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Exploring the Circular City: A Bibliometric and Definition Analysis



Quirien Reijtenbagh, Zhaowen Liu, and Daan Schraven

Abstract Having a high demand for materials and vast emissions, cities are ideal laboratories for exploring the circular economy. The circular city as a city label has attracted a lot of attention from academics and practitioners. However, it remains unclear what a circular city is in the context of the circular economy in the urban environment. To improve our understanding of how circular cities have been defined and developed by scholars, this book chapter reviews academic literature. First, we set a search scope of relevant literature using a bibliometric approach to build a database with 109 peer-reviewed articles. Then, we compile a final list of 28 definitions which are analyzed to find the dimensions of a circular city. These circular city dimensions are: system structure, components, principles, goals, and organizational characteristics. In sum, this chapter provides a comprehensive understanding of the current central themes of circular cities and their shortcomings.

Keywords Circular city · Circular economy · Sustainable development

1 Introduction

Cities are increasingly attracting residents because of their modern businesses and services, diverse employment opportunities, and accessible infrastructure. In 2020, 55% of the world's population were living in cities, and this proportion is expected to increase to 68% by 2050 [7]. Global-scale urbanization has witnessed economic

Q. Reijtenbagh (✉) · D. Schraven
Faculty of Architecture and the Built Environment, Delft University of Technology, Delft, The Netherlands
e-mail: Q.A.M.Reijtenbagh-1@tudelft.nl

D. Schraven
e-mail: d.f.j.schraven@tudelft.nl

Z. Liu
Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, The Netherlands
e-mail: z.liu-8@tudelft.nl

growth, but it has also inevitably led to massive resource consumption and production in cities [31]. Meanwhile, the convenience and diversity of urban lifestyles resulted to an increase in the amount and complexity of municipal waste generation [13, 24].

An alternative to this take-make-dispose economy is the circular economy, which proposes development strategies that extend the life of products and transform waste into resources [8, 14]. In practice, the circular economy aims to drive sustainable development by reducing the demand for (virgin) raw materials and by extending product use through innovating business models which involve and/or address a plurality of societal actors while minimizing environmental impact [16]. Besides, its main principles aim to dematerialize and diversify material supply, to ultimately relieve future resource scarcity issues [9].

Many countries and regions have adopted the circular economy as one of the key strategies for sustainable development [16]. As an economic system with high consumption patterns and emissions, cities are naturally the best laboratories for exploring the circular economy. For example, as a concept, the circular economy has already trickled down from strategic documents into the international level (e.g., EU Circular Economy Action Plan) and national level (e.g., national program of the Circular Economy), to the local level (e.g., city of Amsterdam). In scholarly literature, the use of the “circular city” as a city-label purporting “circular economy” in the urban setting, has been published a notable number of times, especially around 2020. However, a clear definition is yet absent [20], which may be partly due to a variety of definitions about the circular city found in the academic literature.

To address this unclarity, in this chapter we offer an overview of what the circular city is about. We do so by answering the question: *what is a circular city in the context of the circular economy in the urban environment?* First, by means of bibliometric analysis we identify various thematic elements, popular topics discussed amongst scientists, and points of convergence to demarcate how the circular city has been used in the academic literature. Second, we identify the compositional dimensions of a circular city by means of reviewing and recognizing patterns among existing definitions for ‘circular city’ (e.g., the dimensions or levels of the circular city).

The results show that the most important themes of the circular city include: adaptive reuse, indicators, nature-based solutions, and smart digitalization. In terms of dimensions of the circular city, these are: system characteristics (i.e., the traits of the circular city as a system), components (i.e., the entities or elements of a circular city), principles (i.e., the fundamental rules that guide action or decision-making toward a circular city), goals (i.e., for what reason or purpose is the circular city pursued), and the organization of a circular city (i.e., the way to establish the structure, processes, and relationships necessary for realizing a circular city). Based on these findings we formulated a conceptual framework of the circular city concept (Fig. 4).

2 Method

In this section, we describe the methodological steps for conducting the study. Firstly, we describe how we collected the relevant literature for the study. Secondly, we elaborate on the use of bibliometric techniques. Thirdly, we detail the steps of the content analysis on definitions, supported by an inductive coding process.

2.1 Literature Collection

For the literature analysis the Scopus database is used. Scopus indexes more journals than Web of Science, including more international and open access journals [1]. It is therefore able to provide literature on a wide variety of angles and disciplines. This is especially useful for the explorative nature of this chapter, where openness is warranted to find the diversity of dimensions that the concept of circular city may have received. In following the main question for this chapter, the query we deployed in Scopus reads:

TITLE-ABS-KEY ({circular city} OR {circular cities} AND {circular economy})

The query was conducted on March 4th, 2023, and was limited to (1) the last completed publication year, i.e. 2022; and (2) the most common academic language, i.e. English. With these limitations, we retrieved 109 articles, spanning between 2018 and 2022. For the thematic analysis, these articles were subject to bibliometric enquiry.

For the definitions analysis, we required that an additional criterion needs to be met for articles. It is argued that at the basis a proper definition needs to have a mature and scrutinized academic scholarly work behind it, i.e., journal articles or review articles. We ended up with a refined dataset of 84 articles.

We then searched definitions of the circular city in the full text of these 84 articles following four steps: (1) search for "def", "circular city" and "circular cities" in each publication; (2) read all the searching results; (3) extract the definitions; (4) remove duplicate definitions resulting from original citations. This resulted in a list of 28 original definitions (see Appendix). These identified definitions were subjected to a definitions analysis by coding in ATLAS.ti to identify the aspects that have been discussed in circular city definitions and to synthesize a conceptual framework of the circular city.

2.2 Data Analysis Approach

In this section we describe the analytical steps of the study. First, we describe the bibliometric analysis on the broader set of 109 articles retrieved. This is done to

explore the associated themes to the circular city in the academic debate. Next, we explain the steps taken to analyze the 28 definitions retrieved from the set of 84 articles.

2.2.1 Bibliometric Analysis

Bibliometric literature review enables rapid analysis of keyword, author, and bibliographic information in large samples [22]. We applied bibliometric analysis in this study to quantitatively identify the development dynamics and leading trends of studies about the circular city. Specifically, keywords co-occurrence analysis and bibliographic coupling analysis can give insights on the conceptual evolution of a research field [25]. First, a keyword occurrence analysis was conducted to identify the ranking of associated terms to the circular city. Based on this ranking, a cut-off point was established to determine the high-frequency keywords. This is often used to discern the influential themes [18].

