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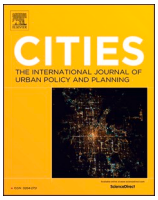

Urban circular economy initiatives: Development and application of a unified theoretical framework

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ABSTRACT

Existing assessments of Urban Circular Economy (UCE) initiatives often fail to address the multidimensional nature of urban circularity, particularly regarding social inclusion and stakeholder engagement. To address these limitations this research develops a unified theoretical framework by integrating three existing frameworks, the 9 DB framework (for identifying the development stage of waste and resource management), the 10R ladder (for defining the depth of adopted circular strategies), and the inclusive circular city (ICC) framework (for assessing environmental, social, economic and spatial dimensions, including participatory engagement). The unified framework is applied to the network of Circular Craft Centres (CCCs) in the Netherlands, a bottom-up initiative launched in 2019. The application of the framework reveals that the CCC network promotes the long-term circulation of materials, including textiles, furniture, electronics and plastics, through multi-stakeholder collaboration involving governments, organizations, businesses, citizens and vulnerable groups, with a focus on labour market integration. It also shows that CCCs have the potential to foster sustainability, circularity, and inclusion while underscoring the importance of place-based policies, the diversity of circular strategies implemented, and the active involvement of stakeholders across ICC dimensions. This study contributes to the development of holistic theoretical frameworks for evaluating UCE initiatives and supporting inclusive urban circular transitions.

1. Introduction

The concept of circular economy (CE) has gained momentum as a transformative economic model for sustainable production and consumption patterns. Various initiatives exist in urban contexts related to circular practices which can be classified according to their focus, i.e., on infrastructures, social consumption, industry and businesses, and urban planning (Petit-Boix & Leipold, 2018). Despite the widespread recognition of these strategies, their implementation remains slow and fragmented. The Circularity Gap Report (2025) reveals a decline in global circularity from 9.1 % in 2018 to 6.9 % in 2024, underscoring the persistence of linear economic models (Circle Economy, 2025). This decline reflects governance challenges, citizen engagement, data and assessment gaps, lack of partnerships and collaborative networks, limited cross-sectoral coordination, integrated approach and weak policy and financial incentives for circular actions at the local level (Bourdin & Jacquet, 2025; Cramer, 2022; Mubarik et al., 2024; Zhao et al., 2025).

Despite the pivotal role of urban circular economy (UCE) initiatives in the context of circular transitions, there is a notable absence of comprehensive knowledge and systematic analysis on grassroots UCE initiatives. Galego et al. (2024) identified various barriers within public policies and administrations. They advocated for the incorporation of a broader range of stakeholders, particularly citizens and grassroots

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organizations, throughout all phases of the policy cycle. They also highlighted the absence of integrated, inclusive, and operational tools to guide cities through intricate circular transitions. Similarly, a literature review by Toboso-Chavero et al. (2025) identified lack of integrated sustainability assessments in urban waste management systems as well as a lack of active stakeholder inclusion and participation.

Several studies have examined how local governments develop and implement CE policies. (Prendeville et al., 2018) analysed six European cities highlighting the diversity of policy instruments and the lack of financial resources as key barriers. (Bolger & Doyon, 2019; Calisto Friant et al., 2023) emphasized the influence of local urban conditions on CE approaches, advocating for a more comprehensive approach. Specific to UCE initiatives, Tsui Tanya (2023) employed spatial analysis to identify optimal locations for urban resource centres, incorporating environmental and cost-related indicators whereas Degli Esposti et al. (2021) provided a conceptual framework for the assessment of reusability and several other authors employed life cycle assessment (LCA) to examine environmental impacts (Castellani et al., 2014; Farrant et al., 2010; Ordóñez et al., 2022). However, the scope of these latter studies was often limited, typically addressing a single dimension (i.e. spatial, environmental and evaluative), and lacking a holistic perspective. This reinforced the idea that there is no universal model for UCE policies at the local level.

Consequently, we develop and propose a unified framework for the comprehensive study of UCE initiatives, which we apply on the Circular Craft Centres (CCCs) network of the Netherlands as a case study to evaluate its practical relevance and analytical usefulness.

