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Recontextualizing Circular Economy Principles at the Urban Scale: A Landscape Architecture Based Framework and a Pilot Evaluation Matrix

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Abstract

Circular economy (CE) assessment tools have been developed mainly for products, materials and buildings (micro scale) or for national and regional policy (macro scale). The city tends to appear in this literature as the place where such tools are applied rather than as a scale with its own assessment logic. This paper asks what the micro and macro scale CE literature actually covers, how far its thematic focuses correspond to the physical, social, ecological, infrastructural and governance dimensions of urban space, and how those focuses might be reformulated as urban scale principles from a landscape architecture perspective. Two Scopus datasets (macro n = 260; micro n = 925) were screened following PRISMA 2020 and analysed by keyword co-occurrence in VOSviewer. The resulting five macro and eight micro thematic clusters were rated against five urban criteria on a Low, Medium, and High scale using pre-defined decision rules. On this basis, five principles of urban circularity are proposed: Spatial Adaptability, Social Inclusion, Ecological Regeneration, Integrated Circular Flows and Adaptive Governance. One of them, Spatial Adaptability, is developed into a pilot matrix of six sub-principles with indicators and qualitative evaluation levels; the other four are outlined but not operationalised. The framework is offered as a starting point for a qualitative urban circularity assessment that can be tested on open-space typologies and refined with practitioner input.

Keywords: Circular economy; Urban circularity; Circularity assessment; Spatial adaptability; Landscape architecture; Bibliometric analysis

Introduction

The circular economy (CE) is accepted as a sustainable economic approach where economic growth is separated from resources use, through the reducing and recirculating of natural resources (Corona et al., 2019). In contrast to the linear economic model, which is based on the extraction, processing, consumption, and eventual disposal of resources as waste at the end of their useful life (Yamoah et al., 2021), the CE replaces the ‘end of life’ concept with several strategies such as reducing, reusing, recycling, and recovering in production, distribution and consumption stages (Arranz & Arroyabe, 2023). The literature on the concept largely converges on the view that circular economy is not merely a waste-management technique but a systemic approach in which production, consumption, business models and governance are treated as interdependent elements. Kirchherr et al. (2017), in their review of 114 definitions, highlight this holistic character, while Korhonen et al. (2018) similarly point to the multidimensional and mutually dependent structure underlying the concept. What remains thin in these definitions is a spatial vocabulary little is said about where circular processes take place or which spaces they require.

For CE principles to become applicable at different scales, they must be transformed into tools that can be evaluated, compared, and incorporated into decision making processes moving beyond mere conceptual definitions (Saidani et al., 2019). For this reason, several assessment approaches, indicator sets, performance metrics, and monitoring frameworks have been developed in the circular economy literature in recent years (Kristensen & Mosgaard, 2020). In the current literature, a significant portion of these studies aimed at measuring and evaluating circularity have focused on materials, production processes, building components, resource efficiency, life cycle assessment, recovery rates, and technical performance indicators (Saidani et al., 2019; De Pascale et al., 2021; Corona et al., 2019). Of the 61 CE indicators catalogued by De Pascale et al. (2021), the majority operate at the level of the product, firm or material

flow; only a small group address the meso scale, and none are designed around the physical organization of urban space.

The application of circular economy principles in cities aims to use natural resources efficiently, reduce waste and lower the ecological footprint of cities (Ellen MacArthur Foundation, 2019). Urban circularity is therefore not only a matter of closing loops (Williams, 2019; Prendeville et al., 2018); where a loop closes, and who has access to it, matter as much as whether it closes.

Therefore, urban circularity needs to be evaluated using interconnected dimensions such as spatial organization, social patterns of use, ecological continuity, infrastructure systems and governance processes (Webb et al., 2018). These dimensions cover efficient use of resources, reusability of existing spatial structures, accessibility for different user groups, ability to strengthen ecological connections, integration of flows such as water, waste, energy and food, and support through long-term maintenance and governance processes (Diep et al., 2019; Surekha et al., 2025).

The concept of Nature Based Solutions (NBS), linked to the CE, has evolved to include design solutions for landscape architecture today. These solutions are based on natural and living materials and policies, measures and actions that stimulate their use to address specific societal challenges common to the built environment (Pearlmutter et al., 2020). Therefore, the relationship between landscape architecture and the circular economy needs to be interpreted not only through material and process management, but also through a systems approach. The choice of landscape architecture as the disciplinary lens is deliberate. Urban planning typically operates at the level of land-use allocation and regulatory policy, while architecture is concerned with the scale of the individual building. Landscape architecture occupies the intermediate terrain between these two, encompassing parks, streets, vacant lots, riverbanks and infrastructural margins, where material flows, ecological processes and public use converge on the same site, and where responsibility for management is, more often than not, held by a single municipal department. It is at this level that the reuse of space, rather than of a product, becomes an observable question.

Two things follow from this brief review. First, urban circularity has largely been discussed through frameworks imported from the product and policy levels, and the dimensions that distinguish a city from a factory or a national economy, namely public space, everyday use, ecological continuity and municipal maintenance, are rarely incorporated into the assessment logic itself. Second, landscape architecture, the discipline that works precisely on these dimensions, has had little presence in the CE assessment debate. The present study addresses both points through three questions:

RQ1. Around which thematic focuses is the micro and macro-scale CE literature organised?

RQ2. To what extent do these focuses correspond to the physical/spatial, social, ecological, infrastructural and governance dimensions of the urban scale, and where do they fall short?

RQ3. How can the focuses that do correspond be reformulated as urban-scale principles, and how might one such principle be developed into an assessment matrix?

Circular Economy Assessment Approaches

Circular economy assessment approaches have been developed at various scales to measure and monitor circularity performance and incorporate them into the decision making process. These approaches are generally aimed at evaluating various dimensions, such as resource use, material flows, waste generation, recovery processes, environmental impacts, economic performance, social impacts, and governance capacity (Oliveira et al., 2021). Existing evaluation approaches nevertheless remain scale specific.

