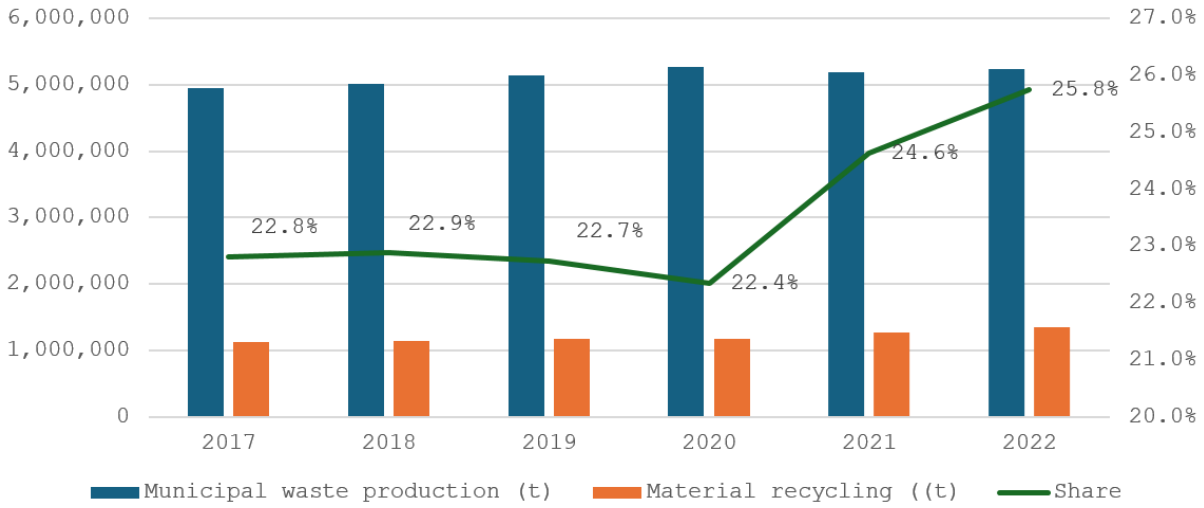


Graph 1. Municipal waste production and GDP development
Source: *The Czech Statistical Office (www.csu.gov.cz/produkty/srovnani-kraju-v-ceske-republice-year, www.csu.gov.cz/produkty/produkce-vyuziti-a-odstraneni-odpadu-2022)*

Graph 1 shows the development of gross domestic product (in current prices) and municipal waste production for the period from 2017 to 2022 (Please note that time series data relating to the production of municipal waste are only comparable over time from 2017 onwards – the methodological note from the Czech Statistical Office).

Similar patterns can also be detected if alternative measures of the economic cycle (such as the nominal average monthly wage, etc.) and municipal waste production (such as waste production per capita, etc.) are used. However, it is important to note the years of 2019-2023, where there was a divergence in the joint development of the mentioned indicators due to the extraordinary circumstances related to the COVID-19 pandemic that had a significant influence on both mentioned variables (such as an increased rate of working from home, significant fiscal stimulus, etc.) that would deserve further elaboration. For the purposes of this article, let us simply assume that the development of these chosen variables is synchronous.

The graph 2, shown below, was created to provide a basic insight into the concept of recycling (including its scale, trend, etc.). By portraying the historic patterns of municipal waste production and its material recycling, this graph serves as an initial foundation for further debates regarding the topic by quantifying its magnitude.



Graph 2. Municipal waste production and its material recycling
Source: *The Czech Statistical Office (www.csu.gov.cz/produkty/produkce-vyuziti-a-odstraneni-odpadu-2022)*

The graph above shows an upward trend in municipal waste production over a given period, including the COVID years (2019-2022). The amount and corresponding proportion of natural recycling is also increasing (this trend, influenced by the COVID years, will have to be confirmed in the future). The material recycling part of municipal waste includes waste for which separate collection and subsequent transformation into secondary raw materials can be feasibly ensured, such as paper, metals and textiles, among others.

1.3. Development of reuse organizations

Organizations such as reuse centers, reuse points and recycling yards represent a potential solution to achieve the strategic goals of a "recycling society". These reuse organizations focus on extending the life cycle of products by reusing and recycling products at later stages of their life cycle and/or by buying/selling used or remanufactured products.

Depending on their focus, there are several main types of such organizations:

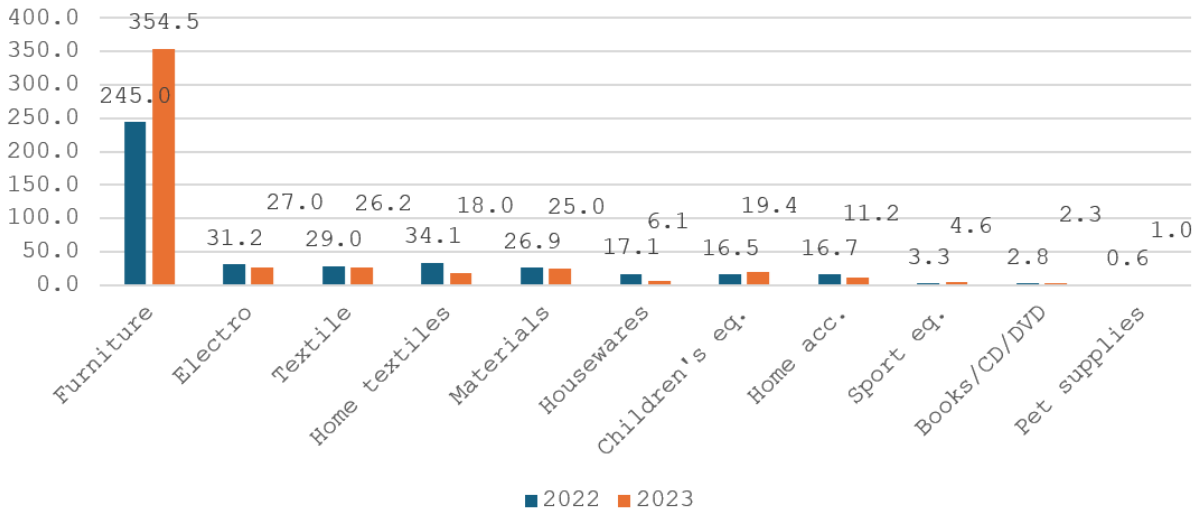
i) Reuse centers, essentially second-hand shops often attached to repair workshops.
ii) Reuse points, designated drop-off points for used goods; and
iii) Furniture banks for unwanted furniture and household items, which are then made available to underprivileged locals or communities to furnish starter homes.

