Circular Cities: the case of Singapore

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Abstract

Purpose
Circular Economy (CE), as a new economic paradigm has gained traction in recent years. Cities' role in driving CE forward has been perceived as being increasingly important to achieve Sustainable Development (SD). For this reason, there is an urgency to understand what a circular city is and how it might be composed. This research explores the ways in which the city-state of Singapore is transitioning to a CE.

Approach
A systematic literature review on CE and cities was carried out using a bibliometric review and a snowballing technique. This review was performed on academic and on non-academic papers.

Findings
This research has confirmed the lack of robust circular cities case studies. As Singapore has already begun its journey towards circularity, this article examines its current efforts and offers recommendations in the design and implementation of CE policies that may be valuable not just for Singapore but also for high-density and rapidly expanding cities around the world that require a new development pathway to emulate.

Originality
This manuscript is the first detailed, independent and comprehensive review of Singapore's approach to Circular Economy.

Keywords: Circular Economy, Zero-waste, Circular Cities, Circular Materials, Sustainable Development, Singapore

1. Introduction

Through past decades, our approach to production and consumption has contributed to world problems, such as the inefficient allocation of resources, social inequity, extreme weather conditions, ocean pollution and loss of biodiversity. It is expected that these issues will expand and reach crisis levels (Stockholm Resilience Center, 2019).

The current economic 'take-make-use-waste' model is leading us to use more resources than Earth can replenish (Stockholm Resilience Center, 2019) leaving the financial yields to the lucky few and the social and ecological devastation to the many. It is time to rethink the way we operate, and transition to a more sustainable future (Geissdoerfer et al., 2017) by means of 'Sustainable Development (SD)' (Pomponi and Moncaster, 2016), i.e. a polysemic and comprehensive concept that attempts to reconcile and fuse together

three dimensions of development: economic, environmental and social (Beaulieu et al., 2015). This approach opens the mind to new and radical ways to reach equilibrium between economic prosperity and social equity, while at the same time living within the Earth's providing capacity.

Amongst the available approaches is the concept of Circular Economy (CE), a new economic and development paradigm that has gained traction in recent years (Ghisellini et al., 2016; Kirchherr et al., 2017). The Ellen MacArthur foundation (EMF) has defined the CE as an economy based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems (Ellen MacArthur Foundation, 2019). However, this concept still needs to be critically questioned and validated (Suárez-Eiroa et. al, 2019, Hobson and Lynch, 2016) in order to ascertain its ability to be the most suitable paradigm for SD.

The remainder of the paper is organised as follows. Section 2 explains the approach we followed for the literature review. Section 3 provides a review of the related literature on CE to place this paper in a proper context. Section 4 discusses the concept of Circular Cities, highlights the lack of a unified approach for its implementation, discusses three of its frameworks and compares Singapore and the city of Porto using one of these discussed frameworks. Section 5 focuses on Singapore as an example of how a city could transition to become a Circular city. In section 6 we highlight opportunities for Singapore to increase its progress towards a CE, particularly in materials and resources. In section 7 we discuss the main challenges for Singapore and we make suggestions for a way forward. Section 8 concludes the paper.

2. Research methodology

Our literature review was carried out through Dimensions (Dimensions, 2019) due to its dynamic research data platform to explore connections and develop meaningful data. Data collected for this study was last updated in May 2020. The research method employed in this article was a bibliometric review followed by a snowballing approach (Jalali and Wohin, 2012) for a more in-depth evaluation. This research process included:

- On the database to search in the title and abstract for the combination of the following terms: 'circular economy', 'cities' and/or 'circular cities'.
- To start using the snowballing procedure we identified a set of papers that are focused on CE and/or circular cities and that are either high on the number of citations (e.g. Ghisellini et al, 2019) or that using our judgment are highly relevant to the topic explored on this paper (e.g. Ferreira A and Fuso-Nerini F, 2019).
- The review was performed on academic papers (e.g. peer-reviewed journal articles and conference papers) and on non-academic papers (e.g. policy documents, reports, CE practitioners' publications, government agencies).

- Just documents written in English were reviewed.

Based on our snowballing technique we reviewed a total of 70 documents. Particularly for section 5 and 6 we also combined our literature review with a narrative technique (Caprotti, 2014) from two of the authors who are residing in Singapore and are professionally engaged with CE (one of the authors is a committee member of ISO/TC323 on CE) and exploring it also on an academic level.

3. Circular Economy

The coining or concept of Circular Economy (CE) cannot be traced back to one single date or author, but to several schools of thought and concepts such as Industrial Ecology, Cradle to Cradle, Performance Economy, Biomimicry, and Blue Economy (Beaulieu et al., 2015).

