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Article

The Global Movement of the Transition from Linear Production to the Circular Economy Applied to the Sustainable Development of Cities

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ABSTRACT

The process of the linear exploration production, production, usage and waste generation has been taking humanity to the planetary boundaries. The transition to circular economy models dissociates the economic growth from the natural resource depletion and from the environmental degradation. The opportunity to make changes and to find vital solutions to the planet's sustainability emerge in the cities, due to its relevance on population growth, production and consumption. The objective of this research is promoting the understanding of the transition from linear production to the circular economy applied to the sustainable development of cities. The methodology is based on the qualitative approach and the applied technique follows the stages of the bibliographic research. The objectives classify this research as an exploratory, descriptive study with explanatory slant. The bibliographic sources are mostly selected from 2015, when the Sustainable Development Goals and the Paris Agreement were signed, until 2020. The search of the existing circular models provides, even in transition from the linear process, valuable contributions to the resource protection, promotion of the production and sustainable consumption, as well as the generation of new income opportunities, of market and of social integration.
The results of the analyzes of the selected studies indicate that the sustainable urban development can be enabled by the implementation of circular systems on a holistic and inclusive approach..

Keywords: cities; sustainable development; circular economy; linear production.

RESUMO

O processo de produção linear de exploração, produção, consumo e geração de resíduos tem levado a humanidade aos limites planetários. A transição para modelos econômicos circulares dissocia o crescimento econômico do esgotamento dos recursos e da degradação ambiental. É nas cidades que surgem a oportunidade de mudanças e soluções vitais à sustentabilidade do planeta, dada a sua relevância no crescimento populacional, produção e consumo. O objetivo dessa pesquisa é promover o entendimento da transição da produção linear para a economia circular aplicado ao desenvolvimento sustentável das cidades. A metodologia tem abordagem qualitativa e a técnica empregada segue as fases da pesquisa bibliográfica. Os objetivos a classificam como exploratória-descritiva, com viés explicativa. As fontes são predominantemente selecionadas a partir de 2015, quando do acordo global pelos 17 Objetivos do Desenvolvimento

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Sustentável e do Acordo de Paris, até 2020. A pesquisa de modelos circulares existentes, mesmo que em transição do processo linear, apresentam contribuições valorosas para a preservação dos recursos naturais, promoção da produção e consumo sustentáveis, geração de novas oportunidades de renda, de mercado e integração social. Os resultados das análises dos estudos selecionados indicam que o desenvolvimento sustentável das cidades pode ser viabilizado pela implementação de sistemas circulares em uma abordagem holística e inclusiva.

Palavras-chave: cidades; desenvolvimento sustentável; economia circular; produção linear.

1. Introduction

The linear model of production process has been being used since the begging of the industrial scale production of the natural resources, production, usage and waste disposal. This fact has taken cities and countries to alarming conditions of waste disposal and pollution in every way. The impact to the environment cause climate changes and affect the health and well-being of all living things.

Researchers warn about the damage to the natural environment since the 1960s. However, countries from the European Union (EU) and China started to take concrete changing measures on their productive chains in order to reduce the waste generation and pollution from the 1990s. The shortage of natural resources added to the public spending with public health and waste management make the national and local governments to examine the principals and practices of the circular economy more closely: the exploration of natural resources and the waste generation are minimized. The resources are recycled, retrieved and remanufactured in order to maintain them longer in the production process.

The thinking of changing from the linear production to the circular economy does not reach every country, not even all of the developed countries. But the research strand, national and local governments and companies that incorporate and implement circular systems on their field of work grow every year.

The circular models are based on manufacturing processes, nonetheless, they embrace changes on the social consumption and on the dissociation of the economic growth from the natural resource depletion and from the environmental degradation (Williams 2019). In this context, cities that harbor half of the world population, having an upward trend by the population growth projections and increasing urbanization, are the cities that consume more: about 2/3 of the global energy consumption and they are responsible for 70% of the greenhouse gas emissions (United Nations 2020; World Bank 2020). The opportunity to make changes and to find vital solutions to the planet's sustainability emerge in the cities due to its relevance on population growth, production and consumption. For this purpose, it is primordial to understand the concepts and principals of the circular economy: its strategies, the social, economic and industrial necessary changes, the holistic benefits to the environment, the role of the stakeholders, the importance of the innovation systems, its direct relation to the Sustainable Development Goals (SDGs), in conjunction with its value and its enforceability in the cities.

The main references of this research are based on materials from Sachs (1986), Williams (2019), Girard and Nocca (2019), Schroeder et al. (2019), United Nations, European Commission (2020), Ellen Macarthur Foundation (2020), among others, mostly published after 2015, when the SDGs and the Paris Agreement were signed.

The research is based on the question: are the principles and practices of the circular economy sufficient to ensure the sustainable development of cities in their basic dimensions: economic, social and environmental? The objective of the research is to promote the understanding of the transition from linear production to the circular economy applied to the sustainable development of cities. For this, the research is structured in 5 sections: section 1 introduces the theme; section 2 demonstrates the applied methodology; section 3 presents the results with data on the transition from linear production to the circular economy and on circular systems in cities; section 4 summarizes and discusses the dimensions and ideals of the circular economy and section 5 presents the research conclusions.

2. Materials and Methods

This research has an applied nature because it engages on formulate questionings about relevant topics to the society, organizing diagnostics and possible solutions (Fleury, 2017). The methodology has a qualitative approach, in which explores, describes and takes an in-depth look on data of facts from diverse and subjective realities (Sampieri et al., 2013). The objectives classify this research as an

exploratory and descriptive study, since its purpose is to present the concepts, principles, strategies and other dimensions that evolve the transition from linear production to the circular economy and its enforceability in urban centers (Marconi; Lakatos 2003). However, this research has also the purpose of explaining the conditions that benefit, or not, this transition (Gil, 2002).

The technique used is bibliographic research aligned with the steps defined by Gil (2002), Marconi and Lakatos (2003) and Sampieri et al (2013) and begins with the definition of the theme: circular economy and the sub-themes: (i) the transition from linear production for the circular economy and (ii) cities and circular systems. The circular economy theme is related to several sub-themes, such as resources, production, waste, energy, technologies, among others, which are connected in the local environment of cities, reflecting nationally and globally. In this context, the study of understanding the transition from linear production to the circular economy and the application of circular systems in cities was selected, given the importance of the topic in the face of current planetary limits.