These reuse organizations may be grouped under the umbrella of the Reuse Centre Federation (RCF), as in the case of the Czech Republic. This initiative is supported by the Czech government through the Operational Programme Environment, covering the 2014-2022 period (ending in 2023), and will continue to be supported in the 2021-2027 phase of the programme.

In accordance with the implementing decision of the EU Commission (Commission Implementing Decision (EU) 2021/19 of 18 December 2020 laying down a common methodology and a format for reporting on reuse in accordance with Directive 2008/98/EC of the European Parliament and of the Council (notified under document C (2020) 8976), the following categories of products for reuse are monitored: as illustrated in Graph No. 3, furniture represents approximately 71.6% of the recycled goods volume, followed by electronics at approximately 5.4% and textiles at approximately 5.3% (all figures are for 2023).

It is worth noting that, despite being a relatively recent initiative, these reuse practices appear to be gaining momentum, particularly among municipalities. The total volume of

recycled goods via reuse organizations (based on data from the Reuse Centre Federation) currently constitutes a relatively negligible percentage of municipal waste production, less than 1% in 2022. However, it is anticipated that this share will increase over time due to the emergence of new reuse organizations (supported by ongoing public initiatives) and the involvement of more existing and new reuse organizations in the RCF, resulting in stronger enforcement of quality and quantity data (in accordance with standardized reporting).



Graph 3. The structure and volume of recycled goods (in Tons)
Source: *The Federation of Reuse Centres (www.reusefederace.cz)*

Given the recent inception of the RCF and the prevailing market structure of premature reuse organizations in the Czech Republic, relevant data have only been accessible from 2022 onwards in a rather limited form (still under development).

Not only do reuse organizations promote the principles of the circular economy locally by reusing goods and materials, but they can also generate a substantial social impact within their communities. They may provide affordable goods to lower-income families, thereby supporting them financially, and they can also foster job opportunities through the establishment of related workshops. Furthermore, these spaces can serve as communal gathering places, which benefits the local community.

1.4. Circular economy (CE) measurement options

As indicated by the European Commission (2011), European citizens have the highest net import of resources in the world, relying heavily on foreign raw materials and energy sources. Ensuring a stable and reliable supply of resources is a crucial economic strategy, while the potential adverse socio-environmental effects on other nations also give rise to concerns.

Given that earth-derived materials used economically are not entirely consumed but form persistent waste, which has the potential to cause environmental harm and unaccounted social costs, experts have warned that under current usage, essential raw materials might not be able to sustain all people's modern living standards (Ayres & Kneese, 1969). It is therefore prudent to transition to the circular economy (CE), an industry model that separates economic growth from material input (Gedvilaite & Ginevicius, 2024). The CE aims to preserve product value, limit waste, and keep resources in the economy even after the products have outlived their usefulness, enabling resource reutilization. This strategy, thus, enhances value generation

from each resource unit, surpassing conventional linear models (Gordon et al., 2005). The notion of a circular economy is regarded as a requisite development approach, effective in mitigating conflicts between environmental issues and economic progression.

The academic literature mentions three primary measurement scales, namely the micro scale, which typically pertains to a single product or business, the meso scale, which refers to eco-industrial parks and industrial symbiosis, and the macro scale, which encompasses larger entities such as cities, provinces, regions or nations, such as Alaerts et al. (2019), Moraga et al. (2019), Zhidebekkyzy et al. (2022a), etc. The OECD Inventory of Circular Economy Indicators (The OECD Inventory of Circular Economy Indicators - OECD (2021) can be considered as the most comprehensive review of circularity at the macro level. This compendium reflects the outcomes of a survey conducted by the EOECD, predominantly in Europe and the Americas. As stated in the inventory report, "The OECD inventory gathers input, process and output indicators employed by governments at different levels, in particular to monitor and evaluate the progress of existing circular economy strategies. The inventory provides an overview of circular economy measurement frameworks. It helps identify measurement gaps and can be a source of inspiration for governments wishing to develop or use indicators to improve circular economy-related policies ". It is designed to be a dynamic tool that will be updated frequently and consistently as nations, regions, and cities formulate circular economy strategies and related measurement frameworks. This report groups CE indicators into five primary categories, which are further subdivided into 33 subcategories and assigned to the 11 sectors to which they are linked.

Since this categorization is generally recognized and accepted, it can serve as a solid foundation and guiding principle for further development of "tailor-made" indicators for specific areas (e.g., reuse organizations can be considered) and/or also for other scales (both micro and meso).