2. The unified theoretical framework

2.1. Three theoretical frameworks

Even though the landscape of theoretical frameworks for analysing circular and inclusive urban initiatives is still evolving, those that integrate CE principles with inclusion and social equity are lacking. As highlighted in recent studies on CE (Corona et al., 2019; Osobajo et al., 2022; Toboso-Chavero et al., 2025; Vanhuyse, 2024) most frameworks exhibit a narrow scope, often focusing on specific dimensions and indicators while excluding social aspects. This fragmentation hampers efforts to conduct holistic analyses that account for the full range of dynamics and complexities within UCE initiatives at local scale.

To address this gap, three complementary theoretical frameworks have been selected for their capacity to support a more integrated and comprehensive analysis of UCE initiatives: (1) The Nine Development Bands (9 DB) (Whiteman et al., 2021) on waste and development ranges from DB1 to DB zero. The 9 DB framework delineates nine different stages (Fig. 1A in the Supporting Information (SI)) or "development bands" which symbolize the progression of waste management systems. It facilitates the evaluation of the prevailing status and advancement of a city or nation's waste management system, the identification of critical challenges, and the formulation of interventions; (2) the 10 R ladder (Potting et al., 2017) constitutes a set of increasingly circular strategies

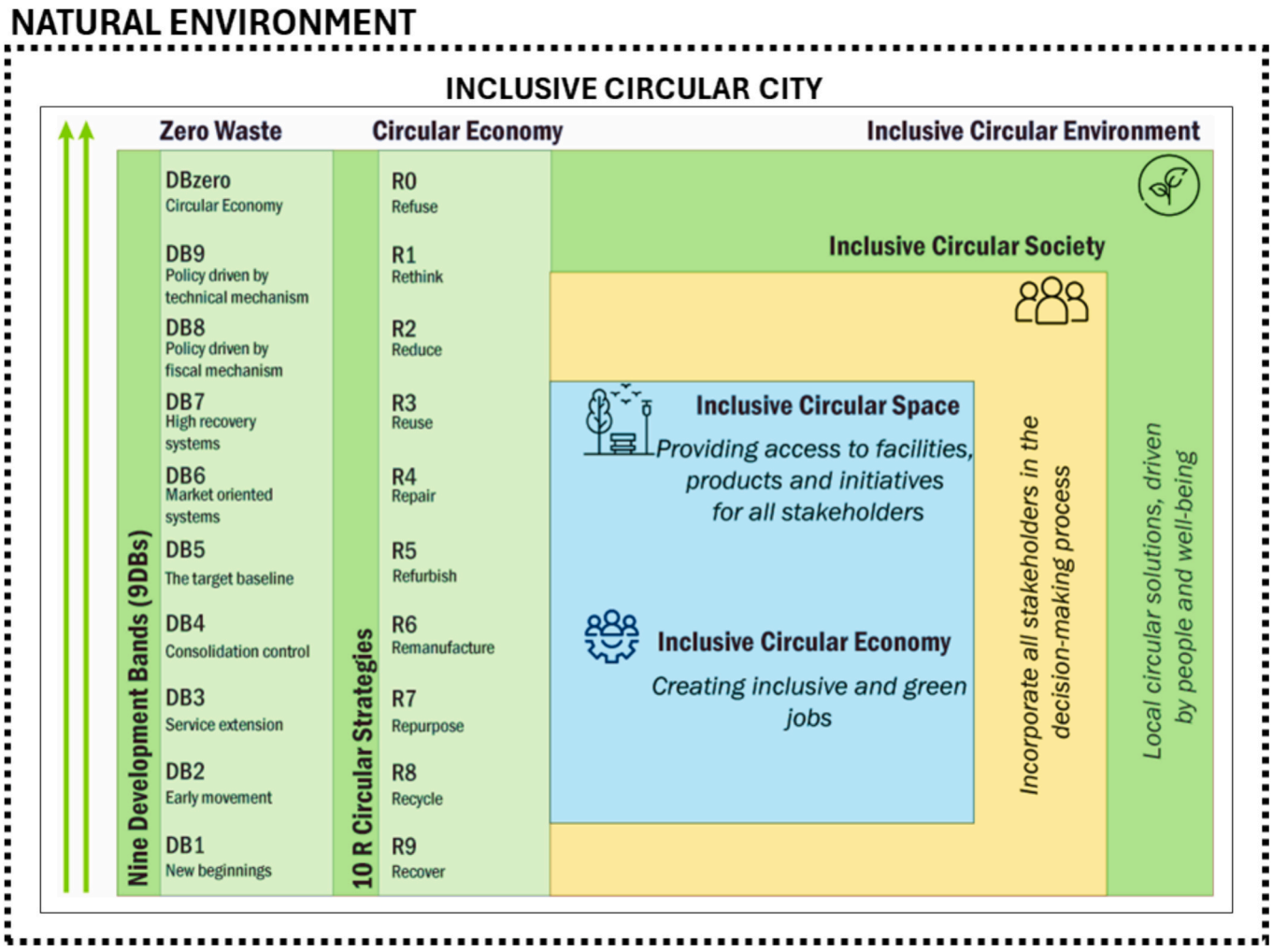

Fig. 1. Integration of the three frameworks, 9 DBs (Whiteman et al., 2021), 10R (Potting et al., 2017), and ICC (Liang et al., 2022; Liu et al., 2023; Toboso-Chavero et al., 2025) for the analysis of UCE initiatives.

that are aimed at minimizing waste and resource use while maximizing product life cycles and material value. They build on the traditional 3Rs by offering a more nuanced hierarchy of CE strategies, ranked from most desirable (R0) to least circular (R9) but still preferable to disposal (Reike et al., 2018) This framework is instrumental in the development and characterization of CE strategies, as it