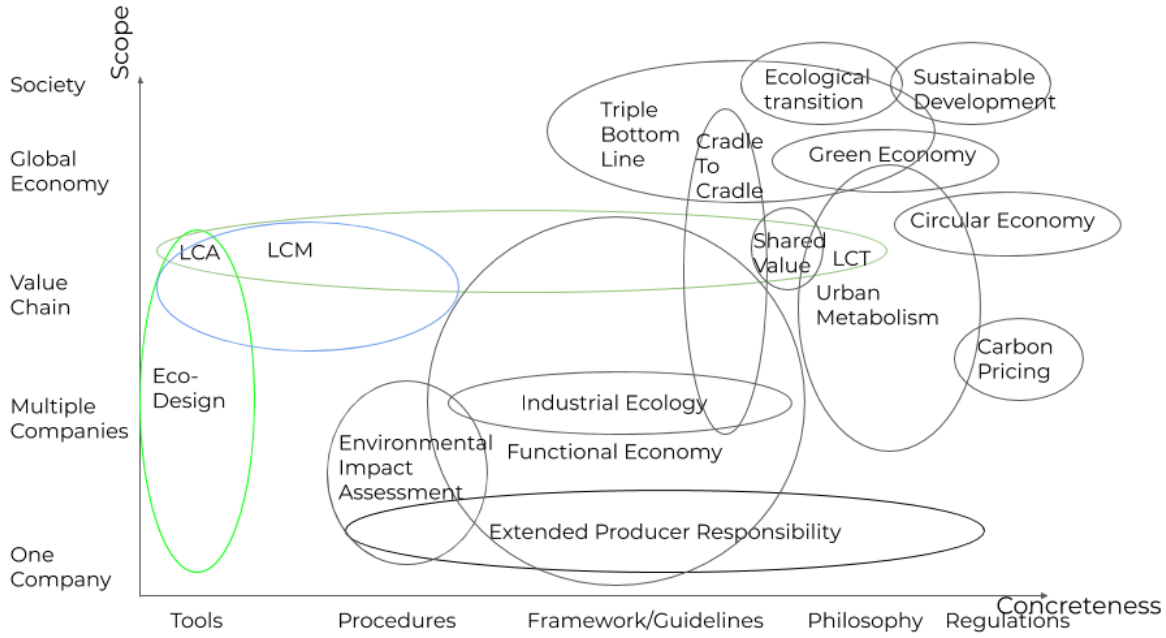

Figure 1. Scope versus concreteness mapping (Updated from Beaulieu et al., 2015) (LCA: Life Cycle Analysis; LCM: Life Cycle Management; LCT: Life Cycle Thinking).

According to Beaulieu et al. (2015), besides SD as a main driver, CE is building on preceding thinking and related concepts of 1) Ecological Transition, 2) Green economy, 3) Functional Economy, 4) Life Cycle Thinking, 5) Cradle-to-Cradle thinking, 6) Shared Value, 7) Industrial Ecology, 8) Extended Producer Responsibility and 9) Eco-design.

As can be seen in Figure 1, the supporting concepts vary in concreteness and scope, leading to a fragmented understanding of what CE is exactly, making not just the definition of CE challenging, but also

measuring and monitoring its performance.

Given this multidisciplinary nature, since its conception CE has been defined in numerous ways (Ruiz-Real et al, 2018). In this article we align with the CE definition proposed by Suárez-Eiroa et al., (2019):

> "A regenerative production-consumption system that aims to maintain extraction rates of resources and generation rates of wastes and emissions under suitable values for planetary boundaries, through closing the system, reducing its size and maintaining the resource's value as long as possible within the system, mainly leaning on design and education, and with capacity to be implemented at any scale" (p. 958).

For the purpose of this research this definition is useful because it integrates operational principles, levels of implementation and objectives of CE, which we will use later in the paper to further discuss its application in Singapore.

In order to determine whether a circular city contributes to SD, the degree of circularity of a city would need to be measured or validated. As Walker et al. (2018) point out, there are various tools to assess product level material efficiency and circularity, such as Life Cycle Carbon Footprint (LCCF), for an output in terms of CO_2 emissions; Life Cycle Assessment (LCA), for a broader set of outputs related to environmental impact such as Global Warming potential, Ozone Depletion potential, eutrophication, photochemical smog, toxicity, resource depletion, and land and water use; Material Circularity Index (MCI), for a focus on environmental circularity; and Eco-Cost, for a focus on economic circularity. However, these tools fail to completely capture the circularity of a city since they were not developed for that purpose, and other relevant factors such as mobility, digitalisation, and connections between sectors, to mention just a few, should be included when measuring how circular a city is.

A common feature of CE indicators, as Walker et al. (2018) argue is that they typically focus on improving resource efficiency by diverting material away from landfill or incineration, but it is less clear how such indicators correlate with wider environmental and social impacts. For example, the MCI just measures the percentage of reused and recycled material, recycling efficiency at manufacture and end-of-life, the product life span and functional unit relative to industry averages. Another example is Eco-cost, i.e. to what extent a manufacturer can account for all the impacts its products have on different circularity measures such as refurbishment or life extension.

A reasonable conclusion is that all these indicators give different results, it is very complex to compare them, and they do not address all aspects that CE should measure. In sum, no common ground for the variety of existing approaches has been established (Kalmykova et al., 2018). We agree with the Circularity Gap Report, 2019 (Wit et al., 2019) which states that the CE is conceptually promoted as a great idea, but when it is time to measure it lacks originality and a well thought-out methodology. Lastly, further developments on measuring CE could extend to complete regions, cities or states and the methodology

could be developed into an official ISO standard (Tuppen, 2016).