Assessment approaches developed at the micro level primarily focus on circularity performance at the product, material, building component, production process, and company levels (Ruiz-Pastor et al., 2024). Life Cycle Assessment (LCA), Material Flow Analysis (MFA), Material Circularity Indicator (MCI), and Circular Transition Indicators (CTI) are among the tools commonly used at this scale (Ellen MacArthur Foundation & Granta Design, 2015; WBCSD, 2020; Rigamonti & Mancini, 2021). These micro scale approaches are powerful in highlighting the technical and measurable aspects of the circular economy. They enable the assessment of issues such as product life extension, reuse, repair, recycling, recovery, resource efficiency, closing material loops, and environmental performance.

Macro level assessment approaches address the circular economy mainly from the perspective of resource management, policy performance, and transformation capacity in national, regional, or urban systems (Gedvilaite et al., 2024). This scale is defined within the European Union Circular Economy Monitoring Framework, Economy-Wide Material Flow Analysis (EW-MFA), Urban Circularity Assessment (UCA), Urban Metabolism, multi-criteria decision-making approaches and institutional assessment frameworks (Assumma & Pittau, 2022; Levoso et al., 2020; Eurostat, 2026).

A body of work on the "circular city" has nonetheless emerged since about 2018, and it is against this work that the present study should be read. Prendeville et al. (2018) mapped six European cities and found that circular strategies were being layered onto existing sustainability agendas without a clear definition of what a circular city is. Williams (2019, 2021) proposed three sets of urban circular actions, specifically looping, adapting and regenerating, and argued that the latter two, concerning the adaptation of the built fabric and the restoration of urban ecosystems, are largely absent from CE frameworks derived from industrial ecology. Paoli et al. (2022) reviewed more than a hundred circular city indicators, the great majority of which measure flows (waste, water, energy) rather than the spatial or social conditions under which those flows are organised. Local government strategies analysed by Bolger and Doyon (2019) show a similar pattern: circularity is framed as waste and procurement policy, with land use and public space rarely mentioned. These studies establish that the urban scale is being discussed, but also that its assessment still leans on indicators borrowed from other scales. The gap this paper addresses is therefore not the absence of urban CE research but the absence of an assessment logic that starts from the properties of urban space itself.

According to Bozeman III et al. (2023), existing assessment approaches remain limited at the urban scale because they primarily address circularity through measurable physical flows, technical efficiency, or higher level policy indicators; this data alone cannot explain how urban spaces are used, their public accessibility, their ecological quality, or their maintenance and governance processes (Chang et al., 2018). Circular economy principles, in other words, cannot simply be transferred to the urban scale; they have to be reinterpreted in line with the urban context (Ochoa et al., 2025).

Methodology

This study aims to propose a landscape architecture based conceptual and methodological framework for developing an urban circularity assessment matrix by linking the thematic focuses emerging at the micro and macro scales in the circular economy literature to the contextual criteria of the urban scale. The study structures this framework around the five fundamental criteria (physical / spatial organization, social patterns of use, ecological continuity, infrastructure systems, and governance processes) of urban circularity. It uses the principle of Spatial Adaptability as a pilot example to illustrate how the matrix development process might proceed.

The design rests on one premise: that CE principles written for products or national economies do not transfer to a park or a street without being rewritten. The following steps undertake this rewriting in an explicit and transparent manner, so that the origin of each principle remains fully traceable. As a result of this comparison, the principles of the circular economy at the macro and micro levels have been reinterpreted in line with the multilayered structure of the urban scale.

Research Design

The research proceeded in four stages. Two Scopus datasets, one macro and one micro, were built and screened following PRISMA 2020. Each was mapped by keyword co-occurrence in VOSviewer to identify its thematic clusters. The clusters were then rated against five urban criteria on a low, medium, and high scale using a predefined rule. Finally, the clusters that related to each criterion were read together to formulate one urban-scale principle per criterion, and one of these was developed into a pilot matrix.

Search strategy and PRISMA screening

The following Scopus search queries were used to distinguish the micro and macro levels: TITLE-ABS-KEY ("circular economy") AND TITLE-ABS-KEY (principle* OR framework* OR strategy* OR policy) AND TITLE-ABS-KEY (macro OR national OR global OR governance). This initial search of the Scopus database produced 1863 publications. The final macro level dataset on the circular economy, compiled as a result of this process, consists of 260 publications.

TITLE-ABS-KEY ("circular economy") AND TITLE-ABS-KEY (product OR building OR material* OR construction OR design OR manufacturing) AND TITLE-ABS-KEY (principle* OR strategy* OR framework* OR model). This search of the Scopus database provided 4745 publications.

The micro scale literature set created as a result of this process, which illustrates how the circular economy is structured at the technical and operational levels, was identified as comprising 925 publications in Scopus.

Both searches were run in 2026 and limited to documents published from 2015 onwards; 2015 was chosen because the Ellen MacArthur Foundation report of that year (EMF, 2015) fixed the vocabulary “principles, loops, building blocks” that most later frameworks adopted (Kirchherr et al., 2017). Screening followed PRISMA 2020 (Page et al., 2021). At the screening stage, the records were excluded if they were (i) not in English, (ii) not journal articles or reviews (conference papers, book chapters, editorials and notes were removed) or (iii) outside the subject areas of environmental science, engineering, social sciences, and energy. Titles and abstracts of the remaining records were read against two eligibility criteria: the document had to address CE principles, strategies or frameworks as its main subject, and it had to do so at a clearly macro (national, regional, global, governance) or clearly micro (product, material, building, manufacturing) level. Records that addressed CE only as a background concept, or that were themselves urban-scale studies, were excluded.

The macro (n = 260) and micro (n = 925) sets differ substantially in size (Figure 1), reflecting the wider publication volume at the product/material level rather than a deliberate sampling choice; because clusters were derived independently within each set, the asymmetry does not affect the within-scale ratings in Tables 2 and 3.