Next, secondary data are collected from journals from the Scopus, Web of Science and Science Direct databases, indexed in the CAPES Periodicals Portal, as well as recognized organizations such as the United Nations and the Brazilian Association of Technical Standards (Associação Brasileira de Normas Técnicas - ABNT), following the criterion of relevance and alignment with the research theme. The initial time limit for data collection was established in 2015, when the Paris Agreement and the 17 SDGs were signed between the countries. Mendeley software is used to organize bibliographic references.

Data analysis is based on content analysis of the Bardin (2008), in which the context category (theme) is defined as circular economy, the analysis categories focus on two subthemes: (i) the transition from linear production to the circular economy and (ii) cities and circular systems. The units of analysis established are: (i) conceptual; (ii) strategies; (iii) social, economic and industrial changes; (iv) holistic benefits; (v) stakeholders; (vi) digital technologies (iots, big data); (vii) innovation; (viii) sustainable development goals; (ix) circular cities.

The results are structured in the two categories of analysis: transition from linear production to the circular economy and cities and circular systems. In the following section, the results are discussed according to the determined units of analysis, outlining the conclusions presented.

3. Results

3.1. Transition from linear production to the circular economy

The linear production model started during the Industrial Revolution in the 18th century with the limitless exploration of the natural resources. In the 1960s, researches pointed the natural environment's interfaces, as well as the consequences of this excessive exploration. During this period, greener economy and eco-industry concepts emerged. Since the 1990s, the circular economy concept catches worldwide attention, mainly when the EU and China adopted politics aligned to the circular economy principles (Prieto-Sandoval et al 2018). These countries realized that it is necessary to act against the harmful effects of the economic growth and the limitless exploration of the natural resources and subsequent waste disposal, resulting on the resource scarcity, pollution and biomes destruction.

Cechin and Veiga (2010, p. 451) point that throughout history, "[…] even with all the divergences between the many schools of economic thinking, – from the Marxists to the neoclassic, from the Keynesians to the Schumpeterian, passing through the institutionalists – all of them share an economical system isolated from the natural environment view". These authors present the thinking developed by Georgescu-Roegen from the 1950s to the 1970s, wherein he argues that the economy and the production system must not be considered as closed systems that do not relate to the natural environment. In all process, there is the natural resource removal and the waste dumping in the nature. Therefore, there is not a way to treat the economy and the environment on different spheres, without considering their connections. However, according to Georgescu-Roegen, only the human necessity on dealing with the scare natural resources will pressure the thinking to change the linear production paradigm and economic growth. In this context, the consumers' choices wield a crucial role to a paradigm shift, acting on the supply and demand regulation of more sustainable products.

The volume of materials extracted has doubled worldwide since 1980, reaching around 72 giga tons in 2010 and it is estimated that in 2030 it will reach 100 giga tons (Schroeder et al. 2019). The predominantly linear economic model generates 2,01 billion tons of waste in the world annually, and it may hit 3,40 billion tons until 2050 (United Nations Environment Programme 2020). Of that total, around 33% of the waste are discharged at open dumpsters, 25% at unspecified landfills, 7,7% at landfills that have gas control and 4% at

controlled landfills, 11% are incinerated and 19% are recycled (13,5%) or composting (5,5%) as the Figure 01 – Global waste disposal and treatment shows. In low-income countries, 90% or more of the waste are discarded in dumps or burnt (Kaza et al. 2018).

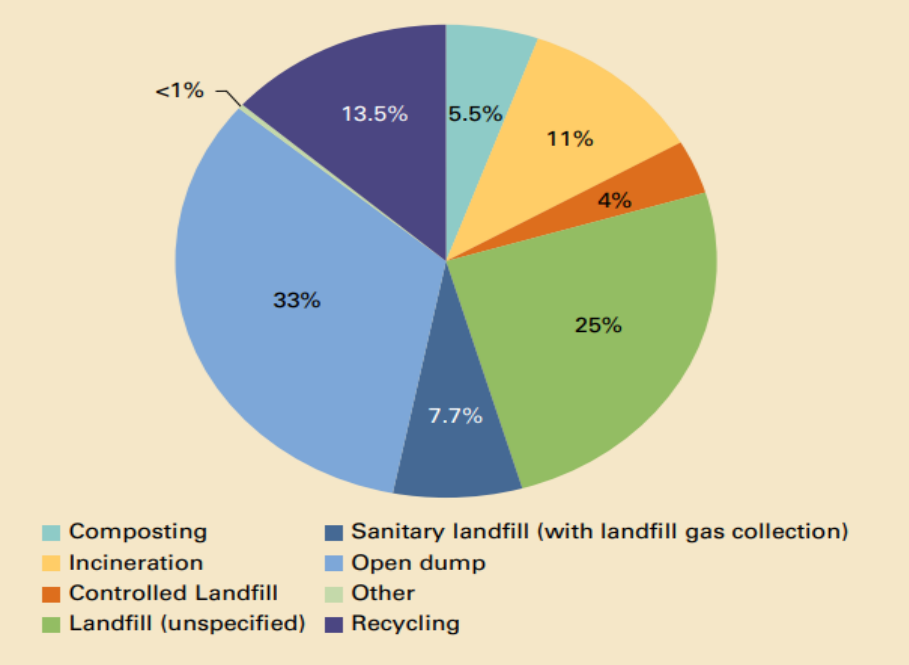

Figure 1 - Global Waste Treatment and Disposal according to Kaza et al.(2018, p. 9).

This scenario has been going on for decades and Sachs (1986) argues that is is necessary to reframe the final product definition, since that in the linear production model this product is going to result in losses and future disposal in the environment.

In an ecologically health relationship between consumption and economic growth, these products are on integrated production systems, in which the losses and disposal are considered resources, another product's feedstock, through recycling process and materials reuse. "The productions process' sustainability involves careful exhaustible resources management and recycling" (Sachs 1986, p. 50).

The concept of circular economy is attributed by a strand of researchers to Pearce and Turner (1990), which were based on the research of Boulding (1966) (Prieto-Sandoval et al. 2018), but the premises of circular economic models were already explored through various lines of research, from environmentalists to economists like Georgescu - Roegen and Sachs, mentioned above..