We pursue this enquiry with descriptive statistics, keyword-co-occurrence analysis, and cluster analysis. Regarding the descriptive statistics of the average publication year for these authors terms, which can show the degree of forward leaning of these concepts. For example, if the frequency of author keywords is counted per publication per year, then the average publication year for a keyword is the statistical middle of these counts expressed in years. It is counted as the average of the sum product of the count per year with the publication years, divided by the frequency of publications. For example, if an author keyword is published in three articles in the years 2020, 2022 and 2022, then the average publication year would be $(1 \times 2020 + 2 \times 2022) / 3 = 2021,33$. These results are shown in Fig. 1. Additionally, we wanted to understand whether these articles were used in a specific moment in time or continually throughout the observed period. For this we created boxplots using the median and first and third quartiles of frequency of occurrence of publication years per high-frequency keyword. The result is visually presented in Fig. 2.

With regards to the co-occurrence analysis, we counted the times that each possible pair of the high frequency keywords occurred together. This helped to produce a square matrix of all the co-occurrences. This was then used to create a social network graph in Fig. 3a.

With regards to the cluster analysis we used the same data set with the statistical software tool called SPSS. A cluster analysis helps to group keywords together based on their co-occurrences. The cluster analysis differs from the social network analysis by looking at the statistical correlations of the raw co-occurrences between keywords. The output of a cluster analysis is presented as a dendrogram, i.e., a tree-like representation of the found clusters (in Fig. 3b).

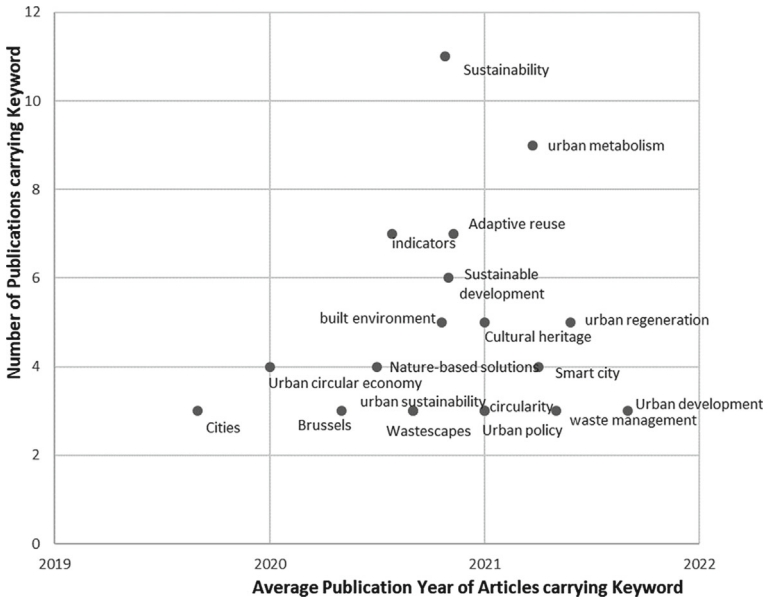


Fig. 1 Average Publication year versus number of publications per keyword

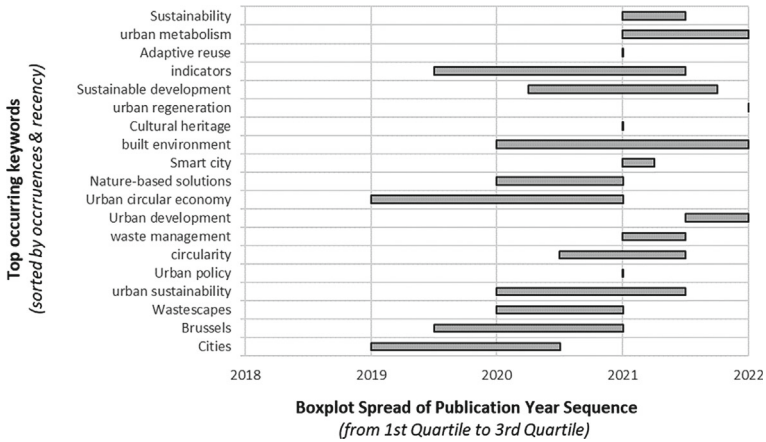


Fig. 2 Boxplot spread of Publication year sequence per keyword

2.2.2 Content Analysis of Definitions

We applied a qualitative coding approach to identify the elements of definitions. To ensure a proper interpretation of the results, two of the three authors with preconceived knowledge on the topic had carried out the coding process together. The

purpose of our data coding procedure was to achieve the final goal: a coding frame that clearly represents all aspects of the circular city definition.

We based our coding process on the coding process for qualitative research recommended by Creswell [6, p. 244]. This procedure starts by an initial reading of the data, followed by segmenting and labelling the text, grouping codes and lastly, deriving themes. This coding procedure to find key elements (categories) was conducted in *ATLAS.ti*. The coding steps we conducted are presented in Table 1. We then used the output of the coding analysis (Table 4) to reexamine all 28 definitions to gather information on the type, amount, and content of (sub)categories included.

3 Results

In this section, we present and discuss the results from the bibliometric study. Then, we show and elaborate on the definitions and conclude with the conceptual framework.

3.1 Results from Bibliometric Analysis

In academic articles, authors often think of keywords that make their study easier to find. Therefore these keywords act as important descriptors of the essence of a field of study. Taking stock of this for circular cities, we conducted a keyword occurrence analysis. For this, one counts the number of single occurrences among the pool of articles. In this case, the total number of articles are 109 until the end of 2022. In order to find the associated terms for circular cities, we removed the three keywords that were actual search terms in our query, i.e. “circular city”, “circular cities” and “circular economy”. We then sorted the remaining terms from high to low.

Table 2 presents the top 19 ranking keywords with cut-off point for 3 occurrences. It shows that sustainability is the most associated term to circular cities, which is no surprise, provided the wide range of the scope of this term. More specific terms include: “urban metabolism” (9 hits), “adaptive reuse” (7 hits), “urban regeneration” (5 hits), “nature-based solutions” (4 hits), and “waste management” (3 hits) to describe certain strategies in the circular economy in an urban context. Terms like “built environment” (5 hits), “cultural heritage” (5 hits), “smart city” (4 hits), “urban development” (3 hits) and “urban policy” (3 hits) refer to the spatial nature of the city for such strategies (Fig. 3).

The keywords are occurring with a certain distribution over the years. The time-aspect is particularly useful to gain a better understanding of the recency and spread of used keywords. It can tell us more about the possible shifts in attention and association of circular city in studies as time progressed. We therefore created a scatter plot, by showing the total occurrence and its average publication year of articles that carry a certain keyword resulting in Fig. 1.