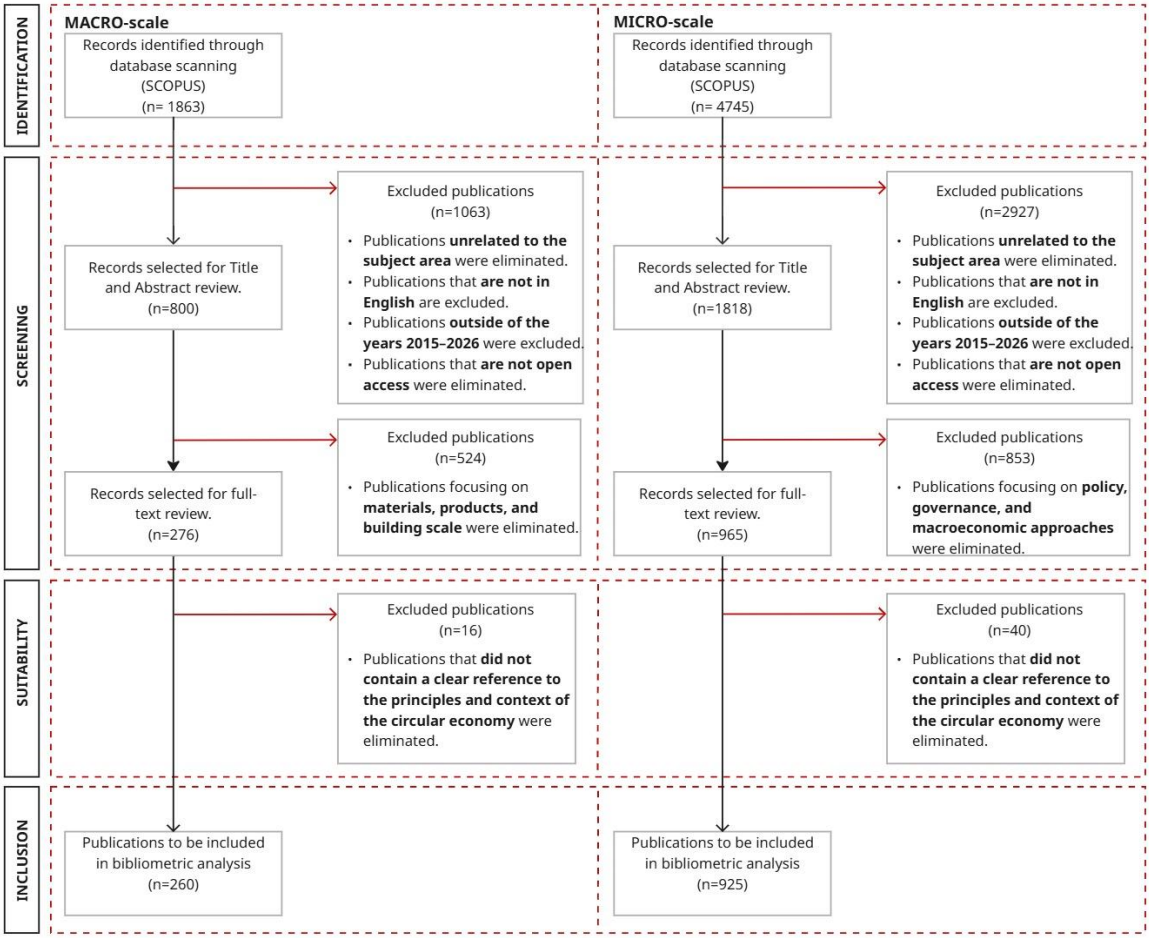


Figure 1. PRISMA Guidelines: Screening Stages and Final Sample Size at the Micro and Macro Scale.

Bibliometric Analysis

The micro and macro scale sets of publications obtained as a result of the PRISMA based screening were treated with bibliometric analysis using the VOSviewer 1.6.20 software. Keyword co-occurrence analysis was used as the type of analysis, and the "all keywords" option which includes both author keywords and index keywords was used as the unit of analysis. The "full counting" method was applied to determine the relationships between keywords, and a keyword was included in the analysis only if it appeared at least 5 times ($n \geq 5$). In the resulting maps, node size represents keyword frequency, links co-occurrence, link strength its intensity, and colours the clusters (van Eck & Waltman, 2010).

Criteria for the Low, Medium, and High Overlap Assessment

To determine the degree of overlap between thematic focus points identified through bibliometric analysis and the urban scale, five contextual criteria were pre-defined based on the literature: physical/spatial organization, social use patterns, ecological continuity, infrastructure systems, and governance processes.

Each criterion was given a short lexicon of keyword families drawn from the urban design, landscape and urban metabolism literature (Table 1). A cluster keyword was considered to "map" onto a criterion if it belonged to, or was a direct synonym of, a term in that lexicon.

Table 1. Criterion lexicons used in the overlap assessment.

Criterion	Lexicon (keyword families)	Main sources for the lexicon
Physical/spatial organization	built environment; building; construction; urban form; landuse; design; adaptive reuse; infrastructure siting	Williams (2019); Carmona (2019)
Social patterns of use	consumer/user; community; public participation; behaviour; social; accessibility; local production–consumption	Prendeville et al. (2018); Gehl (2010)
Ecological continuity	environmental impact; climate change; biodiversity; ecosystem; carbon footprint; green infrastructure; nature-based solutions	Gómez-Baggethun & Barton (2013); Pearlmutter et al. (2020)
Infrastructure systems	waste management; material flow; energy; water; supply chain; recycling; industrial ecology; urban metabolism	Kennedy et al. (2011); Levoso et al. (2020)
Governance processes	policy; governance; regulation; strategy; institution; monitoring; stakeholder; business model	Folke et al. (2005); Bolger & Doyon (2019)

Each thematic cluster obtained from the bibliometric analysis was evaluated according to these five criteria, examining not only the frequency of component keywords but also the conceptual and contextual meaning of these keywords within the broader literature. In this context, three levels of overlap were identified by the following rule. A cluster was rated Low on a criterion if none of its keywords mapped onto that criterion's lexicon and the representative source did not discuss the criterion's subject matter. It was rated Medium if at least one keyword mapped onto the lexicon, or if the representative source discussed the subject matter as a context or implication without making it an object of assessment. It was rated High if at least two keywords mapped onto the lexicon, one of them a central node of the cluster, and the representative source treated the subject matter as something to be assessed or designed.