provides a structured approach for the prioritization and implementation of circular strategies, based on the principles of resource efficiency and value retention (Potting et al., 2017), and (3) the Inclusive Circular City (ICC) (Liang et al., 2022; Liu et al., 2023; Toboso-Chavero et al., 2025), an ICC relies upon four distinct dimensions (Fig. 1). The framework emphasizes the integration of environmental, social, economic, and spatial dimensions to create a holistic approach for urban development.

By unifying these three theoretical frameworks (Section 2.2) cities can effectively categorize and evaluate initiatives, ensuring they are inclusive and contextually responsive. This approach will aid in identifying synergies and trade-offs across different initiatives, ensuring that the CE contributes to more just and resilient urban environments.

2.2. Development of the unified theoretical framework

The integration of the three theoretical frameworks facilitates a multidimensional analysis. The 9 DB framework can be used to categorize a city or country's waste and resource management system into nine progressive bands ranging from minimal service provision to the aspirational stage of "zero waste". Complementing this, the 10R circular strategies provide a detailed set of value retention options (refuse, rethink, reuse, etc.) that guide specific strategies to keep materials in use and extend product life cycles. Finally, the ICC framework can integrate the various sustainability dimensions of a city while adopting an inclusive perspective of stakeholders across dimensions. The ICC framework has the potential to be applied to complement results-oriented policy approaches such as the promotion of community engagement and ensuring inclusive participation in urban circular transitions. The integration of all three frameworks results in the creation of a unifying and multidimensional lens. This lens has the capacity to comprehensively capture the multifaceted aspects of an UCE initiative, not only about "what" is included, and frameworks resulted but also "for whom" and "on what terms" (Table 1).

