How does circularity bring resilience to cities? Understanding urban circularity.

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Executive Summary

With a world that is growing increasingly urban and facing greater ecological and social challenges, it is essential that urban development becomes sustainable. A new concept is emerging, the circular city. But how can we ensure that circular city strategies really contribute to sustainability and resilience, and how can we measure progress towards this goal?

Despite an abundant literature, the concepts of sustainability, resilience and circularity are ill-defined and ambiguous, leaving room for interpretation and an uncertain path towards the realisation of circular, resilient and sustainable cities.

This thesis first analyses the different concepts to (1) define them and (2) understand the relationships between them.

One of the findings is that circularity as a whole is not widespread since the focus in literature and practice is on the circular economy, which is micro-level and business-oriented. This restrictive definition is a risk for the social and environmental dimensions of cities that wish to apply a circular model. This is for example the case with smart cities, one of the failed trends of sustainable cities, which privileged technology at the expense of social equity and the environment. The components of circular cities must therefore be identified and defined to ensure that the interpretations of different actors do not distort the model.

Another key point is that resilience is a core element of sustainability, for if a system cannot recover from a shock, it will not be able to meet future needs and thus meet the fundamental intergenerational equity principle of sustainability. Unlike sustainability, resilience can be observed on shorter time scales and is therefore easier to implement and measure. For this reason, policy makers should aim for resilience in cities. The circular city must therefore contribute to improving urban resilience to be a sustainable urban model.

The components of circular cities should be identified and defined so that on the one hand no dimensions of the cities are neglected and a holistic approach is taken, and on the other hand the interpretations of different actors do not distort the model.

In order to further explore this new and ill-defined model of the circular city, a benchmark of circular initiatives in cities is presented to gain some insights. Several forms are investigated: citizen projects, living laboratories, circular practices in existing cities and circular knowledge

hubs. This exploration highlights the need for a holistic strategy, the need for a joint bottom-up and top-down approach and the need for a standardised language and emerging evaluation framework.

Based on a review of the literature, this thesis then presents several frameworks for assessing urban circularity and urban resilience. No assessment framework of urban circularity exists to date, although several are under development, either by the cities themselves or by research organisations. The few existing (often circular economy frameworks that have been adapted) lacks a unifying framework and could be better aligned with the different dimensions and challenges of cities. Urban resilience is better defined, in particular through the *Urban Resilience Index*, a comprehensive measurement tool. This tool, developed by Arup and the Rockefeller Foundation, and Yamagata and Sharifi's (2016) *Urban Resilience Assessment* both identify the qualities (characteristics) of resilient systems, providing a better understanding of what contributes to increased resilience. For a circular city to improve its resilience, its components must contribute to the qualities of resilient systems.

The thesis provides recommendations for future research on circularity assessment. For the focus to be urban, all dimensions of a city must be reflected: this brief presents the most common categories in the literature, applicable to all cities, to ensure that no aspect is overlooked. As cities are context-specific systems, the choice of indicators can be left to the cities as long as all these categories are represented. One should also be careful about cherry-picking, i.e. choosing indicators only according to the availability of data, which would lead to a watered-down view of reality.

In conclusion, this thesis offers a review of the different concepts of circularity and urban resilience. Urban circularity is a promising model for the future of cities as it contributes to several qualities of resilient systems, but it needs to be better defined and framed. This work highlights key points for reaching and measuring progress towards sustainable urban development.

Section 1. Introduction

1.1 Context that led to the research

This thesis was born out of the observation that the population is constantly growing and the ecological challenges are becoming more and more pressing. But there is one place where this demographic pressure is really felt: the cities. 'Currently, over half of the global population live in urban areas and it is estimated by the United Nation that this percentage will rise to 68% by 2050' (Elmjid, 2018). We live in an increasingly urban world which is shaping our environments and our future and cities are 'both the culprits and the source of innovative solutions to megatrends such as climate change. So, as existing cities grow bigger and new cities are formed, sustainable urbanization is key for a healthy planet' (UNHCR innovation, 2017).

And there we have circular economy, which looks beyond the current take-make-waste extractive industrial model. The 3 core principles, as stated by the Ellen MacArthur Foundation, are (1) design out waste and pollution, (2) keep products and materials in use and (3) regenerate natural system. 'This concept, often associated with manufacturing, can also be applied to cities, creating climate-smart hubs to save money, lower emissions, and improve living standards'.

Also defined by the Ellen MacArthur Foundation (2017), resilience of cities is 'the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow, no matter what kinds of chronic stresses and acute shocks they experience'. That being said, what are the implications of applying a circular economy model to cities?

Circular economy activity has been seen to increase the resilience of businesses to external shocks, so an exploration of how circular economy activity could increase urban resilience to both shocks and stresses could offer insights into the role a circular economy plays in influencing the fabric of urban environments (Ellen MacArthur Foundation, 2017).

Which leads to my initial research question: How does circularity bring resilience to cities?

1.2 Motivation for the research

In the first semester of this academic year, I took the seminar course on sustainability and smart territories (HEC ULiège). I really enjoyed it, and as part of the exam I read a paper by the Ellen MacArthur Foundation on circular cities (Cities in the circular economy: an initial exploration, 2017). The paper identified some research gaps and raised several questions, including 'how does circular economy activity create economic, social and environmental resilience in cities?' The paper argued that, as circular economy activity increases the resilience of businesses to external shocks, an exploratory look at how circular economy activity might enhance urban resilience could offer valuable insight into the role that a circular economy plays in influencing the fabric of urban environments. Concepts such as resilience and urban circularity are becoming increasingly popular, but interpretations differ. An exploration of the concepts, frameworks, and initiatives in practice could therefore provide some insight for city decision makers. I thus decided to look into this research gap, as the subject interests me greatly and fits with my Masters in Social and Sustainable Enterprise Management.

1.3 Structure of the thesis

This thesis is divided into several sections. The present section consists of the background that led to the research and the motivation for the research.

Section 2 defines all the key concepts that will be addressed in this thesis: resilience, circularity, sustainability, city as well as smart city and sustainable city. As these concepts are quite innovative and increasingly studied, there is no real standard definition, hence the interest in defining everything from the start.

Section 3 examines the relationships between the concepts defined in section 2. The link between sustainable city and smart city, circular city, resilience and sustainability, and urban resilience are explored. This section is necessary to better understand the synergies and trade-offs of these different notions.

Section 4 is a global benchmark of urban circular practices, to get a more concrete idea of how circularity is applied to cities. This section is classified in 4 parts: urban circular citizen projects, living labs, concrete circular applications in best-in-class cities, and circularity knowledge hubs. The section ends with a conclusion to reflect which aspects of urban circularity are highlighted in these different cases.

Section 5 looks at the most relevant assessment frameworks for urban resilience and urban circularity that exist in the literature.

Section 6 summarises the main findings of the previous section followed by the conclusion of the thesis. Limitations, challenges and perspectives for the future will also be discussed.

Sections 7 and 8 are the bibliography and appendix respectively.

Section 2. Definition

2.1 Circularity – circular economy, circular model, circular development

As defined by the Ellen MacArthur Foundation, 'a circular economy seeks to rebuild capital, whether this is financial, manufactured, human, social or natural. It looks beyond the current take-make-waste extractive industrial model and aims to redefine growth, focusing on positive society-wide benefits. It entails gradually decoupling economic activity from the consumption of finite resources, and designing waste out of the system.'

The Ellen MacArthur Foundation highlights that 'transitioning to a circular economy does not only amount to adjustments aimed at reducing the negative impacts of the linear economy. Rather, it represents a systemic shift that builds long-term resilience, generates business and economic opportunities, and provides environmental and societal benefits'.

The circular model (or circularity), is based on three principles (Ellen MacArthur Foundation, 2017):

- 'Design out waste and pollution'
- 'Keep products and materials in use'
- 'Regenerate natural systems'

In my thesis, I will use the term 'circularity' which I find more holistic and comprehensive than the term 'circular economy'. Indeed, the major use of the concept of circular economy remains business-oriented and substantial amount of circular economy theory and practice tends to forget about social equity and 'reducing' materials use (Kirchherr, Reike, & Hekkert, 2017), prioritizing recycling in growth-oriented economic systems (Ghisellini, Cialani, & Ulgiati, 2016). The circular economy is an over-hyped, under-researched and therefore still poorly defined concept. It is currently dominated by a narrative focused on businesses (micro level) to gain competitive advantage, which raises questions about the place of the circular economy in a broader urban sustainability agenda (macro level). As a city is not just a collection of businesses, it would be reductive to measure a city's level of circularity by summing up the number of circular economy businesses.

Since the term circularity does not have a clear definition in the literature, I therefore define it as follows: noun from the adjective 'circular', refers to the circular nature of something (The Free Dictionnary, 2016) and embodies the same 3 core principles stated above by the Ellen MacArthur Foundation. Circularity should provide environmental and societal benefits.

Systemic shift from the current take-make-waste model: designing waste out of the system	
Redefining Growth	Society-wide benefits
Keep products and materials in use	Environmental benefits
Regenerate natural systems	Economic opportunities (not 'growth')

Table 1: Circularity key take-away.

2.2 Sustainability – sustainable development

The online Oxford learner's dictionary defines sustainability as 'the ability to continue economic, social, cultural, and environmental aspects of human society and the non-human environment', and defines sustainable development as development that 'meets the needs of the present without compromising the ability of future generations to meet their own needs'. The latter is the definition from the Brundtland Report[1] (1987) and is the most frequently cited, even if there is currently no consensus on both definitions.

Meeting human needs is at the heart of sustainable development, but the report does not specify what those needs are. Economist Kate Raworth proposes an economic tool, the doughnut, which defines the social priorities of the world's populations that must be met within the limits of the planet.

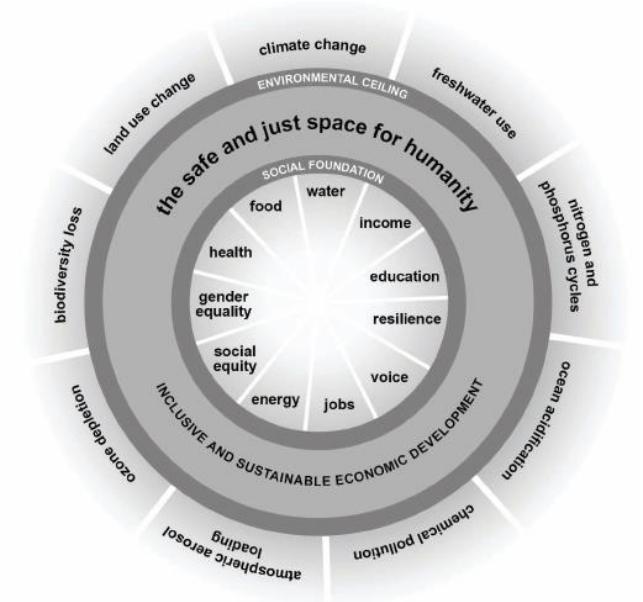


Figure 1: The Doughnut of social and planetary boundaries. K. Raworth, 2017.

[1] The Brundtland Report is the name commonly given to a publication, officially entitled Our Common Future, by the UN World Commission on Environment and Development. This report used (and defined) the term 'sustainable development' for the first time.

The outer circle represents our environmental ceiling, i.e. 9 planetary limits defined by Rockstrom et al (2009) that must not be exceeded if we are to remain in a safe ecosystem. The inner circle represents our social floor, the 12 basic needs defined by the SDGs, minimum social standards that must be met for humanity to prosper. The middle zone is the zone in which sustainable and inclusive economic development can take place, and thus sustainable development (Raworth, 2017). Sustainable development is a complex subject, and these clearly identified and quantifiable needs and limits help to create a common language to guide action and better define the concept.

Sustainability is increasingly a stated goal of businesses, non-profits and governments, but it can be difficult to measure the degree of sustainability of an organization or the pursuit of sustainable growth. Another well-known approach to measuring (and by extension defining) sustainability is the Triple Bottom Line, created by J. Elkington in the mid-1990s to measure corporate sustainability. According to J. Elkington (1997), The Triple Bottom Line (TBL) 'is an accounting framework that incorporates three dimensions of performance: social, environmental, and financial in addition to traditional reporting measures'. The TBL dimensions are also commonly referred to as the three Ps: people, planet and profits.

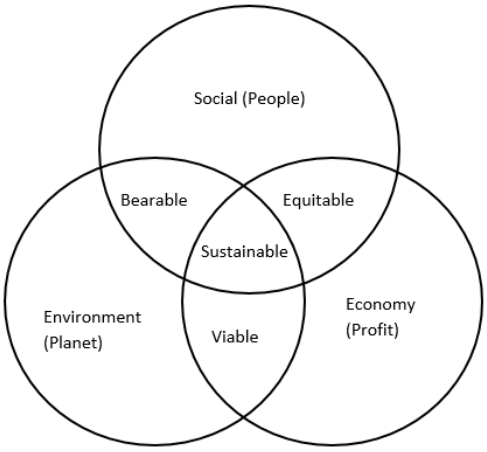


Figure 2: TBL diagram (environmental economy), adapted from J. Elkington, 1997.

This representation of sustainable development according to the 3 pillars of economy, social and environment (there is no hierarchy) is a model used in environmental economy (fig1). The most widely used definition of sustainable development, i.e. 'meeting the needs of the present without compromising the ability of future generations to meet their own needs', emphasises intergenerational equity. However, this vision is absent from the graph.

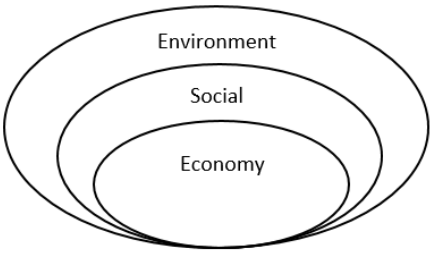


Figure 3: Ecological economy, adapted from K. Maréchal, 2020.

It would indeed be more accurate to represent sustainable development graphically in another way (fig 2). This graph refers to the ecological economy: 'hierarchy and conditioning are imposed by the different levels of the graph, i.e. there are limits to economic activities that are imposed by the environment' (K. Maréchal, personal communication, February 06, 2020). The living imposes limits on economic activity. These two ways of looking at things imply fundamentally different conclusions. Yet the latter view is less explored in the literature and in mainstream economics, since it challenges our entire societal and economic model based on infinite growth. Circularity should relate more to the ecological economy, as it is intended to be disruptive to the current system, but many understand circularity as a way to continue our growth model through better resource optimisation.

Finally, one of the most widely used frameworks for achieving sustainability is the 17 Sustainable Development Goals (SDGs) from the United Nations (2015). This 2030 Agenda for Sustainable Development, adopted by all UN member states in 2015, is 'a shared blueprint for peace and prosperity for people and the planet, now and in the future'.

2.3 Cities

As it is difficult to find a harmonized definition of cities, the EU-OECD has defined cities in a 2019 paper, and more specifically functional urban areas (FUAs) which are a combination of cities and commuting zones.

A functional urban area can be defined in four steps (Dijkstra, Poelman, & Veneri, 2019, p. 3):

1. 'Identify an urban centre: a set of contiguous, high density (1,500 residents per square kilometre) grid cells with a population of 50,000 in the contiguous cells';
2. 'Identify a city: one or more local units that have at least 50% of their residents inside an urban centre';

3. ‘Identify a commuting zone: a set of contiguous local units that have at least 15% of their employed residents working in the city’;
4. ‘A functional urban area is the combination of the city with its commuting zone’.

Since the terminology ‘city’ is the most prevalent in the literature and overwhelmingly refers to FUAs, we will continue to use it even to refer to FUAs in this thesis.

Cities can be considered as social-ecological system, which consists of 'a bio-geo-physical' unit and its associated social actors and institutions. Glaser, Krause, Ratter, & Welp (2008) define social-ecological systems as complex, adaptive and delimited by spatial or functional boundaries surrounding ecosystems and their respective contexts.

2.3.1 Smart cities

In the current context of urban demographic pressure, cities are evolving towards a still-emerging concept: the ‘smart city’.

As defined on the European Commission website, ‘a smart city is a place where traditional networks and services are made more efficient with the use of digital solutions for the benefit of its inhabitants and business. A smart city goes beyond the use of digital technologies for better resource use and less emissions. It means smarter urban transport networks, upgraded water supply and waste disposal facilities and more efficient ways to light and heat buildings. It also means a more interactive and responsive city administration, safer public spaces and meeting the needs of an ageing population’.

Although the term Smart City is not a new concept since it emerged about 20 years ago (Daniélou, 2014), there is still no unanimously accepted definition. The Smart City Institute of the University of Liege, which specializes in the study of Smart cities, defines it as follows: ‘a multi-stakeholder ecosystem engaged in a sustainability strategy using (information and communication) technology as a catalyst to achieve its sustainability goals’. This approach involves the progressive development of a common strategic vision and the implementation of concrete initiatives in different areas in order to generate sustainable economic development and to offer a better quality of life and a wise management of natural resources.

The Smart City Institute furthermore concludes that there is no right answer to the question ‘What is a Smart City’. The multiple definitions are therefore not wrong as long as they denote a sustainable and unifying project for the future of cities.

In practice and in the literature, the concept of the smart city and its actual contribution are criticised. These criticisms have been fed by the realities visible in cities which identify themselves as smart (see section 4, Masdar city) but neglect the social aspects of sustainable development and the basic social dimension of the city (Kummitha & Crutzen, 2017). Prendeville, Cherim, and Bocken summarise the major criticisms of the smart city concept as 'the blind adoption of technological solutions, the lack of integration (digital fracture, bias, etc.) and consideration of how this influences human behaviour, as well as the socio-environmental impacts of information and communication technologies on future cities' (2018, p. 3).

I found it relevant to define the concept of Smart city as Smart city technology is one of the key tenets of the Ellen MacArthur Foundation's Circular Economy Framework to efficiently monitor resource flows (Ellen MacArthur Foundation, 2015). Furthermore, article 4 shows that many cities that want to become circular also follow a smart city strategy and sustainable strategies.

2.3.2 Sustainable cities

A sustainable city, urban sustainability, green city or eco-city (also ecocity) is ‘a city designed with consideration for social, economic, environmental impact - commonly referred to as the triple bottom line - (F. Slaper & J. Hall, 2011), and resilient habitat for existing populations, without compromising the ability of future generations to experience the same’ (Wikipedia contributors, July 2021)[2]. The UN Sustainable Development Goal 11 defines sustainable cities as ‘those that are dedicated to achieving green sustainability, social sustainability and economic sustainability’ (United nation, 2015). Urban sustainability is about resilience and liveability beyond the city’s infrastructure and technology.

2.4 Resilience

The term ‘resilience’ originated from the technical area of mechanical and engineering sciences to describe the properties of materials, such as timber or iron, and their ability to withstand severe conditions (Hollnagel et al. 2006). It is now used across many academic fields with different interpretations ranging from engineering to psychology, economics and social

[2] Although Wikipedia is not a proven scientific source, this definition concisely summarises the phenomenon of the sustainable city. The definitions found in the literature are extensive and complex, so I decided to include this definition for a short and effective summary of the concept.

sciences to ecology and environmental science (Bhui 2014). The conceptual similarities lie in understanding the responses to shocks, surprises, unforeseen or hazardous disturbances.

The concept of resilience varies according to the field in which it is used, but also within the same field, which proves that the concept remains ambiguous and lacks harmonisation and clarity. A table is provided in the annexes (Appendix 1) to review the different definitions and get an overview of the concept.

The Resilience Alliance[3] define resilience as 'the capacity of a social-ecological system to absorb or withstand perturbations and other stressors such that the system remains within the same regime, essentially maintaining its structure and functions. It describes the degree to which the system is capable of self-organization, learning and adaptation' (Resilience Alliance, n.d.). This definition is more relevant for this thesis as it focuses on urban resilience (the city being a socio-ecological system).

[3] The Resilience Alliance is a research organization that focuses on resilience in social-ecological systems as a basis for sustainability. Their explanation and characteristics of resilience are widely accepted (Holling 1973, Gunderson & Holling 2002, Walker et al. 2004).

Section 3. Key relationships between key concepts

3.1 Smart and sustainable cities

Does the concept of smart city systematically encompass the notion of sustainable cities? In recent years, there has been a shift in cities striving for smart city targets instead of sustainability goals (Marsal-Llacuna, Colomer-Llinàs, & Meléndez-Frigola, 2015).

The European Commission's definition of smart cities (section 2) highlights certain concepts that can be linked to sustainability, mentioning 'better use of resources and reduced emissions', 'improved water supply and waste disposal facilities', as well as 'more efficient ways of lighting and heating buildings'.

The definition of the Smart City Institute (section 2) clearly mentions the term sustainability in its definition ('technologies are used to achieve the sustainable strategy of the city') and come to the conclusion that a city cannot really be smart if it is not sustainable.

In a 2017 study to determine the differences between the concepts of smart city and sustainable city, Ahvenniemi, Huovila, Pinto-Seppä, and Airaksinen analysed 16 sets of city assessment frameworks [4] (eight smart city assessment frameworks and eight urban sustainability assessment frameworks) with 958 indicators in total. The main observation is that urban sustainability frameworks contain a large number of indicators measuring environmental sustainability, while smart city frameworks lack environmental and energy-related indicators. The latter frameworks focus more on social and economic aspects, but especially on modern technology and intelligence. This suggests that environmental and energy aspects may not be sufficiently considered in smart city frameworks, indicating future development needs for smart city performance measurement systems or a need to redefine the smart city concept to better encompass the concept of sustainability.

The 2017-study points that sometimes the fashionable term 'smart city' is also used for branding (Vanolo, 2015) or marketing (Shelton, Zook, & Wiig, 2015 ; Söderström, Paasche, & Klauser, 2014) purposes, with lack of integrated approach covering sustainability concerns.

Another 2019 study by Yigitcanlar et al. examined the question of whether cities can become smart at all without actually being sustainable, looking at the links between the smart city

[4] The purpose of the city assessment frameworks is to give guidance for decision-making, enable target setting for cities as well as allow assessing whether the development is proceeding towards the wanted direction.

literature and urban sustainability. The results highlighted an expectation in the academic literature reviewed that cities must first become sustainable to be considered truly smart. The study identified three major weaknesses or challenges of smart cities in achieving sustainable outcomes: 'strong technocentricity, complexity of practices, and the ad hoc conceptualization of smart cities'.

These two studies show that it is erroneous to use the term smart city alone to refer to a sustainable city, as the notion of sustainability is not always included in the concept of smart city in practice. Therefore, the term should be used with caution.

3.2 Circular cities

How can we apply the notion of circularity to a city?