Findings

Bibliometric analysis and co-occurrence mapping at the macro scale

When the 260 documents obtained from the Scopus database were filtered using a threshold value ($n \geq 5$) in the VOSviewer software, a total of 19 keywords were identified that dominate discussions on circularity at the macro scale.

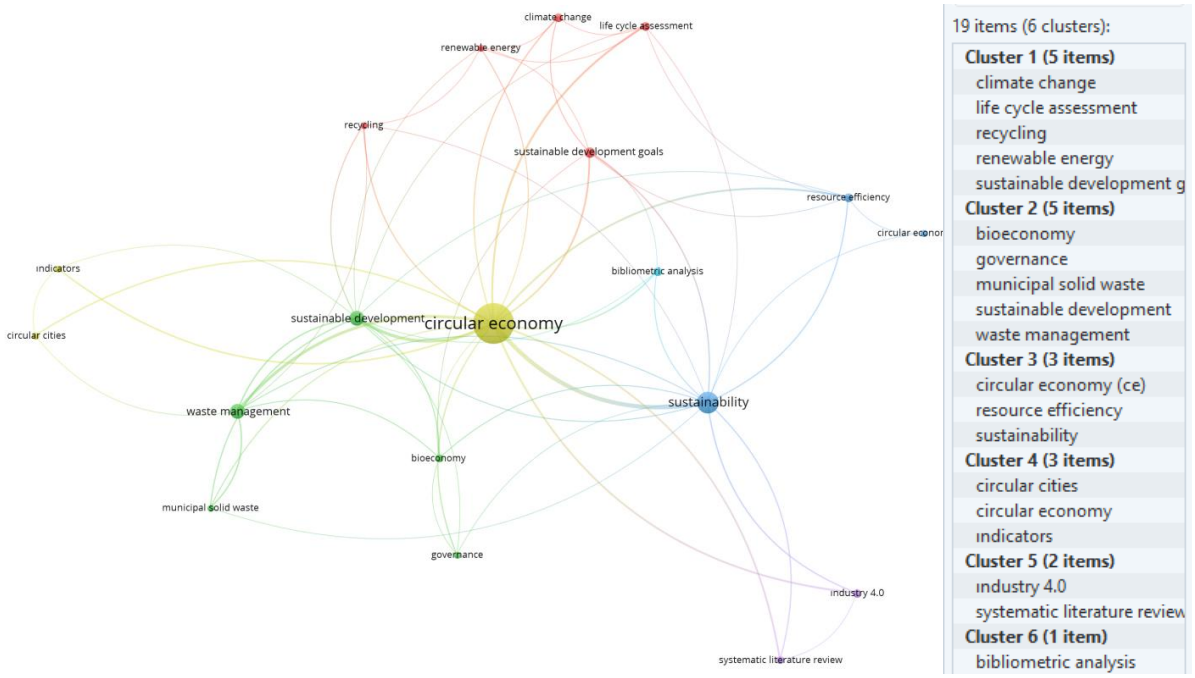


Figure 2. Macro Scale Bibliometric Network Map and Conceptual Clustering (VOSviewer 1.6.20 from Scopus data retrieved, 2026)

Upon examining the co-occurrence network created in the VOSviewer environment, it can be seen that the concept of "Circular Economy" is at the center of the network and establishes strong connections with the concepts of "Sustainability" and "Sustainable Development" (Figure 2). "Carbon neutrality", "energy transition", "renewable energy" and "supply chain management" form the second tier of the network. Macro scale CE research, in other words, is organised around the energy transition and production systems.

At the macro scale, the network is organised around environmental, economic and governance concepts; spatial organisation, urban planning and design appear only marginally. Five thematic clusters were identified using VOSviewer (Governance and Development, Climate and Energy, Industrial Infrastructure, Waste and Recycling, Resource Management).

The primary focus of each cluster was determined based on the "central nodes" within that cluster that possess the highest connectivity. For each cluster, one representative source was selected: the most highly cited document carrying the cluster's central keyword.

Clusters 1 (Governance and Development) and 4-5 (Waste and Recycling; Resource Management) address the circular economy largely through policy, governance, and recycling concepts, without establishing a direct link to the physical organization of urban space or user practices. The relationship between these macro scale thematic focuses and the contextual criteria of the urban scale is compared in Table 2.

Table 2. Overlap Matrix Between the Macro and Urban Scales in the Circular Economy

Thematic Focus Area	**Physical / Spatial Organization**	**Social Patterns of Use**	**Ecological Continuity**	**Infrastructure Systems**	**Governance Processes**	**Overall Urban Alignment**
Governance and Development	Medium	Medium	Low	Medium	High	Medium
Climate and Energy	Medium	Low	Medium	Medium	Medium	Medium
Industrial Infrastructure	Low	Low	Low	High	Medium	Low

Thematic Focus Area	Physical / Spatial Organization	Social Patterns of Use	Ecological Continuity	Infrastructure Systems	Governance Processes	Overall Urban Alignment
Waste and Recycling	Medium	Low	Low	High	Medium	Medium
Resource Management	Medium	Low	Low	Medium	Medium	Medium

*Low/Medium/High levels reflect the qualitative intensity of the relationship between each thematic focus and the corresponding urban criterion, assessed according to the criteria defined in Section 3.1.3.

An examination of Table 2 reveals that while the themes of governance and development, climate and energy, resource and waste management hold significant potential at the urban scale, they are integrated only to a limited extent with the physical organization of urban space and its social uses. Table 2 shows the macro literature strongest where the city is treated as infrastructure and weakest where it is treated as a place people use.

Bibliometric analysis and co-occurrence mapping at the micro scale

When the 925 documents obtained from the Scopus database were filtered using a threshold value (n≥5) in the VOSviewer software, a total of 25 keywords were identified that dominate discussions on circularity at the micro scale.