The repercussion and the world mobilization to minimize and stop the climatic changes impact made the researches and the world leaders visualize the transition to the circular economy more carefully, reconstructing the current linear production model.

According to researches made by European countries, the changeover to the circular economy model is going to reduce 70% of the greenhouse gas emission and it is going to increase the job opportunities in 4% because new abilities and skills are necessary on each circular economy stage (Stahel 2016).

"Circular economy is a model for production and consumption (with heavy emphasis on production), whose ultimate goal is to achieve the decoupling of economic growth from natural resource depletion and environmental degradation" (Williams 2019, p. 2749). The European Commission (2020) of the EU countries describes the circular economy as the one that is "[…] fostering sustainable consumption, and aiming to ensure that the resources used are kept in the EU economy for as long as possible".

The European Commission's conceptual strand is based on most of the latest researches about circular economy, such as Stahel (2016), Michelini et al. (2017), Ritzén and Sandström (2017), Pauliuk (2018), Taelman et. al. (2018), Girard and Nocca (2019), Fiep System (2019), Greer et al. (2020), Fogarassy et.al. (2020), Palafox-Alcantar et al. (2020).

The circular economy's core strategies are based on the products' and materials' life extension, on their reuse and remanufacture. The waste, losses and discarded products reduction is going to reduce the usage of new resources and, consequently, there will be improvements to the environment. The production and the consumption as from the production resources and services as from the

families are key points to the circular economy success (European Commission 2020). The circular economy "[…] aims to 'design out' waste, return nutrients, and recycle durables, using renewable energy to power the economy" (Williams 2019, p. 2974).

The circular economy process begins on the products' design and on the production planning, whose may minimize the usage of natural resources and may be projected to the sustainable management of the production chain, generating new business and increasing population income. The circular economy analyzes how the energy is produced and utilized, greenhouse gas emission, pollution in all its forms, food and material wastage, as well as the stock of products by the society.

On the closing of the cycle the materials and products are reintroduced in the economy to produce new products (Michelini et al. 2017; Taelman et al. 2018; European Commission 2020).

The benefits of the circular economy are noticed on companies of any size or nature, in the society and on the environment as: (i) make sustainable products; (ii) empower consumers and public buyers; (iii focus on the sectors that use most resources and where the potential for circularity is high; (iv) ensure less waste; (v) make circularity work for people, regions and cities; (vi) improvements in the environmental rates (European Commission 2020).

The Ellen MacArthur Foundation (2020) advocates that it is necessary to reorganize the current take-make-waste system. The resources, the way of producing and the usage of products must be managed. Besides, what is done with the left over or outdated materials have to be reconsidered within the planetary limits, considering that the predominant system is causing serious damage to the environment, to the society and to the companies. The circular economy enables economic, natural and social capital generation and can be applied to large and small organizations, collectively and individually, globally and locally.

The circular economy requires social, economic and industrial changes, based on legislations that structure the circular economy and on public politics that support business products and models more sustainable (Prieto-Sandoval et al. 2018; Williams 2019b).

Sachs (1986) highlight the importance of changing the production and consumption patterns and reinforce important changing points that align to the circular economy principles: to implement materials recycling and reusing processes, to prioritize the renewable resources usage in place of finite resources, to phase out the material wastage on industrial and domestic scale, to choose technologies that are suitable to the environment and to the social local, to turn waste into wealth, to promote behavior changings to phase out the wastage, to produce more durable tools and goods, to embed the social and environmental responsibility on the products' design, to rationalize the transport of people and material flows, as well as to integrate the local, regional and national economies.

Girard and Nocca (2019), Fogarassy et al. (2020) emphasize that the circular systems' success mostly depends on changing the consumption habits and that the digital marketing contributes to the behavior changings, especially among the youngest members of the society.

The demand for more sustainable products and services press the market and the stakeholders on the productive chain for circular innovation. The interaction and cooperation between the stakeholders have the potential to promote and to qualify an interrelated circular innovation ecosystem through agreements and treaties (Girard & Nocca 2019; Greer et al. 2020).

The Ellen Macarthur Foundation cooperates with private and public sectors through the "multistakeholder CE 100" platform, transmitting from linear to circular systems of companies, governments and cities, startups and other organizations. The CE 100 is in partnership with the UN Environment Cities and with the C40 Cities Climate Leadership Group. Companies including Unilever, H&M, Renault, Philips and Google form the list of the CE 100 companies (Ellen Macarthur Foundation 2020).

Public events such as exhibitions and congresses play a role in the learning, connection and cooperation between the stakeholders, in which the society is an active constituent. The cooperated action among the several actors, aligned with the circular economy principles, facilitates the cocreation of sustainable and circular ideas more successful in their implementation (Greer et al. 2020).

The circular economy's main principles are to reduce, reuse and recycle (Prieto-Sandoval et al. 2018). These principles mean: (i) to project and eliminate waste and pollution from the outset; (ii) to keep materials and products in use; (iii) to regenerate natural systems. To this end, the economic activity prioritizes the use of renewable resources and suppresses the waste from the production system. The waste and leakages are treated as materials that put themselves back on the production cycle.

The circular economy model contemplate two cycle types: (i) biological: materials such as food, wood and cotton return to the system through the composting process and anaerobic digestion, regenerating living systems; (ii) technical: material and products are restored through reuse, repair or recycling (Ellen Macarthur Foundation 2020).

The circular economy processes occur in three levels: (i) micro, company and citizens level; (ii) meso, big companies, eco-industrial parks and cities level; (iii) macro, regional, national and international level (Girard & Nocca 2019).

Bressanelli et al. (2018) expose that the digital technologies as the Internet of Things (IoT), Big Data and analysis technologies act as facilitators in the circular economy's implementation and back up the maximization of the resource's efficiency and increase the product's lifespan. These authors highlight eight main digital technologies features that support the circular economy's efficiency: (i) to improve the product's design; (ii) to enhance the marketing activities; (iii) to monitor the product's usage and to allow its sharing; (iv) to facilitate the technical support's provision; (v) facilitate the preventive and predictive product's maintenance; (vi) optimize the product's usage; (vii) provide the product's update; (viii) subsidize the renovation, manufacture and recycling activities. The employed digital tools can be intended to present and analyze results or intended to improve the products usage's performance, that extend the product's lifespan and the cycle's closure.