According to the Ellen MacArthur Foundation (2017), circular cities integrate the three principles of the circular economy - that is, a principle of circularity - into all of its functions (eliminate waste and pollution, maintain products and materials in use, regenerate natural systems). A circular city seeks to generate prosperity, increase liveability, and improve the resilience of the city and its citizens.

In a simplified way, a stakeholder survey by the European Commission[5] defines the Circular City as 'the notion of Circular Economy –circularity – applied to a defined territory (city, region, etc.). Because of their scale and competences, territories are key players in the transition towards a circular economy by being privileged places of experimentation'.

While this basis is common to the majority of circular city definitions, there are some specificities.

In addition to adopting the three principles of circularity, the City of Amsterdam – one of the early adopters of the circular economy concept at city-level – developed seven principles to guide its transition (Circular City Funding Guide, 2020):

- 'Closed loops – all materials are re-used and recycled infinitely'
- 'Reduced emissions – all energy is generated from renewable sources'
- 'Value generation – resources are used to generate shared (financial and societal) value'

[5] Stakeholder survey on circular and smart cities on the European website Smart Cities Marketplace.

- ‘Modular design – all products are designed in a modular and flexible way and production chains enable the adaptability of systems’
- ‘Innovative business models – all new implemented business models enable the shift from possessing goods to using goods through services’
- ‘Region-oriented reverse logistics – logistics systems are shifted to a more region-oriented service with reverse-logistics capabilities’
- ‘Nature systems upgradation – all human activities positively contribute to ecosystems, ecosystem services, and the reconstruction of “natural capital’

In a 2020 report, the United for Smart Sustainable Cities (U4SSC) initiative extends the concept of circularity beyond the economy to include different aspects of city management, hence the term 'circular' cities. The report states as an example that ‘public spaces in the city (which are not economic products but public goods) can be used for different social activities at different times (i.e. sharing public spaces as a city good). Similarly, household items can be shared between individuals and households or reused for different purposes. These examples transcend economic activities and enhance the use of city assets beyond economic activities’.

In her book *Circular cities* (2021), J. Williams defines circular city as ‘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’. According to her, there are three actions fundamental to both a circular city and circular development:

1. ‘Looping actions (reuse, recycling and energy recovery) – a circular city is an open system with many linear processes; however, where possible these processes will be closed. This reduces waste and promotes the most efficient use of resources. Examples include waste-heat recovery systems; food-reuse cafes; bio refineries; grey-water recycling systems; adaptive reuse of buildings and land reclamation’.
2. ‘Ecologically regenerative actions – regenerate the urban ecosystem and ecosystem services. Ecologically regenerative actions are often operationalised through the inclusion of green and blue infrastructure (e.g. permeable surfaces, reed-bed, retention ponds, green roofs) into the urban fabric or the management of urban ecosystems (e.g. conservation, farming, forestry)’.
3. ‘Adaptive actions – build capacity within the urban fabric and communities to adapt to change. Capacity is built through the use of flexible design, collaborative planning, co-provision and systems for learning’.

How do the concepts of sustainable, smart and circular cities intersect? For the AMS Institute[6] (2018), the urban development model of the future cannot be considered truly 'smart' unless it is also 'circular' - waste-free and regenerative by design (Disruptive Innovation Festival - DIF, 2018). The concepts of smart, sustainable and circular cities are therefore closely linked.

This is a conclusion also reached by Prendeville, Cherim, & Bocken (2018, p. 17) as they mention that 'the circular economy concept is variously co-opted into smart city visions and sustainability strategies'. For these authors, the circular city is 'the latest in a series of urban sustainability trends (green city, smart city, zero waste city, etc.) that have arguably failed' (2018, p. 2). In their paper, they perform a case study of 6 cities claiming to be circular. They remark that the concept of the circular city is blurred between these different concepts (smart city, urban sustainability, circularity) and is also interpreted differently by politicians, often in a unique way. It is indeed difficult to capture the concept of circularity in day-to-day practices. Prendeville, Cherim, & Bocken (2018, p. 17) conclude by defining the concept as follows: 'a circular city is a city that practices CE [circular economy] principles to close resource loops, in partnership with the city's stakeholders (citizens, community, business and knowledge stakeholders), to realize its vision of a future-proof city'.

A recent publication by Circle Economy and Holland Circular Hotspot (2019) dares to put a percentage for the systems (Infrastructure, Mobility, Food, Water, Energy, Consumer Goods, Plastics and Industrial Park) that need to be realised to move from a linear city to a circular city (Appendix 2) Technology, social innovation, eco-design and collaborative coalition building are all approaches that need to be combined to achieve a circular city (Carrière, Rodríguez, Pey, Pomponi, & Ramakrishna, 2019).

3.3 Resilience and sustainability?

In the face of persistent environmental and social challenges, research from Xu, Marinova, and Guo (2014) highlights that the context of sustainability thinking has shifted from climate change avoidance to how resilient society can be. 'Resilience thinking for ecosystems and social-ecological systems (SESs) is asserted to be one of the active focusses within sustainability' (Xu and Marinova, 2013, p. 1).

[6] Amsterdam Institute for Advanced Metropolitan Solutions (AMS).

The principle of resilience is similar to the goal of sustainability. If a system is resilient, it is able to maintain its current state of equilibrium despite external disturbances - whether caused by nature or human activities. This equilibrium is based not only on the stock of natural resources, but also on the degree of social and economic well-being that constitutes the three pillars of sustainability (TBL: balance and intersection between economy, social and environment).

A system that is not resilient cannot be sustainable since the principle of sustainability is 'to meet the needs of the present without compromising the ability of future generations to meet their own needs' (World Commission on Environment and Development, 1987). If a system cannot recover from an external shock (environmental or human), it will not be able to meet future needs and the fundamental principle of intergenerational equity.

The main difference is that resilience thinking does not emphasise the long-term temporal dimension and intergenerational equity (meaning that the resources of future generations are not less than those of the current generation), which are two fundamental principles of sustainable development. Resilience focuses more on the state of a system in the face of disturbances. Indeed, in some cases, the system remains resilient as long as critical tipping points are not crossed, even if the stock of resources is reduced and less available than before. Therefore, resilience alone is not sufficient to ensure sustainability and cannot be used to fully replace sustainability as the ultimate goal.

Why use this concept then? Marchese et al., (2018) enlighten the temporal scale of implementation as one important difference between sustainability and resilience. As sustainability is a 'long term' concept that is difficult to measure at one point in time, it is easier to consider the resilience of a system which is more easily measured. Resilience links the visionary and general theory of sustainability with more specific practices, namely the applications of resilient thinking to different areas of the pursuit of sustainability.

In practice, human activities can only be seen as an operational concept of sustainability if the system is resilient. As Xu, Marinova, and Guo (2014, p. 7) enhance, 'sustainability can be deemed to be the desirable objective of human development[7], whilst resilience thinking is the way to get to this goal'.

Cities policies should aim for resilience as it is easier to implement and measure.

[7] In the context of this thesis, urban development.

3.4 Urban resilience – City resilience

Resilience has become an important goal for cities, especially in the face of climate change.

City resilience reflects the overall 'capacity of a city (individuals – particularly the poor and vulnerable –, communities, institutions, businesses and systems) to survive, adapt and thrive no matter what kinds of chronic stresses or acute shocks they experience' (The Rockefeller Foundation & Arup, 2014). Resilience focuses on improving the performance of a system in the face of multiple risks, rather than on mitigating or preventing the loss of assets due to specific incidents.

Meerow, Newell, & Stults proposed a new definition for urban resilience (2016, p. 3): 'the ability of an urban system-and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales-to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity'. This definition is based on a literature review and bibliometric analysis of 176 studies and 25 definitions.

The analysis also revealed that the differences and inconsistencies between the existing different definitions of urban resilience stem from 6 fundamental concepts: (1) 'the definition of urban', (2) 'the understanding of system equilibrium', (3) 'positive or neutral (or negative) conceptualisations of resilience', (4) 'the mechanisms of system change', (5) 'adaptation or general adaptability' and (6) 'the timing of action'.

The new definition of urban resilience explicitly takes a position in these 6 concepts, but remains sufficiently inclusive and flexible to allow for adoption and collaboration between different disciplines.

Section 4. Global Benchmark – Urban circularity

As noted in section 3, the concept of the circular city is recent and is interpreted differently by cities, due to the lack of a harmonised definition and because of the synergies between the concepts of sustainable city (eco-city, green city) and smart city. In order to gain more insights, it therefore seemed appropriate to present several concrete urban application of circular practices. This benchmark focuses on how citizen projects, living laboratories, existing cities and knowledge centres understand, apply and play a role in shaping urban circularity.

4.1 Citizen Projects

A citizen project 'is a project which, in one way or another, integrates one or more dimensions of territorial interest and which is controlled by citizens and/or their representatives' (Energie Partagée, 2013, p. 3). These are incubator and bottom-up projects that can be replicated in other places. Many citizen projects exist, and I will limit myself to presenting two of them because they cover the properties of citizen projects (bottom-up approach, local focus, holistic focus and not economy-focused).

4.1.1 Circularium Brussels

Circularium is '20,000m2 of industrial space transformed into a large centre for local innovation and circular production dedicated to the city of Brussels'. Launched in March 2020 for a period of at least 5 years, it is a place devoted to short circuit, to the actors of cultural life and to neighbourhood life, a space for working, living and meeting for all. Its occupation can be flexible in time and space according to specific needs (Circularium, 2021). The aim of this transitional occupation is to inject a new dynamic into this former car complex, to reconfigure it into an innovative, attractive and sustainable place for a new type of entrepreneurship and urban economy that would host an interesting mix of long-term projects, start-up projects, pop-up projects and event-based projects.

This 5 year period allows for the study and testing of new types of market. The project has several stakes (Circularium, 2021):

- **Production**. 'Search for actors active in the production of consumer goods related to urban needs'.

- **Circularity**. ‘The urban economy is inseparable from circularity. Circularium wants to welcome companies, start-ups and other project leaders with a circular economy logic to work together and develop’.
- **Flexibility**. ‘Circularium allows for infinite flexibility both in terms of duration (at the request of users, leases that can be revised according to their availability and needs for a minimum occupation period of 6 months) and in terms of surface area and ceiling height (modularity and possibility of expansion). This flexibility is a major asset when you don't know what tomorrow will bring’.
- **Neighbourhood**. ‘Circularium plays an activating role in its neighbourhood. It is an essential crossroads for local residents, a landmark not far from the canal where it is good to work and relax. Because it is by integrating itself into its neighbourhood that Circularium will be successful’.

For the moment, the site already hosts several stakeholders such as a non-profit organisation for the regularisation of undocumented migrants, a cooperative for the re-use of construction materials, an eco-responsible design company, a non-profit organisation for the valorisation of products that would have been thrown away or not consumed, a training association for facilitating access to technology for anyone suffering from the digital divide in Belgium, etc.[8]

4.1.2 R-Urban

Based on the principle of ‘produce what we consume and consume what we produce’, R-Urban (by the Parisian Atelier d’Architecture Autogérée (AAA)) proposes the creation of a series of ecological and civic facilities using urban and rural land in a reversible way.

The aim of R-Urban is to act as an accelerator and incubator to encourage the development of local networks, short ecological, economic and social circuits and the transmission of collaborative and solidarity-based practices (urban agriculture, composting, recycling, etc.). In this way, through the development of ecological practices and solidarity networks, the inhabitants become actively involved on a daily basis and modify their lifestyles, housing and working methods in a sustainable way for a new balance between production and consumption (R-Urban website).

R-Urban is active in several geographical areas. An agency has been set up in Colombes, in the north-western suburbs of Paris, to pilot the implementation of the first specific units that

[8] All actors are listed on the Circularium website.

catalyse the formation of short circuits, networks and practices around waste recycling and eco-construction, urban agriculture and cooperative housing. Although not explicitly stated, R-Urban applies a circular philosophy.

Several pilot projects have been developed (R-Urban, 2016):

- AgroCité – 'a civic urban agriculture unit consisting of an experimental micro-farm, community gardens, educational and cultural spaces and energy production, composting and rainwater harvesting facilities. After the launch and a few years of collaboration, AAA left Agrocité in the hands of the community who took full ownership of the project. It understands circularity as production of commons: a civic and ecological economy, developing from the bottom-up'.
- Recyclab – 'a recycling and eco-construction unit built around a series of equipment for recycling urban waste and transforming it into sub-assemblies for eco-construction'.
- ECoHab – 'a residential, cooperative and ecological unit made up of a number of experimental dwellings and collective spaces that are partly self-built. This unit was planned in the initial R-Urban Colombes strategy but was not realised'.
- AnimaLab – 'a domestic farm located in the Agrocité and composed of micro-structures such as beehives and a henhouse. The harvested products are integrated into the short circuits through the local shop of the Agrocité'.

As stated on its website, R-Urban is expanding to other cities in Ile-de-France and is currently being developed in Bagneux and Gennevilliers. R-Urban is also present in London, in the Hackney Wick area, where a project is being developed. The project is called WOW - Whick on Wheels – 'a mobile production unit that encourages collective production in situ, using local materials and know-how'. This unit is being developed by Public Works in London.

R-Urban, is not about 'sustainable development' but about societal change and political and cultural re-invention, addressing issues of social inequality, power and cultural difference (Petcou & Petrescu, 2011). R-urban emphasizes 'circular' resilience as a close relationship between citizens, the territories that they inhabit, and the resources that they consume and produce. It focuses on closing material loops within the city (Marin & de Meulder, 2018).

4.2 Living laboratories

This category includes real or virtual projects that have been set up explicitly to study circularity through concrete cases. It is not about circular initiatives implemented in existing cities, but rather about specific initiatives studied in context, which will be scaled up if they are successful. Citizens, stakeholders, businesses and users are considered key actors in the research and innovation process, hence the name 'living laboratory'.

4.2.1 Masdar City

Masdar, 'the world's most sustainable city', is a smart and eco-city with the objective of being zero waste and zero carbon. The project started in 2008 and is located in the desert, 17 kilometres from Abu Dhabi (Saudi Arabia). Masdar was created to be a living, experimental laboratory for technology, waste management, clean transportation and renewable energy to diversify the country's oil economy (Masdar City, n.d.-a). 'The city has been designed according to the principles of the circular economy, which seeks to bring the functioning of industrial systems closer to the cyclical functioning of natural ecosystems' (Veolia Group, 2014).

The city itself is designed to maximise quality of life and minimise environmental impacts, with several key features described on the Masdar City website:

- 'Connection to Abu Dhabi by a system of driverless electric vehicles for rapid transport of people and goods'.
- Intelligent vernacular architecture to allow natural ventilation and energy optimisation (narrow street, orientation of buildings to protect from the sun, sustainable materials, natural ventilation towers, green spaces, etc.).
- The city is home to one of the world's largest low-carbon building complexes: they use 40% less water and energy than similar buildings, and are built with low-carbon cement and 90% recycled aluminium.
- The city's water supply comes from desalinated sea water. Waste and resources are used to the maximum, such as wastewater for landscape maintenance.
- The city is energy efficient: each home can control its own consumption, and electricity from a concentrated solar power plant will power a 100% electric public transport system.

- At the heart of Masdar City is a knowledge institute for sustainability (Global Green Growth Institute), with a special economic zone to attract green and clean technology companies.
- The first artificial intelligence university was launched in Masdar City in 2019.
- Resource flows are closed within Masdar City's boundaries, importing new materials and resources to construct Masdar City from scratch in the desert.

In 2016, The Guardian newspaper reported on Masdar City's goals as a model for sustainable living, and found that they had been partially abandoned. In that year, only 300 students were actually living in the city, which was only 5% complete of the original plan. The autonomous vehicle system, intended to connect Abu Dhabi and Masdar, 'was abandoned after two of the 100 planned stops were built, as new car technologies [that they had not anticipated] made it obsolete'. (Goldenberg, 2020).

In a 2015 article, Cugurullo F. analyses the limitations of the Masdar City project. According to him, the city focuses too much on the commercial and technological aspects of the project: its development is overly dictated by a market logic. 'Behind the implementation of the so-called Emirati eco-city, there is no ecological analysis to study the biophysical environment surrounding Masdar City but only market analyses that study the economic environment surrounding the clean technology market. Challenges to Masdar City's sustainability, such as water and energy supply chains, which affect the environmental performance of the new city, are not addressed. Instead, they are seen by the Masdar initiative as obstacles and are simply ignored or bypassed. Ideas of economic feasibility and profitability shape the understanding of what needs to be supported, and aspects of city building that cannot be turned into immediate sources of profit are excluded from the agenda' states the paper. The author also addresses the lack of equity: the economic benefits of the project are not distributed fairly, the regime is undemocratic, and there is little social justice. Cugurullo concludes as follows: 'The unsustainability of the UAE ecocity project stems from Abu Dhabi's policy agenda, Vision 2030, which is designed around the economic interests of local elites. Masdarian's experience shows that in order to develop sustainable cities, governments must first develop policy agendas that also target economic and environmental development for the benefit of the entire population. Without these conditions, any 'ecocity' will be the utopia of the few and the dystopia of the many' (2015, p. 14, 15).

4.2.2 Reburg

Reburg, 'the most circular city', is a virtual project in Belgium to explore what life would be like in a circular city. This concept of a circular city of the future was commissioned by Vlaanderen Circulair[9].

Reburg visualises what life in a circular city would look like, what kind of businesses would thrive there and how the circular city would materialise. On the website of the Reburg project, three dimensions can be distinguished:

- **Construction** – 'It is an exploration about the future of building. Smart and versatile buildings adjust to the needs of their users. Unfit building parts are repurposed, upgraded or reprocessed into new materials'.
- **Manufacturing** – 'it is all about making, materials and resource loops. Hyperlocal fab-cities[10] with local co-working and co-manufacturing spaces make for local circularity'.
- **Dematerialization** – 'the last part concerns smart cities and virtualization - The real, the augmented and the virtual reality are mixed into a seamless whole, thus reducing material and logistic needs'.

Pantopicon, the Flemish design studio that produced the virtual city, tells through a series of multimedia scenarios how circular economy ideas could be adopted in the present. Here are some examples (Pantopicon, n.d.-a):

- 'Optimised loops - Reburg is connected with other cities, creating the global circular trade system'.
- 'Urban livers - Those process residual streams into new high-value chemical components for Reburg's industry'.
- 'Coffee shops - The coffee shops at Reburg collect used grain to process them into new bio-chemical applications'.
- 'Symbiosis tower - A vertical industrial park, where one business' waste is another's resource'.
- 'Revive lane - A high-end shopping street for repurposing goods and services'.
- 'Fab-centre - The intelligent start-up zone for the urban manufacturing industry'.

[9] A partnership of government, business, civil society and knowledge community for the circular economy in Flanders (Vlaanderen Circulair Website).

[10] Locally productive, globally connected cities – cities that have pledged to work towards producing everything they consume by 2054 (Fab City Global Initiative, 2021).

On the Pantopicon's website, it is noted that Vlaanderen Circulair's vision for the future of the circular economy 'was translated into a series of relevant themes, which would become the framework for the upcoming interview pieces and the pillars of Reburg. They would be: entangled realities, fab cities, bio-synthetics, and hybrid systems. Picking up on certain developments, both present and future, allows for the possibility to speculate on how they might manifest and affect our daily lives, especially how it shapes the current and future social fabric and interactions'.

Reburg offers virtual urban solutions derived from trends for a circular economy and therefore seeks to stimulate circular entrepreneurship. However, this conception of the circular city is not complete. As Marin & de Meulder point out in a case study of Reburg (2018), the solutions imagined are purely technocentric and commercial. Social and environmental dimensions (social equity, deep democracy, socially integrated economy and ecological balance between nature and humans, etc.), are not explored at all.

Moreover, Reburg is a virtual utopian conception at a fixed time. While it identifies trends and suggests some ways forward for circular initiatives, it skips the question of how existing urban fabrics can become more circular and resilient.

4.2.3 Toyota Woven City

Presented on a YouTube video, the Toyota Woven City is a prototype, hydrogen-based city of the future, based at the foot of Mount Fuji in Japan where a former Toyota factory is located. The city, seen as a living laboratory, will be a fully connected ecosystem powered by hydrogen. Toyota initially plans to house about 2,000 residents in its 175-acre city, mainly Toyota researchers and employees, who will be full-time test subjects to evaluate the potential of this city of the future (Woven City, 2021).

The project is very technology-oriented: the digital twin[11] of the project includes technologies such as autonomy, robotics, personal mobility, smart homes and artificial intelligence in a real environment. As Toyota is a car manufacturer, they are looking to test what they see as the mobility of the future in a real environment, and this is predominant in the design of the city. But it also plans to be sustainable. At the CES 2020 technology show in Las Vegas, Toyota CEO Akio Toyoda revealed plans for the initiative and its key points: circular process, no waste,

[11] A digital twin is a virtual representation that serves as the real-time digital counterpart of a physical object or process.

ecology and climate are also mentioned to be part of this infrastructure of the future (Appendix 3).

In the same conference, Danish architect Bjarke Ingels, founder and creative director, explains the design of this city of the future, reported in a 2020 Toyota corporate press release (Toyota, 2020). The city is planned to be entirely sustainable, with buildings constructed from low-carbon materials such as wood, mixing traditional and robotic production. Energy will be produced using hydrogen and solar power, via photovoltaic panels on the roofs of the buildings. Vegetation will be present in the city, as well as hydroponic crops. There will also be spaces designed for social gatherings, to strengthen communities and human connection. Toyota Woven City also aims to test how AI can facilitate intergenerational life: the houses will be equipped with the latest technologies to serve the inhabitants (health sensors, connected technology to ensure efficient use of energy, smart fridges that refill themselves, etc.). Regarding mobility, the main arteries will be reserved for fully autonomous and zero-emission vehicles. Autonomous Toyota e-Pallets will be used for transport and deliveries via underground routes. There will also be green pedestrian-only streets and soft mobility routes.

The project has only just started, and therefore cannot be evaluated. The plans and budgets are not yet public: for the time being, only the information given at CES 2020 technology show in Las Vegas by Toyota CEO Akio Toyoda and Danish architect Bjarke Ingels is available. So far, although the project is energy and techno-focused, it also places sustainability and social well-being among its objectives.

4.3 Circular practices in existing cities

More and more cities are adopting circular strategies to improve their resilience and overcome demographic, economic and climate pressures. This is particularly the case for European cities (but not only), as the Commission adopted the new Circular Economy Action Plan (CEAP) in March 2020 as part of the European Green Deal (European Commission, 2020). It presents legislative and non-legislative measures targeting areas where action at EU level brings real added value, and further initiatives and legislation are expected to arrive in the coming years. This is a real leap forward for urban circularity, and some cities are already taking advantage of this momentum.