Table 1 Coding procedure of circular city definitions

Coding steps	Explanation	Outcomes
Step 1. Data preparation and familiarization	We prepare a clean dataset of definitions and preliminary scan reading of all the definitions	28 definitions of the circular city (Appendix)
Step 2. Set the coding rules (<i>collectively</i>) and conduct coding (<i>individually</i>)	Following Creswell [6], we apply the coding rules as: <ol style="list-style-type: none"> every part of the definition needs to be coded, unless the parts of the definitions were very vague or unspecified in meaning (e.g., “generate accomplishment”, “enhance the flexibility of the city and its people” and “complex system” and “social consumption”) if codes were overlapping (i.e., meaning the same) they were merged (e.g., “economic growth” and “economic prosperity” are merged into “economic prosperity”) 	120 codes from author A and 67 codes from author B
Step 3. Group codes (<i>individually</i>)	Codes with similar characteristics are grouped (e.g., actors mentioned in the definitions are categorized in the sub-category “stakeholders”)	20 groups from author A and 16 groups from author B
Step 4. Merge groups into preliminary categories (<i>individually</i>)	Each author classifies the groups and identifies four categories. Each category may have two to three sub-categories	Categories from author A: system elements, system boundaries, goals, and principles; categories from author B: components, goals, circular city system, organization/means
Step 5. Finalize the categories (<i>collectively</i>)	This step involves the comparison of codes and preliminary categories from step 4, and the overall similarity is high. Some changes are made to create the final coding framework: <ol style="list-style-type: none"> non-similar codes are added (18 codes were added), non-similar categories and sub-categories are discussed and merged 	Five aspects of the circular city that emerged from the coding process (Table 4)

Table 2 Occurrence analysis of most associated keywords to circular city

Rank & Keyword	# of occurrences
1 Sustainability	11
2 Urban metabolism	9
3 Indicators	7
4 Adaptive reuse	7
5 Sustainable development	6
6 Built environment	5
7 Urban regeneration	5
8 Cultural heritage	5
9 Smart city	4
10 Nature-based solutions	4
11 Urban circular economy	4
12 Urban development	3
13 Urban sustainability	3
14 Brussels	3
15 Waste management	3
16 Circularity	3
17 Wastescapes	3
18 Urban policy	3
19 Cities	3

Figure 1 shows that around 2020 frequently occurring keywords were “cities”, “urban circular economy” and “Brussels”. In 2021, the focus shifted more towards operationalization efforts, by studying “indicators” and “circularity” approaches associated with solutions or strategies deployable in a circular city such as “nature-based solutions”, “adaptive reuse” and “urban policy”. After 2022, terms like “urban development”, “urban metabolism”, and “urban regeneration” appeared in tandem with the concept of the circular city. This indicates that the term circular city was consolidated with older debates on transformations in the urban space.

Given that the average number of publications per year does not yet improve our understanding on the commonplace of the coined keywords, we further clarified this by visualizing the spread of the publication sequence of the various terms. We created boxplots of the publication sequence per keyword, ranging from the 1st to the 3rd quartile of the sequence. Usually boxplots are known for their whiskers at the sides of these quartiles, but provided the short span of publication period (5 years) we removed these from the figure. This helped in focusing the message of the visual on the identification of the continued and short-lived momenta of the keywords in the circular city literature. In this way Fig. 2 reveals that some terms have been packed while others were more regularly spread across the years. To compare positioned keywords easier, we sorted the keywords across their reading direction in Fig. 1, first by their occurrence and then by their recency.

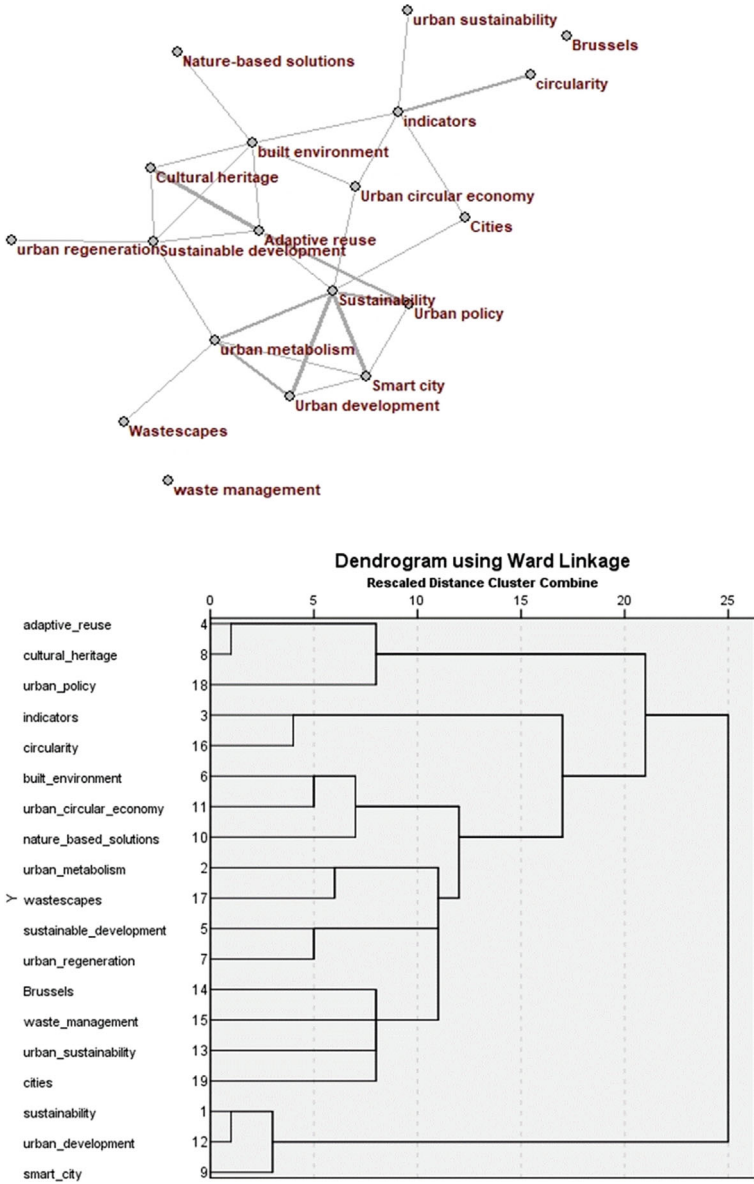


Fig. 3 a. Social network analysis. b. Cluster analysis

The largest spread over the past five years occurred for the terms “indicators”, “built environment” and “urban circular economy” (Fig. 2) which indicates their longevity in the academic debate. Interestingly, the terms related to solutions appear to have been published quite close after one another, as revealed by the narrow

spread of “adaptive reuse”, “cultural heritage”, “smart city” and “urban policy” but no conclusions can be drawn about the underlying reasons.

In the previous descriptive statistics, we focused mainly on the keywords that were mentioned in the studied literature most frequently. By just relying on these terms, we would omit other terms that studies have associated to the circular city label. To study the extent that the label has been converging with the most frequent occurring words, we separated the keywords that contributed to the divergence (i.e., the sum of all single occurrences) from the convergence (i.e., the sum of all > 1 occurrences) of the circular city label. These were then separated across the publications years to elucidate the change in the extent of divergence versus convergence (Table 3).

The converging ratio increased from 22% in 2018 to 41% and 30% in 2021 and 2022, respectively, indicating that associations to the circular city concept had a steady pace towards a consolidated understanding.