A comprehensive and multidimensional analytical framework is essential for the systematic evaluation of UCE initiatives when combining three interrelated frameworks: the 9 DB, the 10Rs framework, and the ICC because they offer distinct yet complementary perspectives (Fig. 1 and Table 1). The **9 DB** [based on (Whiteman et al. (2021)] provide a structured method for assessing the maturity level of an initiative within its specific urban, regional, or national context. It categorizes systems into one of nine bands of development by assessing system characteristics, recurring challenges, and key pressure points. For example, the attainment of DB5 indicates that a significant milestone has been reached. The **10Rs** framework (Potting et al., 2017; Reike et al., 2018) classifies circular strategies into short (R0–R2: refuse, rethink, reduce), medium (R3–R7: reuse, repair, refurbish, remanufacture, repurpose), and long loops (R8–R9: recycle, recovery) including associated material volumes, thereby illuminating the operative mechanisms of circularity embedded within the initiative. The **ICC**, in turn, evaluates the broader systemic integration of the initiatives by identifying the urban dimensions in which they intervene (economic, environmental, social, and space related dimensions) and assessing the extent to which it incorporates inclusion, for example, by jointly designing processes and stakeholder participation, identifying their roles and levels of involvement (Liang et al., 2022; Liu et al., 2023; Toboso-Chavero et al., 2025). The latter are analysed using the ladder of citizen participation (Arnstein, 1969) ranging from non-participation to degrees of citizen power (Table 1).

As the UCE initiative progresses towards the upper levels, it concurrently achieves greater success in implementing zero-waste, CE principles and strong sustainability. The overarching objective is to achieve a zero-waste paradigm, underpinned by a CE and strong sustainability principles. This entails the prioritization of social equity and planetary boundaries over market efficiency (Ayres et al., 2001). The unified framework under discussion facilitates a holistic and comparative analysis of UCE initiatives, allowing the identification of patterns, current status, gaps and best practices in different urban contexts. The integration of circular material strategies, and environmental and socio-spatial inclusion offers a novel approach to advancing in UCE initiatives, transforming usually fragmented efforts into a coordinated and inclusive transition framework. In response to the systemic deficiencies identified by Galego et al. (2024), which include policy fragmentation, adoption

Table 1
Comparison of the three frameworks: 9 DB (Whiteman et al., 2021), 10R (Potting et al., 2017), and ICC (Liang et al., 2022; Liu et al., 2023; Toboso-Chavero et al., 2025), and integration of the three frameworks with the types of relevant questions and analysis to be done.

Framework	9 DB (development bands)	10R circular strategies	Inclusive Circular City
What is included?	Level of progression of waste management systems	Lists specific material loop strategies	It examines who participates, who benefits, how governance works, and in which dimension
Why is it included?	It benchmarks system evolution and maturity	It diagnoses "what is being done"	It ensures social justice, legitimacy, and inclusion
Overlap	DB6–9 ≈ with advanced R strategies	Some Rs map directly onto DBs	It applies to every band and every R strategy
Gap	It does not address inclusion and is not explicit on sustainability dimensions	It does not address inclusion and is not explicit on sustainability dimensions	It lacks detail on materials, strategies, or level of maturity
Questions	Which band?	Which Rs?	Which dimension? Who and how are they involved?
Analysis	Band number (1–9) based on (Whiteman et al., 2021) Considering: A. System characteristics B. Common challenges C. Pressure points	Type of strategies applied and material volumes per strategies. Based on (Potting et al., 2017; Reike et al., 2018) 10 R strategies: • short loops: R0: refuse, R1: rethink, R2: reduce • medium loops: R3: reuse, R4: repair, R5: refurbish, R6: remanufacture, R7: repurpose • long loops: R8: recycle, R9: recovery	Type of dimension. Based on (Liang et al., 2022; Liu et al., 2023; Toboso-Chavero et al., 2025): • Environmental • Social (including the political dimension) • Economic • Spatial Involved stakeholders in each dimension and how they are involved. Based on (Liang et al., 2022; Liu et al., 2023; Toboso-Chavero et al., 2025) and the ladder of citizen participation (Arnstein, 1969) • Nonparticipation (Manipulation and therapy) • Degrees of tokenism (Informing, consultation and placation) • Degrees of citizen power (Partnership, delegated power and citizen power)

reluctance and weak stakeholder inclusion.