A literature review conducted by Carrière, Rodríguez, Pey, Pomponi, and Ramakrishna (2019) reveals that there is a lack of robust case studies on circular cities. Also, there is no consensus

on the recommendation of a model to adopt and implement (Ferreira and Fuso-Nerini, 2019). Therefore, I decided to mention cities that came up most often in the literature as 'most circular cities', 'cities with a circular strategy' or that had been analysed by circular economy actors (EMF, Circle Economy, and Circular Economy Club). Here are some cities that are showing leadership and progress in the transition to circularity.

4.3.1 Amsterdam

The city of Amsterdam wants to be a forerunner in circularity and has a good starting position because it is a pillar of its sustainability policy, and many citizens, companies, start-ups and institutions are convinced of the need for a circular economy (Smart City Hub, 2020). Amsterdam pictures the circular city as a cleaner, greener and more pleasant living environment where the well-being and health of the citizens are paramount, with more justice, both inside and outside the city limits (City of Amsterdam & Circle Economy, 2020).

The city has a clear circular ambition and the political climate in place is supportive (various clean air, energy, climate neutral and sustainability policies exist, in addition to a circularity policy). Amsterdam works with districts, institutions and citizens to promote circularity, and collaborates with central government and Europe on policy choices to promote the transition, such as shifting taxation from labour to raw materials and energy for example. Amsterdam plans to be 100% circular by 2050 and has published its 2020-2025 strategy which gives a direction with different challenges and milestones. This plan focuses on three value chains, selected with external parties such as TNO and Circle, for their importance and potential impact: food and organic waste streams, consumer goods and the built environment. The details of the ambitions are available in the appendix (Appendix 4).

Food and organic waste streams
• 'Ambition 1: Short food chains provide a robust sustainable food system' • 'Ambition 2: Healthy and sustainable food for the people of Amsterdam' • 'Ambition 3: High-quality processing of organic waste streams'
Consumer goods
• 'Ambition 1: The City sets the right example by reducing its consumption' • 'Ambition 2: Using what we have more sparingly' • 'Ambition 3: Amsterdam makes the most of discarded products'
Built environment

- ‘Ambition 1: The transition to circular development requires a joint effort’
- ‘Ambition 2: The City sets the right example by formulating circular criteria’
- ‘Ambition 3: A circular approach to the existing city’

Table 2: The 3 value chains of Amsterdam Circular Strategy, City of Amsterdam 2020.

The city wants to apply circularity in the maintenance of public spaces, buildings and infrastructure, as well as in the supply of sectors such as hospitality and electronics. The stimulation of innovation and cooperation between companies and institutions is emphasised. The city adopts a sectoral approach by concentrating its efforts on impact sectors: these include hotels, hospitals and port and industrial companies. Standards and laws are written to stimulate and facilitate the work of pioneers and pilot projects. Amsterdam, besides explaining its involvement, also describes in its 2020 - 2025 strategic plan the role to be played by businesses and residents. The city wants to foster two approaches: a top-down approach, where the city formulates informed objectives, and a bottom-up approach, ‘making room for circular projects and initiatives to accelerate and develop’ (City of Amsterdam & Circle Economy, 2020).

Amsterdam also uses the 10Rs approach to define the circularity, described in its strategy plan: refuse, rethink, reduce, reuse, repair, refurbish, refabricate, repurpose, recycle, and recover. This circularity scale (Appendix 5) allows the city to consider several aspects, such as the need to redefine consumption, the change of economic model (sharing economy), the environment and energy. At the request of the city of Amsterdam, the economist Kate Raworth (section 2) wrote The Amsterdam City Doughnut, an assessment framework for making Amsterdam circular from four angles: social, ecological, local and global (Doughnut Economics Action Lab & Circle Economy, 2020). The city is also developing a Monitor to determine the social and ecological impact of the transition: it indicates to what extent Amsterdam's economy has become circular and identifies areas where more needs to be done (City of Amsterdam, TNO, & TU Delft, 2020).

The city is therefore making its circular transition in a holistic way, considering its different stakeholders, sectors, policies and challenges. It has brought in external parties to assess its situation, draft a roadmap, a new business model and an evaluation framework to measure and monitor its objectives. Collaboration is emphasised, and the city's political situation creates a framework for success.

4.3.2 Charlotte

The 2018 Circular Charlotte report states that ‘Charlotte is the first city in the United States to make a commitment to adopting the circular economy as a public sector strategy. In its circular future, all of the material resources that now end up in landfills will be the basis for Charlotte’s next industrial revolution: the foundation for an era of green manufacturing that unlocks new technological advances, increases local resilience, and supports workforce development’

In this report, the City of Charlotte imagines from a 2050 perspective what it could look like if it achieved the full spectrum of a circular economy. The aim is to apply high-level circular ideas to the city. This vision is organised around four thematic areas (Circular Charlotte, 2018).

1. **Charlotte as a zero waste city.** The city aims to achieve a "zero waste" target by 2050, where 98% of waste would be collected separately. Every household could be equipped with smart sorting containers with integrated technologies to ensure optimal, error-free sorting for recycling. Sorting would be incentivised through a system of reward points paid directly to citizens in their digital wallet. These points would be used to purchase local products bearing the Circular Charlotte label, many of which may have been remanufactured or grown from the same waste streams, to encourage the real, local economy. If there are any reward points left over, these could be used to pay renewable energy bills or taxes. The city also plans to create a dashboard to track resources in real time, with indicators such as the quantity or quality of residual goods. These waste resources would be automatically directed to various processing facilities around the city, run by both large companies and small entrepreneurs.
2. **Charlotte as a resilient and healthy city.** Charlotte and its region plan to become increasingly independent of foreign imports by producing materials through local cycles, thanks to the development of the circular industry. Through the advancement of vertical farming technology and the reuse of organic waste streams as fertiliser, local food production would also gain momentum. The city is also considering installing small-scale aquaponics structures in its schools, for educational and practical use, but also to provide fresh produce and fish to school cafeterias. Other efforts to improve the city's health and resilience could focus on decentralising some utilities, renewable energy, decentralised battery storage and smart energy distribution. In this way, Charlotte's energy system would be resilient to the impact of storms or floods, with most damage remaining localized.

3. **Charlotte as an innovative city of the future**. A brand new City Materials Laboratory (CharM) will be set up in 2023, a joint project of several incubators and accelerators, to experiment with the conversion of collected organic waste into new materials. As innovation is a key factor in being more circular, the University of North Carolina at Charlotte will be required to create a new educational institution, the Charlotte Institute of Circular Design and Engineering (CICDE). Through R&D as well as a new resource stream brought by the circular economy, the city hopes to develop new industries. Charlotte aims to position itself as a global leader through its "Circular Charlotte" brand, and to perform in global rankings such as the Sustainable Cities Index.
4. **Charlotte as a city with opportunities for all**. The city's goal is to have less than 0.5% of its population living in poverty by 2050. In order to achieve the above, it is necessary to develop skills and train through inclusive programmes citizens, especially the economically disadvantaged, so that they can benefit from the creation of new jobs related to the circular sector. The city is also thinking of social projects, such as a test rehabilitation programme for the homeless community launched in 2019, offering jobs in sorting and repurposing plastic waste into street furniture, bins or trophies for school sports events. Some of the trainees participating in the pilot programme could then set up their own businesses focused on recycling and product manufacture.

In its report, Charlotte presents its current level of circularity[12], its challenges and strengths, current barriers, the opportunities and potential for circularity that can be expected as well as case studies of several identified opportunities, such as the development of a local closed-loop textile supply chain (to make uniforms for schools, hospitals, etc.) or the scaling up of food waste collection and the establishment of a commercial-scale facility to recycle food waste into larvae for livestock feed. Besides developing a strategy, the city also chooses key performance indicators to monitor the progress of the programme. It is therefore a comprehensive analysis and a solid roadmap.

4.3.3 Glasgow

In 2009, the Climate Change (Scotland) Act was passed and in 2010, Scotland's Zero Waste Plan was published, leading to the creation of Zero Waste Scotland, a government-funded organisation that aims to drive change towards a zero waste country. The mission is therefore

[12] At present, only 11.5% of discarded materials are recycled, making Charlotte a very linear city (Circular Charlotte, 2018).

being promoted by the national government and Glasgow is developing knowledge to drive the transition (Prendeville, Cherim, & Bocken, 2018).

According to the Circle Economy, the City of Glasgow is ‘on the road to becoming one of the world's first circular cities’. Scotland is one of the pioneering nations in the circular economy. Zero Waste Scotland has launched an investment fund to support local businesses, the government plans to drive the circular economy with its 'Making thing last' programme and has already committed to reducing food waste to 25% of current levels by 2025.

Glasgow City Council has submitted to the Circle Cities programme, which addresses where and how circular strategies can be implemented in cities (Circle Economy, 2017). The city was analysed with the City Scan, a tool that illustrates practical and scalable circular opportunities that create jobs, increase resource efficiency and stimulate economic growth. The Circle Economy Action Plan written in 2016 for Glasgow City identifies nine potential circular strategies (Appendix 6) in the following three food and drink sub-sectors: Bakery, Meat & Fish and Beer & Spirits. Following discussions with stakeholders, it was agreed to focus on four circular strategies to be implemented first (Circular Glasgow, 2016):

- ‘Heat recovery – Bakery. Heat from bakery ovens can be recovered and redirected to boilers using heat exchangers, saving 15-30% of the energy currently used in the baking processes.
- ‘Aquaponics - Meat and Fish. A promising technology in which fish farming is combined with soil-less cultivation, resulting in substantial water savings (90%) compared to traditional agriculture’.
- ‘Bread to Beer - Beer & Spirit. Usage of bread waste in the beer brewing process, thus saving 1/3 of the resources used in the brewing process. Food waste is also reduced’.
- ‘High value cascade - Beer & Spirit. The residual streams from the brewing process (spent grain) can be used to replace up to 50% of the flour needed for bread production in the baking industry’.

These pilot projects should be tangible examples of how the circular economy can be implemented, how businesses will benefit and what positive effects it will have on the people of Glasgow. They should be replicated on a larger scale if successful.

Glasgow want to further progress in the following areas (Ellen MacArthur Foundation, 2019):

- ‘Built Environment: capacity building in circular construction techniques, following learnings from the Commonwealth Games Athletes Village’.

- ‘Food: reducing food waste, addressing food insecurity, supporting local food economy and continuing to work with Sustainable Food Cities’.
- ‘Textiles: convening with universities and colleges to embed circular design principles in textile design courses and with textile procurement departments of the public sector’.
- ‘Energy: powering the equivalent of 15% of the city’s homes using renewable energy’.
- ‘Plastics: developing and publishing a strategy and action plan scheduled for 2019 to address discarded plastic through reducing, recycling and repurposing’.

In Glasgow, a focus combining social, environmental and economic aspects of the circular economy is conveyed. The strategy is to gather information and develop knowledge to enable Glasgow businesses to develop circular proposals and business models.

The city is starting its transition with concrete projects limited to a few sectors and mainly concerns companies, but the national situation is favourable to the development of circularity.

4.3.4 Montevideo

In its 2018 resilience strategy, Montevideo, Uruguay, has given special attention to the concept of the circular economy, aiming to become a circular city by ‘integrating the principles of the circular economy across all its functions’ (Resilient Cities Network, 2020). The city faces many challenges such as social and regional inequalities, ageing infrastructure, coastal flooding and vacant housing.

In its 2020 report ‘Circular cities of Tomorrow’, the Enel Group points out four areas of cross-sectoral collaboration were identified to guide collaboration between different city departments and help achieve the city's resilience goals:

- Material: ‘Reduce the pressure on the waste management system by adopting a cradle-to-cradle approach to extend resources’ lifecycle and prevent waste production’.
- Buildings: ‘Reverse the constant expansion of unauthorised construction, by using existing empty or underused buildings instead of adding new ones’.
- Transport: ‘Increase the capacity of the existing transport system by improving public service, implementing shared transport systems and encouraging active mobility options’.
- Water: ‘Mitigate flood risks through adaptive, nature-based measures’.

The following are some of the priority initiatives identified in each area of analysis.

- Reuse and repair hubs: the city of Montevideo already has an effective waste separation system and disposes of only 2% of municipal solid waste in landfills, and wants to go further by opening reuse and repair hubs to keep clothes and small electronics in circulation longer, or to find new users for these items. These hubs, run locally by individuals, cooperatives or social organisations, would also create new jobs and be strategically located in the most densely populated areas. Supportive policies, quality certifications, tax reductions on repaired goods and online activities were identified as possible catalysts to facilitate successful implementation.
- Unused space: although the city of Montevideo suffers from suburban sprawl, it has estimated the value of its unused and empty spaces at over US$10.5 million. Redeveloping and using these spaces for new permanent or temporary uses (municipal and community services, co-working spaces) would encourage businesses to return to more central locations and create employment opportunities. The city plans a system of digital platforms that can match available space with demand to make the project a success.
- Public transport rental: As the city's current transport system is outdated and inefficient, Montevideo has devised a new multi-party (government and private transport provider) leasing model based on performance. This model will reduce the total expenditure for a new hybrid, hydrogen-based transport fleet and allow the local government to invest in other means of transport.
- Sustainable drainage system networks: In order to avoid flooding, the city wants to strengthen drainage systems to better drain rainwater and redirect the flow to increase the biodiversity of an area by combining existing drainage systems (green roofs and rain barrels) with new sustainable systems (bioswales, i.e. drainage channels with vegetation, and rain gardens) and by involving landowners.

The city, through its pilot projects, has already reclaimed empty buildings throughout the city with plans to revamp and repurpose the structures. It has also built new small-scale rain city gardens and is studying the feasibility of large-scale natural solutions, such as wetlands along waterways. Montevideo is also planning a new initiative to facilitate the reduction of waste generated by the food and hotel sectors, and is mapping all the reuse and repair centres in the area (a digital hub will help create connections between the people and organisations mapped).

As the Montevideo Intendancy states in its resilience report, ‘a resilient city is open to innovation and is able to recognise alternative ways of using resources in pursuit of its goals.

Montevideo is exploring the possibilities offered by the principles of the circular economy to achieve a different type of development. It has established a roadmap to integrate these circular economy principles, with the aim of achieving a regenerative territorial system from the design phase' (Intendencia de Montevideo & 100 resilient Cities, 2019). The city shows a good example of solutions derived from circularity to solve social, economic and environmental problems and to anticipate natural disasters (e.g. drainage system).

4.3.5 Peterborough

The City of Peterborough in England aims to operate as a truly circular city by 2050. Through its Circular Peterborough programme, the city seeks to apply the principles of the circular economy in an urban way to make the most of local resources, support economic resilience, develop strong communities and increase environmental sustainability.

On its 'Future Peterborough' website, the city describes its 7 commitments:

Rethink	'Challenge why things are done the way they are and look for more economically viable and sustainable solutions for the products and services that surround us'.
Redesign	'Create things that last longer and are easier to upgrade, repair, pull apart and reuse'.
Repurpose, reuse and share	'Seek to maximise products' and services' lifecycles. Underused items should be shared or swapped instead of being thrown away'.
Repair	'Promote and offer opportunities to repair broken items'.
Remanufacture	'Taking back items once they reach their end of life, recover the usable components or materials in them and produce new ones with the recovered materials. Promote take-back schemes and leasing'.
Recycle	'If items can't be repaired, re-used or remanufactured, then they should be recycled'.
Recover	'Items always retain value, even at their end of life. Peterborough has its own energy recovery facility which diverts 90% of residual household waste from landfill and provides energy to 15.000 homes in the city'.

The city has already implemented several pilot projects, also detailed on its website:

- Re-localising food system thanks to "Big Barns". As consumers become increasingly disconnected from the origin of their food, Big Barn's mission is to encourage people to

get out of the supermarkets and buy real food locally: it provides a simple map to show consumers where they can find fresh, local produce.

- Upskilling and Upcycling Carezone: Care Zone is an innovative furniture recycling and employability skills training project that is run by Kingsgate Community Church in Peterborough.
    - Furniture recycling project: Families in need (homeless, victims of domestic violence, etc.) are referred by local statutory and community agencies to Carezone to receive emergency assistance: last year, recycled furniture was provided for 700 properties.
    - Syrian Refugees Families Project: Care Zone is part of a multi-agency project to resettle Syrian refugee families in the city who have been displaced by the civil war in Syria. Care Zone are partnering with the public and local businesses who are donating household items to furnish the houses for the Syrian families.

In addition to its roadmap, the city is working on the development of an urban maturity model in order to measure the progress made towards becoming a circular city. Indeed, there is currently no harmonised framework for measuring a city's progress towards circularity. Peterborough has adopted a two-stage approach. First, work with local businesses to co-create a model that can measure the progress of businesses towards circularity. Second, scaling this model to incorporate social and citizen-centred elements to create a model that measures circularity at the city level. Peterborough has also partnered with University College London and Cranfield University to further develop their indicator set (Ellen MacArthur Foundation, 2019 Case study).

To date, the city has already organised workshops on circularity to raise public awareness and has avoided some waste through its initiatives. It should be noted, however, that social objectives are not reflected in the 7 commitments, even though the city's first project (Carezone) combines economic and social objectives.

4.3.6 Singapore

The island city-state of Singapore has recognised the need for strong policy measures that will enable sustainable growth and resilience to climate change, and the attractiveness of circular initiatives (Expertise France, 2021). Singapore has determined that 2019 will be ‘Zero Waste’ and has announced a ‘Zero Waste Masterplan’ (Appendix 7): new regulations are planned for

the food, electronic and packaging waste sectors over the next five years. Circular missions were also conducted in Singapore by the EU to finance circular economy projects and provide advice on circular economy risk financing (Circular Economy Club, 2020).

The City of Singapore has also adopted a 'Green Plan' with several concrete targets, such as producing 30% of the city's nutritional needs locally by 2030 (the '30 by 30' target), reducing landfill waste by 20% per capita per day by 2026, adding more than 130 ha of new parks and upgrading about 170 ha of existing parks with more lush vegetation and natural landscapes by 2026, etc. The plan also takes into account enablers such as new regulations and green financial products, as well as technology and innovation, to become a leading player in green finance in Asia and dominate the transition (Singapore Green Plan 2030).

The Circular Economy Club identifies several key activities in Singapore that promote circularity in their 2020 report:

1. Extended producer responsibility (EPR). 'This system obliges producers to recover e-waste and ensure that it is reused or recycled. Similarly, companies using packaging will have to collect data on packaging placed on the market and present their plans to reduce it (MEWR, 2020)'.
2. Financing circularity. The city aims to develop its expertise in risk management, green finance and to develop policies to accelerate the transition.
3. Urban farming on top of shopping centres. The 'Comcrop' farm on the roof of a shopping centre uses vertical supports and hydroponics to grow vegetables and herbs, which are sold to nearby restaurants. This initiative also fixes nitrogen, refreshes the rural area and prevents rainwater runoff.
4. Bring-your-own (BYO) school programme. The S.E.A. Aquarium supports ocean conservation efforts by reducing marine litter through educational activities. Through the BYO Schools programme, young people are encouraged to reduce single-use plastics and protect the marine environment. The programme promotes reusable products (bottle, container, utensils or bag) and rewards diligent school children through a card system.
5. Electricity from wastewater and food waste. Sewage sludge is mixed with wet organic fractions extracted from food waste. It forms biogas, which is used to generate electricity.

Singapore is a pioneering example of how 'circular' cities develop. It is a high-density, rapidly expanding city with a strong government, state land system and planning tradition (Diao, 2018).

Although the city is not at all circular at the moment (Singapore has the seventh largest ecological footprint in the world according to the World Wildlife Foundation (WWF) report (McLellan et al., 2014)), some of the sustainable innovations initiated in Singapore, especially in transport, have already been applied in other cities such as London, Stockholm and Shanghai (Diao, 2018). With its recent commitments, the city is increasing its efforts to become circular and sustainable.

However, the city is very much on the innovation, technology and green finance side: its Green Plan neglects social aspects. Also, the Singapore Zero Waste Masterplan (Towards Zero Waste, 2019) emphasises waste streams based on recycling rates (Singapore National Environment Agency, 2019) as well as targeted studies on reuse. However, recycling is not the only lever for circularity. Therefore, the city's numerical targets do not guarantee that all the potential of circularity will be explored.

4.4 Knowledge Hubs

Knowledge centres and companies specialising in circular consultancy are also useful to analyse. These knowledge hubs provide information such as case studies, roadmaps, thematic reports or frameworks to encourage policy makers to make the transition to circular cities.

4.4.1 Ellen MacArthur Foundation (EMF) – Circular economy in cities

The Ellen MacArthur Foundation, a pioneer in circular economy research, has a section on its website dedicated to the circular economy of cities. Several online resources are listed, and are designed to support city leaders in their transition.

The Ellen MacArthur Foundation sees the circular economy in cities as focusing on opportunities in three key urban systems - **buildings, mobility and products**. Its Circular Economy in Cities project looks at how city governments can work to enable a transition to a circular economy, addressing several modules: (1) vision, (2) fact sheets, (3) policy levers, (4) case studies, (5) other networks and resources.

In a Project Guide written in 2019, the Ellen MacArthur Foundation and its knowledge partner ARUP[13] detail the important stages of the transition.

- Planning – ‘It is important to free up valuable land previously used for roads and car parks for green spaces, shops, offices, homes and leisure. The layout and design of cities

[13] A consultancy firm at the heart of many projects in the field of the built environment and industry.

changes the way materials and products flow. A new system will allow for greater proximity between places to live, work and play, better interaction between different actors and a more liveable city'.

- Design – 'Alongside urban planning, the principles of the circular economy are transforming the design of elements within cities. Infrastructure, vehicles, buildings and products must be designed to be sustainable, adaptable, modular and easy to maintain and reuse. Design must be biomimetic, materials sustainable and renewable and recyclable, and energy renewable'.
- Manufacturing – 'Buildings, vehicles and products need to be assembled using techniques that eliminate waste, and allow for repair and reuse. This means changing construction methods and storage requirements, which will require ingenuity and higher levels of local expertise'.
- Access – 'People have access to the things they need whether it is space, products or transport in new ways. There needs to be a shift from ownership to sharing'.
- Operation and maintenance – 'Products are no longer used only once and operate within a loop, and infrastructure must be maintained in order to be used effectively. New opportunities and jobs are emerging. Cities that incorporate the principles of the circular economy become more prosperous, liveable and resilient'.