4. Circular Cities

Cities are driving the global economy. Currently over 55% of the global population lives in cities, and this is expected to increase to 80% by 2050 (World Bank, 2019). City-dwellers generate 80% of global GDP. Furthermore, cities as a whole currently require 40 billion tonnes of resources in order to maintain their ecosystems, and this is likely to reach 90 billion tonnes by 2050. This is far more than is considered responsible or even sustainable (Swilling et al., 2018). Cities are concentrators of flows between consumers and businesses too. Because of this, cities' role in driving CE forward and reaching a sustainable future has been perceived as increasingly important and necessary (Lorbach et al,. 2016, Bonato and Orsini 2017). Cities offer the optimal scale and context for CE in terms of production and consumption of resources, allowing cities transitioning to CE to use the self-declared label of 'circular hotspots' (Prendeville et al., 2017). The European Union (EU) acknowledges all of these and promotes CE to tackle these challenges, by dedicating funds towards its implementation (e.g. Horizon 2020; LIFE) and as a part of the economic recovery strategy of the EU long-term budget 2021-205 (e.g. European Green Deal and its new Circular Economy Action Plan) (European Commission, 2020).

The Asian Development Bank (2019) forecasts that in 2025, 21 out of 37 of the world's megacities - cities with 10 million or more people - will likely be in the Asia and Pacific region. Asia's cities generate 80% of the region's GDP, use 60-80% of all energy and resources and create 75% of the region's carbon emissions. Lastly, seven Asian countries alone will contribute to 45% of global GDP in 2050 (China, India, South Korea, Japan, Indonesia, Thailand and Malaysia) (Asian Development Bank, 2015). Furthermore, in the 2015-2030-time span, cities will become accountable for 91% of global consumption growth (Mckinsey & Company, 2016). Should there be any doubt of the relevance of a CE in Asia – or any other alternative that will be able to counter the effects of the rise of this densely populated, climate change-prone region, these figures would relieve us of that hesitation.

Hence, there is an urgency to gain understanding on what a circular city is, what is it for and what its composition would be, not just in a general way, but in one that also considers the local context where it will be implemented.

In the midst of a general confusion and ambiguity between 'circular city' and other terms such as 'sustainable cities', 'green cities', 'smart cities', 'knowledge cities', etc. (Jong et al., 2015)—which also predominate as terms to denominate forward-thinking cities—it is necessary to give a definition. Prendeville et al. (2017) who studied six cities in a transition from the current dominant linear economy to a circular economy concluded that in cities CE is still a confusing term. Therefore, they proposed a

definition of what a circular city constitutes: “one that practices CE principles to close resource loops in collaboration with its stakeholders to accomplish a future-proof city” (Prendeville et al p. 187).

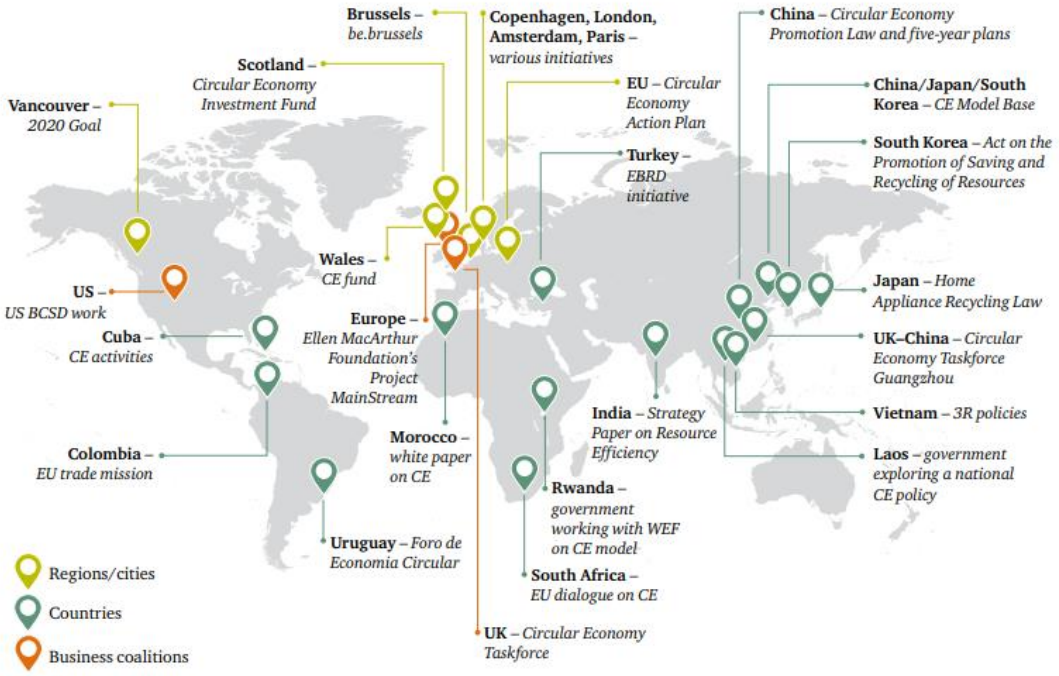

Figure 2. Circular Economy Activity around the world (Preston and Lehne, 2017).