As highlighted above, there is a wide range of alternative indicator methodologies exists for measuring circularity. The majority of studies that prioritize the micro-level perspective (focusing on reuse organizations), employ a specialized single indicator methodology (rather than a standardized one) to assess recycling, reuse, and material flow performance. These indicators are mostly paired with two important CE tenets – the use of recyclable resources and the flow of natural resources. For instance, Di Maio and Rem (2015) developed a single indicator to measure the degree of a product's circularity - the CE indicator, quantified as the derived material value of recycled products relative to the material entering the recycling process. Conversely, Park and Chertow (2014) offered a unique material-specific indicator called the reuse potential indicator (RPI), which indicates how resource-like rather than waste-like a material is based on currently available technologies.

However, considering only one dimension, such as resource use, hinders a comprehensive evaluation of CE frameworks and overlooks important aspects such as emissions and energy use, as noted by Geng et. al. (2012) and Štreimikienė (2024). The enactment of CE policies requires new organizational and logistical structures, industrial processes, and product innovation, which usually implies a redefinition of the business paradigm, as pointed out by the EEA (2016). For successful implementation, these transformations must maintain economic, social, and environmental sustainability.

Based on the previous evidence, the authors propose a method for measuring the implementation of Circular Economy (CE) practices at the level of reuse organizations by developing and applying an appropriate model of single specific indicators. In this regard, the authors posit that the comprehensive and user-friendly CE indicator proposed in this study could facilitate the attainment of the social, environmental, economic, and strategic objectives pursued, or at least initiate discussion on this emerging phenomenon. The objective is to

represent the economic value of materials incorporated in consumer goods as a value that can be quantified and accounted for.

This article aims to propose a methodological framework for possible model structures to quantify and measure the circularity of reuse organizations. The volume of municipal waste processed by reuse organizations is proposed as a primary circularity criterion/proxy, reflecting ongoing economic cycles and associated customer behaviors in the context of early-stage development in the Czech Republic.

2. Methodological approach

Unfortunately, there is currently no standardized and mandatory methodology for tracking data at the level of individual reuse organizations that would consistently define the scope, structure and quality of the required data. This significantly limits any attempt to implement, quantify and evaluate selected circularity indicators. Therefore, the partial objective must be to propose the necessary database (structure, relevant variables, etc.) that could serve in the future as a source for the application of selected circularity indicators and their measurement. At present, aggregated data collected at the RCF level are very limited (both in quantity and quality). It should be noted that only a fraction of the reuse organizations are members of the RCF (membership is not mandatory), i.e. the mentioned database only contains inputs from a limited number of reuse organizations. The current availability/non-availability of the required data is discussed below in the context of the proposals for individual indicators.

Based on the analysis of various studies presenting alternative options for measuring circularity in the context of different constraints, expected development scenarios, the scope of the investigated phenomenon, etc., as discussed in the preceding text, core assumptions are defined that the proposed methodological framework should meet for implementation in reuse organizations.

Although these organizations represent a relatively small and very specific niche within the circularity field, the analogy method can also be partially applied to refine the specific proposal of selected circularity indicators. This can start with relevant studies focusing on recycling facilities (such as car recycling capacities, which recover various metals and other materials from car scrap on a large commercial scale).

Given the complexity of the circularity phenomenon and the potentially wide range of activities conducted by reuse organizations, the application of the decomposition method seems promising. This approach allows the consideration of the multi-dimensional/multi-functional impact of their activities on individual key elements of circularity or their immediate environment (such as the economic, environmental, social dimensions etc.). To gain a basic understanding of the starting position (including previous historical development) of the monitored phenomenon, with a focus on municipal waste production and management, which is relevant for reuse organizations in the context of the Czech Republic, the description method was used.

The results thus obtained were verified by conducting a focus group with a heterogeneous group of participants. The heterogeneity was pre-planned in order to capture different perspectives. Representatives from academia, the business sector, the Federation of Furniture Banks and reuse centers, a waste management software developer and a representative from the Ministry of the Environment took part in the verification. In total, 10 representatives participated in the focus group. The aim of the research was to verify the proposed solutions.

Following the application of selected circular economy indicators to the currently available data for the Czech Republic, the paper concludes with a comparison of the results obtained for each dimension, including future recommendations.

In September 2024, the number of reuse centers was surveyed through repeated e-mail inquiries sent to all municipal and city authorities in the Czech Republic.

In order to verify dependencies, data from a questionnaire survey was used. The questionnaire survey was conducted in May 2024 using a representative sample of 1,300 respondents. The samples (set by the Laboratory for the Study of Human Behavior) reflect the overall distribution of the population with quotas by gender, age, education, income level, the size of residence, and economic activity (sometimes also occupation).

The survey data were analyzed using the Pearson's chi-squared test (or Pearson's χ^2 test of independence), which is appropriate for assessing relationships between two categorical variables. This test has been selected as it allows to examine associations between demographic characteristics (in this case the size of the respondent's place of residence and their age) and shopping behavior in reuse centers. The chi-squared test compares the observed frequencies of responses within categories with the frequencies which would be expected if there was no relationship between the variables. In the final analysis, the significance levels were set not only at 0.1 and 0.05, but also at a more stringent significance level of 0.01 to minimize the risk of false positive results.

We test the null hypothesis

$H_0: \pi_{ij} = \pi_{i.} \cdot \pi_{.j}$, that the variables *x* and *y* are independent,

against the alternative hypothesis

$H_1: \pi_{ij} \neq \pi_{i.} \cdot \pi_{.j}$, that the variables *x* and *y* are dependent.