Next, we place our focus on high frequency keywords to represent the core content of the studied literature, to offer an insight into the potential directions that the debates are moving toward, and to illuminate the core aspects of the circular city. The number of high-frequency keywords can be identified by following the proposed model by Donohue (1973). In this model, the tail of sorted single keywords help to determine the statistically expected cut-off point for the high frequency keywords. The formula for calculating this is:

$$I_n = \frac{1}{2} \left(-1 + \sqrt{1 + 8 \times I_1} \right)$$

In the formula I_1 represents the number of keywords that occurred just once and I_n represents the total number of high-frequency keywords. A total number of 304 articles occurrence only once. That meant that for this dataset of the circular city literature this equals a maximum of 24 keywords. Table 2 shows that the position 12 through to 19, have 3 hits. The 2 hits exceed the 24 keywords limit, and hence we set the cut-off at the top 19 keywords for further analysis of the underlying relational structure among them.

Figure 3a shows the results of the social network analysis conducted on frequently occurring keywords surrounding the concept of circular city. A few groups can be distinguished. The first group that can be identified, concerns urban aspects like “urban metabolism”, “urban policy”, “urban development” and “smart city”. These are all tied strongly tied to the keyword “sustainability”. The second group surrounds “cultural heritage” and “adaptive reuse”. These focus strongly on the changes in

Table 3 Percentage diverging/converging keywords

Years	2018	2019	2020	2021	2022
Diverging keywords	14	44	53	91	102
Converging keywords	4	17	17	63	44
Converging ratio	22%	28%	24%	41%	30%

Table 4 Results on aspects of the circular city that emerged from the coding process

Categories	Sub-categories	Description	Code examples
Circular city system description	Characteristics	Terms that characterize the circular city. This could be adjectives but also nouns that describe an ability of the system	Adaptive; regeneration; innovation; technical system; socio-ecological system
	System boundaries	Terms that describe the boundaries of the circular city. These are directly mentioned boundaries, but can also be related nouns	Functional boundaries, nature boundaries, spatial boundaries, city-region; bio-geo-physical unit
Circular city components	Stocks	Stocks are the resources that are accumulated and stored within the city, including man-made, social, cultural, human, natural, and digital capital	Built environment; mobility; industry; infrastructure; cultural heritage capital; digital technology
	Flows	Flows are the movement of these resources through the city's economy	Resource flow; waste flow; information flow; energy flow
Circular city principles	10R+ strategies	Terms about 10R frameworks, including, as well as other Rs that have been mentioned	Recover; reduce; redesign; repair; reject; re-naturalization
	Other circular economy principles	Terms about circular economy principles other than R strategies, including prolonging the lifespan of products, waste management, and renewable-energy	Waste elimination; waste to resource; renewable energy; closing, narrowing, slowing the loops
Circular city goals	Economic development	Terms that related to the ideas on economic development in the circular city	Economic prosperity; value creation; value extension; efficiency improvements
	Environmental quality	Terms that related to the use of natural resources in the circular city	Ecological impact; environmental benefits; renewable natural resources
	Social well-being	Terms that related to social well-being in the circular city. This could both be adjectives	Healthy; human centered; inclusive; social-wellbeing; increase habitability

(continued)

Table 4 (continued)

Categories	Sub-categories	Description	Code examples
Circular city organization	Stakeholder engagement	Terms that related to organizing stakeholders in the design and implementation of circular city	Collaboration; stakeholders; institutions; knowledge sharing; integrated network
	Circular industry development	Terms that related to organizing businesses that contributes to a circular city	Industrial symbiosis; business model; logistical services
	Circular actions, practices and initiatives	Terms that related to practices and behaviors in realizing a circular city	Circular economy initiatives; circular economy practices; behavior change

the built environment, and then more clearly, on the management of historical or existing buildings. Finally, there is a recognizable group on “indicators” and “circularity”, which clearly share the emphasis on clarifying how to measure the circular performance of the city.

Figure 3b shows the cluster analysis as a dendrogram. There exist many similarities between the formed clusters from this figure confirming three distinct emphases in the debate. First, the keywords “sustainability”, “urban development”, and “smart city” contain the dominant terms. Also “adaptive reuse” and “cultural heritage” form a strong bond regarding how to deal with the existing building stock. Third, the keywords “indicator” and “circularity” form a separate topic on measuring performance. The keywords which capture various urban aspects seem to be interrelated but it is striking to note a detachment of waste-related topics like waste management and wastescapes from the circular city concept.

3.2 Results from Definitions Analysis

3.2.1 Finalized Coding Framework

In this section we present the result of content analysis of definitions. Following the coding procedure that introduced in Sect. 2.2.2, five main categories were found in the definitions, including: (1) *circular city system description*, (2) *circular city components*, (3) *circular city principles*, (4) *circular city goals*, and (5) *circular city organization*. Table 4 displays the five aspects, their subcategories with descriptions, as well as the examples of codes in each sub-category.

Table 5 Occurrence of categories and sub-categories in definitions

Definitions that mention X of total	Frequency in definitions	Percentage in definitions (%)
Circular city definitions (total)		
-	28	100
Circular city as a system		
System characteristics	8	29
System boundaries	8	29
Circular city components		
Circular city stocks	18	64
Circular city flows	7	25
Circular city principles		
R-strategies	15	54
Other CE principles (e.g., close, narrow, slow the loops)	7	25
No principles	6	21
Circular city goals		
No goals	18	64
At least one goal	10	36
<i>Include three dimensions of goals (ED, EQ, SWB)</i>	5	18
Economic development (ED)	5	18
Environmental quality (EQ)	10	36
Mention social well-being (SWB)	6	21
Circular City organization		
Stakeholder engagement	12	43
Circular industries	7	25
CE actions/practices/initiatives	9	32

3.2.2 Analysis of Five Aspects of Circular City

Because of the length of final list of definitions, the list is found in the Appendix 28 in the end of this chapter. For proper referencing and increasing text readability, the numbers in the first column of Appendix correspond to the numbers in brackets in the text. For example, reference [1] in the text refers to [1] in the Appendix, that is the definition provided by Vanhuyse et al. [29] provided at page 3 of their article (Table 5).

Circular City as a System

Eight definitions (29%) refer to different type and reach of boundaries of the circular city. For example, definition [7] indicates that the circular city has *spatial and functional boundaries*. Some definitions give a notion of a cross-boundary nature of the circular city, due to input and output material flows beyond the city borders. These definitions indicate that the circular city is a *part of regional development* [2], or a *city-region* [12] implying a *multi-scalar* relation to creating circular material flows, as a result of collaboration between actors from the *hinterlands* [19].

Eight definitions characterize the circular city as a ‘system’. These notions range from *urban (eco)system* [9,11] to *self-sustainable urban system* [12, 19] to *socio-cultural system* [21] and *socio-ecological system* [7]. Often the circular city is described as a *regenerative urban system* [2, 7, 12, 20]. The characteristics of the circular city differ between the definitions. For example, the circular city is regarded as a *movement* [14], is *smart* [13], *self-sustainable* [12, 19] and regenerative [2, 7, 12, 18, 20] and is a *place for innovation to trial and scale-up solutions* [9].