3. Validation of implementing the unified theoretical framework

3.1. Case study (circular craft centres)

For the illustration of the unified theoretical framework, we have selected the CCC network in the Netherlands as an example of local initiatives aiming to enhance resource circulation and social inclusion. Since their inception in 2019, these centres have undergone a substantial expansion from 43 to 96 across the country (Ministerie van Infrastructuur en Waterstaat, 2025). CCCs or *Circulaire Ambachtscentra* in Dutch, have been formally defined as *"locations or networks where parties work together to reduce waste flows and realize high-quality product and material reuse. At a minimum, the functions of a recycling point, thrift store, repair services, education and the social domain are combined, which means that items and materials remain in use for longer and unnecessary dumping and incineration is prevented"* (translated from Dutch) (Ministerie van Infrastructuur en Waterstaat, 2025). Each CCC is structured in **five building blocks** that define its nature and purpose. These building blocks encompass 1) recycling points, 2) repair services, 3) thrift stores, 4) educational activities, and 5) social employment (Fig. 2 and section 3.1 in the SI).

This CCC network is complex as it is characterized by a diverse array of stakeholders, heterogeneous circular strategies, evolving synergies, and varying governance structures. Therefore, a comprehensive theoretical framework is needed to effectively capture the multiplicity of interactions and systemic dynamics involved. To support this, data has been carefully collected within the scope of the framework through a combination of desk research, field visits, informal interviews, and direct observations conducted across 15 different locations, obtaining verbal and/or e-mail consent for data processing. The methodology used was rapid ethnography, offering a flexible yet rigorous way to quickly gain deep insight into local practices, stakeholder interactions, and socio-technical systems (Genzuk, 2003).

3.2. Illustration of the unified theoretical framework in the case study

The CCC network was used to test the proposed unified theoretical framework. This is an appropriate example, given that waste management in the Netherlands has evolved significantly over several decades (Loorbach, 2007) (see further details in section 3.2 in the SI).

In terms of the **9 DB**, the Netherlands can be classified in the highest bands, DB8–9 (Table 2), for the following reasons. In terms of **system characteristics**, the country has highly efficient systems for preventing, reusing, and recycling waste [57.6 % (2023) (Eurostat, 2025)] as well as for recovering energy while minimizing landfill through strict regulations (Rijkswaterstaat. Ministry of Infrastructure and Water Management, 2025). It also transparently monitors and reports data in real time and has strong policy frameworks and economic incentives (Chioatto et al., 2023; Chioatto & Sospiro, 2023). The national strategy for a fully circular economy by 2050 marks a key step, with a current circular material use rate of 30.6 %, well above the EU average of 11.8 % (Eurostat, 2025). This strategy includes different initiatives, such as our case study, the CCC network (Government of the Netherlands, 2024). The **common challenges** in the Netherlands are already being addressed in its national CE program (Government of the Netherlands, 2024). The CE program has the objectives of reducing raw material usage, replacing primary with secondary raw materials and sustainable bio-based materials, making longer and more intensive use of products and components through reuse and repair, and high-grade processing. The **pressure points** in the Netherlands include the increasing consumption of material resources and the decreasing of the global circularity rate (Circle Economy, 2025). This indicates that the current use of materials, if sustained, will impede reaching the national target for 2030