As shown in Figure 2, the cities in our findings that show leadership and progress in transitioning to CE are Amsterdam (Roemers et al., 2018), Glasgow (Circle Economy, 2016) Rotterdam and Charlotte (Gladek et al., 2018). In addition to the map, Bilbao (Circle Economy, 2018) and Porto (Ferreira and Fuso-Nerini, 2019) are also on their journey to become circular cities. These cities are using existing data to map a transition path toward a ‘fully circular city’ that matches their local situation, thereby defining new metrics, strategies and policies, and monitoring tools to track the various values that could come with circular transition. Moreover, several guiding models have been proposed for cities implementing CE (Prendeville et al., 2017, Marin and Meulder, 2018, Sylva, 2018). However, no framework yet has been widely used or put to test to prove of being effective. Nonetheless, in the next paragraphs we will briefly explain three of the approaches that are worth mentioning given its orientation towards its implementation; a vision for a Circular city (1), the ReSOLVE framework (2) and the Circular City Analysis Framework (CCAF) (3).

1) A recent publication by Circle Economy and Holland Circular Hotspot (2019) suggests a shift from linear to circular, in certain percentages, for the following systems that together operate within a city, thereby creating a circular city as shown in Table 1 below. The approach looks at utilising technology, social innovation, design and coalition building in a collaborative manner, and analyses the ways major industries and sectors can be turned circular, as well as the overall benefits a city can gain from moving to a circular system.

Table 1. A vision for a circular city (Holland Circular Hotspot, 2019).

Housing and 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.

2) The ReSOLVE framework (Regenerate, Share, Optimise, Loop, Virtualise, and Exchange) was introduced by the Ellen MacArthur Foundation (2015) and identifies these six pillars that organisations should implement for a transition to a CE. This approach was not designed particularly for CE implementation in cities but we believe some of its principles contribute towards a circular city if they are applied systematically. The 'Regenerate' pillar (Re) seeks to restore natural capital and increase the ecosystems' resilience by returning the valuable biological nutrients safely to the biosphere either by anaerobic digestion or composting. This is enabled by the cradle to cradle philosophy which states that technical and biological nutrients should be kept separate through a product's whole life cycle from the initial design stage onwards. In the built environment this pillar promotes the use of renewable energy

to power buildings. The 'Share' pillar (S) pursues the maximum utilisation or reuse of components, products or assets throughout sharing schemes, exchange platforms, or other sharing practices (e.g. office sharing or peer to peer renting). The 'Optimise' pillar (O) is about increasing the performance and efficiency of a product and leveraging big data, automation, remote sensing and steering, but also removing waste in the production and the supply chain. This pillar is aligned closely with the Total Productive Management philosophy. The 'Loop' pillar (L) has four main objectives: to recycle material; to extract biochemicals from organic waste; to digest waste anaerobically; and lastly to procure the manufacture of products and components. The 'Virtualise' pillar (V) focuses on two types of dematerialisation: direct (e.g. dematerialise conventional books and transform them into e-books, and use the same process with music, movies, etc.); and indirect dematerialisation, where the product in itself is not virtualized but the way of obtaining it, is (e.g. online shopping). The last pillar, 'Exchange' (E), has three categories: innovation by choosing new products or services (e.g. multimodal transport); new technologies (e.g. 3D printing); or the replacement of old materials with new materials.

3) Circular city Analysis Framework (CCAF) (Ferreira and Fuso-Nerini, 2019). This is the most recent published framework for implementing and tracking CE discovered through our literature review. This framework has been applied for tracking purposes already to the city of Porto, Portugal. The CCAF proposes to split 27 different indicators in three different circles (inner, intermediate and outer):

    1. In the inner circle the indicators included are: wind potential; solar potential; green roofs; and a balance between imports and exports.
    2. In the intermediate circle the indicators are:
        a. Transportation: public transport usage and electric energy consumed
        b. Building sector: retrofitting and the percentage of degraded buildings
        c. Food sector: the percentage of food waste treated in general and the percentage of food waste treated in small and medium enterprises
        d. Water management sector: safe water and water efficiency
        e. Waste management sector: landfill waste and the percentage of separated waste
        f. CE innovation: The percentage of governmental budget allocated to CE innovation
        g. In specific industries: recycling rate and the percentage of synergies.
    3. In the outer circle the indicators measured are:
        a. The percentage of students not completing high school and the percentage of students achieving a tertiary level qualification.
        b. Digitalisation: accessibility to smartphones

c. Demographics: the balance between men and women, most representative age group in years, and the percentage of working age citizens
d. Policies: the percentage of men and women in politics.

As the first two approaches could serve on how to transition to a circular city, the simplicity and applicability of this framework were among the main characteristics that made us choose this approach. We especially find this framework handy to make comparisons between cities when measuring which city is more circular than others. Lastly, we were pleased to see that a target in each indicator was set for tracking purposes within this framework. However, we also found certain elements that we would like to be included, particularly indicators that overlap in the three dimensions (social, environmental and economic), which could measure more completely the circular level. For example, economic polarisation (e.g. the income gap between rich and poor and the percentage of middle class citizens), the economic mobility, life quality index and the perception of corruption to mention just a few. Additionally, another indicator worth mentioning to include is a foresight key performance indicator that can tell us if the government from a city has run long-term projections on the possible futures the city could be challenged with. Nonetheless, as Ferreira and Fuso-Nerini (2019) proposed, this approach could be further enriched by the work of other CE practitioners and the CE research community.