Theoretical frequencies $n'_{ij}, i = 1, 2, \dots, l, j = 1, 2, \dots, m,$ represent the frequencies of individual combinations of the *i*th-variation of variable *x* and the *j*th-variation of variable *y*, provided that the null hypothesis is true, i.e., that the attributes are independent. Therefore, the more the actual observed frequencies differ from the theoretical frequencies, the more dependent the attributes are. Thus, to test the null hypothesis, the χ^2-test of independence in the contingency table is used. To use this test, the condition of sufficiently large theoretical frequencies must be met. A rule requiring that all theoretical frequencies be greater than five is used. If the rule of sufficiently large theoretical frequencies is not satisfied, the rows or columns of the contingency table must be merged so that the rule is met. At least two rows and at least two columns must remain after merging. Only adjacent rows or adjacent columns (or both) shall be merged for reasons of factual or numerical proximity. *r* is the number of rows of the contingency table after a possible combination and *s* is the number of columns of the contingency table after a possible combination. The test criterion measures the differences between the observed and theoretical frequencies in proportion to the theoretical frequencies. These values must be added up.

$$\chi^2 = \sum_{i=1}^{r} \sum_{j=1}^{s} \frac{\left(n_{ij} - n'_{ij}\right)^2}{n'_{ij}} \tag{1}$$

The test criterion has approximately χ^2-distribution of $(r - 1)\cdot(s - 1)$ degrees of freedom. High values of the test criterion (1) indicate significant differences between the observed and theoretical frequencies, and thus argue against the null hypothesis. The null hypothesis should be rejected in the case of high values of the test criterion. The critical interval of size α is as follows:

$$W_{\alpha} = \left\{\chi^2 : \chi^2 \geq \chi^2_{1-\alpha;(r-1)\cdot(s-1)}\right\}, \quad (2)$$

Where the critical value $\chi^2_{1-\alpha;(r-1)\cdot(s-1)}$ represents $100\cdot(1 - \alpha)\%$ the quantile of the $\chi 2$-distribution with $(r - 1)\cdot(s - 1)$ degrees of freedom. If the value of the test criterion (1) falls within the critical region (2), then the null hypothesis is rejected and the alternative hypothesis is accepted. In such a case, the dependence between the variables *x* and *y* is proved at the significance level α. If the value of the test criterion (1) does not fall within the critical region (2), the null hypothesis is not rejected, but the null hypothesis is not true (we do not know the error probability). In such a case, one can conclude that at the α level of significance, the relationship between the variables *x* and *y* has not been established.

3. Conducting research and results

The introduction of any Circular Economy Indicator (CEI) should demonstrate conceptual simplicity, thereby increasing the robustness and reliability of the proposed concept. In addition to conceptual simplicity, the associated cost is a critical factor to consider. This implies that the calculation process for the indicator may require ready-to-use financial reporting data or additional modifications or measurements.

It would be optimal to select indicators that can be automatically computed or directly derived from financial statements, eliminating the necessity for additional interventions or adjustments. The objective is to implement and utilize straightforward, inexpensive indicators that target specific policy aspects while also correlating indirectly with other facets.

Gutowski et al. (2013) highlight the importance of recycling and reuse as key elements of the circular economy model. This is often regarded as a fundamental aspect of a broader vision for the sustainability of a closed-loop society.

Since reuse organizations can process a wide range of inputs from diverse origins and material compositions, it is not feasible to apply a simplified CEI type, such as the one proposed by Di Maio and Rem (2015), with any degree of reliability. A combined approach is, therefore, necessary. In addition to recycling and remanufacturing goods to prolong their lifespan, reuse organizations may also recycle primary materials, such as metals, to serve as a secondary supply source for upstream industries. This further complicates the definition of CEI.

The authors believe that the Inventory of circular economy indicators on the macro level, created and continuously updated at the OECD level, provides an excellent and potentially unique starting point for measuring the circularity level of reuse organizations. Furthermore, the aforementioned study offers more than just a simple overview of potential indicators for circularity. It also presents a structured classification according to their character into selected main categories, capturing the complexity of circularity from different aspects (economic, infrastructure, social, etc.).

In line with the guiding principles of simplicity, cost-effectiveness, and data availability, the effort can be divided into three logically connected steps/phases:

1) Initial phase – This entails selecting appropriate macro indicators that can effectively capture the activities of reuse organizations (involving the reuse and/or recycling of goods and/or materials). The Commission Implementing Decision (EU) 2021/19 serves as a general guideline for the selection of these indicators.
2) Adjustment phase - It is based on the evaluation and, if necessary, the appropriate adjustment of selected macro indicators to ensure their suitability for use at the micro level, either at the level of individual reuse organizations or at the level of aggregated clusters (such as the RCF

or regional aggregation). This is done in order to meet the specific needs of the reuse organizations in question.

3) Implementation phase – It stems from the practical application and calculation of predefined circularity indicators based on the currently available data database (The RCF database as a primary source if currently available.).

Initial phase

Based on the OECD nomenclature (as mentioned above), only approximately 8% of all screened indicators pertain to recycling and/or reuse activities. This figure represents a relatively low percentage, which suggests that reuses and/or recycling are not the primary focus of circularity measurement. This supports the opposing idea, namely, that these activities are considered a niche from the perspective of circularity.

As the first step, the following macro indicators from all alternative categories and subcategories following the OECD nomenclature, as depicted in the table below, were selected due to their relevance to reuse and/or recycling activities, potential availability of underlying data (currently or in the future), calculation simplicity, and potential scalability, which should not be overlooked.

Table 1. Selected circularity indicators (macro level)

Category	**Indicator**	**Units**
Environment	Materials recovered through recycling and reuse	metric tons
	Relative change in material recovery	%
Economy and business	Economic value added of recycled and reused materials	currency
Social	Number of jobs created in reuse organizations	number
Others	Number of awareness raising activities (onsite visits, workshops for alternative stakeholders etc.)	number
	Number of reuse organizations in specified locality	number

Source: *The OECD Inventory of Circular Economy indicators, OECD (2021)*

The selected indicators should ideally represent a robust and useful sample covering a wide range of aspects to address the topic of reuse organizations and the circularity of resources. It should be noted that the precise definition and exact calculation formulas for particular indicators are not available, even though the calculation may be very straightforward in some cases. Only partial hints in the form of resulting units provide guidance for constructing and deriving individual relationships, which can be deduced more or less intuitively. The proposed partial indicators can thus be seen as a general guide, which can be adjusted as needed for their individual applications. This allows for the tailoring of adjustments to fit the particular problem under discussion, rather than applying a one-size-fits-all approach to problem applications.