The British Standards Institution published in 2017 the BS8001: 2017 – Circular Economy guideline, in order to provide subsidies to implement circular business' systems and models in any size or nature organization. The researches started in 2013 and evolved several stakeholders from the UK and outside about resources management and waste prevention themes. The guideline gives recommendations and clarifications about the circular economy structure. However, it does not qualify for certifications.

The corporative transitions to the circular business and sustainable models occur in parallel to the global goals of sustained development, which include the circular economy's precepts, as the resources and waste efficient management (Pauliuk 2018). To the author, the efficient management of the materials' cycle is relevant to the success of the transitions to circular economies.

However, in order to reach dimensions beyond the corporative world, it is necessary to embed national politics and strategies that visualize the circular systems in a holistic view, in order to positively impact the natural and social environment. According to Schroeder et al. (2019), companies wield an important role as a propelling actor of the sustainable development with potential to spread the circular economy's principles and techniques in the society. Then, it is going to cooperate to the transition from the linear to the circular economy.

In Brazil, according to the Brazilian National Standards Organization (2020) the Special Studies Commission of the Circular Economy - CEE-323 was created in 2020 in order to format the Brazilian version of the ISO/TC 323 (in development). Besides, this version also intends to provide standard guidelines to the organizations to circular economy's implementation and, therefore, to contribute to the transition from the linear to the circular economy.

The Figure 02 – Linear Economy, the Figure 03 - Transition from the linear to the circular model and Figure 04 – Closing loops schematize the linear economy's models main characteristics, its transition to the circular economy and the circular economy's closing loops.

Figure 2 – Linear Economy

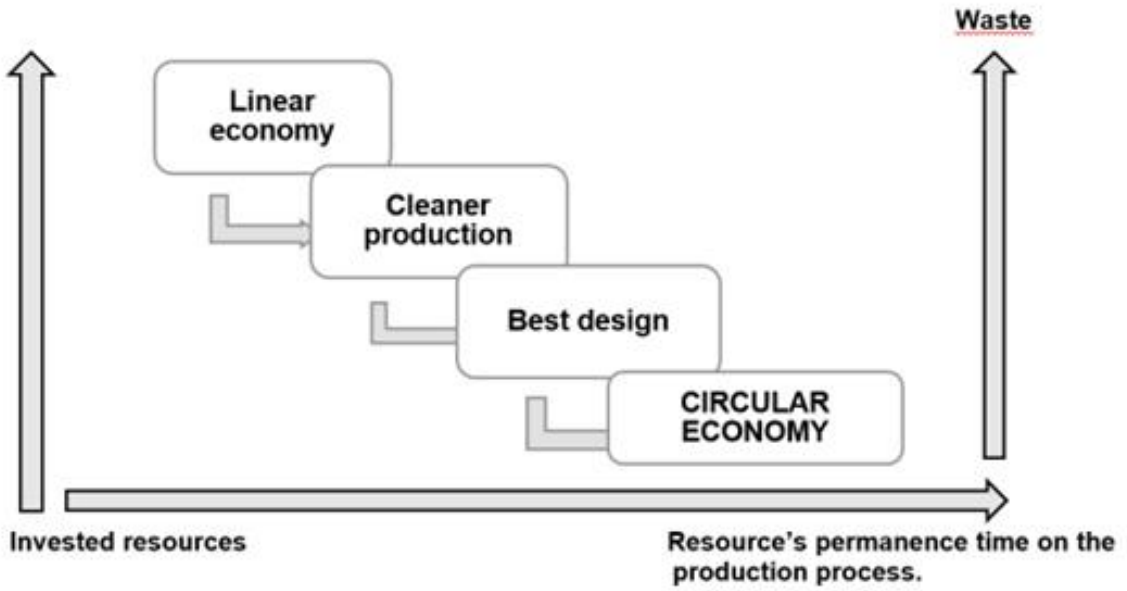

Figure 3 - Transition from the linear to the circular model

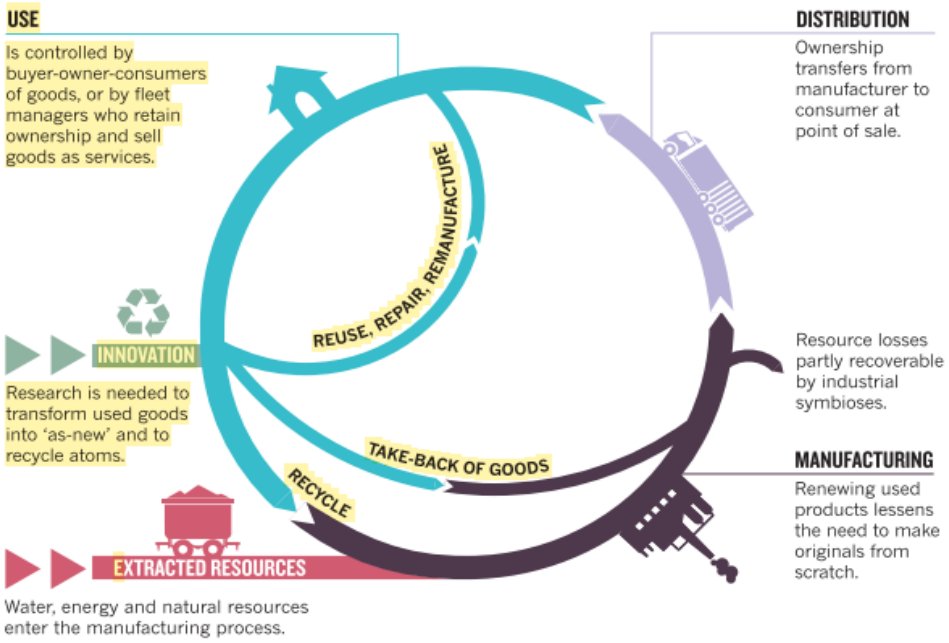

Figure 4 – Closing loops according to Stahel (2016, p.436).

In Figure 2 it is indicated the take-make-waste production process, prevailing on most companies since the Industrial Revolution. Figure 3 shows the transition from the linear to the circular economy, passing through an initial awareness level of a cleaner production and then it leads to the design's improvement to more sustainable products and implementation of the circular economy. According to Silva, Moraes and Machado (2015), the fundamental principle of the cleaner production methodology is to increase efficiency and reduce waste during the production process, not at the end.