In 2016, the Ellen MacArthur Foundation also launched a network called the 'Circular City Network', to bring together pioneering city leaders to exchange best practices. Nine initial cities - Austin, Boulder, Copenhagen, London, Ljubljana, New York City, Peterborough, Phoenix and Rio de Janeiro - formed the basis of this knowledge exchange network, and regular video conferences were planned to share innovations. Unfortunately, the web page has disappeared and the project seems to have been abandoned today.

4.4.2 The Circular Economy Club (CEC)

The Circular Economy Club (CEC) is the non-profit arm of its parent organization, the Circular Economy Institute (CEI). It is the largest international network of circular economy professionals with over 260 CEC local clubs worldwide (see members in Appendix 8). CEC envisions a world in which every city in every country functions and thrives on circularity, ending the age of waste. The organisation's mission is to provide clarity and timelines to help cities.

In 2012, CEC was established by Anna Tari, who realized that there were a number of circular enthusiasts lacking a platform to play their part in implementing a circular economy. The CEC was set up to bridge this gap by establishing a platform for the circular economy community. The CEC has a 'circular economy' map to identify local circular initiatives around the world.

In February 2020, the CEC celebrated its inaugural global event, Circular Cities Week, an annual, decentralised global event. The aim was to promote idea sharing, raise awareness of the circular economy and push for the implementation of circular economy strategies in cities around the world. The participating cities organised a kind of ideathon[14] to think about circular solutions to concrete urban problems. The ultimate goal is to collect the suggestions and compile them into a global report. CEC believes that the circular economy is a model that will help cities become more resilient. Circular Cities Week took place online from 26 October to 1 November 2020, alongside the UN World Cities Day.

The global report thus presents the results of the event 'Circular Cities Week', including the circular challenges and opportunities for cities. The report represents a crowdsourcing tool for cities around the world to implement the circular model. The five main findings of the 2020 edition are:

1. 'The role of new technologies introduced as using big data and map the material flows of the city. New tech enables cities to establish a tangible direction for setting up circular projects by mapping the various value flows amongst stakeholders such as money, materials, and energy'.
2. 'Creating new markets such as creating a platform for buying, selling or sharing waste can provide opportunities in which waste can be reused across sectors and can be a kick off for the right infrastructure to be in place'.
3. 'Clear incentives need to be put in place for circular implementation which could convince and support companies to adjust circular business models and for consumers to change their mindset and behaviour'.
4. 'Policies can promote circulation through a revision of the concept of waste, including circular requirements in procurement, demanding the implementation of AI and blockchain tech to require supply chain transparency'.

[14] Ideathons are intensive brainstorming events where individuals from different backgrounds, skills and interests converge to diagnose predefined problems, identify the best opportunities and ideate the most viable solution.

5. ‘The role of reverse logistics which is the return flows of manufactured goods back from consumers. Cities need to invest in providing the right infrastructure so that reverse logistics can be implemented’.

The objectives of the CEC by 2022 are ‘to bring together local stakeholders to create circular economy strategies in 200 cities, and provide training and certification in the circular economy to over 2,000 people so that the profession is recognised worldwide at different levels of public and private organisations’ (Circular Economy Club, 2020).

4.4.3 Circle Economy

Circle Economy is an Amsterdam-based consultancy firm specialized in circular economy. It enables companies, cities and nations to put the circular economy into action via three major solutions they have developed: the Circularity Gap Report, the Knowledge Hub, and the Circle Scan, described on their website.

The Circularity Gap Reporting initiative highlights the urgent need for a transition to a circular economy via its annual Circularity Gap report. ‘It is an annual report that measures the state of circularity. Its aim is to inspire action and achieve a global circular economy. The Circularity Gap Report is launched each year at the World Economic Forum Annual Meeting’ (Circle Economy, n.d.). As detailed on their dedicated website, the aim of this initiative is to empower key decision makers in both government and business to coordinate actions to accelerate this transition. To do this, the current state of circularity is measured and stakeholders from business, government, academia and NGOs are brought together to contribute and assess findings on the state of the transition based on the latest scientific evidence. In addition to the annual reports, countries and regions can also request detailed reports. Four countries and regions have taken advantage of this initiative: Austria, the Netherlands, Norway and Quebec. The methodology used and the annual reports are public. In 2020, ‘the world was only 8.6% circular, leaving a huge circularity gap’ (Circle Economy, 2021). To guide impactful action, the initiative presents ‘the Intervention Vortex’ (Appendix 9) that highlights the most powerful circular strategies to double circularity by 2023 (Circle Economy, 2021).

The Knowledge Hub is a sort of circular Wikipedia. It is a participatory platform to exchange reports, case studies, policies, key elements and progress related to circularity. Knowledge partners are Circular Norway, Circular Jobs initiative, Footprints Africa and World circular textile days (WCTD).

The Circle Scan, as defined on their website, is ‘a fact-based innovation and transformation process based on a local multi-stakeholder model that aims to develop practical and scalable solutions in cities to accelerate the transition to a circular economy’. The scan identifies circular opportunities based on multiple stakeholders and socio-economic & material flow analyses. Considering every cities’ individual context, the found opportunities are translated into a visual roadmap for action. Several cities and regions submitted to the Scan, such as the Kongsvinger region, Bern, Prague, Glasgow, Basel, Amsterdam, Bilbao, etc. All reports are accessible and therefore provide an extensive review of the strategy and circular status of the cities analysed.

This company, thanks to its numerous initiatives, is a leader in the field of circularity, and makes interesting insights available.

4.5 Conclusion

Citizen projects, living laboratories, initiatives in existing cities and knowledge centres all contribute to advancing circularity in cities. These four levers of action are all necessary for the emergence of urban circularity thanks to their specificity and should be combined.

4.5.1 Citizen projects

Citizen projects articulate emancipatory political positions, acting from within a site (city area, city) to achieve radical change. ‘In a way, acting from within the site means setting up a process that starts from (the critique of) the existing, a dialectic between the existing and the necessary’ (Marin & de Meulder, 2018). R-urban highlights the need to invent a new model, different from the current capitalist regime, by radically changing the way resource flows are governed. Circularium reimagines a site for citizens, a circular intersection of innovation, business, social and community. Both projects envisage a societal shift in the way resources, spaces and communities are articulated: they privilege social, ecological and cultural dimensions, and consider technology and economy as secondary driving forces. A project for the citizen by the citizen: circularity serves the needs of citizens. It is a means, not an end.

4.5.2 Living laboratories

What these three living laboratories have in common is the adoption of a technocentric vision, which emphasises measurements and flows in concepts such as 'zero waste', 'carbon neutrality', 'sustainable city' or 'circular economy'. These three cities are 'new', which means that they do not take into account any existing contextual parameters. Reburg is even virtual. The aim is to

make them generic and replicable models of circularity and sustainability. These three cities consider the circular economy from the point of view of the production and consumption system, they focus on the technological and economic dimensions and consider the social and environmental dimensions as a consequence of these. Even worse, in the case of Masdar, these dimensions are ignored when they do not serve economic interests.

In their 2018 paper, Marin & De Meulder criticise this utopian view of circularity at a fixed point in time as these models avoid the question of how existing urban fabrics can shift to circularity and become more resilient. As synthetic visualisations, Reburg, Masdar City and Woven City ignore the temporal dimension of cities, the city as a process, and focus on circularity as a 'finished' or closed product or outcome.

This increased technocentricity echoes the criticism that smart cities (sections 2 and 3) do not contribute to sustainability in practice (while a city cannot really be smart if it is not sustainable).

4.5.3 Circular practices in existing cities

These cities around the world have recurring commonalities (see table 5 below): they have all publicly committed to a circular strategy, have published a roadmap, and have KPIs (Peterborough and Amsterdam are even developing their own evaluation framework). For the most part, they have called on external experts (Arup, Ellen MacArthur Foundation, Circle Economy, etc.) and policies are aligned with their plans.

	Circular strategy	**Roadmap**	**KPIs**	**External expert**	**Favourable policy**
Amsterdam	Yes	Yes	Yes	Yes	Yes
Charlotte	Yes	Yes	Yes	Yes	Ongoing
Glasgow	Yes	Yes	Yes	Yes	Yes
Montevideo	Resilience strategy w/ circular actions	Yes	Ongoing	Yes	Yes (strategic guidelines w/ allocated resources)
Peterborough	Yes	Yes	Yes	Yes	Ongoing
Singapore	Green & Zero Waste Plan	Yes	Yes	Yes	Yes

Table 3: Summary of the circular commitments of the cities analysed.

In contrast to the circular projections of living laboratories, cities take a holistic approach. Indeed, they base their strategies on an analysis of their challenges and bring circular solutions. Social and environmental aspects are not forgotten in favour of purely technological and economic aspects. A perfect example is the Carezone upskilling & upcycling facility in

Peterborough, which is an innovative project to reduce waste and combine economic, environmental and social aspects (families in need, Syrian refugees).

However, one must be cautious as many cities, at the same time as following a circular strategy, also follow a 'smart' strategy. The concept of the circular city has indeed emerged after (and in some respects follows from) that of the smart city. Although the two concepts are intertwined and often left to the appreciation of cities (see section 3), the shift from smart cities to circular cities ‘requires a shift from a viewpoint mainly focused on new technologies and their benefits, to one where technology continues to play an important role but is integrated into a holistic vision with objectives of economic competitiveness, environmental sustainability and social inclusion’ (Enel, 2020). The city of Singapore, for example, focuses more on technological and financial initiatives than on social ones, as it is still evolving in a ‘smart’ logic.

4.5.4 Knowledge Hubs

Knowledge centres are definitely important in this transition, as they serve as accelerators. Almost all the cities analysed have called upon circularity consultants to establish their strategies. Whether through ideathons or studies, research, case studies or paid tools and services, the exchange of good practices is vital if the world is to succeed in its transition. The danger of having actors so established in a field is that their conception of circularity is the one that is most widely adopted.

Section 5. Assessment Frameworks

I selected the assessment frameworks that were most relevant to my research (measurement framework) and the most recent, circularity and resilience being concepts that are increasingly studied.

5.1 Review of existing assessment frameworks – Urban circularity

Currently, there is no framework for assessing urban circularity, but some work is laying the foundations for a future framework.

The Circular Cities Analysis Framework (CCAF) and the United for Smart Sustainable Cities (U4SSC) Circular Cities Guide are frameworks specifically designed for circular cities: they both aim to assess the level of circularity of a city and help decision-makers to make the transition. The ReSOLVE framework, from the Ellen MacArthur Foundation, will also be analysed as it appears widely in the literature and in case studies.[15]

Although the Circularity Gap Report (section 4) provides metrics to quantify the circularity of the world (and countries), it only focuses on waste flows[16] (Circle Economy, 2021). It will therefore not be analysed, as a circular city is a broader concept than just the amount of waste produced.

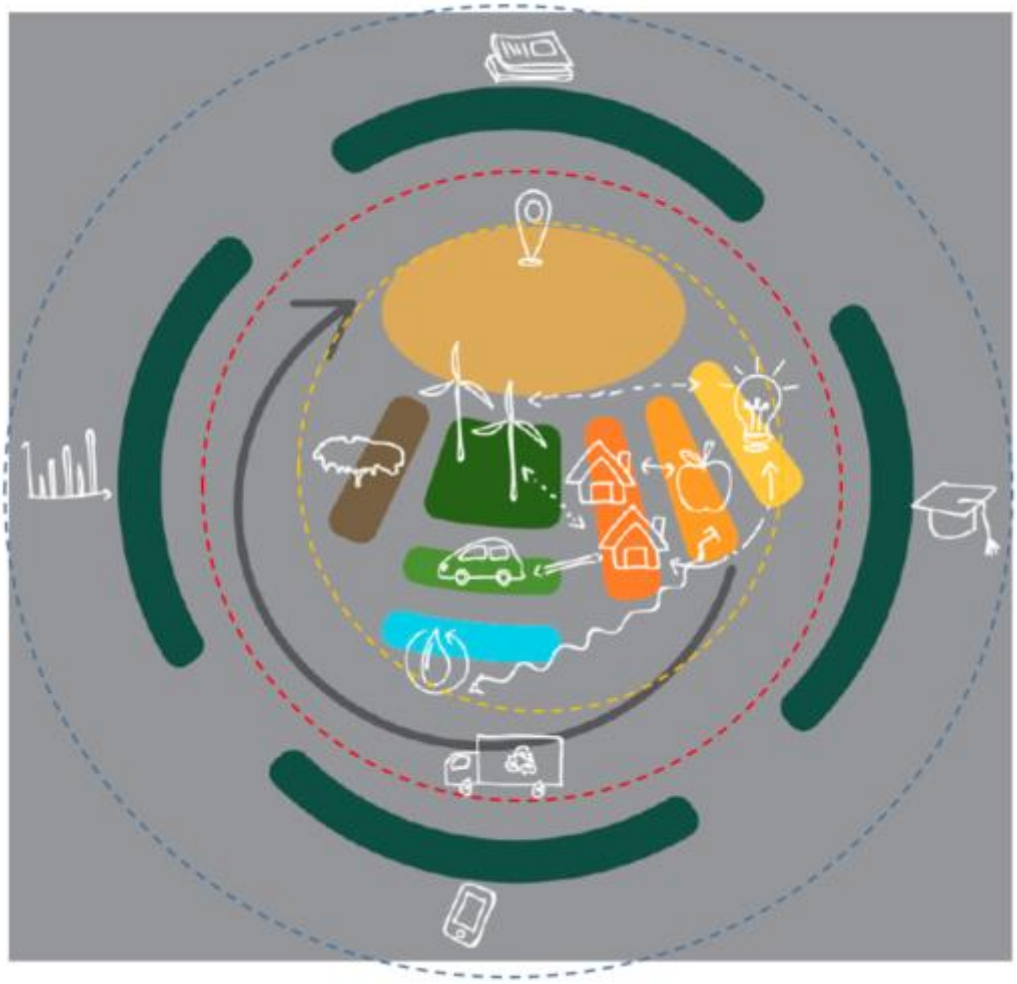
5.1.1 Circular City Analysis Framework (CCAF)

The Circular City Analysis Framework (CCAF), presented by Cavaleiro De Ferreira and Fuso-Nerini in a 2019 paper, aims to reflect the key concepts of the circular economy adapted to cities and seeks to analyse circularity in cities in a simple and intuitive way to improve the understanding of the many agents in the city.

The CCAF consists of the Circular City Diagram (CCD), presented below, and three tables. This diagram aims to represent the holistic perspective of a city, as well as its multi-sectoral aspects. The CCD is organised into three zones:

[15] Research query on google scholars: “ReSOLVE framework” AND "circular economy" since 2015, 387 results and "ReSOLVE framework" AND "case study" since 2015, 266 results. August 2021.
[16] Data from the Extended Multi-Regional Input-Output Analysis for the Environment (EE-MRIOA), macro-economic viewpoint.

1. The inner circle ‘gives information about the circularity of the city, as well as the source of the different businesses, materials and energy flows’ (water management, buildings, food, circular innovation, waste management).
2. The middle circle ‘focuses on the industries and sectors that characterise each city’ (local resources, specific industry, transport, renewable energy). However, it does not reflect all relevant aspects of a city.
3. The outer circle aims ‘to capture aspects with a broader scope’ (demographics, digitalization, education, policies).



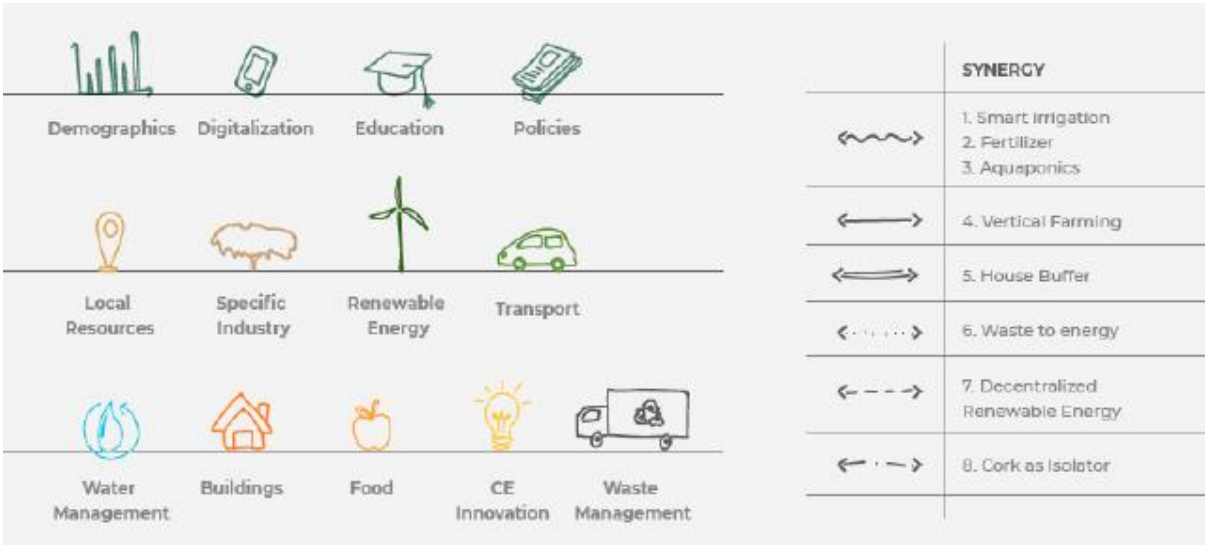


Figure 4: Circular City Diagram. Cavaleiro De Ferreira & Fuso-Nerini, 2019.

The field table, synergies table and policies table complement the CCD (Cavaleiro De Ferreira & Fuso-Nerini, 2019).

Firstly, the table of fields (see complete version in Appendix 10) describes the sectors, the relevant agents, technologies and behaviours of these sectors, as well as indicators: the goals and the current situation. Each field should be composed of one or more indicators that aim to reflect the level of circularity of the city (e.g. for water treatment, two indicators could be accessibility to drinking water and water efficiency). In addition to the indicators, it is necessary to select targets, chosen by identifying realistic levels of circularity in a city or in line with a certified target set by the EU, country or region. For each of the indicators, the percentage of achievement of these targets is represented in the 'current' column.

Field	Description	Agents	Technologies/behaviours	Indicators	Current	Goals
Water management						
...						
Policies						

Table 4: Reduced Fields table. Adapted from Cavaleiro De Ferreira & Fuso-Nerini, 2019.

Secondly, the synergies table describes the synergies illustrated by arrows, the sectors they undermine, the objectives and the current situation. The synergies described in the diagram table come from a case study of the city of Porto, which the authors carried out to test this evaluation framework. Similarly, several indicators can be selected by synergy. However, it is more difficult to have quantitative indicators for this table. An example given in the Porto case study is the following: for the fertiliser synergy presented in the table, the goal is 'Extract most

of phosphorus and cellulose fiber, reusing it in fertilizers, reducing dependency on it' and current is "Águas do Porto [actor] investing to make it real".

Synergy	Fields	Description	Current	Goals
Example: fertilizer	Food + waste management	Collection of nutrients from wastewater and transformation into fertilizer for food production		
…				

Table 5: Synergies table. Adapted from Cavaleiro De Ferreira & Fuso-Nerini, 2019.

Finally, the policies table lists the policies, their level (regional, national or international) and the areas they affect, description and alternatives.

Policies	Level	Fields affected	Description	Recommendation
Example: Circular Economy Action Plan (CEAP)	EU	All	Mainstream CE; showcase CE impacts; creation of second-life market for products	
…				

Table 6: Policies Table. Adapted from Cavaleiro De Ferreira & Fuso-Nerini, 2019.

One difficulty highlighted by the authors and designers of the CCAF is the lack of established and standardised indicators and the lack of data. This is a real barrier to moving towards a more circular city, as this transition will require relevant indicators that can be measured. Research by the European Academies' Scientific Advisory Council (EASAC), 2016, identifies indicators 'sets currently in use that could be relevant to a circular economy' (Appendix 11). But these indicators are not sufficient for urban circularity: a new set of urban circular indicators needs to be developed to feed into circular cities. Indeed, there are many sets of indicators for the circular economy, but nothing dedicated to cities, and even if most of these indicators can be reused, they lack vision and standardisation. Despite recent progress, there is still room for improvement, particularly in terms of indicator standardisation and data collection (Pauliuk, 2018).

To conclude, there are indicators, but no pre-established set for circular cities. And if even some of these indicators are available, the data to feed them are not necessarily available. Therefore, in the Porto case study conducted by Cavaleiro De Ferreira and Fuso-Nerini (2019), a more pragmatic approach was adopted, using available data and indicators. The analytical framework devised is useful as it allows for the selection of existing indicators, but caution is needed: indeed, the authors' intention was primarily to produce a simple and intuitive evaluation

framework, and is therefore deliberately simplified. The 13 fields might not reflect all aspects of urban management.

5.1.2 Guide to circular cities – U4SSC

The United for Smart Sustainable Cities (U4SSC) initiative is a global platform to help cities around the world become smarter and more sustainable. U4SSC is coordinated by the International Telecommunication Union (ITU), the United Nations Economic Commission for Europe (UNECE) and the United Nations Human Settlements Programme (UN-Habitat), with the support of 14 other UN agencies and programmes (United for Smart Sustainable Cities, 2020).

U4SSC is dedicated to developing strategic guidelines and measurement tools to implement the 17 UN Sustainable Development Goals. In this context, the organisation has developed a guide for circular cities, containing an implementation framework with a four-step methodology that provides a coherent method for assessing, prioritising and catalysing different circular actions. This guide aims to extend the concept of circularity: by including the different aspects of city management, U4SSC wants to move from a circular economy to a circular city.

The Circular City Implementation Framework identifies four key components for achieving circularity in cities:

- *City assets and products* – encompass various city infrastructures, city resources, city goods and services available for use/consumption in the city. This category is further detailed in Appendix 12.
- *Circular actions* – specific, output-orientated actions that can be applied to city assets and products that include (1) sharing, (2) recycling, (3) refurbishing, (4) re-using, (5) replacing, and (6) digitizing.
- *Circular city outputs* – they are the results of when circular action items are applied to *city assets and products*. For example, purified and reused water is a *circular output*: the *city asset* 'water' undergoes the *circular actio*n of 're-use'.
- *Circular city enablers* – various supplementary and complementary items that are used to catalyse and support *circular city outputs*. A *circular city enabler* is any entity, activity or initiative that, through its functions, can catalyse and promote circularity in cities (such as KPIs, trust, regulations, etc.). The complete list is in Appendix 13.

The circular city implementation framework consists of four steps (United for Smart Sustainable Cities, 2020, p. 13):

1. Assessing current circularity (baselining).
2. Determining potential for future circularity and prioritizing circularity actions. This is done via a prioritisation matrix with two axes, 'value' and 'ease of implementation'.
3. Catalysing circularity: the city can utilize an appropriate mix of enablers to maximize the chance of successfully implementing the selected circular initiatives.
4. Assessing projected circularity impact. Cities are strongly recommended to retrospectively and objectively conduct assessments and compare the actual outcomes with the intended ones.