We have included in Table 2 below a comparison between Singapore and the city of Porto, using 19 of the CCAF indicators (we excluded 8 indicators out of 27 because the corresponding information was not found available for the case of Singapore). This comparative table reveals contrasting results. On the one hand, it shows that Singapore could do much more to increase the percentage of renewable energy penetration, green roofs and recycling rate. On the other hand, this table also shows Singapore's progressive position in the transport sector by its public transport and electrical energy high percentage use. In the social dimension we found also contrasting results. While it is positive for digitalisation and consequently for circularity that the percentage of people with access to smartphones is high and that the percentage of students that quit basic education is low; there is still to improve on the social dimension on the balance between women and men in politics. We also believe that to allocate a CE budget (indicator 7), would be a logical starting point for a transition to CE and to show improvements in the areas that Singapore is lagging, and to claim a global leading role in areas such as the transportation sector.

Table 2. Singapore and Porto comparative table using the CCAF (Ferreira and Fuso-Nerini, 2019 and our own sources)

Field	Indicator	Singapore	Porto
Local Resources	1. Wind Potential (m/s)	3.98 [1]	6.78
	2. Solar Potential (W/m2)	1652 [2]	1750
	3. Green Roofs (%)	0.34 [3]	0.50
	4. Import / Exports (%)	0.9 [4]	1.5
Renewable Energy	5. Renewable energy penetration (%)	8 [5]	63
	6. Access to electricity (%)	100 [6]	100
CE innovation	7. CE Innovation Budget	0 [7]	0.009
Food	8. Food Waste Treated (%)	17 [8]	21
Transport	9. Public Transport Usage (%)	60 [9]	19.6
	10. Electrical energy use in transportation (%)	5.5 [10]	0.6
Recycling	11. Recycling rate	60 [11]	100
Water Management	12. Safe Water Accessibility (%)	100 [12]	100
Waste Management	13. Landfilled Waste (%)	2 [13]	1
Education	14. Basic Education Quitting (%)	6 [14]	11
Digitalisation	15. Accessibility to Smartphones (%)	90 [15]	71.6
Demographic	16. Balance between Women & Men (%)	42 [16]	55
	17. Heaviest Age Group (years)	45-54 [17]	60-69
Policies	18. Active Population (%)	67.7 [18]	59.2
	19. Women & Men balance in Politics %	23 [19]	38

[1] https://globalwindatlas.info/area/Singapore
[2] https://globalsolaratlas.info/?s=1.3,103.8
[3] https://sustainabledevelopment.un.org/content/documents/19439Singapores_Voluntary_National_Review_Report_v2.pdf
[4] https://tradingeconomics.com/singapore/balance-of-trade
[5] http://www.ren21.net/wp-content/uploads/2018/06/17-8652_GSR2018_FullReport_web_final_.pdf
[6] http://www.ren21.net/wp-content/uploads/2018/06/17-8652_GSR2018_FullReport_web_final_.pdf
[7] https://www.singaporebudget.gov.sg/budget_2019/budget-measures
[8] https://www.nea.gov.sg/our-services/waste-management/waste-statistics-and-overall-recycling
[9] https://www.straitstimes.com/singapore/more-singaporeans-take-bus-mrt-to-work-government-survey
[10] https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/SES18/Publication_Singapore_Energy_Statistics_2018.pdf
[11] https://www.nea.gov.sg/our-services/waste-management/waste-statistics-and-overall-recycling
[12] https://ourworldindata.org/water-use-sanitation
[13] https://www.nea.gov.sg/our-services/waste-management/waste-statistics-and-overall-recycling
[14] https://www.oecd.org/pisa/PISA-2015-singapore.pdf
[15] https://www.todayonline.com/singapore/smartphone-penetration-singapore-highest-globally-survey
[16] https://data.gov.sg/dataset/resident-population-by-ethnicity-gender-and-age-group
[17] https://www.populationpyramid.net/singapore/2018/
[18] https://www.singstat.gov.sg/sif
[19] http://archive.ipu.org/wmn-e/arc/classif010219.htm

5. Singapore

Our literature review reveals that there is a lack of robust circular cities case studies and also that there is no consensus on recommending a model to be adopted and implemented (Ferreira and Fuso-Nerini, 2019). Indicators and measurements of CE in cities could not be weighed against each other. Just a few case studies that contributed to the understanding of CE implementation were found during our literature review (e.g. Prendeville et al., 2017; Ferreira and Fuso-Nerini, 2019). Furthermore, a detailed and comprehensive review of Singapore's approach to CE is currently not available. The following section offers a call to further research in applying the above-mentioned framework on a deeper level, potentially creating a starting point for tracking the progress of CE in Singapore, i.e. carrying out a 'baseline study'.

Pioneering the way forward, Singapore is an example of how 'circular-to-be' cities are developing, and is therefore worthy of analysis. Singapore's experiences on the CE will differ from that of developing countries, yet experiences could offer valuable insights in the design and implementation of CE policies for high-density and rapidly expanding cities with similar characteristics, such as strong government, a state land system and planning tradition (Diao, 2018). Despite the singularity of Singapore as a small island state, it has seemingly contrasting performances. On one hand, Singapore has the seventh-largest ecological footprint in the world according to a recent World Wildlife Foundation (WWF) report (McLellan et al., 2014). This impact is very high considering Singapore´s economy ranked number 37 last year in terms of GDP, according to the International Monetary Fund (2018). On the other hand, Singapore is regarded as Southeast Asia's most modern city in terms of construction of buildings and commercial developments (Liew, 2018). Also, some sustainable innovations initiated in Singapore, particularly in the transportation field, have already been applied in other cities such as London, Stockholm and Shanghai (Diao, 2018). Many initiatives come together under the collective vision of the 'City in a Garden', dating back to 1963 (Singapore National Environment Agency, 2019), or the future vision 'A City in Nature' as recently published by Singapore's Centre for Liveable Cities, a governmental body that is a part of the Ministry of National Development (2017).