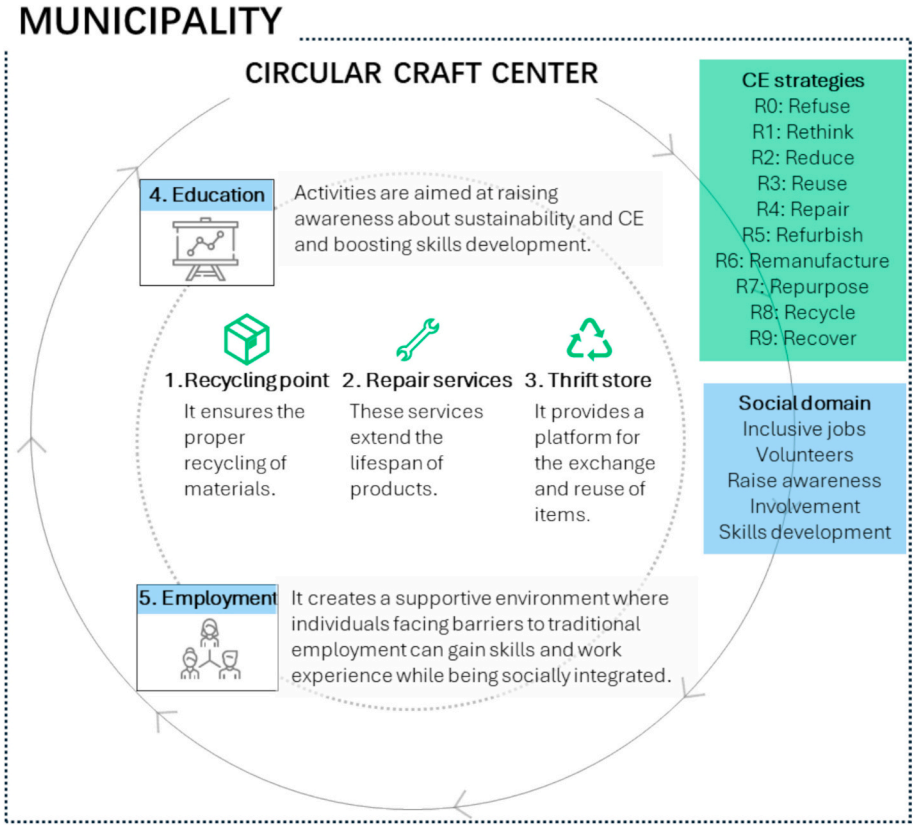

Fig. 2. Five building blocks of CCCs and their definitions. CE: Circular Economy.

Table 2
Analysis of CCCs using the unified theoretical framework for UCE initiatives. Lighter green means indirect contribution and darker green means direct contribution in the 10R circular strategies.

Framework	Analysis									
9 DB	DB1	DB2	DB3	DB4	DB5	DB6	DB7	DB8	DB9	DB Zero
10R	R9	R8	R7	R6	R5	R4	R3	R2	R1	R0
Inclusive Circular Environment	* Reduction of environmental impacts through the 10 R CE strategies * Minimum consumption of raw materials and energy * Inclusion of green and circular practices in the CCCs and stakeholders									
Inclusive Circular Society	* Opportunities for locals, especially vulnerable groups * Intergenerational and multicultural exchange * Inclusion of citizens: Raise awareness, also including different vulnerable groups * Multilevel governance: municipality, organizations, citizens									
Inclusive Circular Economy	* New business model based on circularity, sustainability and inclusion. Network of social organizations, making possible because the Netherlands is already in DB9 * Promotion of green, circular and local jobs and municipal economy * Volunteer is also part of the inclusive business model									
Inclusive Circular Space	* Accessibility to all types of facility, sense of community via workshops, events, etc.									

of reducing primary abiotic resource consumption by half (PBL Netherlands Environmental Assessment Agency, 2025). In addition, there is a need of a real shift from incineration and recycling, which are the prevailing circular strategies, to higher levels of the waste hierarchy such as rethink, reuse, and repair (PBL Netherlands Environmental Assessment Agency, 2025; Savini, 2021).

Regarding the 10Rs of the unified theoretical framework, CCCs contribute to directly or indirectly to all of them (Table 2). Within a CCC, circularity is of paramount importance. The integration of various building blocks, such as thrift stores, recycling points, and repair services, enables these entities to maximize their potential with greater effectiveness than stand-alone facilities. Undeniably, the **recovery circular strategy (R9)** is the least preferred option which is why CCCs aim to circulate all flows and optimize their reuse. However, CCCs do produce some residual waste that cannot be reprocessed (different CCCs, personal communication, May 2024). The circular strategies of **recycling (R8), repurpose (R7), and remanufacture (R6)** are well-developed in CCCs. They endeavour to maximize the separation of waste streams and to implement in-house recycling through repurposing or remanufacturing processes. Illustrative applications include the transformation of white cotton or denim jeans into yarn to produce new textiles, and the creation of plastic lamps or seats through repurposing of plastic materials (Stunt, 2025).