For the purposes of this thesis, the most interesting step is the first one, as it allows us to assess the current level of circularity in a city and will therefore be detailed below. Assessing circularity involves conducting a quick baseline audit, analysing the following three components:

- Key performance indicators (KPIs) related to circularity of cities.
- City-level circular initiatives and relevant action items.
- Various *circular city enablers* to assist in implementation.

Each of the above components is explained briefly below.

- **Baselining based on existing circular city KPIs**. According to the U4SSC circular guide, assessing the performance of cities using existing key performance indicators, such as the percentage of waste recovered or the share of local green energy, can guide the implementation of the circularity approach. These KPIs measure performance and also allow progress to be monitored. Cities can define their own circularity KPIs for their specific sectors/industries. Below is a template proposed in the guide that cities can use to collect data.

City circularity (KPI)	Baseline value (if known)	Target value and timeframe (if known)	Measurement frequency	KPI owner	Comments
KPI1					
…					
KPIn					

Table 7: Template to data collection for evaluating city circularity using KPIs. U4SSC, 2020.

- **List of initiatives / action items to promote circularity in cities**. In addition to the KPIs, initiatives, pilot projects and actions that promote circularity should be listed.

City circularity initiative / action item name	City circularity KPI (if any)	Brief explanation	Milestones	Owner	Comments
Initiative/Action item 1					
Initiative/Action item 2					
…					
Initiative/Action item n					

Table 8: Template for developing a list of circularity initiatives and action. U4SSC, 2020.

- **Enablers**. *Circular city enablers* are actions and initiatives that can stimulate *circular city output*. The use of these enablers could increase a city's chances of success in implementing its circular initiatives/actions. A simple model of city enablers is provided in the guide (see the complete table in Appendix 14).

Assessment element	Currently exists?	Brief description	Comments
Are there awareness programmes for circularity-related initiatives in the city?			
…			
Are there existing financial incentives in the city for circularity related implementation projects?			

Table 9: Template for assessing circular city enablers. U4SSC, 2020.

Circularity in the context of cities is a relatively new concept that offers significant opportunities and the guide, through the method detailed above, has identified a generic approach to promoting circular actions in cities and assessing the state of circularity.

Nevertheless, this approach does not really allow for a clear measurement of the level of circularity of a city (no proposed indicators, target "scores" or percentages). Rather, it is a qualitative approach to assess where a city stands and to identify the next circular actions. This method does not emphasise the key dimensions of the city: the city chooses what is important to measure, which means that some key topics might be left out.

5.1.3 Resolve Framework

The ReSOLVE framework, introduced by the Ellen MacArthur foundation in 2015, offers companies and countries a tool to generate circular strategies and growth initiatives. The three key principles of the circular economy (design out waste and pollution, keep products and materials in use, regenerate natural system) can be translated into a set of six business actions: "Regenerate, Share, Optimise, Close, Virtualise and Exchange" - together, the ReSOLVE framework (see complete diagram in Appendix 15).

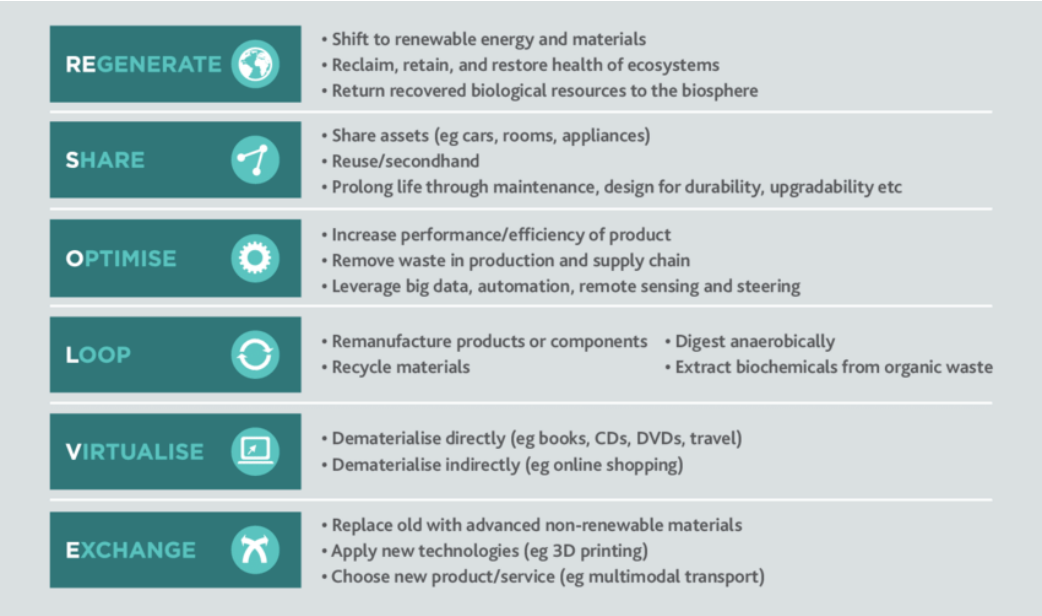


Figure 5: ReSOLVE Framework. Ellen MacArthur Foundation, SUN and McKinsey Center for Business and Environment, Growth within: A Circular Economy Vision for a Competitive Europe (2015).

This framework provides a structure for looking at opportunities: cities should try to apply these six business actions and the principles derived from them as much as possible. Unfortunately, this tool is very business-oriented and only lists the properties of the circular economy: it does not help to measure the circularity of a city, nor does it provide dimensions, indicators or standards to be achieved. But the six pillars should be implemented systematically in all dimensions of a circular city, and therefore deserve to be mentioned.

5.1.4 Urban circularity assessment framework

The Urban Circularity Assessment Framework (UCAF) project aims to provide a city-level adaptable circularity assessment framework that will help cities to move towards a circular economy. The framework will allow cities to measure their level and potential of circularity,

and can be adapted to different decision-making contexts and sector-specific demands (Stockholm Environment Institute, 2021).

By bringing together researchers, the private sector and local governments, this project, which started in 2020, will (Stockholm Environment Institute, 2021):

- 'Co-develop an urban circularity assessment framework to measure the level and potential of circularity at the city level, which can be adapted to different decision-making contexts and specific sector demands';
- 'Identify opportunities for resource and energy recovery, through the application of the assessment framework to a specific city or region';
- 'Mapping the impact of the transition to a circular economy for businesses, citizens and policy makers, enabling the understanding of the societal effects of the transition and uncovering any negative effects of the transition'.

This project is still ongoing, and therefore cannot be analysed. Nevertheless, it is interesting to note that this type of framework specifically designed for urban circularity is under construction, which indicates a lack of such a framework.

5.2 Review of existing assessment frameworks - Urban Resilience

With regard to urban resilience, the work of the Rockefeller Foundation and Arup to determine a city resilience index is very advanced (literature search, field study, case study, online assessment tool tested by several cities, several reports, etc.). As for the other framework for assessing urban resilience, Sharifi and Yamaga have published numerous articles on urban resilience, their literature reviews are very comprehensive and result in a nearly complete classification (abilities, criteria, dimensions, characteristics, etc.).

5.2.1 City Resilience Index (CRI)

The aim of the index, supported by the Rockefeller Foundation and developed by Arup, is to establish a tool that would promote a common understanding of urban resilience to enable cities to monitor and measure the multiple factors that contribute to their resilience.

The index is intended to be robust, based on what actually contributes to resilience (the seven qualities of a resilient system, see below) as well as best practice in measuring urban resilience. The development of such an index also takes into account the fact that it should be meaningful

for all cities, regardless of their size, capacity and location. The index is also constructed to measure the performance of a city over time, not specifically the performance between cities. Indeed, resilience is a very context-dependent concept: one city does not face the same challenges as another. However, having a common language facilitates dialogue and exchange between cities.

A resilient system is reflective, robust, redundant, flexible, resourceful, integrated and inclusive (The Rockefeller Foundation & Arup, 2014). See the definition of the qualities in Appendix 16.

The city resilience index is structured as follows (The Rockefeller Foundation & Arup, 2014):

- 4 dimensions:
    - Health and well-being dimension, ensuring the health and wellbeing of everyone living and working in the city. This dimension concerns the primary needs of the inhabitants: access to water, shelter, etc. especially in times of crisis.
    - Economy and society dimension, the social and financial systems that enable urban populations to live peacefully, and act collectively. This dimension concerns the organisation of cities, living together, collective identity and the economy, and is only possible if the physiological needs of citizens are respected.
    - Infrastructure and environment dimension, manmade and natural systems that provide critical services, protect and connect urban citizens. This dimension concerns the place, the quality of the ecosystems which surround and form the city.
    - Leadership and strategy dimension, the need for informed, inclusive, integrated and iterative decision making in cities. This dimension is largely shaped by knowledge: a decision, to be informed, needs to be based on evidence.
- 12 Goals - These four dimensions comprise 12 goals that every city should strive to achieve in order to be resilient - their relative importance depends on each city. The research for this index shows that these 12 goals matter most when a city is faced with a disaster.
- 52 Indicators - The 52 indicators refine and specify the 12 goals, identifying factors critical to urban resilience and incorporating the seven qualities of resilient systems identified above.

The detailed goals and indicators are available in Appendix 17.

The index allows cities to measure and evaluate their current performance and the trajectory of their resilience strategy. The assessment is based on qualitative and quantitative information. Specifically, there are 156 qualitative and 156 quantitative questions that measure a city's resilience. The assessment is available on the Resilient City Index website. The qualitative questions are scored on a linear scale with values between 1 and 5. Similarly, the quantitative questions also give a score between 1 and 5 depending on the data encoded, based on a standardised performance scale. See an example in Appendix 18. So far, 12 cities have completed the assessment.

The assessment takes place on an online platform, designed to facilitate data entry and generate resilience profiles based on qualitative, quantitative and quality indicators (some indicators contribute more strongly than others to the qualities of resilience) in a dashboard. This allows cities to monitor, understand and communicate their performance (The Rockefeller Foundation & Arup, 2014).

Leitner, Sheppard, Webber, & Colven however, in a 2018 article, give reasons to be sceptical about the ability of this model to deliver social and environmental justice. Indeed, the language of participation and inclusion is very much present in the urban resilience frameworks disseminated by these major actors. However, when the 100RC programme[17] reached Jakarta, the participatory element was dictated from above, in terms of who should participate and how. 'At the first resilience strategy definition workshop in Jakarta (2016), a large group of actors - mainly planners […] - were instructed by AECOM on how to use the city resilience index to identify priority areas. This reduced participation to working within a framework […]. It is telling that the large number of actors at the table excluded some of Jakarta's local NGOs known for working with and on behalf of the city's most vulnerable populations'.

Nonetheless, the City Resilience Index is a powerful tool for measuring resilience, monitoring progress and prioritising projects that can enhance a city's resilience. It is the most comprehensive framework currently available. No dimension of the city is left out.

[17] In 2013, The Rockefeller Foundation pioneered 100 Resilient Cities (100RC) to help more cities build resilience to the physical, social, and economic challenges that are a growing part of the 21st century. Cities in the 100RC network have been provided with the resources necessary to develop a roadmap to resilience (the Rockefeller Foundation, 2020).

5.2.2 Urban resilience Assessment – Yamagata and Sharifi (2016)

Noting that recent years have seen a proliferation of studies on resilience, Yamagata and Sharifi (2016) conducted an extensive literature review to identify a set of principles and useful indicators for measuring urban resilience. In order to guide urban planners towards more resilient choices, the authors propose a matrix that links different indicators to the underlying characteristics of resilience.

Resilience is a normative, interdisciplinary and contested concept, making it difficult to define. The authors have therefore, by reviewing the literature, identified the *characteristics* necessary for an urban system to be able to prepare and plan for, absorb, recover from and adapt to a shock - that is, abilities to be resilient. These are: Robustness, Resourcefulness, Flexibility, Redundancy, Stability, Coordination capacity, Diversity, Foresight capacity, Independence, Connectivity, Adaptation, Self-organization, Creativity, Efficiency, Equity, Collaboration, Agility. Their definition can be found in Appendix 19 (Sharifi and Yamagata 2014, 2016). The authors also point out that there are synergies and trade-offs between these *17 characteristics*.

After analysing 29 resilience assessment frameworks (in various contexts, not specifically urban resilience), the authors identified five dimensions of urban resilience, which will be used to classify the 122 criteria they also found. The complete tables (dimension, sub-dimension, criteria) are found in Appendix 20. Here are the five dimensions:

1. **Materials and environmental resources**. The availability and accessibility of resources, which provide ecosystem services, are essential for human communities to thrive. Consequently, resource protection and management must be taken to ensure that communities are resilient.

The following 4 dimensions also have sub-dimensions.

2. **Society and well-being**. This dimension is prominent in the literature on urban resilience: the influence of physical characteristics alone are not sufficient to create resilient communities.
3. **Economy**. The prosperity of a city also depends on its economy. The presence of small, medium and large enterprises, the diversity of industries, the local economy and the skills of the population are all factors necessary to ensure resilience to potential business interruptions.
4. **Built environment and infrastructures**. The multi-functionality of urban areas and facilities enhances the diversity and efficiency characteristics that are essential for shock

absorption and rapid recovery. For example, while green spaces and parks are primarily used for recreation, thermal comfort and air pollution mitigation, they can offer additional benefits in terms of evacuation and flood mitigation. Likewise, sports stadiums and educational institutions can be used as temporary shelters in times of need.

5. **Governance and institutions**. This dimension links all of the above. Governance and institutional rules define how different activities are communicated and what mechanisms exist to develop contingency and mitigation plans and ensure that they are implemented. Strong leadership improves resilience by strengthening the links between different parts of the system. In addition to stable institutions and strong leadership, citizen involvement and community collaboration is also key (bottom-up approach).

The aim of the authors is first and foremost to provide policy makers with an evaluation framework that enables them to make better decisions for urban planning. They have therefore proposed matrices (Appendix 21) to see the relationship between the dimensional criteria, the urban resilience abilities and the 17 resilience characteristics. These matrices were designed to better prioritise the resources allocated and the activities to be developed in the city to increase resilience.

The elements presented in this assessment are interesting. However, it is more a tool to guide planning choices, not a tool to actually measure resilience. The authors conclude that this is a preliminary work: it is a conceptual framework that will be used to develop a real urban resilience assessment tool.

Further research is needed to define precise indicators (qualitative or quantitative) for each criterion of each dimension. They also point out that calculating resilience is very context-specific: finding relevant indicators is therefore difficult as, depending on the context, such indicators will not be useful for all applications.

5.3 Comparison and conclusion

5.3.1 Urban Circularity

Currently, there is no dedicated index or framework for urban circularity (it is noteworthy that the Urban Circularity Assessment Framework (UCAF) is currently being developed).

In the frameworks analysed for circular cities, sets of indicators have not been proposed, leaving cities to choose their own indicators. Existing indicators can be used for circular cities (e.g.

number of waste recycled), but there are no indicators specifically designed for urban circularity. At best, there are indicators designed for the circular economy.

The availability of data is also a problem, noted by the authors of the CCAF: in their case study of Porto, they followed a pragmatic approach and used only the available indicators and data. However, cherry-picking is reductionist and biased. Indeed, weak theoretical framing that allows the selection of indicators according to data accessibility leads to choosing only the available indicators without thinking about their integration (Cohen, 2017).

The citizenship and social aspect of these frameworks should not be forgotten either. Indeed, a city is not only a geographical unit. If we take up the definition of a circular city in section 2 from Prendeville, Cherim, & Bocken (2018), the urban management aspect is highlighted: ‘a circular city is a city that practices CE [circular economy] principles to close resource loops, in partnership with the city's stakeholders (citizens, community, business and knowledge stakeholders), to realise its vision of a future-proof city’. The stakeholder aspect is therefore important. The U4SSC circular city guide reflects this principle quite well through its ‘circular city enablers’ component. The Circular City Analysis Framework (CCAF) also proposes certain fields such as demography, digitalisation, education and policies, which allow the complexity and context of a city to be better considered. However, the ReSOLVE framework only focuses on more business-oriented actions, and the citizen and community participation aspect is not included: it is not a holistic enough framework for urban circularity.

5.3.2 Urban Resilience

In terms of urban resilience assessment frameworks, the Urban Resilience Index is the only comprehensive framework of its kind, providing dimensions, goals, indicators and qualitative and quantitative questions to measure a city's resilience. The framework developed by Yamagati and Sharifi, based on an extensive literature review of existing resilience frameworks and indicators, provides a good overview of what urban resilience is, identifying the characteristics and assets of a resilient system as well as the dimensions and criteria of urban resilience. However, the framework is not sufficient to measure a level of urban resilience: it is indeed a preliminary work to a real assessment framework, as no indicators are proposed.

It is interesting to note that the Urban Resilience Index and the Yamagata & Sharifi Urban Resilience Assessment are constructed in a similar way. Here is a summary table of the two frameworks.

	Urban Resilience Index	Urban Resilience Assessment – Y & S.
Identified Qualities of Resilient System	Robustness, Resourcefulness, Flexibility, Redundancy	
	Reflectivity Integration Inclusivity	Stability Coordination capacity Diversity Foresight capacity Independence Connectivity Agility Adaptation Self-organization Creativity Efficiency Equity Collaboration
Structure		
Level 1: **Level 2:** **Level 3:** **Level 4:**	4 Dimensions, 12 Goals 52 indicators 2 x 156 questions (sub-indicators)	5 Dimensions 20 Assets (sub-dimensions or theme to regroup the criteria) 122 criteria No sub-indicator (ongoing research)
Level 1 (Dimensions)	Health & Well-Being Economy & Society Infrastructure & Ecosystems Leadership & Strategy	Materials and Environmental Resources Society and Well-being Economy Built Environment & infrastructure Governance and institution
Status	12 cities have undergone the assessment	Framework still to be developed

Table 10: Comparison between CRI (2014) & Yamagata & Sharifi urban resilience assessment framework (2016).

The distribution is different but the same concepts are broadly found in both frameworks, although the difficulty created by the inconsistency of the vocabulary (lack of consistent definition of the terms principles, characteristics, qualities, pillars, assets, dimensions, criteria, indicators, sub-indicators, etc.) should be noted. Yamagata and Sharifi's framework is more precise and provides more detail in the categories, resulting in 17 qualities of a resilient system (compared to 7 for the Urban Resilience Index) and 122 criteria (compared to only 52 indicators in the Urban Resilience Index). It should be noted, however, that a framework must remain intuitive and simple enough to be usable and applicable for cities: the urban resilience index therefore makes a good compromise between detail and coverage.

5.3.3 Conclusion

Looking at all these assessment frameworks, I personally noticed that the urban resilience frameworks were better constructed than the urban circularity framework. Indeed, although the

circular economy is trendy, urban circularity is a very recent concept, whereas urban resilience has been explored for a longer time.

Moreover, the hyper-focus on the circular economy impoverishes the frameworks for assessing urban circularity: not all dimensions of the city are reflected and some aspects of urban management are neglected. Indeed, the frameworks start from the properties of the circular economy which they try to apply to cities, without taking into account the specificities of the city as a system, with its different sectors and actors. This can be seen, for example, in the Living Labs, where the urban circularity concept is techno-centric and economy-centric, whereas the circular city initiatives analysed in section 4 were more based on real challenges and the strategies were mostly holistic. The urban resilience frameworks, on the other hand, followed an opposite approach. These frameworks start from the dimensions of the city, define desirable goals for cities, and then indicators that link these desirable goals to the qualities of resilient systems.

I therefore believe that urban circularity assessment frameworks should follow the same methodology as urban resilience assessment frameworks. Indeed, cities are complex socio-ecological systems, and they require holistic approaches. If we take for example the Smart City Strategy Index (Roland Berger, 2017), we notice that there are also dimensions (Government, Buildings, Health, Mobility, Education, Energy and Environment). Indeed, a city would not be truly smart if it only performed in one sector. The three urban resilience frameworks proposed specific dimensions, whereas the different urban circularity frameworks did not clearly propose any (a guide to circular city by U4SSC timidly proposed “circular city enablers”). And this critique of urban circularity assessment frameworks that focus too much on circular economy characteristics echoes a point made by Kirchherr, Reike, & Hekkert, 2017 in defining circularity (section 2). According to the authors, who conducted an analysis of 114 definitions of the circular economy, circularity remains too business-oriented, social equity is not sufficiently represented and the 'recycling' aspect is most emphasised by policies, to the detriment of the ‘reduction’, ‘reuse’ and ‘recovery’ aspects.

It would therefore be interesting to build an urban circularity assessment framework by applying a ‘city-centred’ reasoning and only afterwards a circularity reasoning.

Section 6. Discussion & conclusion

To date, there is no comprehensive and easily applicable framework for quantifying the degree of circularity of a city or its potential for circularity. I will therefore identify the key points necessary for the emergence of an urban circularity framework. This will be followed by a discussion of the limitations and perspectives of this thesis, and a final conclusion which attempts to answer the question 'how does urban circularity build resilience in cities' with all the points made in the previous sections.

6.1 Desired features of an urban circularity framework

Until a standard framework emerges, I will endeavour to highlight the points that should be included in an evaluation framework for urban circularity according to the literature that has been read, the benchmarking and the various findings made throughout this thesis.

In a 2017 article, Cohen conducts a systematic review of the literature on urban sustainability assessment frameworks. Some of his findings can be applied to urban circularity frameworks. Out of 69 studies included in his analysis, the author notes that most of the assessment frameworks (of urban sustainability) are index or indicator frameworks (25) and rating systems (16). However, he believes that the use of goals and objectives based on guiding principles would be more beneficial but there is a gap in the literature as urban sustainability is an ill-defined principle. This also applies to urban circularity: it is interpreted differently by many actors. As the near emergence of a consensus on the definition is uncertain, it is important that a framework for measuring urban circularity redefines the key concepts, fix clear objectives and ensures that it has a focus on the city (macro-level).

Following on from this first point, Cohen (2017) also notes that the selection of indicators for urban sustainability assessment is often not guided by a theoretical framework, as the literature framing sustainability assessment mainly targets national and global scales. A parallel can also be drawn here with circularity assessment frameworks, which usually target businesses, hence the double importance of having a dedicated focus on the city. In order for the indicators to better reflect the purpose of urban circularity, it is important to understand what makes a city, and to represent all the dimensions inherent in cities. Cohen (2017) identifies 10 recurring dimensions in the literature for urban sustainability (Appendix 22). Albino, Berardi, and Dangelico in a 2015 study to define the concept of Smart city, carry out a literature review to identify the key dimensions of a smart city (Appendix 23). The Urban Sustainability Framework

(USF), created by the Global Platform for Sustainable Cities (GPSC), also distinguishes between enabling dimensions and outcome dimensions (Appendix 24). The enabling dimensions emphasise the enabling environment to be established within cities in order to achieve results that cities can achieve (i.e. the outcome dimensions). Identifying enabling dimensions is interesting since one of the common features of the cities analysed in section 4 is the presence of favourable policies.