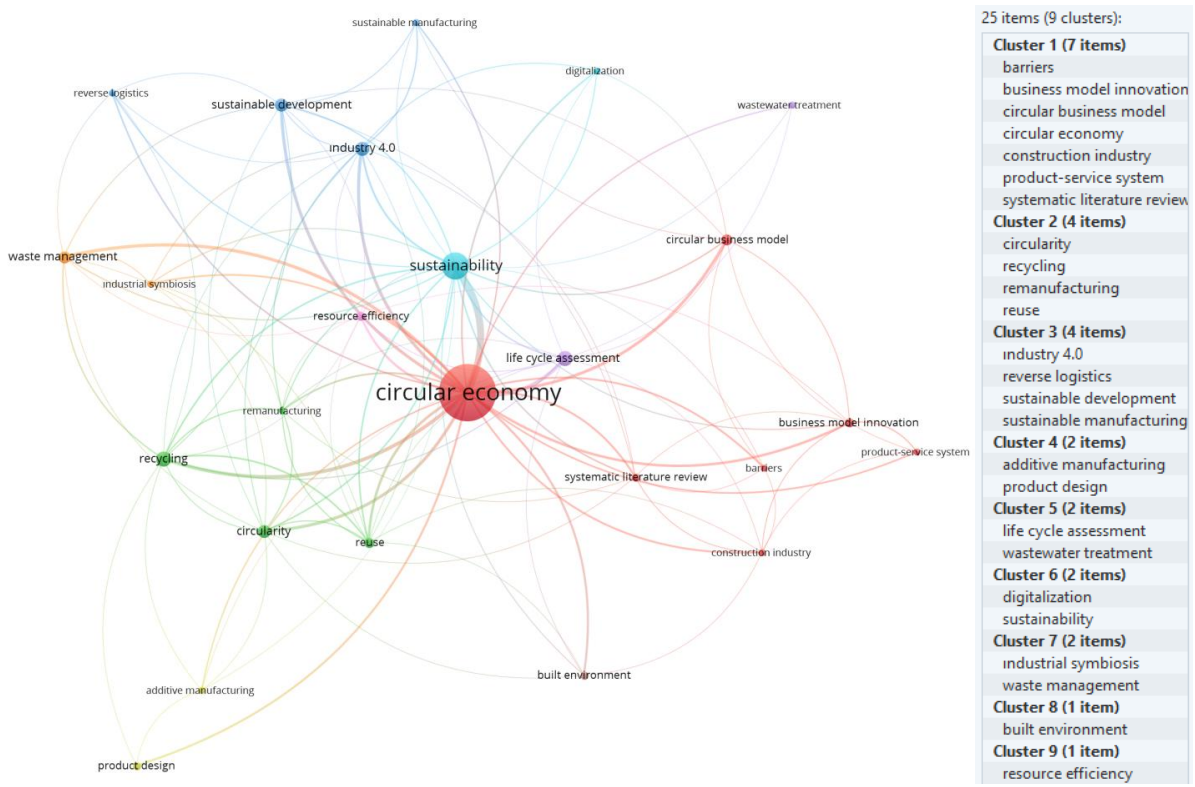


Figure 3. Micro Scale Bibliometric Network Map and Conceptual Clustering (VOSviewer 1.6.20 from Scopus data retrieved, 2026)

Upon examining the co-occurrence network, it is observed that the concept of the "Circular Economy" occupies a central position within the network just as it does on a macro scale and establishes strong connections with other concepts (Figure 3). When the network structure depicted in the map is evaluated as a whole, it becomes evident that the literature on the micro scale circular economy is concentrated around three main axes. The first of these is the product and design focused circularity axis. Concepts such as "Product Design", "Design for Sustainability", "Circular Design", and "Eco-Design" demonstrate that circularity begins at the design stage on a micro scale. These keywords point to a design-stage understanding of

circularity, one concerned with the lifespan of the product rather than with the space the product occupies.

The second axis is shaped by material and resource flows. Concepts such as “Material Flow Analysis”, “Recycling”, “Resource”, “Waste Management”, “Waste Valorization”, and “Plastic” indicate that, in the micro scale literature, circularity is largely defined in terms of closing material loops, reusing waste as a resource, and developing recovery processes. The micro scale's strongest contribution to the circular economy therefore lies in the technical management of physical resource and material cycles.

Finally, the third axis is related to environmental performance and life cycle assessment. The inclusion of concepts such as “Life Cycle Assessment”, “Carbon Footprint”, “Environmental Impacts”, “Climate Change”, and “Energy Transition” on the map indicates that even in micro scale studies, circularity is addressed in conjunction with the measurement of environmental impacts and performance evaluation.

What the map does not contain is as telling as what it does: no keyword refers to public space, everyday use, ecosystems in the urban sense, or local government. On this basis, eight thematic clusters were identified (Environmental Performance; Industrial Ecology; Reuse; Circularity Measurement; Materials and Waste Management; Economic Efficiency; Built Environment; Sustainable Development).

Clusters 1, 4, and 8 (Environmental Performance, Circularity Measurement, and Sustainable Development) link circularity to measurable environmental outputs, life-cycle indicators, and broader sustainability goals, but leave out qualitative dimensions such as urban quality, social accessibility, and spatial continuity. Clusters 2 and 7 (Industrial Ecology and Built Environment) address design decisions, material flows, and construction, yet remain confined to the product or building level without demonstrating how these resource flows integrate with the urban landscape or user practices. Clusters 3 and 6 (Reuse and Economic Efficiency) tie circularity to sectoral business models and cost-effectiveness, but do not address multi-stakeholder structure, public value, or spatial equity at the urban level.

The VOSviewer output was then read into a comparative matrix (Table 3).

Table 3. Overlap Matrix Between the Micro and Urban Scales in the Circular Economy

Thematic Focus Area	**Physical / Spatial Organization**	**Social Patterns of Use**	**Ecological Continuity**	**Infrastructure Systems**	**Governance Processes**	**Overall Urban Alignment**
Environmental Performance	Medium	Low	Medium	Medium	Low	Medium
Industrial Ecology	Low	Low	Low	Medium	Medium	Low
Reuse	Medium	Medium	Medium	Low	Low	Medium
Circularity Measurement	Low	Low	Low	Medium	Low	Low
Materials and Waste Management	Medium	Medium	Low	Medium	Medium	Medium
Economic Efficiency	Low	Low	Low	Low	Medium	Low
Built Environment	High	Low	Medium	Medium	Low	Medium
Sustainable Development	Medium	Medium	Medium	Medium	Medium	Medium

*Low/Medium/High levels reflect the qualitative intensity of the relationship between each thematic focus and the corresponding urban criterion, assessed according to the criteria defined in Section 3.1.3.