Circular City Components

From the 28 definitions, around 64% mention resources that are accumulated and stored within the city. These definitions pose that the circular city is about a different (circular) use of resources either in the form of regenerating capital or in the form of creating circular resource flows (and efficient energy flows).

Stocks (i.e., cumulated resources) are referred to as human, man-made, social, and natural capital [16, 17] or to social, environmental, and economic resources [18]. Some definitions include specific territorial resources in their definition, like *infrastructure* [9, 15, 21, 22], *housing* [9] and *land* [21] that can be *redesigned, reused or recycled*. Other key elements identified in the definitions are *clean and efficient mobility* [10, 21] and (*digital*) *technology* to empower circular solutions [13, 20]. Human capital is mostly mentioned in the terms of certain stakeholders, i.e., *social* [7, 23], *economic actors* and *institutions* [13, 27], as well as *industrial actors* [6]. Resource flows are mostly referred to as *material, waste, and energy flows* [1,10]. One definition even included specifics on material flows, mentioning *food, nutrition, and water* [9].

Circular City Principles

About 54% of the definitions mention R-strategies. Besides the 10R-strategies of Potting et al. [23, p. 5] (i.e., *refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, and recover*). Three additional strategies are also highlighted in some of the definitions: *redesign of industry, infrastructure and logistics* [21], *re-naturalizing the city* [17], and *regeneration* [2, 7, 11, 12, 16, 17, 18, 20, 27]. Regeneration is mentioned in three ways: first, as a characteristic of the economy of

the circularity city, being a *regenerative economy* that sustains the ability of natural ecosystems [2]. Second, as a characteristic of the whole urban system [7, 11, 12]. Third, as the regeneration of natural [16, 17], cultural, social, economic, produced, and human *resources or capital* [17]. Other R-strategies mentioned were *redesign* and *re-naturalize*. Redesign refers to the “*redesign of infrastructure, logistics and industry*” [21]. Re-naturalize refers to creating more nature in cities and “*sharing*” resources [4, 9].

About 25% of the definitions include other circular economy principles as overarching strategies for the application of *circular economy principles* in the circular city [20] or more specifically for “*closing, narrowing or slowing the loops*” [4, 6, 8, 10, 13]. Two definitions explicitly note the idea behind the application of circular economy principles as “*using resources as long as possible at their highest value*” [9, 18].

Circular City Goals

From all definitions, 64% of the definitions do not include goals of the circular city. Of those which do, the goals mentioned are related to the three dimensions of sustainable development: economic prosperity, social well-being, and environmental quality.

The most often mentioned goal of the circular city is environmental quality (e.g., restoration, regeneration, conservation). Examples include the use of local renewable natural resources [4], the preservation of the ability of natural ecosystems to secure production and maintain diversity [2], the regeneration of natural capital [16, 17], and the reduction of the environmental footprint [3].

With respect to economic development as a goal, half of the definitions include a specific idea on economic development within the circular city. These are: *having economic prosperity* by a *regenerative economic system* [2], *having economic growth* by reducing the environmental footprint [3], *being competitive* by using resources as long as possible in their original form [9], *providing economic benefits* by being a circular city [14] and lastly, *creating positive economic externalities* by using regenerative capacity of the system [18].

Lastly, 21% definitions include the goal of social well-being for creating a certain *social well-being* [2, 27], *ensuring well-being for locals* [3], and striving for an *inclusive and healthy city* [9].

Circular City Organization

Many definitions refer to various ways of organizing circular cities by engaging stakeholders, promoting circular industries, and conduct circular actions, practices, and initiatives. 43% definitions mentioned *stakeholder engagement*. For example, this included mentioning *stakeholder cooperation* (e.g., including citizens, community, business and knowledge stakeholders) [8, 9, 18, 19, 23] and *knowledge sharing*

[9, 15]. With respect to circular industry development, definitions refer to (*industrial*) *sybioses and clustering* [18, 19], the application of *circular business models* [6, 11, 27, 28], and business activities related to organizing recycling, remanufacturing, storage, and (*reverse*) *logistics* [26]. Some definitions also show that creating a circular city involves actions on “*scaling up integrated networks, retrofitting existing businesses, and creating new operational practices across scales*” [27], and drawing *lessons from best practices* [24].

Lastly, the circular city is established by *governance on multiple levels* [21]. This refers to the cross-boundary nature [27] of material flows and waste and material regulations, that require *multi-level policy integration* [21]. Hence, local governments have limited capability to adjust regulations when these are governed at the regional, national, or international level.

Based on the findings from definitions analysis, we synthesize a conceptual framework of the circular city (Fig. 4).

CC system description	CC components	stocks	man-made, social, cultural, human, natural capital
		flows	energy, material, water, and waste flows
characteristics: e.g., adaptive smart competitive	CC principles	10R+ (e.g., reduce, redesign, remanufacturing, recover, re-naturalization)	
		circular economy strategies (e.g., closing, narrowing, slowing the loop)	
boundaries: e.g., spatial, functional	CC goals	social well-being (e.g., improved habitability, societal need provision)	
		environmental quality (e.g., sustaining the ability of natural ecosystems)	
		economic development (e.g., economic benefits, efficiency improvements)	
	CC organisation	engaging multiple stakeholders (e.g., collaboration, networking, alliances)	
		creating circular industries (e.g., application of circular business models, industrial symbiosis)	
		circular actions, practices, and initiatives (e.g., creating behavioral change in circular projects)	

Fig. 4 A conceptual framework of the circular city

4 Discussion

4.1 Discussion on the Bibliometric Results

The bibliometric results highlight a few notable things. First, a few conjoined and clearly identifiable themes appear to have received attention. The measurement of circularity with indicators is a very clear theme that was called out through the keywords. This debate has been ongoing for at least the past two years, making it a fundamental aspect of the conceptual development of the circular city.

Also, the concept of adaptive reuse and cultural heritage appear to be anchored in the circular city domain. This speaks to a clear strategy for keeping buildings functioning, if not for one specific role, then for another. The idea that buildings can be quickly adapted for a plethora of functions is therefore a viable route. These topics were published in a very narrow window around 2021 which could be an indication of very specific and time-bound research.

Interestingly, waste management has been mentioned only fairly recently, but it has not been manifested as a strong link with other circular city author keywords. This signals that the subject of waste management is young in the debate on circular cities, but not yet firmly connected with other debates, like urban regeneration and urban development.

4.2 Reflections on Definitions of the Circular City

The coding analysis revealed five aspects of the circular city: the system, the components, the principles, the goals, and the organization. In this section we provide a critical review on these definitions.