The scheme presents the transition related to the invested resources, resource's permanence time on the production process and the waste generation. It can be observed that the invested resources and waste generation are high for a shorter period of time in the linear economy, comparing with the circular economy.

On the circular economy's closing loops exposed in the Figure 4, the natural resource extraction and energy consumption are reduced through reuse, remanufacturing, repair and recycling of materials. The production is distributed to the product's consumption or usage. The circular economy introduce the product usage's concept and not necessarily its property. The consumer, for example, may opt for the use of a car or of a washing machine for a period or for a number of times, without having its property. Goods start to be commercialized as services, contributing on reducing the need for new resources and better material's utilization. For this end, it is necessary to invest on researches that enables innovations to convert used products into new material to reenter the production process (Stahel 2016).

The circular economy's practices have been increasing as the sustainable themes reach bigger spotlights on local, regional and national levels. Although the business environment is the most interested on this, the perception that the circular economy model can contribute to the sustainable development grows, as well as the SDGs of the 2030's Agenda's outreach (Schroeder et al. 2019; Girard & Nocca 2019).

The circular economy's concepts are directly related to the SDG 12 - Sustainable consumption and production and to the goals of the SDG 6 – Water and sanitation, SDG 7 – Energy, SDG 8 – Decent work and economical growth and SDG 15 – Life on land. The alignment of the circular economy's principles with these SDGs and the correlation among them cooperate to the other SDGs' outreach (Schroeder et al. 2019). These authors expose that this relation is treated with bigger attention by developed countries. However, the developing countries began with circular economy's practices recently, mainly with the waste recycling, which helps the public management with the waste management. The developing and developed countries realize the circular economy's potential on providing new income generation ways. However, it is necessary to invest on education to develop new abilities and capacities. Those investments are more efficient when they came from public-private partnerships.

The SDG 12 has purposes that align with the circular economy among its goals: 12.2 by 2030 achieve sustainable management and efficient use of natural resources; 12.3 by 2030 halve per capita global food waste at the retail and consumer level, and reduce food losses along production and supply chains including post-harvest losses; 12.5 by 2030, substantially reduce waste generation through prevention, reduction, recycling, and reuse; 12.a support developing countries to strengthen their scientific and technological capacities to move towards more sustainable patterns of consumption and production.

As a reflexive example, from all of the foodstuffs produced annually, one third becomes waste, whether by waste or waste generation, and at the same time, millions of people around the world starve every day. It is the costumers' responsibility to change their habits, to choose more sustainable products, without accumulating or wasting, while it is the business' responsibility to innovate on solutions to avoid losses and waste, as well as to make the products be more durable (United Nations, 2020).

Girard and Nocca (2019) highlight the link between the circular economy and the SDG 11 – Sustainable cities and communities. The United Nations (2020) through the New Urban Agenda (2016), in topic 71, points its involvement with the sustainable management of the resources and the waste reduction in a transition to the circular economy, considering the connection among the urban and the rural.

3.2 Cities and circular systems

Currently, cities consume around 70% of the natural resources, 60% of the global energy, generate around 50% of the global waste and emit 75% of the greenhouse gases. It is estimated that the large cities are responsible for 91% of the consumption growth and 81% of the total consumption between 2015 and 2030 (Petit-Boix & Leipold 2018; Williams, 2019). In this context, according to these authors, around 50% of the cities with more than 100 thousand inhabitants are already suffering with water scarcity, considering that this number is increasing fast. In addition, the lack of food, the energy failure and the lack of inputs exacerbate urban challenges at the same time as it is needed to deal with increasing natural disasters, as the climate changes effects

Cities are considered complex ecosystems, in which several independent actors act on the production and consumption of combined resources to range of activities, fields and scales (Williams 2019). Adopting circular models imply the understanding of the complex relation between the different usage and resources value, the roles and the network necessity (Girard & Nocca 2019).

Over time, cities were no longer auto sufficient and became dependent of fossil fuels, nonrenewable energies and globalized resources and products. The urban area enlargement has moved away the productive lands and the local food supply from the urban centers, as well as has led the waste exportation to other cities or even to other countries (Williams 2019).

The increasing urban population scenario, the rising demand for richness and the fast estrangement to obtain resources strengthen the cities necessity to choose circular business models in order to reduce the urban waste flow and quantity. The looping on local and global scale is argued as vital to sustainable urban ecosystems (Petit-Boix & Leipold 2018; Prendeville et al. 2018; Williams 2019; Girard & Nocca 2019).

The circular systems application on cities may facilitate the sustainability of the urbanization, reducing the greenhouse gas emissions, promoting the renewable energy usage, efficient management of resources and waste, better life quality and preserve the cultural heritage (Girard & Nocca 2019). These authors highlight that urban circular systems invest on the cultural and physical asset restauration and reutilization, extending its usage value.

Urban centers are the biggest resources consumers and the place of the most wastage, whether by losses, waste generation or materials, vehicles and buildings underspend. Therefore, it is there where public and private investments should be applied in order to eliminate waste and pollution in every way, to restore the environment, to keep materials and products in use for a longer period and to regenerate the materials and products' value in the production and services chains.

Circular systems bring economic, social and environmental benefits to the city, increasing the economic productivity, generating income opportunities, creating conditions to urban, social and environmental health and helping the local production (Williams 2019, Girard & Nocca 2019; Ellen Macarthur Foundation 2020). Technologies as the Big Data and the IoTs are strong allies to the structural support to the transition to the circular economy (Bressanelli et al. 2018; Girard & Nocca 2019; Ellen Macarthur Foundation 2020).

Ellen Macarthur Foundation (2020) supports the initial application of the circular economy principles in on urban systems of: (i) mobility: to vary the modals to clean energies and bring people closer to their workplaces; (ii) urban buildings: to refurbish and reuse, reducing the underspending of building areas and the materials wastage; (iii) products and foodstuff: to increase the products durability, reuse, remanufacture and recycling in addition to reduce and eliminate food losses and wastage. Specific politics directed to the incentive to share products and areas, to limit the usage of disposable plastic and to the fast fashion textile process and to more healthy and sustainable food productive chains, avoiding losses and wastages appear to be effective on the urban centers.