That having said, almost all of the Singapore city-state is less than 30 years old and is managed in a way so that randomness is excluded. As the famous architect Koolhaas (Soleri, et al, 2013) indicates, "if you ever find chaos in Singapore, it is intentional, even nature is entirely remade". Moreover, the story of Singapore describes how it overcame obstacles to be transformed from a colonial backwater into a thriving metropolis; for example, in global studies that measure innovation rates Singapore is always placed in the top ten of the world's most innovative economies (Gin, 2017). Yet as everything is planned and remade,

the adoption of the iterative process that the development of a circular city promotes, may present a challenge.

CE is increasingly a less-fragmented concept across Singapore, even though currently mainly a concern of consultancy agencies, NGOs and individual businesses and ministries, primarily the Ministry of the Environment and Water Resources (MEWR). Nonetheless, Singapore has adopted 2019 as the Year towards Zero Waste (Towards Zero Waste, 2019), as it is working towards becoming a Zero-Waste nation by reducing its consumption of materials and increasing reusing and recycling rates.

During the summer of 2019, Singapore's Zero Waste Masterplan (Towards Zero Waste, 2019) was published, which has a focus on three waste streams: e-waste, packaging waste, and food, and new technologies and innovation that the government is exploring to close waste loops completely. Currently, the understanding of these waste streams is based on the recycling rates (Singapore National Environment Agency, 2019) as well as focus studies for reuse. From a CE perspective, in addition to recycling, the 10R approach suggests 8 additional ways to retain the value of resources during their life cycle: refuse; reduce; repair; refurbish; remanufacture; re-purpose; recover (energy) and re-mine (landfill mining) (Walker et al., 2018). And this merely reflects the resource level; it does not touch upon the impact of design and education, nor its relation to the planetary boundaries our definition of CE refers to. Therefore, the figures only give a partial impression of Singapore's current practice and potential in adopting CE.

Also during the summer of 2019, the Resource Sustainability Bill was released. Once ratified, it will "impose obligations relating to the collection and treatment of electrical and electronic waste and food waste, to require reporting of packaging imported into or used in Singapore, to regulate persons operating producer responsibility schemes, and to promote resource sustainability" (Singapore Statutes Online, 2019, p. 1). In contrast, the recently released Economic Budget for 2020 (Singapore Budget, 2020) shows no compelling signs of CE and little on sustainability economic policies on the backdrop of COVID19 coronavirus pandemic. This is contrasting with practices in China and Europe, where CE is increasingly evident in policy and annual budgets aiming to maintain economic growth while at the same time improving social equity and environmental quality. However, it remains to be seen what the effects of the policies and assigned budgets are in driving the change towards CE in the aforementioned countries and regions, as CE is under development and being implemented by an iterative process; its ultimate results might only be known decades from today. At the same time, the apparent effects of climate change and other social and ecological indicators of planetary health are that severe, that remaining inactive as a leading economy is not an option.

However, we see Singapore is making multiple efforts towards a CE in recent years that are worthwhile to note. Within specific context or by favour of specific, influential stakeholders are starting to explore a CE model, such as JTC, the industrial land authority that is researching how the industrial area 'Jurong

Island' may become more circular (Metabolic, Witteveen + Bos, 2019). A recent partnership with the Finnish firm Neste, the world's leading supplier of renewable diesel will allow Singapore to lead the production of this fuel and also jet fuel by 2022 (Tan, 2019), by converting raw materials such as waste animal fat, plant oils, and potentially liquefied waste plastic to renewable energy. Also, explorations into optimising infrastructure such as Pneumatic Waste Conveyance Systems and new treatment facilities allow Singapore to venture in depth into resource recovery (Towards Zero Waste, 2019).

Taking into account the scale of the city-state and its current CE ambition as 'Towards a Zero Waste Nation' allows for optimism when it comes to thinking about Singapore as a circular city. Singapore is agile and as soon as she has set her focus on an idea or methodology, it will grow into a leading force. This may happen on a national level, such as the case was with adopting an economic focus on fin-tech.