In the end, some of the dimensions overlap and are the result of a choice of grouping or definition. It would therefore be interesting to identify more precise categories (sub-dimensions), common to each city despite their size, wealth, culture and location, the grouping into dimensions being secondary. Cohen (2017) provides an extensive table of categories of urban sustainability found in the literature (Appendix 25). Covering all the aspects presented in that table (Appendix 25) ensures that the complexity of cities is integrated. As the author points out, a 'study on urban sustainability in Manila, Philippines, may identify the eradication of HIV/AIDS and malaria as urban development goals, while case studies from Northern countries do not necessarily identify these diseases as relevant concerns, but many consider public health to be important'. It is therefore more relevant to identify common categories applicable to each city, and leave the choice of indicators to them. However, when choosing indicators, one should not rely solely on the availability of data, to avoid the risk of cherry-picking.

It is in the choice of indicators that the circular aspect must be taken into account, with the 3 definition points of (1) eliminating waste and pollution, (2) conserving products and materials in use and (3) regenerating the natural system, while seeking social and environmental benefits. This table (Appendix 26) lists several sets of indicators that may be applicable to a circular city.

The Global Platform for Sustainable Cities (GPSC) also recommends benchmarking against other cities (best in class) for a quick assessment of performance and to easily identify good practice, although care is needed when choosing benchmark cities (regional or national variations and level of ambition).

6.2 Limitations and challenges

Initially, this thesis aimed to measure the urban circularity of three different cities and compare it to their respective level of urban resilience, to see if there was a correlation between their level of resilience and circularity. However, this was not possible for several reasons.

The first limitation was the lack of harmonisation of concept definitions. The concepts of resilience, sustainability, intelligence and circularity are intertwined and overlapping, leaving policy makers with interpretations that lead to policy mistakes. There is a lack of consensus on what the circular city is: in these circumstances, one has to be very careful in drawing conclusions.

The second limitation was that I realised in the course of my research that there was no comprehensive and standardised framework for measuring urban circularity to date. Some of this problem stemmed from the lack of a general definition of the concept (the first challenge). Furthermore, the urban circularity frameworks analysed are built on the principles of the circular economy, and the specificities of the city seem secondary. Measuring the level of circularity of a city was then compromised.

The third limitation was the futility of comparing the resilience of two different cities at one point in time. Indeed, resilience is a temporal concept for which spatial comparison is of little interest. As stated in the Urban Resilience Index brochure, resilience is also context-dependent: the performance of one city is not comparable to the performance of another. An urban resilience assessment framework should be used by cities as a tool for monitoring their own performance over time and through shocks. The emergence of a common assessment framework and index is therefore not intended for comparison between two cities, but is there to foster dialogue between cities and knowledge sharing (common language). My initial idea, which was to measure the circularity of cities and their level of resilience and compare them to see if the most circular cities were also the most resilient, was therefore biased: the comparison must be made over time, not from city to city.

For all those reasons, my research question evolved slightly, and I decided to identify the basis for a future urban circularity assessment framework, based on the analysis of the different frameworks and the benchmarking.

6.3 Suggestions for further research

The continuation of this research therefore requires the assembly of a standard urban circularity framework with the proposed recommendations. Interviews with different stakeholders to determine the preferred characteristics are essential to verify the validity of the model with concrete cases. There is already a lot of literature on this subject, and urban circularity depends on the (city) context, so interviews seem to be the next step.

In order to achieve the initial aim of measuring a level of urban circularity and comparing it to a new level of urban resilience, it is preferable to carry out a contextual study which extends over several years. As many cities are currently following circular strategies, it would be interesting to measure their level of urban resilience (via the urban resilience index) and to repeat the exercise in 5 years, when several circularity objectives have been achieved, to see if the resilience of these cities has improved.

It would also be interesting to have a dialogue with the cities to see the preferred medium for an evaluation framework. For example, the Urban Resilience Index offers the calculation of the index on a website and provides visual feedback, but it needs the support of the city's policy makers to complete it as the information needs to be correct and is not always available online. Assessment frameworks should above all be tools to guide and monitor the progress of cities, and should therefore be intuitive and time-efficient. A complex framework which requires the participation of many actors (due to the presence of many specific indicators and different dimensions) must be able to be filled in simultaneously: a digital dashboard, which can be used by several parties at the same time, is therefore interesting.

6.4 Final Conclusion

Sustainability should be the desired goal of humanity, but it is an ill-defined and long-term concept. Xu and Marinova (2013) argue that resilience is an active component of sustainability: a non-resilient system cannot be sustainable. As resilience has the advantage of being easier to measure than sustainability, it is the means to achieve this goal of sustainability. Human activities (and thus urbanisation) can only be considered as an operational concept of sustainability if the system is resilient.

The circular city is the latest concept in this mode of urban sustainability, so it is interesting to see whether it improves the resilience of cities (as opposed to, for example, smart cities, which have shortcomings).

As explained above, it was not possible in this thesis to measure a level of urban circularity associated with a level of resilience, due to several limitations. Nevertheless, it is possible to provide pieces of an answer to the question 'how circularity brings resilience to cities' without correlations and metrics.

Yamagata and Sharifi's work on resilience and the Rockefeller Foundation/Arup Urban Resilience Index identify different qualities or *characteristics* (section 5) needed to achieve and

maintain the abilities (prepare and plan, absorb, recover and adapt) of resilient systems. These qualities are important properties that prevent failure or breakdown and can provide a more comprehensive measure of resilience than conventional sustainability indicators (e.g. energy efficiency). Contributing to these qualities can therefore improve the resilience of a system.

Urban Resilience Index	**Urban Resilience Assessment – Y & S.**
Robustness, Resourcefulness, Flexibility, Redundancy, Reflectivity, Integration, Inclusivity	Robustness, Resourcefulness, Flexibility, Redundancy, Stability, Coordination capacity, Diversity, Foresight capacity, Independence, Connectivity, Adaptation, Self-organization, Creativity, Efficiency, Equity, Collaboration, Agility

Table 11: Qualities/characteristics of resilient systems - Yamagata & Sharifi (2016) and Rockefeller Foundation & Arup (2015)

Several of these qualities can also be imputed as properties of circularity. If circularity objectives have resilient qualities (or circular indicators contributes to resilience qualities), then presumably they advance resilience. As the properties of urban circularity are not defined in the literature, I cannot say with certainty to which quality circularity definitely contributes. But it is easy to see, for example, that a circular city is resourceful, because waste is recovered.

Indeed, Arup and the Global Network of Resilient Cities have found that circularity can help to, for example, reduce unemployment by creating, through closed and regenerative loops, new business opportunities, supporting social cohesion with shared access to goods and services, and creating shorter and less complex supply chains that are less sensitive to external shocks. In summary, the fact that circularity is distributive and diverse in nature helps to build a more shock and stress resistant city (Enel, 2020).

However, it is important to be aware that there are trade-offs and synergies between the different qualities, so some of the attributes of circularity will not specifically contribute to the resilience of a system. But it is likely that a holistic circular strategy will lead to resilience.

The circular model is therefore promising for the future of cities: the challenge is to establish an effective strategy that does not neglect any aspect of the city, that does not focus solely on the economy, and to be able to measure progress correctly (thanks to the emergence of a comprehensive evaluation framework).

Section 7. Tables and Figures

Section 8. Bibliography

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Report

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Section 9. Appendix

Table des matières

Appendix 1

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2.4 - Resilience definition - Adapted from C. Gonçalves (2013) and Xu, Marinova, & Guo (2014)

Term/categories	Definition	Reference
Social ecological resilience	The capacity of a system to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes.	Carpenter et al. (2001); Resilience Alliance (2012, p. n.p.)
	The ability of groups or communities to cope with external stresses and disturbances as a result of social, political, and environmental change.	Adger 2000, p.347
	The underlying capacity of an ecosystem to maintain desired ecosystem services in the face of a fluctuating environment and human use	Folke et al. 2002, p.14
	Capacity to absorb disturbances, for self-organization, and for learning and adaptation.	Walker et al. 2002
Social resilience	The ability of communities to withstand external shocks, mitigate and recover from hazards.	Adger (2000); Bruneau et al. (2003); Langridge et al. (2006)
Economic resilience	The ability of the system to withstand either market or environmental shocks without losing the capacity to allocate resources efficiently, or to deliver essential services.	Perrings (2006)
Ecological resilience	The measure of the persistence of systems and their ability to absorb unforeseen changes and disturbances and still maintain the same relationships between populations or state variables as well as essential functions, structures, processes, and feedbacks.	Holling (1973); Gunderson (Gunderson and Holling 2002); Walker et al. (2004)
	Latitude (width of the domain), resistance (height of the domain), precariousness, cross-scale relations.	Folke et al. 2004, p.573
	The ability of the system to maintain its identity in the face of internal change and external shocks and disturbances.	Cumming et al. 2005
Engineering resilience	The ability of systems to anticipate, recognise, adapt to and absorb changes, disturbances, surprises and failures.	Holling (1973); Ludwig et al. (1997);
Resilience engineering	The intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions.	Hollnagel et al. (2006), (2011)
Psychological resilience	A set of combined abilities and characteristics that interact dynamically to allow a person (especially children and a family) to bounce back, handle successfully, and function above the norm in spite of significant stress or adversity.	Rutter (1993); Tusaie and Dyer (2004); Walsh (1996)

Appendix 2

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3.2 - A vision for a circular city - Holland Circular Hotspot, 2019

Housing & Infrastructure	Buildings globally account for 45% of global resource consumption. A circular city is literally built with renewable, non-virgin and low-carbon footprint materials.
Mobility	Transportation sharing, and renewable and clean fuel will drive circular mobility for cities, as cities account for 40% of all transport-related emissions.
Food	Cities are expected to consume 80% of all food by 2050 and the worldwide food system is responsible for 20-30% of GHG emissions. A circular food system will focus on locally produced food, minimising food waste by prevention and repurposing of generated waste.
Energy	Already, 75% of worldwide energy consumption takes place in cities. Renewable energy will fuel the circular city by hyper-local, decentralised grids. Energy loss is prevented and energy generated in access, captured.
Water	A circular city minimises extraction and pollution of local water-ways and uses closed loop systems for its water flows; resources are recovered from wastewater.
Consumer Goods	Circular design will offer a completely different approach to production and consumption, monetised by circular business models.
Plastic	A circular city bans traditional single use plastics. New materials or traditional materials are adopted and landfill, incineration or any contribution to the plastic soup is prevented by policy and lifestyle.
Industrial Parks	Circular Industrial Parks are driven by eco systemic functions, symbiosis and the use of waste as a feedstock.

Appendix 3

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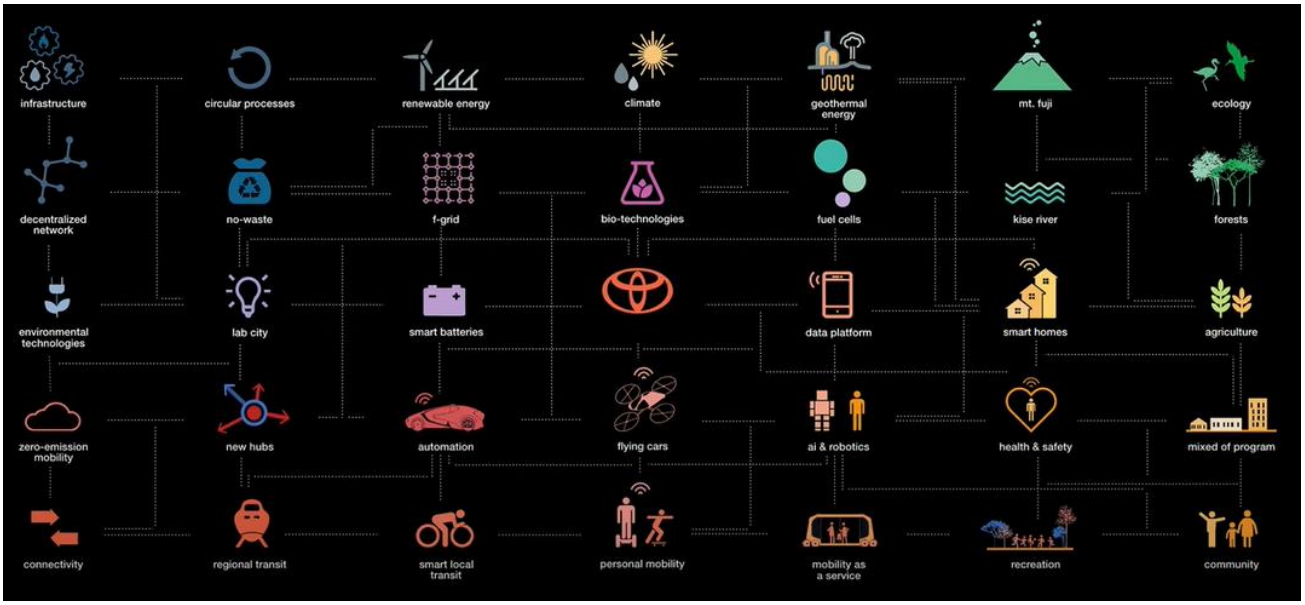
4.2.3 - Toyota Woven city features - Toyota, 2020



Appendix 4

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4.3.1 The 3 value chains of Amsterdam Circular Strategy and detailed ambitions - City of Amsterdam & Circle Economy, 2020

Food and organic waste streams	
Ambition 1: Short food chains provide a robust sustainable food system	We will stimulate urban agriculture to bring food closer to the people of Amsterdam
	The City will purchase regionally produced food
	Sustainable chain parties will collaborate more in order to increase the consumption of regional food
Ambition 2: Healthy and sustainable food for the people of Amsterdam	We will offer Amsterdam residents more opportunities for a healthier diet
	The City is committed to reducing food waste
	Initiatives against food waste and for more efficient production of food will be supported
Ambition 3: High-quality processing of organic waste streams	Working together to ensure the best approach for each city district
	The City will set the right example
	The people of Amsterdam are made aware of the importance of separating waste for uncontaminated waste streams
	Deploying its spatial planning tools and innovation policy, Amsterdam will designate locations for the collection and reuse of waste to stimulate closed nutrient cycles
Consumer goods	
Ambition 1: The City sets the right example by reducing its consumption	The City will purchase fewer new products and instead adopt a policy of access over ownership
	The City will support the development of new circular products and services
Ambition 2: Using what we have more sparingly	Working together for better products in Amsterdam
	Increased awareness of the need to consume less and share more
	Sharing and repairing made easy, accessible and affordable
Ambition 3: Amsterdam makes the most of discarded products	The City, businesses and knowledge institutions will work together to extract value from discarded items
	The business community will help the people of Amsterdam to appreciate the value of their goods
	Amsterdam will treat discarded but useful goods with respect
Built environment	
Ambition 1: The transition to circular development requires a joint effort	Lower limit: use recycled and bio based materials (such as wood) as much as possible
	Draw up a value-chain assessment, which includes raw and other materials
Ambition 2: The City sets the right example by formulating circular criteria	Extend the useful life: use what's available
	Tighten internal municipal processes: encourage circularity
	Organise market research: stimulate innovations
	Municipal assets: what are they worth?
Ambition 3: A circular approach to the existing city	Agreements on circular ambitions: invite extra-municipal parties to the table
	Made-to-measure knowledge: the City provides targeted knowledge and data services
	Affordable and scalable: the City stimulates innovation projects
	Close the loop: retain as much value as possible
	Existing financial and fiscal instruments: make them circular

Appendix 5

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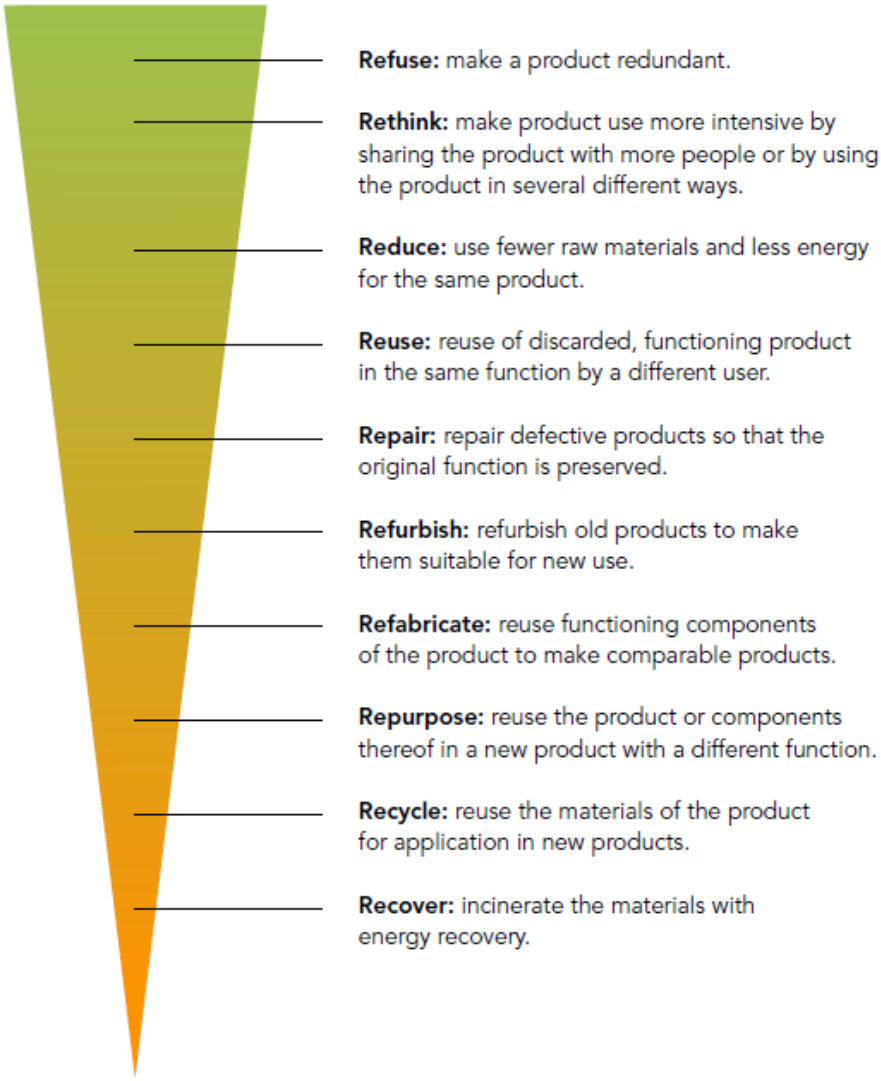
4.3.1 - Amsterdam Circularity Scale – 10Rs - City of Amsterdam & Circle Economy, 2020



Appendix 6

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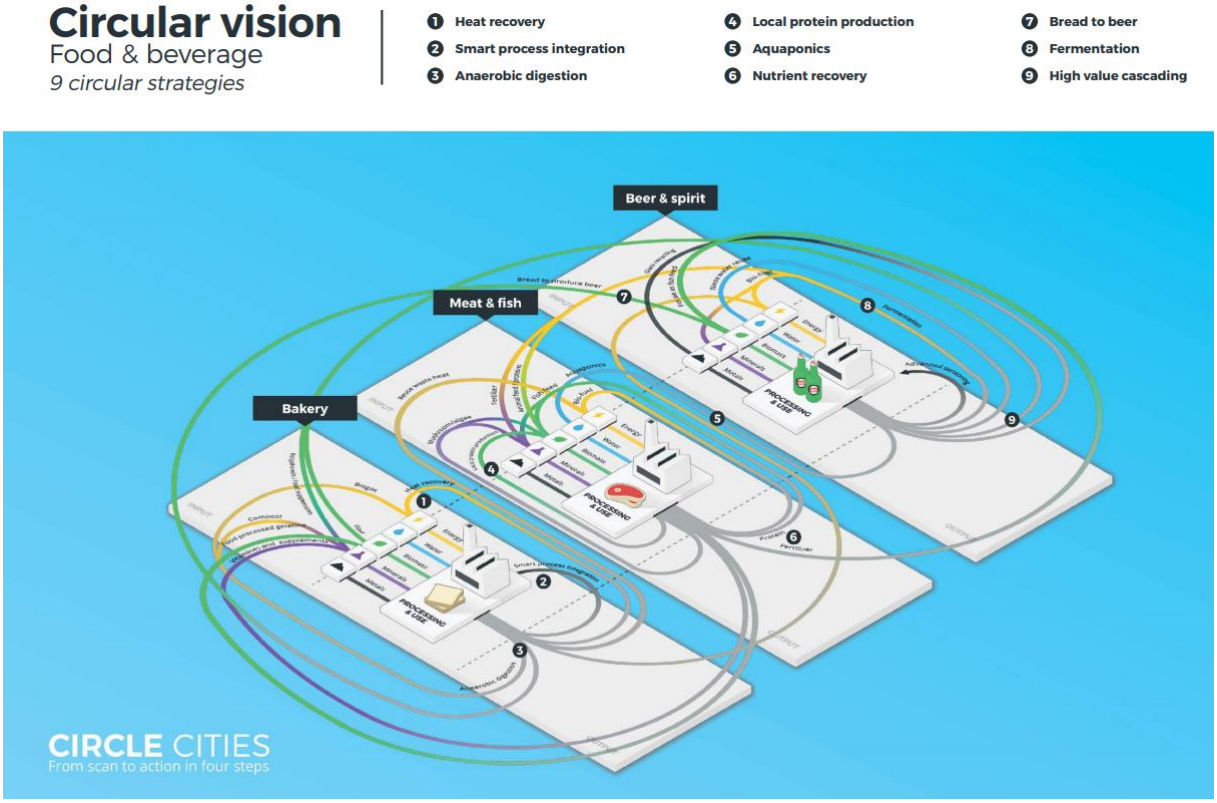
4.3.2 – Identified nine Circular Strategies - Circle Economy Action Plan, 2016