The transition success of a city based on the linear economy to the circular economy demands a holistic and inclusive approach that adds representants from the several actors that are interconnected with the city's context. Each one of these actors have different views about the theme. Therefore, it is necessary for them to formulate ultimate goals to the city, to create a transition plan and to execute it concertedly (Taelmann et al 2018; Girard &Nocca 2019; Palafox-Alcantar et al 2020).

However, it is expected that differences of opinion and interests generate conflicts during the transition process. Thus, it is important that the politics and actions formulators consider to: (i) capture several value perceptions; (ii) facilitate the cooperation among the stakeholders; (iii) ensure that the stakeholders are proactive and cooperative; (iv) increase the awareness and provide regulations to support the circular economy; (v) reach a goal that content all the participants (Palafox-Alcantar et al 2020).

The transition plans have to contemplate short, medium and long term actions and goals. In order to the stakeholders being able to monitor the gains and to redirect the efforts of unsuccessful actions, these actions and goals have to be evaluated and released in determined periods. To this end, the usage of tools as performance indicators, bottom up governance and circular business model investments are essential (Girard & Nocca 2019).

Nowadays, there are several cities that are applying circular practices on their productive chains and on the city's urban planning (Petit-Boix & Leipold 2018; Girard & Nocca 2019). The most common practices are targeted on waste management and social consumption, focusing on recycling the reusing, added to the urban planning that establish regulations to the mobility, construction and environmental issues. These practices, added to the productive chains, form key circular economy elements (Petit-Boix & Leipold 2018).

On the waste management, recycling became a key strategy in the urban centers transition to the circular economy, that include the materials' recycling and its biological treatment (composting, anaerobic digestion). However, the recycling process lacks regulations in several areas and sectors (Tantau et al. 2018).

Prendeville et al. (2018) reinforce that the circular economy is based on cooperation networks among the city's involved parties, that have to consider the city's context and to be adjustable over time. Companies are compelling to investments on circular systems, acting in concert with local governments, in which citizens and communities are included.

The circular city model is not merely the summing of business and circular systems. It consists on the territorialisation of the circular economy principles, where anything is wasted, becoming regenerative and affordable urban systems that unite environmental sustainability, economic productivity and social justice, reducing the social inequalities (Girard & Nocca 2019). It is the city's duty to stablish its circular economy strategies, according to its sustainable goals and local priorities (Petit-Boix & Leipold 2018).

There is not an agreement about the definition of a circular city, as well as there is not an agreement about the indicators to be used to evaluate the circular city's performance because these themes are new in the researches (Prendeville et al. 2018; Girard & Nocca 2019) and each city has a unique reality formed by its territory and its territoriality.

There are several performance indicators used to evaluate circular cities because there are results measures direct from the circular process (as recycling and green workplaces), but there are also other indirect results (as health, human and environmental life quality).

In general, the indicators are related to the basic sustainable dimensions: economical, social and environmental. Indicators directed to the recycling revenue, innovation to circular systems and familiar income originated from the circular economy (that is also considered in the social dimension) are common in the economic dimension. The waste management, renewable energy and greenhouse gas emissions are related to the environmental dimension. The material cycles indicators, (as the city's recycling) are the most available, while the indicators to measure the adopted strategies barely exist. Although there are social indicators related to the circular economy, they are short when compared to the economic and environmental indicators (Girard & Nocca 2019).

Next, the results are discussed according to the units of analysis structured in the collection and analysis of data published after 2015, when the 17 SDGs were established.

4. Discussion

Summarizing the mentioned aspects of the circular economy model, Table 1 presents the dimensions and ideals supported by the selected authors that form the research analysis units,

Dimensions	Ideals	Authors – Entities
Conceptual	- Dissociation of the economic growth from the natural resource depletion and from the environmental degradation. - To maintain the products' value, and to maintain the resources and materials for the longest possible in the economy, minimizing the waste generation.	Stahel (2016), Michelini et al. (2017), Ritzén and Sandström (2017), Pauliuk (2018), Taelman et al. (2018), Pietro-Sandoval et al. (2018), Girard and Nocca (2019), Sistema Fiep (2019), Williams (2019), Greer et al. (2020), Fogarassy et al. (2020), Palafox-Alcantar et al.(2020), Ellen Macarther Fondation (2020), European Commission (2020).
Strategies	- To lengthen the products and materials useful life, by reutilizing and remanufacturing. - To reduce waste, losses and discarded products. - To reduce the usage of new resources. - Environmental improvement.	Stahel (2016), Michelini et al. (2017), Ritzén and Sandström (2017), Pauliuk (2018), Taelman et al. (2018), Pietro-Sandoval et al. (2018), Girard and Nocca (2019), Sistema Fiep (2019), Greer et al. (2020), Fogarassy et al. (2020), Palafox-Alcantar et al. (2020), Ellen

		Macarther Fondation (2020), European Commission (2020).
Social, economic and industrial changes	- Sustainable product design. - Sustainable planning and management of the productive chain. - Sustainable consumption patterns.	Sachs (1986), Michelini et al. (2017), Taelman et al. (2018), Pietro-Sandoval et al. (2018), Williams (2019b), Fogarassy et.al. (2020), Girard and Nocca (2019), European Commission (2020), Ellen Macarthur Foundation (2020).
Holistic benefits	- Materials and energy economy. - Efficient ways of production and consumption. - Waste reduction. - Feedstock auto sufficiency. - Make circularity work for people, regions and cities. - Improvements in environmental performance.	Sachs (1986), Pauliuk (2018), Schroeder et al. (2019), Williams (2019), Girard and Nocca (2019), European Commission (2020), Ellen Macarthur Foundation (2020), United Nations (2020).
Stakeholders	- Interaction and cooperation among the stakeholders promote and qualify a circular innovation ecosystem.	Taelman et al. (2018), Prendeville et al. (2018), Girard and Nocca (2019), Greer et al. (2020), Ellen Macarthur Foundation (2020), Palafox-Alcantar et al. (2020).
Digital Technologies - IoTs, big data	- Circular economy implementation facilitators. - They allow the results analysis and presentation. - Improvements on the products use performance.	Bressanelli et.al. (2018).
Innovation	- Investments in research that facilitate innovations to convert used products into new materials in order to reenter the production process. - Development of new abilities and capacities.	Stahel (2016), Schroeder et al. (2019), Girard and Nocca (2019).
Sustainable Development Goals - SDGs	- SDGs contribute to the sustainable development and to reach the 17 SDGs of the 2030's Agenda.	Schroeder et al. (2019), Girard and Nocca (2019), United Nations (2020).
Circular cities	- Territorialization of the principles of circular economy. - Application of the circular economy can make urbanization sustainable.	Petit-Boix and Leipold (2018), Taelman et al. (2018), Prendeville et al. (2018), Tantau et al. (2018), Girard and Nocca (2019), Williams (2019), Ellen Macarthur Foundation (2020), Palafox-Alcantar et al. (2020).