4.2.1 Regional Boundaries Contrast with Cross-Region Flows

Many definitions describe the circular city as a system with spatial/regional/geographical boundaries. Campbell-Johnston et al. [5] concluded that circular cities aim to create more local material flows of formerly dispersed flows. While this is contrary to the cross-city-boundary stocks and flows as components of a circular city, it does bring up the discussion of whether it is feasible and favorable to reach circularity within the city boundaries. Since some definitions also include cross-boundary aspects. For example, the recycling of metals and critical raw materials is an (inter)nationally organized practice that goes beyond the city boundaries [26]. Thus, it can be concluded that circular city boundaries could contrast with the traditional notion of a city as a contained entity with defined boundaries due to the cross-boundary nature of material and energy flows.

Furthermore, we observe that the most recognized characteristic of a circular city is that of “regeneration”, referring not only to natural capital, but also to cultural and social capital which are also present beyond the geographic city boundary.

Lastly, regulations that are enforced on multiple levels (i.e., regional or (inter)national) require multi-level governance and collaboration with stakeholders outside the city boundaries.

4.2.2 Principles Do Not Align with Multidimensional Goals

Almost all definitions that include circular city goals emphasize the importance of environmental quality. This is in line with the strong sustainability view that natural capital is essential for providing the well-being of the (future) population and cannot be replaced by productive capital [4]. Furthermore, it supports the view that a circular economy in cities is a means for transitioning towards a society that can achieve social well-being, environmental quality, and economic prosperity [30].

Most definitions are explicitly referring to the application of circular economy principles, such as looping strategies or 10R-strategies in the city. These principles prioritize resource efficiency in economic systems over other goals of circular city, such as social-wellbeing. To achieve social goals of circular cities such as inclusion, equity, and health, the guiding principles of the circular city must go beyond the limits of the circular economy to address potential trade-offs and unintended consequences.

What stands out from the results is that circular city is relatively often characterized as a regenerative system. Regeneration can refer to the regeneration of abandoned, degraded, or deserted places by creating new purposes or through redesign [12] or urban ecosystem restoration by creating green and blue infrastructures or natural capital in the city to provide ecosystem services (e.g., urban heat effect reduction) [31]. Interestingly, though regeneration was referred to in multiple ways, “*regenerating the loop*” was not recognized as a circular city principle. This is not in accordance with the latest insights in academia on the circular economy strategies, as these include economy: closing, narrowing, slowing, and regenerating the resource loops [3, 10, 15].

4.2.3 Biased Role Recognition of Stakeholders

Definitions of the circular city mention several urban stakeholders ranging from industrial actors to local inhabitants, as being part of the circular city. In general, actors in industries and businesses are described as key actors since they take a lead in the production process and business models [28, 29, 32]. Meanwhile local governments are politically empowered as circular policy makers and project leaders [5, 21].

However, the *citizen* as part of the circular society is described as a rather passive stakeholder. The circular city is considered a means to provide well-being for local inhabitants, rather than local inhabitants being active contributors to creating the

circular city. This brings forth an implicit bias on different stakeholders whereby some are described as drivers of a circular transition and others are only passive actors or participants. It is not in accordance with the modern view on circular economy that citizens need to become active participants [19] and are expected to fulfill certain roles (e.g., social initiative organizers, green consumers) with circular behaviors [11, 17].

5 Conclusion

5.1 Academic Contribution

In this chapter, we addressed the question: *what is a circular city in the context of the circular economy in the urban environment?* With bibliometrics, we were able to show that a circular city is related to a few circular strategies for reducing the material use. The analysis suggests that the circular city is about keeping the built environment operating through adaptive reuse, by ensuring the adoption of nature-based solutions in the urban setting, while ensuring that waste management is addressed. A circular city also looks into the urban development practices and strives for urban regeneration.

From the definitions analysis, we uncovered that there are five dimensions of a circular city: the system description, the components, the principles, the goals, and the organization. These dimensions provide us with the understanding that the city materializes in the form of diverse forms of stocks and flows of materials, waste, water and energy. The way these flows and stocks are made circular is through circular principles or R-strategies. At the same time, a circular city pursues social wellbeing, environmental quality, and economic development. In order to achieve these goals, the city is organized by engaging with multiple stakeholders, create circular industries through circular business models and fosters circular actions, practices, and initiatives.

Furthermore, we reached to a few key conclusions on the circular city. First, the inclusion of “hard” city-scale boundaries into the definition contradicts the very idea of exchanging waste and material flows across the city boundaries. Furthermore, the principles of the circular city in terms of the strategies that it can deploy, do not necessarily contribute directly to all of the circular city goals. Such strategies can be reviewed to which extent these improve the city in all three sustainable development dimensions. Finally, the debate on engagement of certain actors or stakeholder, leans mainly towards industrial and governmental actors, rather than towards the citizens who are meant to be active participants in creating a circular economy. Hence, a perspective on city boundaries and citizen inclusion is still missing in the conceptualization of the circular city.

5.2 *Practical Contribution*

Based on our findings, we encourage practitioners concerned with the circular economy in the urban context to stimulate circular strategies that not only concern closing, narrowing, and slowing, but also regenerating the loop. Additionally, we think that there is much potential in mobilizing local capital and engage local/regional actors (government, business, and citizens) to sustain the circular economy. Also, striving towards creating a ‘circular city’ should rather be perceived as an instrument to create a sustainable society and environment, not as a goal in itself.

Lastly, based on the dimensions of the circular city, the following question can operate as a guidance for building a conceptual understanding of the circular city:

- For which flows would we like to execute the circular economy principles in our city?
- How is the implementation of circular economy principles organized and which stakeholders are involved?
- How can (local) capital (e.g. human, social, physical, natural etc.) help to execute these circular principles?
- What governance (e.g., regulations) is required and on which level?

5.3 *Limitations*

The limitations of this study are mainly reflected in the fact that the collection of definitions of the circular city focused only on the academic literature. However, the circular economy is not only an emerging field in academic literature but also in practice, the addition of definitions that are present in non-scholarly/grey literature would help to improve/validate the results. To compensate for this shortcoming, the follow-up study can include non-scholarly definitions, such as descriptions of circular cities from policy documents, to gather more insights in the aspects of the circular city.