Appendix 7

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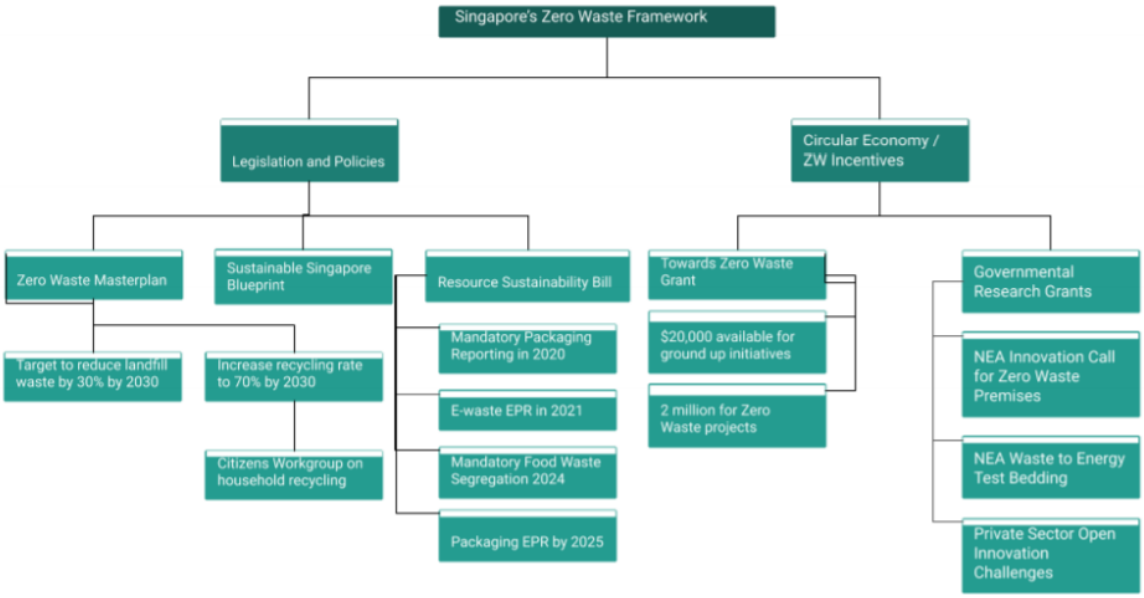
4.3.6 - Singapore's Zero Waste Framework broken down - Carrière, Rodríguez, Pey, Pomponi, & Ramakrishna, 2019



Appendix 8

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4.4.2 - CEC Chapters that signed up to host the Circular Cities Week - Circular Economy Club, 2020

Africa	Americas	Asia, Middle East & Oz	Europe
Congo - Kinshasa Ghana - Accra South Africa - Durban Morocco - Casablanca Uganda - Kampala	Bahamas - Freeport, Nassau Brazil - Belo Horizonte, São Paulo Chile - Santiago Canada - Gatineau Colombia - Bogota, Cartagena Ecuador - Cuenca & Quito Mexico - Cholula, Merida, Mexico City, Puebla and Saltillo Paraguay - Asunción St. Luisa - Castries Trinidad & Tobago - Port of Spain and San Fernando United State - Austin, Orlando and Seattle	Armenia - Yerevan Australia - Melbourne, Perth & Sydney French Polynesia - Papeete Hong Kong - Hong Kong India - Bangalore, Gurgaon, Hyderabad, Mumbai, New Delhi and Pune Japan - Tokyo Israel - Tel Aviv Malaysia - Kuala Lumpur and Petaling Jaya Pakistan - Karachi Singapore - Singapore UAE - Dubai	Austria - Vienna Belgium - Brussels Bulgaria - Sofia & Varna Czech Republic - Prague Finland - Helsinki France - Toulouse Georgia - Batumi Germany - Berlin & Stuttgart England - Bath, Birmingham, Brighton & Hove, Kendal, London, Reading and York France - Paris Italy - Milan and Torino Ukraine - Kyiv Portugal - Lisbon and Porto Romania - Râmnicu Vâlcea Serbia - Belgrade Spain - Alicante, Barcelona, Bilbao and Madrid Switzerland - Lugano Wales - Carmarthenshire and Swansea

Appendix 9

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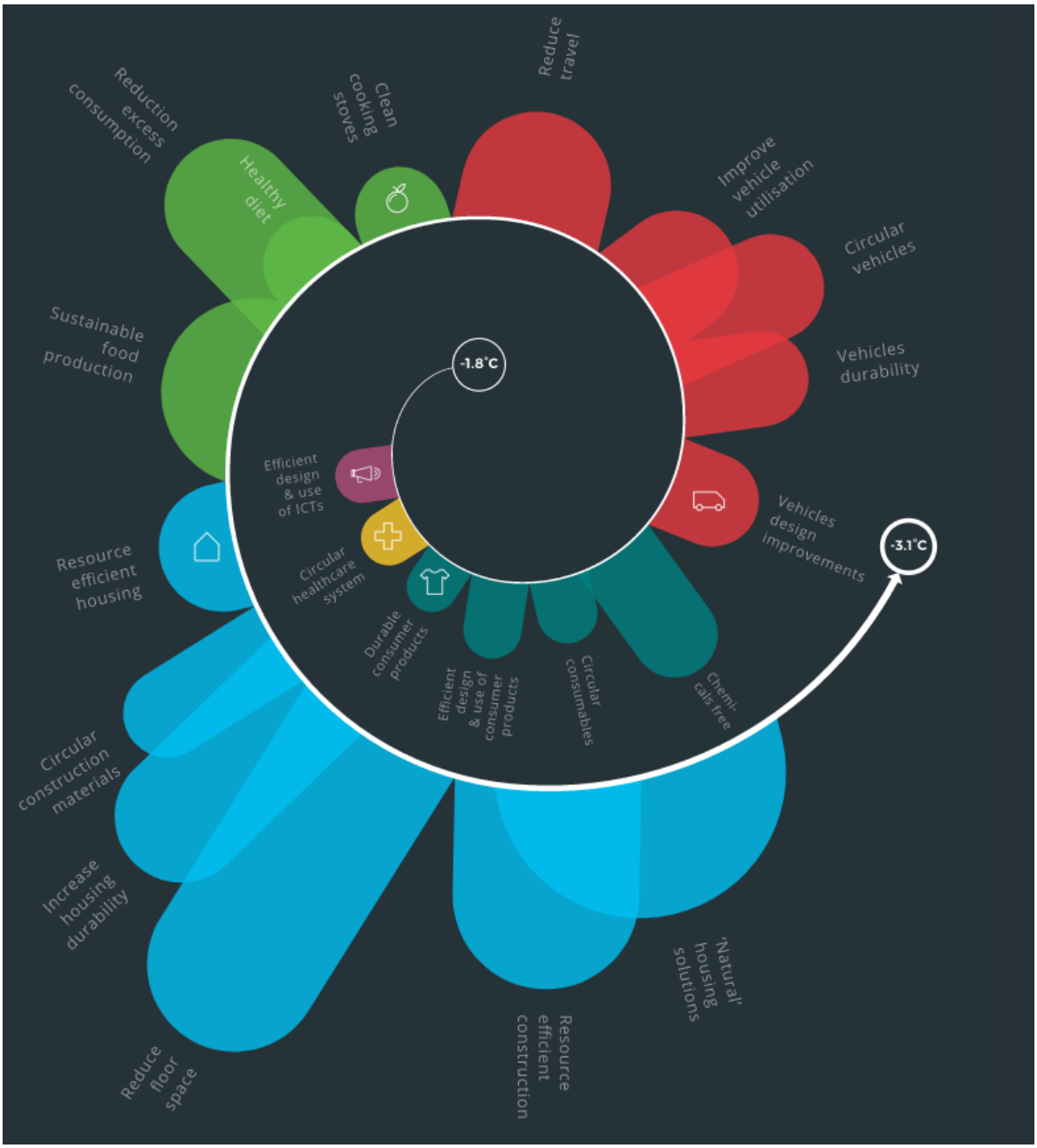
4.4.3 – Circle Economy Vortex – Circle Economy, 2021



Appendix 10

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5.1.1 - Circular city analysis framework – Complete Field table - Cavaleiro De Ferreira and Fuso-Nerini, 2019

Field	Description	Agents	Technologies/behaviours	Indicators	Current	Goals
Water management						
Buildings						
Food						
Circular innovation						
Waste management						
Local resources						
Specific industry						
Renewable energy						
Transport						
Demographics						
Digitalization						
Education						
Policies						

Appendix 11

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5.1.1 – Indicators currently in use relevant to a circular economy - European Academies Science Advisory Council (EASAC), 2016

Indicators currently in use relevant to a circular economy (EASAC, 2016): considered sets			
Indicator set	Advocated by	Characteristic / data source	N° of indicators
Sustainable Development indicators	UNEP	Major global environmental issues	10
SDGs	UNDP	End poverty, fight inequality and injustice, and tackle climate change	17 (and more sub-indicators)
Corporate Sustainability	GRI	Sustainability-relevant indicators for organisations	>100
Environmental sustainability index (ESI); environmental performance indicator (EPI)	Yale and Columbia Universities	Environmental indicators	21 (ESI) - 20 (EPI)
Little Green Data Book	World bank	Environment and sustainability	50
Green growth indicators	OECD	Environment, resources, economic and policy responses	25-30
Economy-wide material flow accounts EW-MFA	Eurostat, Wuppertal Institute	Focused on material flows	6
Circular economy indicators	EMF	Indicators currently available	7
Resource efficiency	EURES	Eurostat, EEA and others	32
Raw materials	EIP	Raw Materials Scoreboard European Union Raw Materials Knowledge Base (EURMKB)	24 4

Appendix 12

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5.1.2 - A guide to circular cities: City assets and products - United for Smart Sustainable Cities, 2020

Figure 1: City assets and products categorization

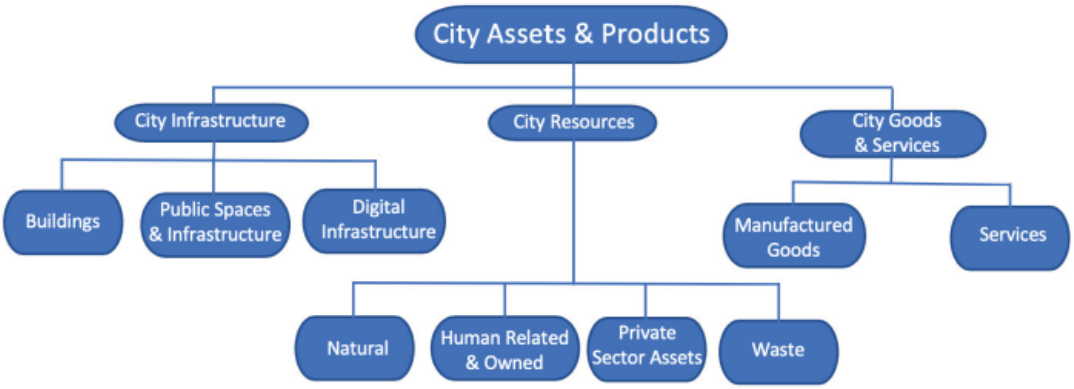
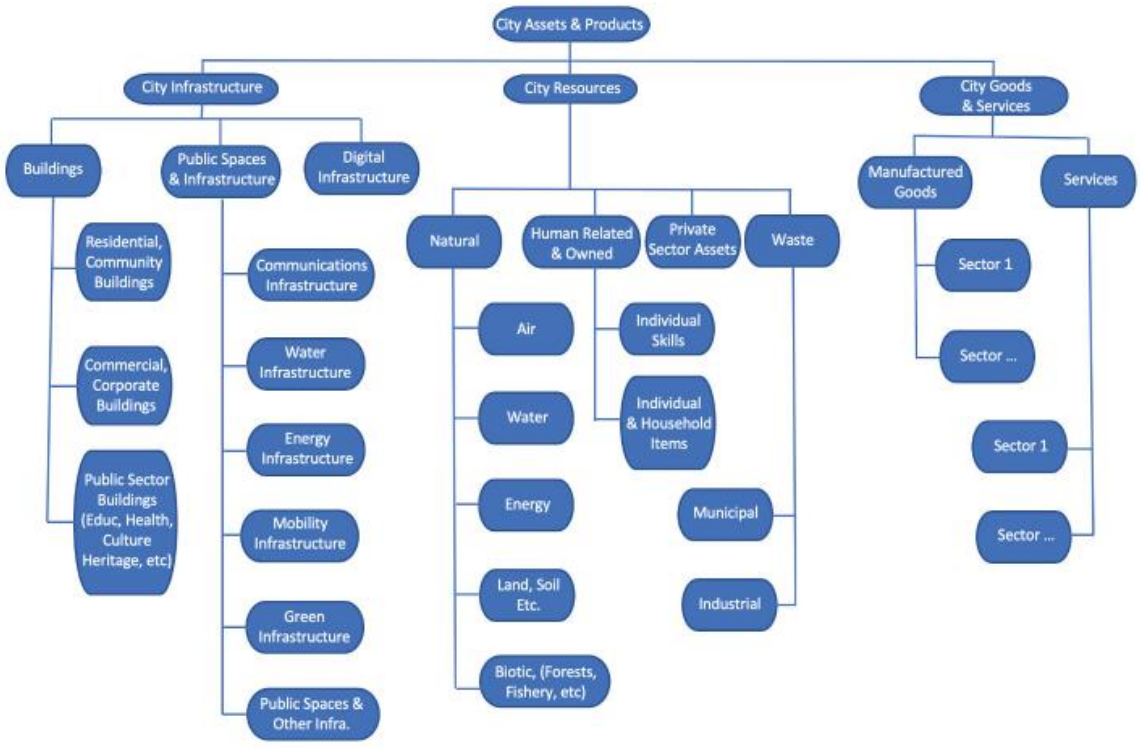


Figure 2: City assets and products detailed categorization



Appendix 13

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5.1.2 - A guide to circular cities: City assets and products - United for Smart Sustainable Cities, 2020

Circular KPIs and their baseline and target values: Key Performance Indicators (KPIs) are useful for measuring progress and evaluating outcomes of activities supporting circularity. Indicators to measure cities' performance have been formulated, some of which measure circularity in cities. Examples of earlier formulated circular city-related KPIs are provided below:

- U4SSC KPIs for Smart Sustainable Cities: The U4SSC has developed the KPIs for Smart Sustainable Cities to evaluate the smartness and sustainability of a city.
- The Ellen MacArthur Foundation has undertaken a project called 'The Circularity Indicators Project'. The project provides a methodology and tools to assess the performance of a product or company in the context of a circular economy. The project has published a toolkit and methodology for circularity indicators.
- ISO 37120: The International Organization for Standardization (ISO) has developed the Standard ISO 37120 under the ISO/TC 268 to help cities measuring their performance in improving quality of life and sustainability. Some of the KPIs in ISO 37120 can be utilized in the framework of circular cities (e.g. waste management-related KPIs).
- ITU, through its ITU-T Study Group 5, has developed a series of international standards to help cities assessing their sustainability. For example, Recommendation ITU-T L.1440: Methodology for environmental impact assessment of information and communication technologies at city level provides guidance on assessing the environmental impacts of ICTs at city level. It takes into consideration multiple factors, including the process of raw material acquisition, production, use and end-of-life treatment of ICTs, which could be extrapolated to assess circularity in cities.

Awareness building of circular city initiatives and actions: The success of circular city initiatives depends largely on the awareness of their stakeholders. The uptake of circular city initiatives is highly dependent on city-wide awareness and their adoptability to their potential users. Promoting and explaining their benefits may help to drive cultural and behaviour changes towards embracing circularity.

Training and circularity skills enhancement: Targeted skills enhancement programmes may help in institutionalizing circularity in cities. Academic programmes (e.g. university degrees and courses, related curricula changes) will help to enhance circularity skills through formal education. Vocational and professional training programmes could also help in this regard. Moreover, sharing and disseminating, for example, circularity-related publications, reports and research may also help to further develop circularity-related skills. These programmes help in creating highly skilled human capital for implementing circularity actions at the city level, as well as bridging skills and expertise gaps that have traditionally been a major obstacle towards circular economy.

Measures to promote trust in circular activities: Circularity includes circular action items such as sharing being applied to various city assets and products. In sharing, it is important to introduce trust among city users and sharing services, service providers should ensure that they address the concerns of their customers, protect their rights, and provide them with reliable and high-quality services to gain their trust. Additionally, it is important for these service providers to ensure the safety and security of shared city assets and products.

Urban industrial symbiosis: It is a subfield of industrial ecology that takes a collective approach to engage separate industries, in order to gain competitive advantages by facilitating the physical exchange of materials, energy and services among them. For instance, waste resulting from one production process can be used as primary inputs (materials or energy) in another production process. This allows the creation of closed loops within, and across, industries, which, in turn, enhances circularity in cities.

Circularity-related strategic planning and policy making: Holistic circularity strategies and policies led by a city administration can align city stakeholders to a common target and mobilize them for successful implementation. Impact investment and corporate social responsibility initiatives undertaken by the private sector can also catalyse circularity in a city.

Utilizing procurement as a lever for circularity: Procurement is a strong lever for emphasizing and enforcing circularity in the public and private sectors. Incentive plans can be used as a tool to avail the supply of circular city assets and products during their procurement (e.g. raw materials, components).
Financial incentives for boosting circularity: City administrations and public sector organizations may utilize financial incentives to boost circularity in a city. Monetary (financial) benefits can be offered to consumers and suppliers of circular city outputs, which would encourage their participation in circularity. Financial incentives include, but are not limited to, tax breaks, tax reductions, tax exemptions, tax holidays, lower loan rates, impact investment alternatives, excise taxes, VAT, and so on.
Public Private Partnerships for circularity: City administrations (public sector organizations) and private sector organizations may collaborate and form partnerships to improve circularity in the city. This approach would allow partners to align and unify their goals, and share the risks and rewards of implementing circularity actions.
R&D programmes for circularity: Circularity provides enormous innovative potential for cities in addressing their sustainability challenges. In some cases, further research and development would be required to turn circularity ideas into reality. Well-designed research and development programmes that target actual city challenges and are led by academia, private and public sector organizations may help to overcome various obstacles of implementing circular actions.
Circularity regulations: City administrations can set out various regulations and standards to boost circularity in the city. They may take the form of circularity-related technical standards, product regulations, compliance standards, trade regulations, and waste and safety regulations. Regulations are, in general, ancillary or subordinate to laws. However, they are enforceable and, therefore, constitute a strong lever for circularity.
National laws and directives: Law is a system of rules created and enforced through governmental institutions to regulate behaviour. Laws can take the form of legislation, directives and acts of parliament and so on, and they are influenced by the constitution. Laws can potentially be used as an alternative tool to change the behaviour of a society towards embracing circularity (in general, laws are made at the national level rather than city level)
Certifications for circularity: Cities can leverage existing certifications or create new ones to encourage and incentivize circularity. Certifications rely on well-defined and verifiable standards to measure or optimize performance and allow certified organizations to demonstrate their commitment towards a specific goal (i.e. circularity in this case). Certifications are usually voluntary in nature, rather than mandatory; however, they can provide a competitive advantage for certified organizations. They are an indicator of compliance to well-defined standards or criteria and are usually issued by a credible third party after an independent auditing process.
Engaging and ensuring participation of stakeholders: It is important for cities to engage and ensure the participation of all their stakeholders during the formulation and implementation process of circularity initiatives/action items. An inclusive and participatory implementation process would be highly beneficial for maximizing collective city capital. Collaborative platforms that facilitate multi-stakeholders engagements among the public and private sectors, academia, NGOs, civil society and cities' inhabitants can also be used by cities to ensure broad engagement.
Circularity related city innovation ecosystem: Fostering a robust and productive ecosystem will help in boosting circularity in cities. Entrepreneurs can be encouraged and incentivized to establish start-ups for addressing circularity challenges in cities. Accelerators and incubators can also be utilized to support circularity-related SMEs. City circularity challenges would drive concrete demand to be met by entrepreneurs and SMEs in the city innovation ecosystem.
Integrated urban services: Such urban services will help in realization of circularity in cities. E.g., WMO is developing the Integrated Urban hydro meteorological, climate and environmental Services (IUS) to support safe, healthy, and resilient and climate friendly cities. Such services involve combining heterogeneous observation networks, high-resolution forecasts, multi-hazard early warning systems and climate services. They should assist cities in setting and implementing mitigation and adaptation strategies that will enable the management and building circular cities.

Appendix 14

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5.1.2 – Circular city enablers - United for Smart Sustainable Cities, 2020

Assessment element	Currently exists?	Brief description	Comments
Are there awareness programmes for circularity-related initiatives in the city?			
Are there skills boosting programmes to enhance and enrich circularity knowledge in the city?			
Are there existing certification programmes in the city for circularity-related implementations?			
Is there a vibrant and rich innovation ecosystem in the city to address and implement circularity-related implementations?			
Are there regulations and laws (e.g. laws, directives, legislations, standards) supporting or impeding circularity related implementation projects in the city?			
Are there established trusted intermediaries (or plans in place) for sharing initiatives in the city?			
Are there existing circularity-related strategies and policies in the city public and private sectors?			
Is public procurement utilized as a lever for circularity-related implementation projects?			
Are there mechanisms in place to ensure the security and safety of shared city assets and products?			
Are there existing collaborations and partnerships in place among city industrial organizations for circularity implementations?			
Are there existing skills in place within public and private sectors to implement circularity?			
Are there existing PPP partnerships in the city for circularity related implementation projects?			
Are there existing R&D programmes and other targeted academic programs for circularity related implementation projects?			
Are the city stakeholders currently aware of circularity initiatives/ action items in the city?			
Are broad stakeholders defined for city circularity initiatives/ action items?			
Are the stakeholders in the city engaged broadly for circularity-related implementations?			
Is there an established financial framework that can promote city circularity implementation?			
Are there existing financial incentives in the city for circularity related implementation projects?			