Refurbish (R5) and repair (R4) are also well-developed strategies in CCCs. These strategies aim to prolong the life span of products and materials as much as possible. Examples of this in many CCCs include bicycle repair services. **Reuse (R3)** is the most desirable of the circular strategies for managing inflows into a CCC. The thrift store functions as the primary platform for the resale of goods, thereby offering both economic and environmental advantages that surpass those of recycling. The range of products that can be resold is diverse, encompassing conventional goods such as textiles and furniture, as well as less traditional categories including building materials and Christmas decorations (De Cirkel, 2025). Strategies such as **reduce (R2), rethink (R1), and refuse (R0),** are indirect consequences of all CCCs. The implementation of these strategies entails a multifaceted approach, such as the organization of events and workshops (Samen Circulair, 2025), the involvement of a diverse range of stakeholders, and the integration of educational activities within academic institutions (Foenix, 2024; Race Against Waste BV, 2024). CCCs have the potential to influence the rethinking of consumption patterns, and the rejection of continuous consumerism.

Regarding the ICC, this framework helps to analyse where the CCC network fits within the ICC dimensions and who is involved and how (Table 2). The **inclusive and circular environment** is an inherent aspect of the daily operations carried out in a CCC for optimizing the handling of discarded products and materials which have been collected in the municipality. The reduction of environmental impacts is achieved by avoiding the extraction and use of new materials and by reducing the impacts of production and distribution. Consequently, CCCs consume a minimal amount of raw materials and energy, thereby reducing their environmental impact by implementing higher CE strategies such as reuse and repair. One illustrative example is a CCC in Meierijstad which manages more than 1 million kg/year of discarded products and materials generated by a consortium of small municipalities (83,000 inhabitants) (Het Goed, 2024). Another CCC in Ede handles 2.37 million kg of discarded products and materials annually (approximately 9 kg per capita), sorting and separating more than 18 different types for reuse, repair or recycling (Restore Kringloop, 2024).

The **inclusive and circular society** is another fundamental aspect within the CCC network because it provides volunteering and employment opportunities to people from a wide range of demographic groups, generations, and cultural backgrounds. Volunteering activities facilitate the involvement of individuals from diverse generational backgrounds including young people and retired individuals. A similar variety of circular jobs is offered, especially for the most vulnerable groups, who can choose to participate in roles that best suit their skills and preferences. A fundamental element in the establishment of these centres is to guarantee the social inclusion of diverse groups, integrating them into the network and providing them with a platform to articulate their concerns (see further details in section 3.2 in the SI).

The **inclusive and circular economy** of the CCC network becomes evident from their operations. A well-developed network of organizations, creative makers, artists, and businesses, located in or near the same city, has the potential to facilitate the processing and sale of various discarded products and materials. In this regard, a CCC functions as a catalyst by bringing all these actors together, and with municipalities offering support and promoting the initiative. For instance, the municipality of Haarlem, with the objective of becoming a circular city by 2040, has created a city alliance of professionals and businesses, fostering collaboration among entrepreneurs, designers, and raw material "coaches" focused on reuse (Haarlemse Waardemakers, 2024). In the same way, CCCs ensure **inclusive and circular space** for all citizens by facilitating equal access to opportunities for diverse groups within a municipality. This applies to physical spaces, services, and a wide array of volunteer and employment opportunities.

4. Reflections on the unified theoretical framework

The application of this unified theoretical framework facilitates a more integrated examination of UCE initiatives. It provides a contextualised approach by considering the stakeholders involved and the institutional, environmental and socio-political context in which they operate. A first analysis of a city within the 9 DB is imperative to facilitate the advancement of effective UCE initiatives and to assess their

degree of success and evolution. The 9 DB framework has the capacity to facilitate an initial theoretical evaluation and selection of specific UCE initiatives, thereby establishing the context for subsequent analysis of the UCE initiatives implemented, its type, the participants and beneficiaries. Evidently, the development of place-based and context-specific policies is essential for supporting the establishment of these initiatives. Therefore, a municipality's initial involvement and assistance in establishing connections within the region is crucial for creating a cohesive and robust local network of stakeholders (e.g., in the case study, between recyclers, thrift stores, and organizations which reuse, repair, and remanufacture products, but also of other entities which offer social employment and educational activities).