Adjustment phase

The following section will focus on the proposal and derivation of relevant computational formulas (where applicable) for selected indicators, specifically for measuring circularity at the micro-level in the context of reuse organizations in the Czech Republic.

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Environment

As previously indicated, the landscape of reuse organizations in the Czech Republic is underdeveloped and still in the early stages of development. The majority of reuse organizations record their output in volume, adhering to the categorization of products for reuse as outlined in the Commission Implementing Decision (EU) 2021/19. This is done irrespective of the type of recycled or reused goods. For example, recycled books and remanufactured furniture have disparate environmental and energy consumption implications. The available data sets gathered across these organizations reveal inconsistency in both quality and quantity. Nevertheless, preliminary data on the volume and number of recycled and/or reused goods and materials, broken down by type (product category), are available. It should be reiterated that these data are monitored and centrally available only at the RCF level (provided only by members' organizations), and this only for the last two fiscal years (specifically, 2022 and 2023).

Therefore, the selected measure, which represents indicators from the Environment category, is volume value (in both absolute and relative terms) due to its current availability. In accordance with the principles of circularity, the following indicators are proposed: They originate from the Commission Implementing Decision (EU) 2021/19 and are consistent with the OECD methodology, as outlined in the OECD Inventory of Circular Economy indicators.:

A) An indicator of materials recovered through reuse organizations, expressed in volume metric (in tons) over the respective period of time (typically one fiscal year). In other words,

$$CEI_{Materials\ recovered} = \sum_{i=0}^{n} x_{i,t} \qquad (3)$$

Where:

x … is the quantity of the monitored type of recycled and/or reused goods and materials,

i … stands for the selected type of goods and materials,

t … is the selected time period.

This indicator represents a static, volume-driven measure that can subsequently be decomposed into various kinds of recycled and/or reused goods and materials (such as textiles, furniture, and metals) as necessary.

B) An indicator of change in materials recovered through reuse organizations, expressed in relative terms and capturing changes in the selected indicator over time, thus revealing potential trend changes. In other words,

$$\Delta CEI_{Materials\ recovered} = \frac{(CEI_t - CEI_{t-1})}{CEI_{t-1}} * 100 \qquad (4)$$

Where:

t … is the selected time period.

The second indicator is constructed as a percentage change of materials recovered through reuse organizations over the respective period (typically between two years) to capture potential dynamic development of the first indicator. This indicator can subsequently be decomposed into various kinds of recycled and/or reused goods and materials (such as textiles, furniture, metals, etc.) as necessary.

Economy and business

Given the further development of reuse organizations in the Czech Republic and their anticipated coordinated collaboration within the RCF, it would be beneficial to consider more advanced alternative CE indicators expressed in economic terms, based on more detailed data that is currently available. The economic value, which is likely to align closest with current EU policy, poses challenges for quantification due to factors such as the anticipated acknowledgement of the material composition of all recycled and/or reused goods, the varying accounting principles applied among reuse organizations, and other considerations.

Although reuse organizations combine the possibilities of material recycling, in which the life cycle of goods ends and they are transformed into basic materials, and the reuse of selected goods, in which it is assumed that the goods' life cycle is extended, it is believed that it is appropriate to link these two fundamental concepts together and track them through a unifying indicator. The basic assumption of this proposal is that reuse organizations are capable of decomposing individual types of goods into the basic materials they consist of (for the purposes of calculating the indicator, this is meant conceptually and not necessarily to disassemble physically). This involves the creation and use of a standard technical table for material conversion. The two defined figures—the numerator representing the material volume recycled and/or reused, and the denominator representing the reproduction material values - should be available based on the aforementioned assumptions.

In the case of recycling goods and materials, it is possible to proceed from the modified general concept of adjusted gross value added, which is focused on value generation created by the circular economy and circular activities. In this case, added value is defined as the difference between the output and input price for individual types of materials, with the exclusion of other types of costs (such as wage costs, energy costs, and depreciation) that would be difficult to allocate to individual recycled types of goods and materials in practice. The input price is defined as the financial value that may be paid to the supplier of the relevant goods and/or materials. In many instances, the price may be equal to zero, indicating that reuse organizations do not pay any price for these supplies. Conversely, reuse organizations may charge a fee when receiving the relevant goods and/or materials. The output price is defined as the financial value of goods and/or materials that reuse organizations charge their customers for the sale of remanufactured goods and recycled materials. The actual CE indicator can be defined as the ratio between the total adjusted gross value added of recycling and reuse and the material reproduction value. Incorporating the reproduction value of materials (market-based price) into the calculation of this indicator introduces a significant element of flexibility. This allows reuse organizations to make more flexible decisions while considering current market conditions, thus contributing to the financial sustainability of reuse organizations. For example, they can decide whether to sell or donate repaired and/or remanufactured goods on the secondary market or alternatively disassemble the goods into individual material components for sale.

Then this can be expressed as follows:

$$CEI_{Rec} = \frac{Adjusted\ Gross\ value\ added}{Re{-}product\ value\ of\ materials} \quad (5)$$

The aforementioned formula can then be rewritten as follows:

$$CEI_{Rec} = \frac{\sum_{i=0}^{n}(Material\ oupt\ price_i - Material\ input\ price_i)}{\sum_{i=0}^{n} Re{-}production\ value\ of\ material_i} \quad (6)$$

Where,

i … stands for the selected type of materials.