	- Holistic and inclusive approach provides economic, social and environmental benefits. - Circular systems used in the production, service and urban planning chains of the city. - Economic, social and environmental performance indicators.	

Table 1 – Circular economy dimensions and ideals.

it is noted that there is agreement on the circular economy central concept of maintaining the materials' value for the longest possible in the productive chain and reducing the usage of new resources and the waste generation. The strategies follow the conceptive line to promote environmental improvement. To this, it is necessary to promote changes in society for sustainable consumption habits and in production chains that incorporate improvements in the design of products and circular production systems.

The circular economy has the potential to be beyond the economic productivity and improvements in environmental performances by promoting income generation opportunities and social integration if it is stablished with a holistic view, in which all the stakeholders cooperate actively for the transition process. For example, the parties involved in the production chain can support the formation of cooperatives of waste pickers, of incubators and startup accelerators. as well as research and development centers based on the principles of the circular economy and oriented to the sustainable development of cities.

The digital technologies (Iots, Big Data) act as facilitators in the implementation of the circular economy, providing data and analysis, as well as management work tools. However, investments and public-private cooperation are necessary for the development of new technical and social technologies adapted to each place. The sustainable development of cities can be facilitated by the practices of circular economy principles in a holistic and inclusive vision.

However, circular economy systems are also subject to production processes that can incur damage to the health of workers and the environment, which need to be analyzed and improved (Girard & Noca 2019). For example, recycling of electronic equipment requires advanced technologies and skilled workers for the treatment of materials, because there is exposure to hazardous substances that need to be considered. In addition, there are large global waste export flows. Most are from developed regions to poorer regions, without specific waste management regulations, forming large pockets of waste around cities.

Waste management is a global challenge and affects everyone, directly or indirectly. However, people in vulnerable situations are mostly the ones most affected by inadequate waste management. Many of these people work in the separation of waste collected in the streets and waste dumps of the cities to generate income in unsafe working conditions. Without adequate protection equipment and handling in unsafe places to work with waste, workers are exposed to dangerous and toxic substances (mercury, cadmium) causing serious damage to health and well-being. In parallel, the increase in waste generation and its improper disposal compromises the preservation of the environment (Kaza et al. 2018).

The paradigm of unlimited consumption as a pattern of richness imposed by markets and societies generates serious social and environmental impacts, such as the maximization of social exclusion, the shortage of resources and the increase in the generation of waste (Ritzen & Sandstrom 2017). Sachs (1986) expose that a minority of rich and industrialized countries consume the biggest part of the planet's utilized resources, while most of the developing countries try to have the consumption patterns of developed countries, overwhelming the ecosystem. In this context, there is a positive correlation between the income level and the waste generation per capita. It is estimated that the waste generation on low and medium income countries increase 40% until 2050, while the high-income countries increase 19% (Kaza et al., 2018).

Ritzén and Sandström (2017) highlight that the circular systems implementation in territories and in organizations experiment several barriers to be considered since its conception. The barriers are related to knowledge, attitudes, structures, information and technologies.

The main detected obstacles are from: (i) financial order: changes require medium and long terms investments, while the organizations are centered on the short-term return, added to the doubts about the circular models financial profitability; (ii) attitude order: any or superficial knowledge of the circular economy and sustainability concepts and principles, different understandings of the value chain, risk aversion and lack of understanding of the connection between business and sustainability; (iii) structural order: inefficient informational and communicational systems and unequal distribution of the responsibilities affect the integration among departments, hierarchy levels and supply chains; (iv) operational order: problems on the infrastructure management, on the supply chain and disruptive changes on the production process may take the project to failure; (v) technological order: radical innovation and sustainable products design are valuable points to the circular systems progress in any organization because there are no ready models.

Each organization, which in turn is inserted in a given territory, must consider its peculiarities, its territoriality, seeking to align cultural values with the principles of the circular economy, enabling the transition to circular systems, promoting the sustainable development of cities. Essentially, as the circular economy works in closed loops, stakeholder engagement is essential for the successful installation of circular economic models.

Williams (2019b) points out five action challenges and resources to be observed during the circular economy installation in a territory in order to maximize the expected results: (i) political support to the circular systems and business, for example by creating places for activities that promote the circular economy; (ii) regulatory framework that supports changes and avoid conflicts; (iii) standardization of recycled, reused and recovered materials; (iv) efficient and qualified institutional structures and (v) database in which new institutions can collect, analyze and monitor data that subsidizes the stakeholders in the decision making. This author adds that it is important to analyze and clarify the financial viability of the circular business, as well as it is essential that the available infrastructure be flexible and adaptable over time.

An important point to minimize the barriers and maximize the expected results is to aware the population about the circular economy benefits. Most of the consumers do not have knowledge about the circular systems principles and concepts, even tough they know some associations related to products, food production and involved risks. It is necessary to act on people's perception about the circular economy model, in order to motivate them in the right direction, changing their own consumption behavior and allowing them to participate on innovations, by the cocreation (Sijtsema et al. 2019).

In this perspective, countries are in bigger or lower involvement level about formatting public politics that speed up the consumer's awareness for more sustainable products and services, and also for a productive systems responsible for the natural and social environment in a transition to the circular economy.

The EU adopted a set of public politics centered on the circular economy and aligned with the SDGs in 2015, in order to realize the transition from the linear to the circular economy. The policies are related with the products life, production and consumption, waste management and secondary raw materials. In March 2020, a new action plan to the circular economy was adopted, in which are intensified policies that extend the useful life of products, promote the sustainable consumption and add value to the production cycle. The monitoring of the development indicators is made by Eurostat through ten indicators, grouped on four themes: (i) production and consumption, that monitors the maximization of raw materials, sustainable public procurement, waste management and food waste; (ii) waste management, which monitors the recycling taxes and specific waste flows, as packings and e-waste; (iii) secondary raw materials, which analyzes the utilization of recycled materials and the recycling market evolution; (iv) competitiveness and innovation, which monitors the private investments, jobs and business and markets (European Commission 2020).