However, other pertinent features, such as the type of CE strategies being implemented, maybe be overlooked. In this regard, the 10R ladder is more specific providing greater nuances for each strategy implemented because it lists the CE strategies employed in a city, and the way they are articulated, as well as their potential direct or indirect contributions to urban circularity. The integration of these two frameworks enhances the in-depth analysis, thus facilitating more informed and supported decision-making processes, but they lack insight into the location, dimensions and dynamics of UCE initiatives within a city, as well as inclusion aspects. This is where the ICC framework provides a city-specific analysis by situating UCE initiatives within a city context and delineating specific dimensions. This is how the unified framework can enable further analysis of specific CE strategies and the environmental, social, economic, and spatial dimensions in which they are situated. It also allows for the consideration of how all stakeholders are included in the process of transitioning to a CE. This overarching framework outlines specific initiatives to be undertaken, with particular attention to the dimensions to be developed. Undeniably, the efficacy of these initiatives is contingent upon their potential for (different types of) inclusion. This means they must be environmentally beneficial and empower all stakeholders in decision-making processes, ensuring they all derive equivalent benefits. Additionally, the ICC framework has clear implications for urban policy and planning, as UCE initiatives become part of the city's physical, political, social, and environmental fabric playing a pivotal role in shaping the city's morphology, the characteristics of its citizenry, and the way policies influence its development. The structure and combination of diverse theoretical frameworks within a unified framework, emphasizing varied perspectives for analysis, inclusion, participation and open decision-making signifies a substantial advancement, offering practical knowledge to urban areas aiming to tackle the intricacies and challenges inherent in CE transitions (Esposito & Terlizzi, 2024).

The unified theoretical framework offers the foundations for improving the analysis and future implementation of other UCE initiatives, such as the ReTuna in Sweden (the world's first recycling mall (ReTuna., 2025), the RLab in Portugal (a repair and recovery laboratory, as well as a vocational training centre (Partnership on Circular Economy, 2019)), and the CPU in Slovenia (a social organization with five different CCCs (CPU-Slovenia, 2025)). This framework provides a structured yet adaptable instrument with which local governments can enhance their policy capacity to implement and expand UCE initiatives. Municipalities can use the proposed unified framework to create fertile ground for the emergence of circular jobs and volunteering, thereby strengthening social cohesion, boosting citizen participation, and establishing accessible, sustainable, and circular spaces. By applying this framework to UCE initiatives, municipalities will be able to adapt and refine their approaches, thereby improving their environmental and social impact and supporting the overall transition to local CE.

5. Conclusions

Existing assessments of UCE initiatives often lack a holistic perspective, particularly in addressing multidimensional aspects of social inclusion and stakeholder engagement. Here, we synthesize a unified theoretical framework to enable the identification of a city's current position within the waste and resource management spectrum (via the 9 DB) and the types and extent of CE strategies employed (through the 10R ladder) while framing them simultaneously within the ICC framework. The latter captures the environmental, social, economic, and spatial dimensions simultaneously, as well as the degree of participatory engagement across each dimension.

Applying this unified framework on the network of CCCs in the Netherlands reveals their transformative potential in driving urban transitions towards sustainability, circularity, and inclusion. This case study highlights the potential of the unified framework to serve as a context-sensitive tool for evaluating UCE initiatives which accounts for urban complexity and diversity.

CRediT authorship contribution statement

Susana Toboso-Chavero: Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Martin de Jong:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Investigation, Funding acquisition, Conceptualization. **Daan Schraven:** Writing – review & editing, Validation, Supervision, Resources, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Filippos K. Zisopoulos:** Writing – review & editing, Visualization, Validation, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Susana Toboso-Chavero reports financial support was provided by Dutch Research Council (NWO). If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cities.2025.106371.

Data availability

Data will be made available on request.

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