Table 3 shows that the micro scale focuses establish only limited, indirect, and fragmented connections with the urban scale. Although the built environment, reuse, environmental performance, and materials / waste management themes hold specific potential for translation to the urban scale, this potential remains confined to building components, product design, material cycles, and technical performance, without a holistic relationship to urban space.

A Conceptual and Methodological Framework for Developing an Urban Circularity Assessment Matrix

Findings from macro and micro scale bibliometric analyses indicate a distinct conceptual and methodological divergence between scales in the circular economy literature. In this regard, circularity at the urban scale requires the recontextualization of systemic goals at the macro scale and technical strategies at the micro scale through physical/spatial organization, forms of social use, ecological continuity, infrastructure systems, and governance processes.

In Table 4 below, this interpretation process was transformed into five fundamental principles that can be used to develop an urban circularity assessment matrix.

Table 4. A Framework for Transitioning from Macro and Micro Scale Findings to Principles of Urban Circularity

Urban Scale Criterion	Contribution from the Micro Scale	Contribution from the Macro Scale	The Fundamental Principle of the Urban Scale
Physical/Spatial Organization	Built Environment; Reuse; Materials & Waste Mgmt; Environmental Performance	Governance & Development; Climate & Energy; Waste & Recycling; Resource Management	Spatial Adaptability
Social Patterns of Use	Reuse; Materials & Waste Management	Governance & Development	Social Inclusion
Ecological Continuity	Environmental Performance; Reuse; Built Environment	Climate & Energy	Ecological Regeneration
Infrastructure Systems	Environmental Performance; Industrial Ecology; Circularity Measurement; Materials & Waste Mgmt; Built Environment	All five macro clusters	Integrated Circular Flows
Governance Processes	Industrial Ecology; Materials & Waste Management; Economic Efficiency	All five macro clusters	Adaptive Governance

The Sustainable Development cluster was rated Medium on all five criteria and is therefore not listed in Table 4: A theme that relates equally to every criterion does not help to tell them apart.

The transition from the micro- and macro-scale thematic focuses to the five fundamental principles of urban circularity followed a structured, criterion based synthesis process rather than a direct aggregation of scale-specific findings. In developing the five fundamental principles, each urban criterion served as the organizing anchor for this synthesis: for every criterion, the micro- and macro-scale thematic focuses rated Medium or High in their relationship with that criterion were identified as its constituent contributions, as summarized in Table 4. Rather than being listed side by side, these contributions were then jointly reinterpreted within the context of the corresponding urban criterion, so as to produce a single principle capturing how that criterion manifests at the urban scale.

This recontextualization process can be illustrated through the derivation of Spatial Adaptability. The physical/spatial organization criterion was rated High only for the Built Environment cluster at the micro scale; it was rated Medium for Reuse, Materials and Waste

Management and Environmental Performance at the micro scale and for Resource Management, Governance and Development, Waste and Recycling, and Climate and Energy at the macro scale (Tables 2 and 3). Rather than treating these as separate technical or policy inputs, their combined meaning was reinterpreted at the urban scale: whereas the micro-scale literature centers on extending the lifespan of a product, material or building, the urban-scale principle reframes this logic as extending the lifespan of urban space itself the adaptive reuse and reprogramming of existing structures, open spaces, and underutilized areas in response to changing needs.

A similar recontextualization logic underlies the remaining four principles. For Social Inclusion, the passive "consumer" or "end-user" role assigned to individuals in the micro-scale literature is reframed at the urban scale as an active co-producer and participant in shared, everyday, and circular practices within public space. For Ecological Regeneration, reducing a product's environmental footprint is reframed as positioning the urban landscape itself as an active ecosystem-service provider, capable of regenerating biodiversity, managing stormwater, and mitigating the urban heat-island effect (Gómez-Baggethun & Barton, 2013). For Integrated Circular Flows, the infrastructure systems criterion was the most widely supported of the five. Closing material loops within a single product or production system is reframed as the spatial integration of water, energy, waste, material, and biomass flows within the urban open-space system, as an interconnected network rather than as separate technical systems. Finally, for Adaptive Governance, organizational or business-level circular transformation is reframed as flexible, multi-stakeholder, and participatory local governance mechanisms capable of aligning macro-scale policy objectives with local realities (Folke et al., 2005; Chaffin et al., 2014).

A principle stated as a heading cannot be checked on site. Table 5 therefore breaks each of the five down into what it would look like spatially, socially, and in governance terms. The cells of Table 5 are the seeds of the sub-principles: for Spatial Adaptability, the three cells of the first row become the six sub-principles of Table 6, two per dimension.

Table 5. An Assessment of the Spatial, Social, and Governance Dimensions of Urban Circularity Principles

The Principle of Urban Circularity	Spatial Dimension	Social Dimension	Governance Dimension
Spatial Adaptability	Reusable, adaptable structures and open spaces	Flexible use across user groups and shared practices	Flexible planning, maintenance, and interagency coordination
Social Inclusion	Accessible, usable, and equitable public spaces	Community participation, co-production, and social learning	Participatory management across decision making and maintenance
Ecological Regeneration	Green infrastructure, ecological corridors, and habitat continuity	Ecological awareness, stewardship, and community-based practices	Ongoing ecological monitoring and long term institutional responsibility
Integrated Circular Flows	Integration of water, waste, energy, and material flows	User participation in composting, reuse, repair, and sharing	Multi-stakeholder coordination across infrastructure, government, and community
Adaptive Governance	Spatial decisions adaptable to changing conditions	Active community participation in decisions and feedback	Long term monitoring, evaluation, and multi-stakeholder collaboration

Taken together, the five principles recast circularity as a design and evaluation question rather than a resource-management one: what is at stake at the urban scale is the social, ecological and physical quality of open space, not only the efficiency of the flows passing through it.