Appendix 28 Definitions of the Circular City

No	References	Page	Definition
1	Vanhuysse, F., Fejzić, E., Ddiba, D., & Henrysson, M. (2021). The lack of social impact considerations in transitioning towards urban circular economies: a scoping review. <i>Sustainable Cities and Society</i> , 75, 103394	p. 3	Circular cities are cities that apply any of the 10R frameworks, within one or multiple industries, to close, slow and/or narrow the material and energy and waste flows within their geographical area
2	Nurdiana, J., Franco-Garcia, M. L., & Heldeweg, M. A. (2021). How shall we start? The importance of general indices for circular cities in Indonesia. <i>Sustainability</i> , 13(20), 11168	pp. 14, 15	A defined area within a regenerative economic system, with far-reaching regional strategic development that continuously sustains the ability of natural systems to remain productive and diverse, functions at a defined level of social well-being and that implies economic prosperity
3	Gravagnuolo, A., Girard, L. F., Kourtit, K., & Nijkamp, P. (2021). Adaptive re-use of urban cultural resources: Contours of circular city planning. <i>City, Culture and Society</i> , 26, 100416	p. 7	Circular cities strive to reduce their environmental footprint while ensuring economic growth and wellbeing for local populations
4	Paiho, S., Mäki, E., Wessberg, N., Paavola, M., Tuominen, P., Antikainen, M., ... & Jung, N. (2020). Towards circular cities—Conceptualizing core aspects. <i>Sustainable Cities and Society</i> , 59, 102143	pp. 6, 7	The circular city <i>is based on closing, slowing and narrowing the resource loops as far as possible after the potential for conservation, efficiency improvements, resource sharing, servitization and virtualization has been exhausted, with remaining needs for fresh material and energy being covered as far as possible based on local production using renewable natural resources</i>
5	Lakatos, E. S., Yong, G., Szilagy, A., Clinci, D. S., Georgescu, L., Iticescu, C., & Cioca, L. I. (2021). Conceptualizing core aspects on circular economy in cities. <i>Sustainability</i> , 13(14), 7549	p. 13	A circular city is a city that functions through the usage of circular economy practices
6	Williams, J. (2021). Circular cities: what are the benefits of circular development?. <i>Sustainability</i> , 13(10), 5725	pp. 1, 2	Within this literature, circular cities are defined as those in which urban industrial actors adopt closed-loop production processes and business models
7	Williams, J. (2021). <i>Circular cities: a revolution in urban sustainability</i> . Routledge	pp. 14, 15	A circular city is a socio-ecological system, consisting of a bio-geo-physical unit and its associated social actors and institutions. It is a complex, regenerative and adaptive system, delimited by spatial and functional boundaries, surrounding an ecosystem

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No	References	Page	Definition
8	Paiho, S., Wessberg, N., Pippuri-Mäkeläinen, J., Mäki, E., Sokka, L., Parviainen, T., ... & Laurikko, J. (2021). Creating a Circular City—An analysis of potential transportation, energy and food solutions in a case district. <i>Sustainable Cities and Society</i> , 64, 102529	p. 187	A circular city constitutes: “one that practices CE principles to close resource loops in collaboration with its stakeholders to accomplish a future-proof city” (Prendeville et al., 2017, p. 187)
9	Definition from Holland Circular Hots pot (2019), available at: https://hollandcircularhotspot.nl/w-content/uploads/2019/04/HCH-Brochure-20190410-web_DEF.pdf (accessed 3 December 2019)	p. 6	A circular city is a resilient, healthy and competitive; able to provide for all the societal needs of its citizens within the natural boundaries of the Earth. Core elements of circularity are embedded within each key urban system; from water, to housing and infrastructure, to food and nutrition. Much like in a circular economy, in a circular city, resources are kept at their highest potential for as long as possible, through sharing, reusing, repairing, remanufacturing and recycling. Yet a city is inherently a human place; fostering collaboration and innovation to test and scale the solutions to create a truly inclusive, healthy and thriving place for all
10	Fusco Girard, L., & Nocca, F. (2019). Moving towards the circular economy/city model: which tools for operationalizing this model?. <i>Sustainability</i> , 11(22), 6253	p. 4	<ul style="list-style-type: none"> – a built environment designed in a modular and flexible way; – renewable-energy systems and efficient use of energy; – an accessible, economical, clean and effective urban mobility system; – recycling and transformation of waste into a resource; – production systems that encourage local loops closure and waste minimization
11	Williams, J. (2019). Circular cities. <i>Urban Studies</i> , 56(13), 2746–2762	p. 2759	A circular city is about a great deal more than creating a circular economy and circular business models within the urban context. It is about the regeneration and renewal of complex urban ecosystems
12	Gravagnuolo, A., Angrisano, M., & Fusco Girard, L. (2019). Circular economy strategies in eight historic port cities: Criteria and indicators towards a circular city assessment framework. <i>Sustainability</i> , 11(13), 3512	p. 17	The concept of a “circular city” or a “circular city-region” derives from the circular economy model applied in the spatial territorial dimension. It can be associated with the concept of a “self-sustainable” regenerative city. Later they mention: Circular cities can be seen as regenerative and self-sustainable systems

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No	References	Page	Definition
13	Meskers, C., Caffarey, M., & Van Camp, M. (2019). Circular cities, E-mobility and the metals industry—a world in transition. In <i>REWAS 2019: Manufacturing the Circular Materials Economy</i> (pp. 313–318). Springer International Publishing	p. 313	Only in the abstract: Circular cities integrate all aspects of life, connecting across people, economic actors, institutions and geographies. Circular cities are powered by renewable energy and responsible, sustainable materials; have closed resource cycles and are smart. The technical, industrial, economic, cultural and social systems meet, interact and challenge each other
14	Krysovaty, A., Zvarych, I., & Zvarych, R. (2018). Circular economy in the context of alterglobalization. <i>Journal of International Studies</i> Vol, 11(4)	p. 188	A circular city is a movement which promotes and uses a systemic way of thinking that can provide economic, social and environmental benefits to cities, while maintaining economic rationale
15	Cohen, J., & Gil, J. (2021). An entity-relationship model of the flow of waste and resources in city-regions: Improving knowledge management for the circular economy. <i>Resources, Conservation & Recycling Advances</i> , 12, 200058	p. 1, 2	The Circular Cities Hub1 defines a Circular City as a place where (1) "resources can be cycled between urban activities, within city regions" and (2) "cities can be designed so that land and infrastructure can be reused/recycled over time". One area of spatial planning that can directly contribute to (1) is waste management (Gravagnuolo, Angrisano, and Girard 2019; ESPON (European Spatial Planning Observation Network) 2019), and solving this problem requires a holistic approach that integrates knowledge from different domains
16	Bosone, M., & Ciampa, F. (2021). Human-Centred Indicators (HCI) to Regenerate Vulnerable Cultural Heritage and Landscape towards a Circular City: From the Bronx (NY) to Ercolano (IT). <i>Sustainability</i> , 13(10), 5505	p. 3	The circular and human-centred city is able to regenerate all forms of the existing cultural heritage capital (natural, manmade, cultural, social, economic and human) [8, 20] as key factors for achieving the sustainable development goals
17	Gravagnuolo, A., Micheletti, S., & Bosone, M. (2021). A participatory approach for "circular" adaptive reuse of cultural heritage. Building a heritage community in Salerno, Italy. <i>Sustainability</i> , 13(9), 4812	p. 26	The circular economy/circular city model implies also the re-naturalization of cities and the regeneration of the natural capital