Social category and others

The governance indicator in the form of a number of awareness raising activities is relatively easy to estimate. However, how to assess different types of these activities remains an open question. For example, compared to a time-limited public event such as an open day, an all-day educational seminar could be a much more complex activity. It will probably be sufficient to focus on a simple count of these organized activities and in case it turns out over time that their variability is large enough, or that the scale of associated complexity and costs is robust enough. It is possible to consider an alternative construction of a weighted or recalculated number of awareness-raising activities based on their complexity and a predefined scale by type.

From a certain perspective, the activity of reuse organizations can be viewed as a business activity that naturally creates new employment opportunities, especially for socially disadvantaged people. Therefore, the chosen indicator, the number of jobs created, represents a suitable characteristic of the social aspect/dimension of reuse organizations. Of course, jobs can be arranged differently (main employment relationship, agreement on work or activities, etc.) depending on the possibilities and context of individual reuse organizations. However, for the sake of consistency and comparability (regardless of the form of employment relationship chosen), this should refer to a recalculated full-time equivalent for in-house staff.

The last selected category is infrastructure, where the use of the selected indicator from its definition only makes sense in the case of an aggregated view (for example, within a district, urban agglomeration, etc.), but not in the case of individual reuse organizations. The calculation of the specific indicator "number of reuse organizations in a given locality" is relatively simple, as it represents the number of existing and functioning reuse organizations in the chosen geographical area. Of course, it can be argued that there may be differences between different reuse organizations (such as reuse centres vs. reuse points, etc.) in terms of the scope of activities offered/developed, capacity of recycled and/or reused goods and/or materials.

The simplicity and cost-effectiveness of the proposed CE indicator offer significant advantages. Another comparative advantage is its scalability. It can be easily applied at the municipal level, and extended by increasing the aggregated regional coverage (from county to region to whole country level) for comparisons and other purposes.

Implementation phase

Environment

The underlying data required for performance analysis cannot be readily found within corporate financial statements, which necessitates additional data collection at the level of reuse organizations. This requirement stems from the potential variance in legal form (e.g., entrepreneurial, not-for-profit, budgetary and contributory organization, etc.) and different accounting principles and standards (such as, double-entry accounting, non-accrual accounting, etc.) applied by these entities.

The following values can be obtained by applying these CE indicators and using the data currently available from the RCF for the fiscal years of 2022 and 2023.

Table 2. CE indicator – Development of materials recovered

(in ´000 metric tons)	2022	2023
$CEI_{\text{Materials recovered (t)}}$	423.4	495.2

Source: *Own calculations based on the RCF data*

The table above shows that approximately 423.4 thousand tons of goods and materials were recycled and/or reused in 2022, and 495.2 thousand tons were recycled and/or reused in 2023. It is crucial to note that these amounts correspond to the number of operations involved in the RCF (only 11 and 14 reuse organizations in 2022 and 2023, respectively). In other words, the actual amount of goods and materials recycled and/or reused would be significantly higher (not all existing reuse organizations are members of the RCF, as membership is voluntary and therefore their data is not publicly available).

Table 3. CE indicator – Change of materials recovered

(in %)	2023/2022
$\Delta\ CEI_{\text{Materials recovered (\%)}}$	16.97

Source: *Own calculations based on the RCF data*

Table 3 illustrates a positive trend in the increase in the volume of goods and materials recycled and/or reused between 2022 and 2023. This is partly due to an increase in the number of businesses involved in the RCF. Whether this increase is exclusively driven by the addition of new members, and/or by a higher volume of processed goods and materials by the original members, is currently difficult to determine.

It is too early to draw fundamental conclusions about the level of circularity of reuse organizations from a material recovery point of view, since the underlying time series data are not comprehensive: i) from a time perspective (covering only 2 fiscal years), ii) the number of reuse organizations is expected to increase (partly due to ongoing government support), and iii) their potential membership in the RCF is unclear, including their ability and willingness to report the required data, although the RCF can play a crucial role in standardizing procedures, collecting and evaluating relevant data.

Economy and business

Unfortunately, the proposed indicator based on gross value added cannot be calculated due to the current lack of underlying data. However, we assume that efforts to develop the underlying database should be directed in the following way. A detailed inventory of goods channelled through reuse organizations and their subsequent categorization according to similar material composition into superior groups of goods should be carried out. Then, based on the material decomposition of each product group, standard technical tables for material conversion will be generated. The material input prices would be derived by allocating the input prices of the goods in relation to the material shares. Afterwards, the adjusted gross value added can be estimated based on the difference between the material prices on the input and output side. The final step is the calculation of the indicator figure based on the assumption that the reproduction value/price of the affected materials is known.

Social category and others

As mentioned above, the remaining indicators can be used as rather complementary measures, and their calculation is relatively simple, straightforward and self-explanatory. Based on the data available at the RCF level, the following results are obtained (see the table below):

Table 4. CE indicators – Social category and other fields/areas

Indicator (unit)	2022	2023
Number of awareness raising activities	44	47
Number of jobs created in reuse organizations*	207	245
Number of reuse organizations in specified locality	11	14

**Including specific group of commitments*
Source: *Own calculations based on the RCF data*

It should be noted that the above calculations are only indicative and show/demonstrate the possibilities of using the proposed indicators. Again, it is necessary to point out that the RCF does not cover all reuse organizations (membership is not obligatory, it is a voluntary association) and at the same time the number of these organizations is growing at a significant pace (given the grants/subsidies issued by the Ministry of the Environment of the Czech Republic).