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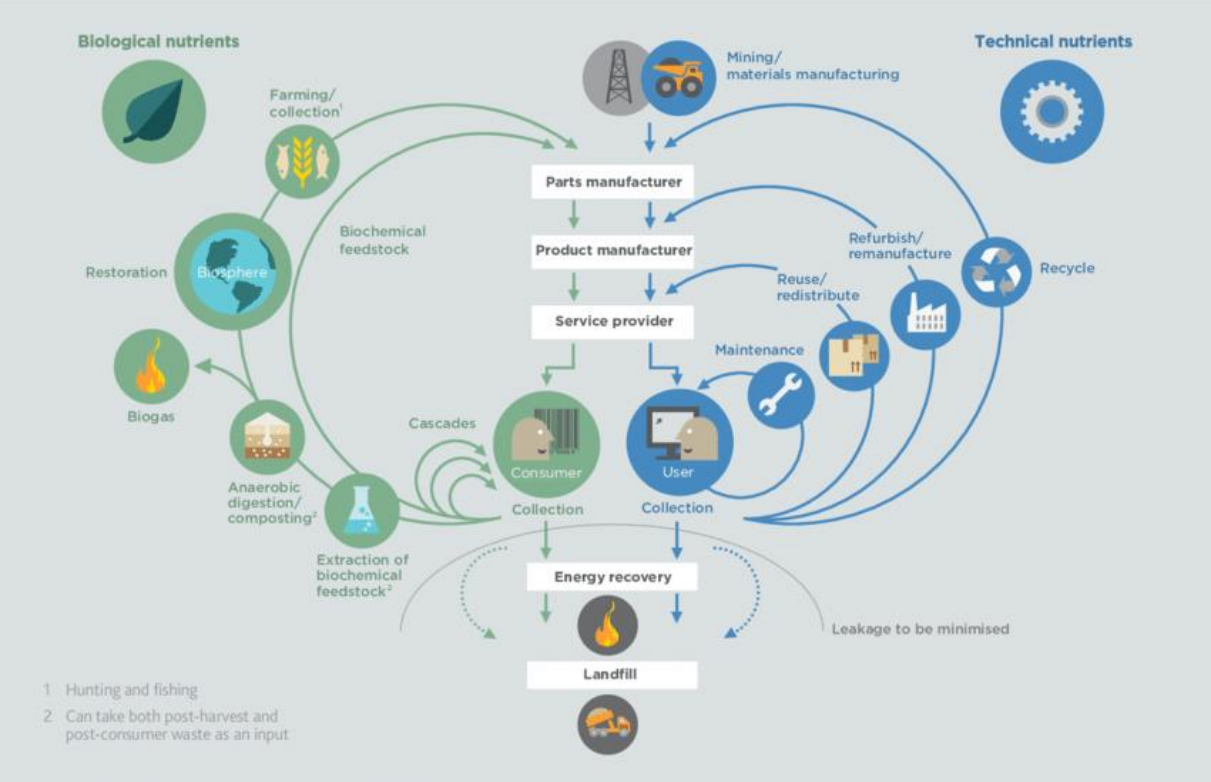
5.1.3 – ReSOLVE Framework Diagram - Ellen MacArthur foundation, 2015



Appendix 16

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5.2.1 - Qualities of a resilient system – Cities Resilience Index – The Rockefeller Foundation and Arup, 2014

Reflective	Reflective systems are accepting of the inherent and ever-increasing uncertainty and change in today's world. They have mechanisms to continuously evolve, and will modify standards or norms based on emerging evidence, rather than seeking permanent solutions based on the status quo. As a result, people and institutions examine and systematically learn from their past experiences, and leverage this learning to inform future decision-making.
Robust	Robust systems include well-conceived, constructed and managed physical assets, so that they can withstand the impacts of hazard events without significant damage or loss of function. Robust design anticipates potential failures in systems, making provision to ensure failure is predictable, safe, and not disproportionate to the cause. Over-reliance on a single asset, cascading failure and design thresholds that might lead to catastrophic collapse if exceeded are actively avoided.
Redundant	Redundancy refers to spare capacity purposely created within systems so that they can accommodate disruption, extreme pressures or surges in demand. It includes diversity: the presence of multiple ways to achieve a given need or fulfil a particular function. Examples include distributed infrastructure networks and resource reserves. Redundancies should be intentional, cost-effective and prioritised at a city-wide scale, and should not be an externality of inefficient design.
Flexible	Flexibility implies that systems can change, evolve and adapt in response to changing circumstances. This may favour decentralised and modular approaches to infrastructure or ecosystem management. Flexibility can be achieved through the introduction of new knowledge and technologies, as needed. It also means considering and incorporating indigenous or traditional knowledge and practices in new ways.
Resourceful	Resourcefulness implies that people and institutions are able to rapidly find different ways to achieve their goals or meet their needs during a shock or when under stress. This may include investing in capacity to anticipate future conditions, set priorities, and respond, for example, by mobilising and coordinating wider human, financial and physical resources. Resourcefulness is instrumental to a city's ability to restore functionality of critical systems, potentially under severely constrained conditions.
Inclusive	Inclusion emphasises the need for broad consultation and engagement of communities, including the most vulnerable groups. Addressing the shocks or stresses faced by one sector, location, or community in isolation of others is an anathema to the notion of resilience. An inclusive approach contributes to a sense of shared ownership or a joint vision to build city resilience.
Integrated	Integration and alignment between city systems promotes consistency in decision-making and ensures that all investments are mutually supportive to a common outcome. Integration is evident within and between resilient systems, and across different scales of their operation. Exchange of information between systems enables them to function collectively and respond rapidly through shorter feedback loops throughout the city.

Appendix 17

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5.2.1 - Goals and indicators - Cities Resilience Index – The Rockefeller Foundation and Arup, 2014

Health & Well-being	
Goals	Indicators
Minimal human vulnerability	Safe & affordable housing
	Adequate affordable energy supply
	Inclusive access to safe drinking water
	Effective sanitation
	Sufficient affordable food supply
Diverse Livelihoods & employment	Inclusive labour policies
	Relevant skills and training
	Local business development and innovation
	Supportive financing mechanisms
	Diverse protection of livelihoods following a shock
Effective safeguards to human health & life	Robust public health systems
	Adequate access to quality healthcare
	Emergency medical care
	Effective emergency response service
Economy and society dimension	
Goals	Indicators
Collective identity & mutual support	Local community support
	Cohesive communities
	Strong city-wide identity and culture
	Actively engaged citizens
Comprehensive security & rule of law	Effective systems to deter crime
	Proactive corruption prevention
	Competent policing
	Accessible criminal and civil justice
Sustainable economy	Well-managed public finances
	Comprehensive business continuity planning
	Diverse economic base
	Attractive business environment
	Strong integration with regional and global economies
Infrastructure and environment dimension	
Goals	Indicators
Reduced exposure & fragility	Comprehensive hazard and exposure mapping
	Appropriate codes, standards and enforcement
	Effectively managed protective ecosystems
	Robust protective infrastructure
Effective Provision of critical services	Effective stewardship of ecosystems
	Flexible infrastructure
	Retained spare capacity
	Diligence maintenance & continuity
	Adequate continuity for critical assets and service
Reliable mobility & communications	Diverse and affordable transport networks
	Effective transport operation and maintenance
	Reliable communications technology
	Secure technology networks
Leadership and strategy dimension	

Goals	Indicators
Effective leadership & management	Appropriate government decision-making
	Effective co-ordination with other government bodies
	Proactive multi-stakeholder collaboration
	Comprehensive hazard monitoring and risk assessment
	Comprehensive government emergency management
Empowered stakeholders	Adequate education for all
	Widespread community awareness and preparedness
	Effective mechanisms for communities to engage with government
Integrated development planning	Comprehensive city monitoring & data management
	Consultative planning process
	Appropriate land use and zoning
	Robust planning approval process

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5.2.1 – Example of qualitative and quantitative question - Cities Resilience Index – The Rockefeller Foundation and Arup, 2014

	Example
Qualitative question: assesses the adequacy of the mechanism and processes in place to achieve the outcome articulated by the indicators	Scored on a linear scale between 1 and 5, based upon consideration of a 'best case' and 'worst case' scenario relevant to a particular area of city performance. • Worst case (1 out of 5): the majority of households and businesses are understood to be uninsured in respect of the high risk hazards facing the city. Affordable insurance cover is not available to most household and businesses. The city government does not have access to adequate, available funds capable of covering the estimated uninsured household losses following a major shock event... • Best case (5 out of 5): assessments have been undertaken to assess the proportion of households and businesses within the city that have adequate insurance against high risk hazards facing the city. Measures have been put in place to encourage all households and businesses to obtain adequate levels of insurance for losses that could be incurred by high risk hazards facing the city...
Quantitative question: identifies quantitative metrics that can be used by cities as proxies for past and current performance in relation to the indicators	Scored on relevant city data in a specific unit as a globally applicable metrics of resilience. A score from 1 to 5 is then automated, based on a standardised performance scale. • For example: percentage of buildings with insurance cover for high risk hazards relevant to the city- %

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5.2.2 – Resilience characteristics – Urban Resilience Assessment – Yamagata and Sharifi, 2016

Robustness	Refers to the system's strength against short-term shocks
Stability	Refers to the system's strength against long-term shocks
Flexibility	Indicates the ability to rearrange structure and functions when facing disruptions
Resourcefulness	Relates to availability of resources needed for enhancing the above-mentioned abilities of a resilient system (prepare, plan for, absorb, recover, adapt)
Coordination capacity	It is needed to make optimal use for resources at disposal of citizens, planners, and decision makers
Redundancy	It is important to ensure that, in case components of the system are out of function, they can be substituted by spare components that have been included for this purpose
Diversity	Refers to inclusion of different components in the system that can be used simultaneously and can make up for each other's dysfunction
Foresight capacity	It is directly related to the uncertainties innate in the urban system and preparatory work that needs to be done to address potential disruptions
Independence	Gives the system a certain degree of self-reliance that may be needed to survive adversities
Connectivity and interdependence	Refer to interactions and relations that need to be established with other systems that exist in a broader scale. This is particularly important for shock absorption and timely recovery
Collaboration capacity	Highlights the need for an inclusive and bottom-up approach towards urban management
Agility	It is related to how fast an urban system can restore its functionality following a disruptive event
Adaptability	It is specifically related to the capacity to learn and to integrate the notion of "living with risk" in planning and everyday life practices
Self-organization	Includes establishing and strengthening community-based and voluntary activities centered on social institutions and networks
Creativity and innovation	They are required to find innovative solutions for addressing emergent and unprecedented problems
Efficiency	Entails considering costs and benefits of actions and developing strategies for maximizing benefits given the limited resources available
Equity	It is important to ensure fair distribution of benefits and impacts across different groups in the society

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5.2.2 – Dimension, assets and criteria - Urban resilience Assessment – Yamagata and Sharifi (2016)

Materials and environmental resources		
Code	Criterion	
M1	Ecosystem monitoring and protection	
M2	Using local and native material and species	
M3	Erosion protection	
M4	Protection of wetlands and watersheds	
M5	Availability and accessibility of resources (air, energy, water, food, soil, etc.)	
M6	Reduction of environmental impacts (various types of pollution)	
M7	Quality of resources	
M8	Biodiversity and wildlife conservation	
M9	Material and resource management (production, consumption, conservation, recycling, etc.)	
Society and well-being		
Asset	Code	Criterion
Socio-economic characteristics	S1	Population composition
	S2	Language abilities
	S3	Car ownership, mobility
	S4	Land and home ownership
	S5	Diver skills (to pool skills at the time of disasters)
Community bonds, social support, and social institutions	S6	Degree of connectedness across community groups
	S7	Volunteerism and civic engagement in social networks
	S8	Collective memories, knowledge, and experience
	S9	Trust, norms of reciprocity
	S10	Shared assets
	S11	Strong international civic organizations
	S12	Place attachment and sense of community and pride
	S13	Existence of conflict resolution mechanisms
	S14	Empowerment and engagement of vulnerable groups, social safety-net mechanisms
Safety and wellbeing	S15	Crime prevention and reduction
	S16	Security services such as police
	S17	Physical and psychological health
	S18	Preventive health measures
	S19	Responsive health measures
Equity and diversity	S20	Gender norms and equality
	S21	Ethnic equality and involvement of minorities
	S22	Diverse workforce in culturally diverse places
	S23	Decency, affordability, and fair access to basic needs, infrastructure and services
Local culture and traditions	S24	Past experience with disaster recovery; learning from the past
	S25	Cultural and historical preservation (identity); awareness of indigenous knowledge and traditions
	S26	Considering and respecting local culture and specificities in the process
	S27	Positive social, cultural, and behavioural norms
Economy		
Asset	Code	Criterion
Structure	E1	Employment rate and opportunities
	E2	Income (equality, multiple sources,…), poverty
	E3	Age structure of working population
	E4	Qualifications of working age population

	E5	Individuals with high and multiple skills; literacy (education)
	E6	Job density (housing-work proximity; extent of out commuting)
Security and stability	E7	Individual and community savings (stockpiles of supplies, monetary, etc.)
	E8	Collective ownership of community assets
	E9	Business mitigation, response and redevelopment plan
	E10	Insurance (domestic and non-domestic) and social welfare
	E11	Financial instruments (contingency funds, operating funds, capital funds etc.)
	E12	Stability of prices and incomes, property value
Dynamism	E13	Inward investment
	E14	Investment in green jobs and green economy (self-sufficiency, urban farming, etc.)
	E15	Integration with regional and global economy
	E16	Business cooperative or working relations (inter and intra)
	E17	Diverse economic structure and livelihood strategies
	E18	Openness to micro enterprises and micro-finance services, self-employment and dispersed ownership of assets;
	E19	entrepreneurialism
	E20	Public-private partnership
	E21	Private investment
	E22	Locally owned businesses and employers
Built environment and infrastructures		
Asset	Code	Criterion
Robustness and redundancy of critical infrastructure	B1	Redundancy of critical infrastructure, facilities, and stocks
	B2	Robustness and fortification (of critical infrastructure, buildings, vital assets, ecosystems, etc.)
	B3	Spatial distribution of critical infrastructure (measure against cascading effects)
	B4	Location of critical infrastructure and facilities
	B5	Consolidation of critical utilities and collaboration between utility providers
	B6	Multi-functionality of spaces and facilities
	B7	Shelter and relief facilities and services
Infrastructure efficiency	B8	Infrastructure efficiency B8 Regular monitoring, maintenance, and upgrade of critical infrastructure
	B9	Retrofit, renewal, and refurbishment of the built environment
	B10	Promotion of efficient infrastructure (technology update, metering, etc.)
ICT infrastructure	B11	Diverse and reliable information and communication technology (ICT) networks
	B12	Emergency communication infrastructure (before, during, after disaster)
Transportation infrastructure	B13	Capacity, safety, reliability, integrated-ness (connectivity), and efficiency of transportation
	B14	Inclusive and multi-modal transport networks and facilities
Land use and urban design	B15	Accessibility of basic needs and services throughout different stages (food, water, shelter, energy, health, education)
	B16	Site selection and avoiding risk areas and habitat areas (floodplain, flood prone; exposed coastal zone, greenfield)
	B17	Urban form (compact, dispersed, etc., SVF, aspect ratio)
	B18	Mixed-use development
	B19	Street type and connectivity
	B20	Density of development
	B21	Public spaces and communal facilities (for recreation, physical activity, etc.)
	B22	Green and blue infrastructure
	B23	Amount (percent) of impervious surfaces
	B24	Aesthetics, visual qualities, walkability
	B25	Landscape-based passive cooling
	B26	Passive lighting

	B27	Passive heating
	B28	Passive cooling
Governance and institutions		
Asset	Code	Criterion
Leadership and participation	G1	Strong leadership
	G2	Stability of leadership and political stability
	G3	Shared, updated, and integrated planning vision (long term)
	G4	Transparency, accountability, corruption etc.
	G5	Multi-stakeholder planning and decision making
	G6	Decentralized responsibilities and resources
Management of resources	G7	Efficient management of resources (funds, staff, etc.)
	G8	Skilled personnel and emergency practitioners
	G9	Population with emergency response and recovery skills (first aid, etc.)
	G10	Redundant capacity in terms of personnel
Contingency, emergency, and recovery planning	G11	Integration of risk reduction and resilience into development plans and policies
	G12	Existence of climate change and environmental policy and plans
	G13	Understanding risk patterns and trends
	G14	Continuous and updated risk assessment; scenario making for different kind of infrastructure and services (costs, losses, etc.)
	G15	Emergency planning and existence of emergency operation centre that integrates different agencies and organizations
	G16	Availability and update of contingency plans (e.g. post-storm traffic management)
	G17	Availability of mitigation plan
	G18	Early warning, evacuation plan, and access to evacuation information
	G19	Inclusion of transient population (tourists, etc.) in emergency planning
	G20	Inclusion of disaster resilience and lessons learned in the recovery plan
	G21	Speed of recovery and restoration
	G22	Ongoing process of revising and monitoring plans and assessments
	G23	Standardized, updated, and integrated databases for action planning, monitoring and evaluation purposes
Collaboration	G24	Cross-sector collaboration (alignment of aims) and partnership among organizations
	G25	MOUs and MOAs with neighbouring communities and agencies within the broader region
	G26	Knowledge and information transfer and best practice sharing (inter and intra-city)
R&D	G27	Innovation and technology update
	G28	Research (funds, facilities) on risks and academy-society collaborations
Regulations/ enforcement	G29	Availability and enforcement of legislations (policing, crime, building code, environmental law, business law, etc.)
	G30	Management of informal settlements
Education and training	G31	Behavioural issues and demand management
	G32	Education (from elementary or secondary school), training, and communication
	G33	Drills and exercises
	G34	Education and training for all linguistic groups; and all groups generally
	G35	Capacity building and enhancing awareness; dissemination of data and assessment results
	G36	Incentives for encouraging mitigation and adaptation (including self-mobilization, self-organization, etc.)

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5.2.2 – Matrices – Urban Resilience Assessment – Yamagata and Sharifi, 2016

Proposed matrix to indicate the relationship between resilience abilities and characteristics.

	Robustness	Stability	Flexibility	Resourcefulness	Coordination capacity	Redundancy	Diversity	Foresight capacity	Independence	Connectivity	Collaboration	Agility	Adaptability	Self-organization	Creativity	Efficiency	Equity
Plan/ prepare for																	
Absorb																	
Recover																	
Adapt																	

Proposed matrix structure to explore association between resilience abilities and urban resilience criteria. Example with the criteria of the materials and environmental resources dimension (Code M).

	M1	M2	M3	M4	M5	M6	M7	M8	M9
Plan/prepare for									
Absorb									
Recover									
Adapt									

Proposed matrix structure to explore association between resilience characteristics and urban resilience criteria. Example with the criteria of the materials and environmental resources dimension (Code M).

	M1	M2	M3	M4	M5	M6	M7	M8	M9
Robustness									
Stability									
Flexibility									
Resourcefulness									
Coordination capacity									
Diversity									
Foresight capacity									
Independence									
Connectivity									
Collaboration									
Agility									
Redundancy									
Equity									
Adaptation									
Self-organization									
Creativity									
Efficiency									

Appendix 22

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6.1 – Sustainability ‘dimensions’ identified in the reviewed literature – Cohen, 2017

Dimension	**Number of instances in the literature**
Environmental	26
Social	26
Economic	22
Integrative	17
Institutional	7
Material	3
Urban form	2
Cultural	1
Energy	1

Appendix 23

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6.1 – Key dimensions of a Smart city - Albino, Berardi and Dangelico, 2015

Key dimensions of a smart city	Source
IT education IT infrastructure IT economy Quality of life	Mahizhnan (1999)
Economy Mobility Environment People Governance	Giffinger et al. (2007)
technology economic development job growth increased quality of life	Eger (2009)
Quality of life Sustainable economic development Management of natural resources through participatory policies Convergence of economic, social, and environmental goals	Thuzar (2011)
Economic socio-political issues of the city Economic-technical-social issues of the environment Interconnection Instrumentation Integration Applications Innovations	Nam and Pardo (2011)
Economic (GDP, sector strength, international transactions, foreign investment) Human (talent, innovation, creativity, education) Social (traditions, habits, religions, families) Environmental (energy policies, waste and water management, landscape) Institutional (civic engagement, administrative authority, elections)	Barrionuevo et al. (2012)
Human capital (e.g. Skilled labor force) Infrastructural capital (e.g. High-tech communication facilities) Social capital (e.g. Intense and open network linkages) Entrepreneurial capital (e.g. Creative and risk-taking business activities)	Kourtit and Nijkamp (2012)
Management and organizations Technology Governance Policy context People and communities Economy Built infrastructure Natural environment	Chourabi et al. (2102)

Appendix 24

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6.1 - The Urban Sustainability Framework (USF) enabling dimensions and outcome dimensions - the Global Platform for Sustainable Cities (GPSC), 2018

Enabling dimension		
1: Governance and Integrated Urban Planning		
Key focus areas		Assessment and Measurement
1.1	Vision and long-term strategic planning	• Sub goal • Rationale • Key question(s) • Indicators
1.2	Stakeholders participation	• Etc.
1.3	Data management	
1.4	Trend analyses	
1.5	Land use and zoning	
1.6	Urban growth patterns	
1.7	Informal settlements	
1.8	Transport and mobility integrated with land use	
1.9	Cultural heritage	
2: Fiscal sustainability		
2.1	Accountability & transparency	
2.2	Creditworthiness	
2.3	Revenue & financial autonomy	
2.4	Expenditure management	
2.5	Management of debt & other obligations	
Outcome Dimensions		
1: Urban economies		
1.1	Economic performance	
1.2	Economic structure	
1.3	Business climate, innovation, and entrepreneurship	
1.4	Labour force	
1.5	Livelihood opportunities	
1.6	Income equality and shared prosperity	
1.7	Global appeal	
1.8	Connectivity and global links	
2: Natural Environment and Resources		
2.1	Ecosystems and biodiversity	
2.2	Air quality	
2.3	Water resources management	
2.4	Solid waste management	
2.5	Consumption and production patterns	
3: Climate action and Resilience		
3.1	Greenhouse gas inventory	
3.2	Energy efficiency	
3.3	Clean energy	
3.4	Climate change adaptation	
3.5	Disaster risk reduction	
4: Inclusivity and Quality of Life		
4.1	Housing	
4.2	Education	

4.3	Poverty reduction, hunger reduction, and food security	
4.4	Drinking water and sanitation	
4.5	Basic physical infrastructure	
4.6	Health and well-being	
4.7	Safety	
4.8	Social cohesion	

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6.1 – Urban sustainability categories in the literature – Cohen, 2017

Category	Total Number of Instances in the Literature	Number of Unique Elements in the Literature	Number of Sources Referencing
Air Quality	19	12	16
Arts, Culture and Recreation	40	15	22
Buildings	49	19	18
Built Environment	30	9	17
Climate Change	18	3	14
Community	22	9	15
Economy	104	41	40
Education	16	6	12
Energy	45	12	33
Equity	73	28	30
Food Systems	14	8	11
Governance	124	32	34
Growth and development	8	5	8
Housing	29	9	20
Infrastructure	29	11	16
Land Use	84	13	36
Management	16	7	10
Manufacturing	6	4	6
Material Use	33	15	22
Mobility and transportation	76	19	32
Natural Environment	99	29	49
Natural Resources	41	18	27
Pollution	15	4	10
Public Health	32	14	16
Quality of Life	23	9	16
Safety	42	12	20
Technology	15	4	13
Waste	32	12	23
Water	64	19	79

Appendix 26

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6.1 - List of potential indicators for a circular city

List of potential indicators for a circular city
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