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No	References	Page	Definition
18	Bosone, M., De Toro, P., Fusco Girard, L., Gravagnuolo, A., & Iodice, S. (2021). Indicators for ex-post evaluation of cultural heritage adaptive reuse impacts in the perspective of the circular economy. <i>Sustainability</i> , 13(9), 4759	p. 13	Further study of Gravagnuolo et al. (2021) specified the conceptual evaluation framework placing CHAR in the perspective of the circular city model, identifying three main critical drivers or “building blocks” of circularity: <ul style="list-style-type: none"> – a “regenerative capacity” linked to the self-regeneration of the cultural assets, as well as of the economic, environmental and social resources needed for its maintenance over time (in analogy with the circular economy principle of extending the use value of resources in the largest time horizon possible) – a “generative capacity”, linked to the net positive economic, environmental and social externalities generated in the area/ territory—which in part come back to the heritage asset – a “symbiotic capacity”, linked to the cooperation and collaboration approaches that enable a more efficient use of resources (such as those realized in “industrial symbioses”), as well as clustering processes in the territory (implementing an “economy of relationships”)
19	Marin, J., Alaerts, L., & Van Acker, K. (2020). A materials bank for circular leuven: How to monitor ‘messy’ circular city transition projects. <i>Sustainability</i> , 12(24), 10351	p. 2	Acknowledging circular cities’ multidimensionality related to the culture of cooperation, synergies, and symbioses that are key to the self-sustainability of urban and territorial systems complicates assessments that go beyond the ‘materials and energy’ dimensions in the circular urban economy Gravagnuolo et al. [12]. And later they mention: circular city projects are multiscale, material objects or urban projects are interdependent with a multitude of hinterlands throughout the materials chain (authors, p.2)
20	Baganz, G., Proksch, G., Kloas, W., Lorleberg, W., Baganz, D., Staaks, G., & Lohrberg, F. (2020). Site Resource Inventories—a Missing Link in the <? xmltex\break?> Circular City’s Information Flow. <i>Advances in Geosciences</i> , 54, 23–32	p. 24	The circular city (CC) generally applies the concept, principles and functions of CE and is thereby enabled by digital technology and foundationally designed as a regenerative and even restorative urban living system (Sukhdev et al., 2019)

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No	References	Page	Definition
21	Campbell-Johnston, K., ten Cate, J., Elfering-Petrovic, M., & Gupta, J. (2019). City level circular transitions: Barriers and limits in Amsterdam, Utrecht and The Hague. <i>Journal of cleaner production</i> , 235, 1232–1239	p. 1233	A 'circular city', the newest iteration of urban sustainability initiatives, increases the 'added value' of urban metabolism by building on industrial ecology and integrating and redesigning infrastructure, logistical services, industries, and the socio-cultural system at multiple levels of governance, including more recently on social consumption
22	Ancapi, F. B., Van den Berghe, K., & van Bueren, E. (2022). The circular built environment toolbox: A systematic literature review of policy instruments. <i>Journal of Cleaner Production</i> , 133918	p. 2	In general, a circular city has the goal of improving the ecological impact of existing in- and out-going flows of materials and energy in urban buildings and infrastructures by making them as circular as possible
23	Paoli, F., Pirlone, F., & Spadaro, I. (2022). Indicators for the Circular City: A Review and a Proposal. <i>Sustainability</i> , 14(19), 11848	p. 1	The topic of the circular city is currently much debated in the literature and is seen as one of the possible solutions for achieving sustainability in urban areas. The transition to circular cities is at the center of this debate. Specifically, this transition involves the creation of an integrated city in which the principles of circular economy are applied to all local government divisions, in a process facilitated by political initiative and support that through good example promotes change among residents and various stakeholders. Thus, the basis of this vision is the employment of circular economy ideals, which include in their foundational design the concepts of second use, remanufacturing, efficient use of resources, elimination of waste, avoidance of toxic materials, and improving and making sustainable waste management through the utilization of the 9Rs strategy (reduce, reuse, recycle, recover, reject, repair, refurbish, remanufacture, and reuse)
24	Nocca, F., & Angrisano, M. (2022). The Multidimensional Evaluation of Cultural Heritage Regeneration Projects: A Proposal for Integrating Level (s) Tool—The Case Study of Villa Vannucchi in San Giorgio a Cremano (Italy). <i>Land</i> , 11(9), 1568	p. 1	In this perspective, the circular city model represents a new way of organizing the city. As demonstrated by a variety of best practices, the entry points for triggering circular processes at the urban scale are various

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No	References	Page	Definition
25	Coskun, A., Metta, J., Bakırhoğlu, Y., Çay, D., & Bachus, K. (2022). Make it a circular city: Experiences and challenges from European cities striving for sustainability through promoting circular making. <i>Resources, Conservation and Recycling</i> , 185, 106495	p. 2	Hence, maintaining the community and sustaining the engagement of makers are important elements for realizing the idea of a circular city, a city that adopted CE to its core production and consumption systems
26	Tsui, T., Derumigny, A., Peck, D., Van Timmeren, A., & Wandl, A. (2022). Spatial clustering of waste reuse in a circular economy. <i>Frontiers in Built Environment</i> , 154	p. 2	The study of circular cities requires a spatial or geographical perspective. For cities, transitioning to a circular economy requires the introduction of circular (industrial) activities into the region, such as recycling, remanufacturing, storage, and (reverse) logistics; which are affected by spatial factors such as proximity to materials, clients, suppliers, and other companies
27	Horn, E., & Proksch, G. (2022). Symbiotic and regenerative sustainability frameworks: moving towards circular city implementation. <i>Frontiers in Built Environment</i> , 7, 178	p. 2	The circular city (CC) framework has become part of a larger transitional dialogue which envisions regenerative circularity and symbiotic resource flows across scales and contexts. Implementing circular principles in cities can involve actions such as scaling up integrated networks, retrofitting existing businesses, and creating new operational practices across scales. In doing so, challenges often exist, and there is a need for new tools, innovation, and approaches to future planning (Baganz et al., 2020). Achieving successful circular cities may be particularly contingent upon a successful transition toward reframing externalities to account for the true invaluable nature of ecosystems health and human wellbeing within economic and urban systems, something which has become all the more evident in light of the COVID-19 pandemic. Likewise, changing societal views and behaviors toward more sustainable practices, which are already in motion, are needed to strengthen a driving and supporting force for change

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No	References	Page	Definition
28	Moraes, F. T. F., Gonçalves, A. T. T., Lima, J. P., & da Silva Lima, R. (2022). Transitioning towards a sustainable circular city: How to evaluate and improve urban solid waste management in Brazil. <i>Waste Management & Research</i> , 0734242X221142227	p. 1	A circular city (CC) is dedicated to closing loops and transforming linear processes into circular processes to eliminate waste and waste generation (Girard and Nocca, 2019). According to the Circular City Declaration (2020), a CC promotes business models and economic behaviours that decouple resources from economic activities, maintaining product value and utility and maintaining components, materials and nutrients for as long as possible. Consequently, cities can close material cycles and minimize harmful resource use and waste generation

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