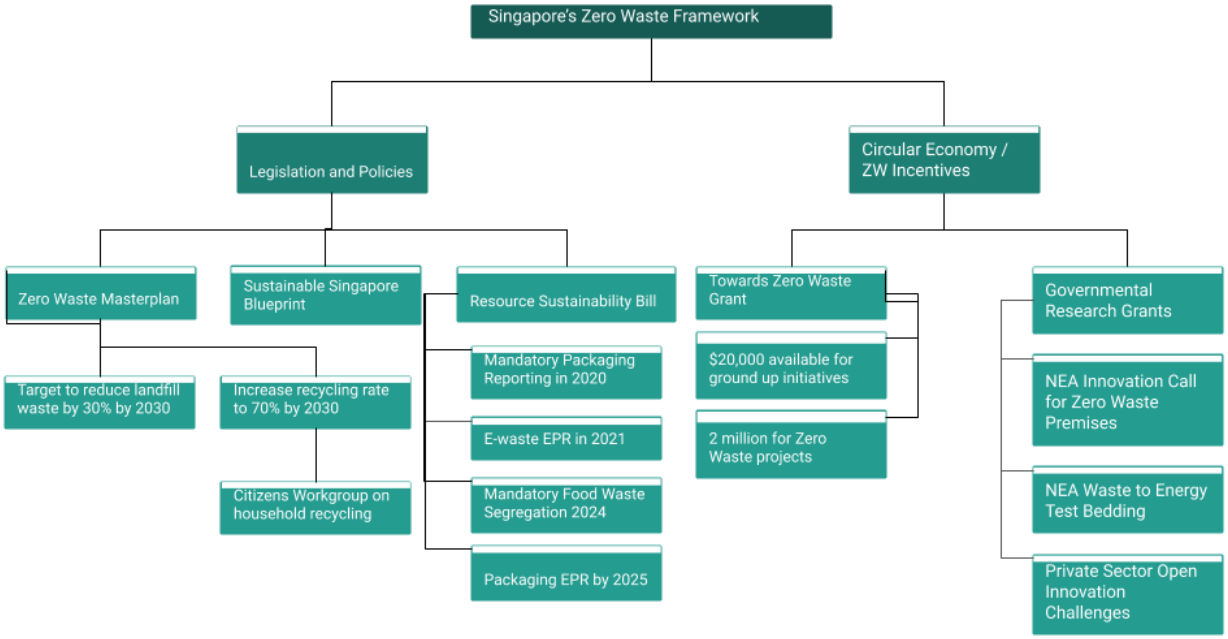

Figure 3. Singapore's Zero Waste Framework (Source: So Now Asia)

Most of Singapore's Zero Waste framework have been established in recent years through recent governmental efforts (e.g. Singapore's Long-Term Low-Emissions Development Strategy), and other legislations that are planned for the next five years to achieve Singapore's main goal of 30% reduction of waste to landfill by 2030, as well as a 70% increase in household recycling. Together with a legislative framework, financial incentives are being introduced to encourage the private sector towards a CE (National Climate Change Secretariat Strategy Group, Prime Minister's Office, 2020).

6. The next steps for Circular Cities

Our literature review has highlighted the complexity of measuring the effectiveness of CE implementations in cities, as the evaluation of the performance of circular city projects still requires systemisation. Furthermore, CE's methodology is still very limited as there is great scope for conceptual improvements and for being more receptive to other research fields (Geissdoerfer et al., 2017, D'Amato et al., 2017). Pomponi and Moncaster (2017) emphasised that CE must take a future-oriented and multidisciplinary approach within cities in order to move from a narrow focus to a wider basis. Moreover, most of the CE academic and practitioner literature appears to be too optimistic and approbatory (Suárez-Eiroa et al., 2019, Leising et al., 2018). Also, the practice of CE is most of the time based on examples taking place in Europe, which risks neglecting important geographical foci and differences.

In order to address the need for standardisation, the International Organization for Standardization (ISO) has established a Technical Committee ISO/TC 323 to develop the requirements, frameworks, guidance and supporting tools that relate to the implementation of CE projects (ISO, 2019). The resulting standard would, in the future, further assist to define the value of a CE for a particular project or application, and hence motivate more businesses to adopt circular measures.

In addition, the guiding principles to which attention should be drawn here are the Sustainable Development Goals (SDGs), a collection of 17 global goals set by the United Nations General Assembly in 2015 (United Nations, 2015). In relation to the further scope of this article, the United Nations Sustainable Development Goals (UN SDGs) may be found relevant, because CE is seen as a systematic approach to complete several of these goals (Ferreira and Fuso-Nerini, 2019).

The United Nations Conference on Trade and Development (UNCTAD) (2019) closely links the benefits of a CE with the fulfilment of the SDGs. Particularly in reference to target number 11 'Sustainable cities and communities' (UN SDG11), so far there is no strong link or direct contribution of CE practices to this target, but just indirect contributions, to 'Water and sanitation' (UN SDG6), 'Affordable and clean energy' (UN SDG7), 'Decent work and economic growth' (UN SDG8), and 'Responsible consumption and production' (UN SDG12), that could impact positively to build sustainable cities (Schroeder et al, 2018). As cities are resource intense systems and contribute to global GDP significantly, it is crucial to understand to what extent is the dominating CE view on how cities should develop desirable and aligned with the UN SDG.

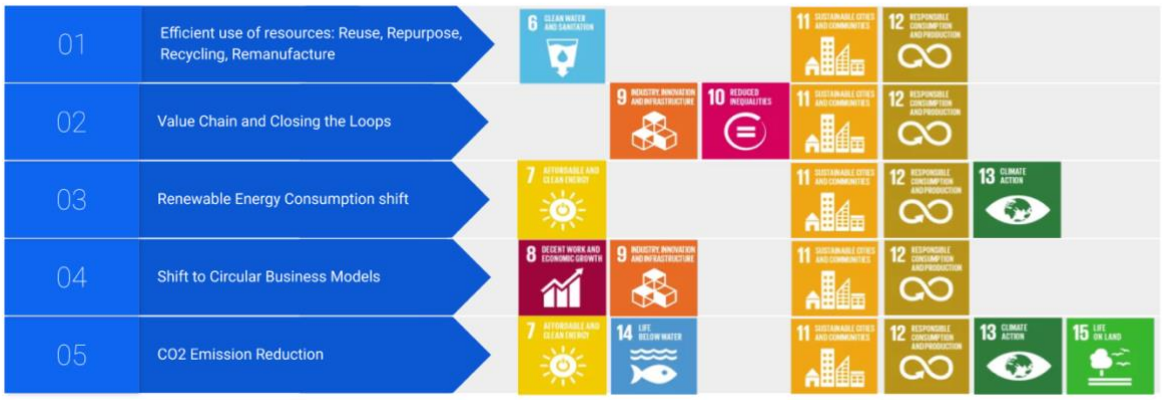

Figure 4. Circular Economy and Sustainable Development Goals (Source: So Now Asia)