The Process of Developing a Circularity Assessment Matrix Based on the Pilot Principle: Spatial Adaptability

Addressing all principles in detail including their sub principles, indicators, and evaluation levels is beyond the scope of this article. Therefore, the principle of Spatial Adaptability has been selected as a pilot principle to demonstrate how the proposed framework can be translated into the matrix development process.

Spatial Adaptability refers to the capacity of urban areas to respond to changing social, ecological, and economic needs; to reuse existing spatial resources; and to repurpose idle, abandoned, or underutilized areas. This principle reinterprets the concept of extending the lifespan of products or materials in the circular economy at the urban scale through the reuse of space, functional flexibility, and adaptability. Its constituent contributions are therefore the Built Environment and Reuse clusters at the micro scale and the Resource Management and Governance and Development clusters at the macro scale (Table 4).

The sub-principles were formulated based on three fundamental rationales. First, each sub-principle aims to make visible the urban scale counterparts of the thematic focuses derived from micro and macro scale analyses. Second, the sub-principles assess urban circularity not merely as a technical performance metric or policy goal, but as a multilayered structure with spatial, social, and governance dimensions. Third, the sub-principles have been formulated so that they can be converted into observable and comparable criteria in the evaluation matrix to be developed in a subsequent stage (Table 6).

The six sub-principles are not new terms; each has a body of literature behind it, which is why they can be treated as observable. Adaptive reuse has been studied for decades at the building level (Bullen & Love, 2011; Plevoets & Van Cleempoel, 2019) and, more recently, for open space and infrastructure (Williams, 2019). The reclamation of underutilised areas draws on work on vacant land and temporary use (Németh & Langhorst, 2014). Multiple use and user centred transformation come from the public space literature (Gehl, 2010; Carmona, 2019). Flexible planning mechanisms and maintenance management draw on adaptive governance (Folke et al., 2005; Chaffin et al., 2014) and on the practical observation, common in landscape practice, that a space's capacity to change is decided as much in the maintenance budget as in the design.

Table 6. Urban Circularity Assessment Matrix Based on the Principle of Spatial Adaptability

Basic Principle	Dimension	Sub-principles	Evaluation Indicators	Low	Medium	High
Spatial Adaptability	Spatial	Adaptive Reuse	Potential for repurposing existing structures or open spaces?	Not suitable for reuse or unused.	Some reuse potential, but limited.	Designed for new functions or adaptability.
		Reclamation of Underutilized Areas	Are unused or defunct spaces being reevaluated?	Underutilized areas exist but remain unaddressed.	Some repurposing, but piecemeal or poorly connected.	Comprehensively reclaimed and integrated.
	Social	Multiple Use	Does the space serve different age or user groups?	Limited to one user group or use.	Multiple uses, but limited user variety.	Accommodates diverse groups, simultaneously or alternately.

Basic Principle	Dimension	Sub-principles	Evaluation Indicators	Low	Mediu m	High
		User Centered Spatial Transformatio n	Compatible with daily activities (access, rest, recreation)?	Weak connecti on to daily practices .	Supports some daily uses, limited durability.	Strong, ongoing connection to daily life.
	Governance	Flexible Planning Mechanisms	Management mechanism for multifunctional use over time?	No mechani sm for usage changes.	Temporary or limited programming .	Systematic managemen t, planning, and coordination .
		Maintenance and Transformation Management	Are maintenance and renovation processes regularly monitored?	Not monitore d.	Performed, but limited monitoring or updates.	Regularly monitored and updated.

Table 6 shows how the principle of Spatial Adaptability can be translated into an evaluation matrix. In this matrix structure, a low level indicates that the relevant sub-principle is not reflected at all in the field or is represented only to a very limited extent. A medium level indicates that certain applications or potentials exist, but that these are fragmented, limited, or have not yet become established. A high level indicates that the relevant sub-principle operates in a spatial, social, or governance-integrated manner and strongly supports the area's potential for circular adaptability. Therefore, the low-medium-high assessment levels should be viewed not as a quantitative scoring system, but rather as a descriptive assessment tool that enables the qualitative comparison of urban areas.

This framework developed based on the principle of Spatial Adaptability should be viewed as an example illustrating how the proposed conceptual methodological framework can be operationalized. The same methodological logic can also be applied to the principles of Social Inclusion, Ecological Regeneration, Integrated Circular Flows, and Adaptive Governance.

Discussion

In recent years, assessment approaches developed in the circular economy literature have made circularity measurable—LCA for products, MFA for regions, monitoring frameworks for states. Their limit is not accuracy but object: they measure what moves, not the space it moves through. However, the literature review and bibliometric analyses conducted as part of this study indicate that existing evaluation approaches are limited in terms of considering for the spatial, social, ecological, infrastructural, and governance integrity of the urban scale.

As established in the Findings, micro scale circular economy approaches remain technically powerful but insufficient at the urban scale: at this scale, reuse involves not merely a product or material but the reclamation of underutilized areas, the adaptation of open spaces to new functions, and the opening of public spaces to different user groups. A similar limitation applies to macro-scale approaches (Abu-Bakar et al., 2024). Although these demonstrate that the circular economy is also an institutional and managerial matter, they remain confined to overarching policy goals and strategic frameworks, without specifying how such objectives translate into design decisions, open space systems, user practices or local governance relationships.

The argument of the paper is summarized in one sentence: the micro scale supplies the means of circularity and the macro scale its ends, and the city is where the two have to meet on a specific plot of land.

How do the five principles relate, then, to existing circular city frameworks? The closest correspondence lies with the framework proposed by Williams (2019). Her "adapting" actions “the adaptation of the built fabric and of urban land to new uses” overlap substantially with Spatial Adaptability, and "regenerating" with Ecological Regeneration; "looping" is distributed here between Integrated Circular Flows and the microscale reuse logic. Two of our principles have no direct counterpart in that triad. Social Inclusion appears in Williams (2019)'s work as an enabling condition rather than as a category of action, and Adaptive Governance is treated as context. We argue that both need to be assessed in their own right, because at the scale of a park or a street they are what decides whether an adaptive or regenerative measure lasts. The contrast with Paoli et al. (2022) is of a different kind: their indicator set is far larger and almost entirely quantitative, and it measures outcomes (tonnes diverted, m² of green roof) rather than the conditions “flexibility of programming, maintenance routines, user diversity” under which outcomes are produced. The matrix proposed here is not an alternative to such indicator sets; it is meant to sit before them, as a way of reading a site's capacity for circularity before one starts counting flows. Prendeville et al. (2018) noted that cities adopt circular vocabulary without agreeing on what a circular city is. The five principles are one answer to that question from the side of the disciplines that shape urban open space.