In 2024, the authors of this article conducted a survey to determine the actual number of reuse centers, reuse points and similar establishments. The survey results are presented in the following figures:

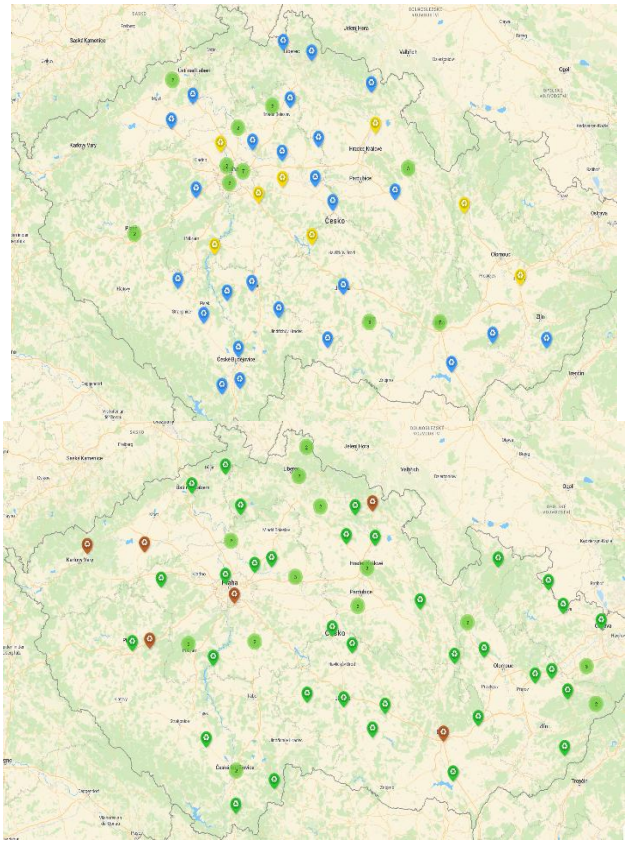

Figure 1 and Figure 2. Maps of reuse establishments in the Czech Republic
Note: Picture on the left: green dots = reuse centers, brown dots = furniture banks. Picture on the right: green and blue dots = reuse points, yellow dots = other establishments (e.g. swap or community centers).
Source: own processing

The pictures show an increase in the number of reuse centers, reuse points, even furniture banks in the Czech Republic compared to the number of member establishments included in the survey of the Federation of Furniture Banks and Reuse Centers. In 2024, a total of 60 reuse centers, 56 reuse points, 10 furniture banks and 10 other establishments were thus identified in the Czech Republic.

The distribution of points on both maps clearly shows that except for the left border of the Czech Republic, the establishments are present in all parts of the country. However, upon closer identification, it is worth noting that the points are clustered in the urban area. This led the authors to the idea of verifying whether there is a statistical dependence between the size of the respondent's place of residence and the willingness to use a reuse center. The results (based on a questionnaire survey) are presented in the following table.

Table 5. The values of the test criterion leading to verify the dependence between the size of the place of residence and the willingness to use reuse centers at different levels of significance

Variables and their categorization	TC	Critical value at the significance level of		
		0.10	0.05	0.01
The size of the residence Answer to the question: Would I be willing to shop at a reuse center within a walking distance?	35.585	33.196 *	36.415 –	42.980 –
The size of the residence Answer to the question: Would I be willing to shop at a re-use center located within 30 km?	42.789	33.196 *	36.415 *	42.980 –
The size of the residence Answer to the question: Would I be willing to shop at a reuse center located more than 30 km away?	49.317	33.196 *	36.415 *	42.980 *

Source: own processing of the questionnaire survey results
Note: TC - the value of the test criterion. * The test is statistically significant at a given level of significance.

Table 5 reveals that the value of the test criterion increases with the distance to the reuse center (for the three distance categories mentioned). It is also evident that the dependence between the size of the respondent's place of residence and their willingness to shop at the reuse center was statistically proved for the commuting distance only at the 0.10 level, and at the 0.10 and 0.05 levels of significance for distances up to 30 km, but for reuse center located at distances above 30 km, the dependence was established at all levels of significance including 0.01. The frequencies of individual responses imply that the willingness to shop at more distant reuse centers increases with the decreasing size of the place of residence, which is a positive finding since reuse centers in the Czech Republic are concentrated mainly in larger cities.

The dependence between the use of re-use centers and other variables of the sample of respondents was also tested. The strongest dependence was found for the age variable (see Table 6).

Table 6. The values of the test criterion to verify the dependence between age and willingness to use reuse centers at different levels of significance

Variables and their categorization	TC	Critical value at the significance level of		
		0.10	0.05	0.01
Age Answer to the question: Would I be willing to shop at a reuse center within a walking distance?	59.134	40.256 *	43.773 *	50.892 *
Age Answer to the question: Would I be willing to shop at a re-use center located within 30 km?	76.253	34.382 *	37.652 *	44.314 *
Age Answer to the question: Would I be willing to shop at a reuse center located more than 30 km away?	87.163	34.382 *	37.652 *	44.314 *

Source: own processing of the questionnaire survey results

Table 6 proves a statistical dependence between the age of respondents and the use of reuse centers at any distance, namely at all levels of significance. The frequencies of responses to all three questions above indicate that the interest in shopping at reuse centers decreases with the increasing age of the respondents, and the strength of this dependence increases with the increasing distance of the reuse center from the respondent's place of residence. Thus, the assumption that the age composition of the population predetermines the use of reuse centers has been statistically established.