Moreover, to prevent CE to be discarded as a partial solution or even reductionist by nature, and to avoid inarticulate CE actions to take place (Turkeli et al., 2018), it is essential that CE is embedded into and monitored from a system perspective. We have yet to determine whether a system perspective in parallel with experimentation on a micro-level is the best approach forward.

In the same way, there is an urgent need for doing more research on the societal aspects of CE regarding other regions in the world implementing CE measures (Preston and Lehne, 2017). Cities are first-and-foremost places for people and their sustainable futures. In any conceptualisation of a circular city, these issues require consideration (Prendeville et al., 2017). Therefore, a necessity throughout the process of building a circular city would be to engage with urban citizens, not just scholars or practitioners, but urban citizens from a range of settings: from deprived communities in deindustrialised cities to informal settlements. These are urban citizens who can be brought around the same table as practitioners, policymakers, and the like. This means including, but also looking beyond, the world of advocates, NGOs, think tanks, and all others with specific and party-political agendas.

7. Challenges and suggestions for way forward

We believe that the cities of the future have to operate differently from the cities of the past, and CE principles could certainly help in this transition. In our attempt to assess Singapore's circularity, we have come to the conclusion that Singapore has many opportunities for progress. With its growing ambitions and initiatives towards SD, Singapore has the capacity to become a leading circular city. A government-wide vision and policy on the CE would enable industries to make the required transition and this is expected to lead to a more rigorous implementation of circular principles. Also, the government can take a leading role by means of its procurement power.

As for a suggestion on how to facilitate CE on a micro-level, Singapore could start by establishing a physical location where a creative community can meet and share their latest developments. This 'Circular Hub' would be constantly innovating on-the-go, allowing start-ups to find the testbeds for their circular concepts and products, including a makerspace enabling the exchange of new technologies and benefiting the evolution of circular practices.

Lastly, there is an urgent need for more research on what the circular city approach may hold for Singapore's systems of food, energy, mobility, housing and infrastructure, water, consumer goods, plastics and industrial parks (OECD, 2019). Without better understanding what resource flows Singapore has and needs in order to sustain itself, circular models and policies cannot be applied and enforced effectively. In addition, in order to contribute to the discourse on CE as potentially the most suitable paradigm for SD— and in order to achieve this development in Singapore— more research is needed on how the SDGs relate to a Circular Economy for Singapore.

By studying Singapore's experiences in endorsing a circular approach, we have raised policy implications crucial not only for Singapore to meet its own future social, environmental and economic demands but also for other cities to achieve SD. We shall also discover if the current framework set about by the Singapore Government (see Figure 4) is sufficient to achieve SDGs, or if further work is necessary.

8. Conclusion, limitations and further research

From a scholarly position Circular Economy is still an evolving field of study, and as a new economic and development paradigm still needs to be critically questioned and validated. We have examined its ability as a suitable paradigm for SD in cities. We believe our research makes a contribution to these questioning and validation by providing a substantial review of the related literature on CE. Our research has confirmed the lack of robust circular cities case studies and has highlighted the complexity of measuring the effectiveness of CE implementation in cities. To bridge this gap, we have put to test a recent Circular City Analysis Framework produced by Ferreira and Fuso-Nerini (2019) and proved it valuable. Using this framework, we have compared the circularity of Singapore city-state and Porto, both quantitatively and qualitatively. Additionally, we have recommended complementary elements for measuring CE progress in cities more holistically.

It is important to bear in mind the limitations of this research. Our bibliometric review might have missed out on some literature that still falls within the scope of our research. Such limitation is possibly due to the query construction for our approach. As we selected publications based on the literal use of the concepts 'circular economy' and/ or 'circular cities' by using these exact keywords, without a wildcard (e.g. 'circular econom*), we may have missed publications containing terms semantically different but with the same meanings, e.g. circular economic. By our snowballing approach we believe we have minimised

the probabilities of missing out relevant publications, however, this approach and our narrative technique on the last chapters are inevitably affected by our subjective judgments.

Despite these limitations, this research is the first detailed, independent and comprehensive review of Singapore's approach to Circular Economy. Among cities proactively pursuing SD, Singapore is a case of particular interest to researchers and policy makers. By focusing on this city-state, examining its current efforts and offering insights for a sound transition to CE we hope to contribute to a starting point for tracking CE progress in Singapore and also to stimulate further discussion in the CE research and practitioner communities that would start to consider other important regions, beyond Europe, for a wider CE implementation. This will certainly positively impact on the global progress for Sustainable Development. Even so, each city has its different needs, different priorities, and different challenges, making one single pathway towards CE impossible.

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