Most existing tools address circularity through questions such as “how many resources were used?”, “how much waste was reduced?”, “which materials were recovered?”, and “which environmental impacts were reduced?” (Sassanelli et al., 2019). At the urban scale, circularity must also address the following questions:

- Where do these resource and material flows occur within the urban environment?
- Which user groups benefit from these processes?
- What ecological processes does the initiative support?
- How does it relate to the open space system?
- What maintenance, monitoring, and governance mechanisms ensure its long term sustainability?

For example, while “reuse” at the micro scale refers to the reuse of a product or material (Bressanelli et al., 2020), in this study it is addressed at the repurposing of existing structures, open spaces, and underutilized urban areas in accordance with the principle of Spatial Adaptability. Similarly, while “resource management” at the macro level is mostly associated with the efficient use of resources and the reduction of waste (Saidani et al., 2019), this study discusses, through the principle of Integrated Circular Flows, the networks through which these resources circulate in the urban environment and the infrastructure, user, and governance relationships that sustain them.

The low, medium, and high rating levels used in the pilot matrix also support this approach. These qualitative levels are meant to indicate an area's strengths and weaknesses rather than to score it numerically, and thereby to identify the dimensions that would need to be addressed before a space could be considered circular. The price of this choice is that two assessors may read the same site differently. The rating rule in Section 3.1.3 and the indicator questions in Table 6 are meant to narrow that difference, not remove it; whether they do so is an empirical question that only field testing can answer.

The matrix is context sensitive by design: a neighbourhood park, a community garden and an industrial brownfield differ enough in function, scale, user profile and management capacity that a single set of weightings would not serve all three equally well. For example, while social inclusion and mixed use become more critical in a neighborhood park, integrated circular flows

and reclamation of brownfield sites may be more critical in an industrial redevelopment area. For this reason, the framework proposed in this study should be viewed not as a fixed and rigid checklist, but as a flexible assessment guide that can be adapted to different urban contexts.

Conclusions

This article has asked whether circular economy principles can be rewritten for the urban scale, starting from the observation that existing micro and macro level approaches, concerned respectively with products, materials and technical performance, and with policy, resource management and systemic transformation, stop short of addressing the city's own spatial, social and governance conditions.

Three findings can be stated. The macro literature is organized into five clusters and the micro literature into eight; across both, no retained keyword refers to public space, land use or urban form (RQ1). When rated against five urban criteria, the clusters relate most strongly to infrastructure systems and least to social patterns of use, with the governance criterion supported almost entirely from the macro side (RQ2). Reading the clusters that do relate to each criterion together, rather than scale by scale, yields five principles, one of which has been developed into a matrix of six sub-principles (RQ3).

In this regard, the theoretical contribution of this study lies in positioning the urban scale within the literature on the circular economy as a distinct level of analysis that requires the formulation of principles based on its own spatial, social, ecological, infrastructural, and governance conditions. At the urban scale, the adaptability of open space, who has access to it, whether ecological systems remain connected, how infrastructure flows are integrated and whether maintenance is funded belong in the assessment alongside material flows.

The methodological contribution is a traceable analytical process that links PRISMA based screening, keyword co-occurrence mapping and criterion based rating of thematic clusters against urban contextual criteria.

The disciplinary contribution of this study lies in its treatment of landscape architecture as a disciplinary interface where the principles of the circular economy are spatialized at the urban scale, linked to ecological processes, integrated with public use practices, and made sustainable through maintenance and governance processes. Landscape architecture's contribution to the CE debate runs through the transformation of underutilized areas, the reuse of open-space systems, the strengthening of ecological networks, user participation and the traceability of maintenance.

However, this study has some limitations. First, the proposed framework and the pilot matrix developed through Spatial Adaptability are based on a literature driven, analytical model development process. Therefore, the study did not test the matrix’s performance through field application in a specific urban area. At this stage, the proposed framework should be viewed not as an empirical measurement tool that directly yields practical results, but rather as a qualitative analytical assessment guide that can be tested and refined in various urban settings.

Second, the macro query was built around governance and territorial terms (macro, national, global, governance) and the micro query around product and building terms. Neither contained the word "urban" or "city". This was intentional, since the purpose was to characterize what the non-urban literature looks like. It means, however, that the limited representation of spatial and urban concepts in the two networks is partly a product of the search design and cannot be read as evidence that such concepts are absent from CE research as a whole. The comparison in Section 2 with the circular city literature is meant to compensate for this.

Third, although the ratings in Tables 2 and 3 were double coded, both coders belong to the research team and share a background in landscape architecture. Coders from planning, industrial ecology or public administration might weigh the same keywords differently, and the same applies to anyone using the pilot matrix on site: the reading will depend on the assessor's expertise and on the data available. Testing the rating rule with a mixed panel, and the matrix with field observation and municipal data, is the necessary next step.

For future studies, a more comprehensive urban circularity assessment matrix can be developed by breaking down all five fundamental principles proposed in this article into sub-principles across spatial, social, and governance dimensions. Additionally, the pilot matrix developed for Spatial Adaptability can be tested on various open space typologies, brownfield conversions, parks, green infrastructure projects, community gardens, neighborhood scale public spaces, or industrial redevelopment sites. In future research, it will also be possible to refine the indicators based on expert opinions and, when necessary, weight them according to the type of field.

The immediate next step is to apply the Spatial Adaptability matrix to two contrasting sites to see whether the Low, Medium, and High levels separate them in the way the sub-principles predict, and to extend the same procedure to the remaining four principles.

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