All the above proposals have been agreed to by all participants present in the focus group and the following conclusions have been reached:

i) Reuse organizations may combine different activities, from the recycling of basic materials to the reuse of selected goods, to varying degrees, which increases the complexity of the observed phenomenon and makes it difficult to monitor;
ii) ii) currently, there is a lack of underlying data, including a comprehensive standardized methodological framework, which requires the definition of the scope, structure and quality parameters of the required data;
iii) the progressive automation and digitalization of warehouse management processes (including the receipt and dispatch of goods and materials) at the level of individual reuse organizations is feasible, according to the representatives of a company specializing in the development and operation of relevant software;
iv) at the same time, future approaches can be expected to shift from simply supporting the establishment of these organizations to a more data-driven support approach based on significantly improved circularity measurement capabilities, according to a public support provider (representative of the Ministry of the Environment); and
v) in order to address the predefined objective of this paper, a broader and more robust perspective is needed to capture the observed phenomenon.

4. Discussion

In recent years, the concept of circular economy (CE) has been intensively explored by various scholars and organizations as a potential means to improve the sustainability of our economic framework. Activities such as reuse, repair and recycling are gaining significant prominence in various sectors, including those involved in reuse initiatives. Such efforts, especially in promoting recycling and recovery strategies throughout the life cycle of a product,

have also been recognized and strengthened by initiatives of the European Union, such as the EEA (2016).

As stated, for example, by Elia et al. (2017) and Haas et al. (2015), contemporary research on the circular economy (CE) shows that despite its broad exploration and numerous case studies assessing its applicability in various scenarios, a coherent framework or set of criteria to quantify the level of circularity in products, companies or geographical regions remains elusive.

The index-based methodology, which has been reviewed and found appropriate by numerous scholars, such as Angelakoglou and Gaidajis (2015), Cucek et al. (2012), Galli et al. (2012), Gasparatos et al. (2008), Herva et al. (2011), and Ness et al. (2007), was mainly used in this study, among others.

The case of the Czech Republic reveals a significant challenge due to a significant lack of underlying relevant data, both qualitatively (standardized variable sets collected) and quantitatively (appropriate time series lengths). As a result, the proposal, construction and evaluation of an index-based typology methodology based on single or multiple synthetic indicators is not feasible. Instead, efforts have alternatively focused on defining specific single indicators that reflect the specificities of reuse organizations, similar to established researchers such as Ellen MacArthur Foundation (2015), Di Maio and Rem (2015), and Park and Chertow (2014). The proposal for specific individual indicators takes into account and respects the technical limitations of the reuse organizations involved in terms of their reporting capabilities and the nature of their activities, with the aim of creating a unified database. However, this requires initial data collection and testing prior to the implementation of the proposed specific single indicators.

Relevant international experience demonstrates that efforts to strengthen circular practices – through both systemic waste management reforms and Extended Producer Responsibility (EPR) mechanisms – have shown measurable impacts and can serve as valuable references for similar indicator development (Zhidebekkyzy et al., 2022b;2024).

Simultaneously, focusing on a single dimension such as material or input recovery represents a limitation in evaluating CE models as it excludes other critical factors such as social and infrastructure aspects Geng et al. (2012) and Moriguchi (2007). To ensure successful implementation, all these aspects need to be considered.

Although, as mentioned in the previous text, the basic inspiration for creating individual specific indicators representing alternative aspects of circularity comes from the OECD nomenclature of indicators for the macro level, following the three main intervention areas of the CE paradigm outlined by Ghisellini et al. (2016), the proposed indicators are designed to be applicable at the micro level, i.e. at the level of individual reuse organizations, and can be scaled up (if desirable or necessary) to measure and compare larger entities.

It is also clear from the text that a fundamental current limitation of research, which can be gradually overcome, is the lack of underlying data, both in terms of quality and quantity. Therefore, an integral part of the text is the identification of missing data structures and the proposal of specific characteristics that should be monitored.

Conclusion

The purpose of the presented paper was to reflect on and propose possible model structures for measuring the circularity of reuse organizations that are sufficiently robust and flexible with respect to their possible differences in legal form, accounting methods, size, etc. The selected/proposed indicators should, on the one hand, reflect various dimensions/aspects of circularity (economic-financial, environmental, social dimensions, etc.) and, at the same

time, cover, due to their nature, different degrees of complexity in the focus and activities of reuse organizations (recycling and/or reuse of goods and/or materials, etc.).

At the same time, reuse organizations in the context of the Czech Republic are still in the early stages of development, which can be attributed to the usual complications (insufficient organization, geographical fragmentation, inconsistency in the structure and scope of tracked data, or even no tracking at all, etc.). Therefore, this text can serve as a kick-off to initiate a discussion on the scope and depth of potential tracking and measurement of the contribution of these organizations to the achievement of broader environmental goals, including the related education of the population in this area, which could play a key role in the identification of the broader population with the intentions of the concept of circularity.

To the best of the authors' knowledge, there are no comparable studies dealing with proposals for measuring the degree of circularity in reuse organizations. This is probably due to their relatively small share in the recycling and/or reuse of municipal waste, which makes them a relatively niche part of the overall circularity efforts. In the case of the Czech Republic, less than 1% of the municipal waste volume is channeled through reuse organizations annually - the calculation is based on actual data collected by the RCF (2023) (both 2022 and 2023).

Thus, the proposed circularity measurements can be considered as a starting point for discussion both on the underlying data (desirable and achievable structure, required complexity including the associated process of their collection, etc.) and on the selection of indicators and own appropriate formulas (to capture circularity from all desirable aspects).

Based on the evaluation of the success and applicability of the proposed indicators in practice, there is a potential future direction of efforts aimed at defining suitable composite/synthetic circularity indices that could aggregate in full breadth both the behaviors/models of all relevant stakeholders and the necessary alternative perspectives on circularity.

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