According to Eurostat's (2020) data, the urban waste recycling has increased from 27,3 % (2000) to 47,5 % (2018) and Germany leaders this number with 67,3 % (2018). The recyclable raw material exportation from EU to other countries numbered 25,5 million tons in 2019, representing an 61% (15,8 million tons) increase comparing to 2004. The municipal generated waste has reduced from 518 kg per capita to 492 kg (2018). The packages recycling rate has increased from 24% (2005) to 42% in 2017. Between 2012 and 2018, the number of employments in the EU related to the circular economy increased 5%, reaching around 4 million. Moreover, the greenhouse gas emissions have fallen 42% between 1995 and 2017.

As of 2021, EU countries are banning from using various disposable plastic utensils such as plates, cutlery, drinking systems (cups and straws) and even cotton swabs. Additional measures such as reducing the usage of packages (especially in deliveries), regulating the

greater durability in the use of batteries and including the right of technical assistance to consumers are being analyzed by the European Parliament, making the companies produce products that have longer durability and educating the consumers to keep the product for longer (European Commission 2020).

On this line, Mexico City, with more than 12 million inhabitants and a metropolitan area that reach 21 million inhabitants and generates 13 thousand tons of daily waste, has adopted the plastic bags usage prohibition in January 2020. The intention is banishing the disposable plastics until 2021. In the United States, Los Angeles and New York have also announced the prohibition for 2020 (United Nations Environment Programme 2020).

The plastic, allied of the global economic growth, is also one of the biggest global challenges of the sustainable development. It is estimated that 10 million plastic bags are used every minute on world (United Nations Environment Programme 2020). In 2016, 242 million tons of plastic waste were generated, that correspond to 12% of the municipals' solid waste. The inadequate disposal of plastic waste makes the sustainable management of waste difficult and as many plastics end up in rivers and seas, it has compromised marine life, due to its durability in the environment (Kaza et al. 2018).

China has also adopted investment politics aligned to the circular economy precepts. The country acts, for example, in the transition to electric mobility systems in Shenzen city. The metropolis of more than 12,5 inhabitants became in 2017 the first city in the world to have its bus fleet totally electric, in order to reduce air and noise pollution. At the time, it was estimated that 20% of the city's air came from fossil fuel vehicles. The transition was sponsored by the municipal and national governments and unleashed several direct and indirect investments in the productive chain, to the vehicle production and to the renewable energy generation. The positive result of the pilot city was extended to other cities and is an example to other countries (Ellen Macarthur Foundation 2020).

In Brazil, according to the National Confederation of Industries (2020), 76,5% of the brazilian industries are already developing actions related to the circular economy. However, only 30% of the companies relate these actions to the theme. Among the practices is the processes optimization, circular inputs, resources recovery, product life extension, consumption or usage of the product as a service, virtualizing and sharing.

Brazilian circular models are rising from the relation between the stakeholders of the productive chain, from the academy and from non-governmental organizations that make sectorial agreements with governmental spheres (Ellen Macarthur Foundation. 2020), aligned with the National Policy on Solid Waste referred by Law nº 12.305/10. The objective of the National Policy on Solid Waste is to regulate the economic, social and environmental aspects related to the solid waste management (Ministry of Environment, Brazil 2020).

The Brazilian Electric and Electronic Industry Association, with more than 400 associated companies and in partnership with Green Eletron, is implementing 5051 delivery points in 400 cities in order to realize the reverse logistics of 17% of the electronics placed on the national market until 2025. This goal is part of the sectorial agreement signed with the Ministry of the Environment on December 10th, 2019 (Brazilian Electric and Electronic Industry Association 2020). Brazil is the 7th biggest global electronic producer, with around 1,5 thousand tons/year and the disposal *per capita* reaches 8,3 kg/year, above the global average of 6,7 kg/year. Globally, around 20% of the electronics are properly discarded, while in Brazil it is around 3% (Baldé et al. 2017).

However, Schroeder et al (2019) emphasize that investments are needed to develop technologies and markets for the repair of products and reuse of materials, such as electronics, which can be accessed by lower-income consumers, providing opportunities for digital inclusion and environmental preservation.

5. Conclusions

Based on the objective of promoting the understanding of the transition from linear production to the circular economy applied to the sustainable development of cities, this research points to some conclusions.

It is observed from empirical experiences that, even when the principles and concepts of the circular economy are not fully adopted, actions such as restrictions on the use of disposable plastic utensils, use of renewable energy, product repair, recycling and remanufacturing of materials contribute to the awareness of the society towards sustainable consumption and production patterns. These actions contribute to the preservation of natural resources and the transition of the economy to circular systems, resulting in new income and market opportunities, such as secondary materials, where reused, recycled and remanufactured materials circulate.

However, studies of circular economy models show that they are focused on technical aspects such as maximization the use of materials and energy, using renewable energy and adding value to waste in the production chain (Schroeder et al.2019). Some social aspects remain excluded from the circular economy (Prendeville et al. 2018), such as the inclusion of waste pickers in the waste value chain and aspects of local culture. Schroeder et al (2019) argues that business models with greater social orientation, such as programs to raise awareness of society for sustainable consumption and production, as well as corporate governance are not fundamental in the existing circular economy models.

Moreover, a circular city should not be only based on the management of the resources and waste flows but insert their inhabitants well-being on the center of its strategical decisions. Well-being is not merely economic prosperity, but also the health and educational necessities, life quality, guaranteed human rights and social cohesion (Girard & Nocca 2019). It is recognized that although some circular economy practices are committed to the ecosystem's sustainable development, the circular economy is still on initial stage on the sustainable development discourses of cities (Schroeder et al.2019).

The circular economy model has the potential to facilitate local, regional and global sustainable development, as it seeks to align its processes with the natural cycle. However, it is clear that the humanistic dimension is almost absent from the main strategies of the existing examples, differently from the waste and energy themes. If circular processes continue to be projected and implemented without considering people at the center of their decisions, the results may not conduct to the territorial sustainable development. The circular economy has to be more inclusive and equitable for people, otherwise the problems will continue in the same gaps left by the linear economy. (Girard & Nocca 2019).

For this, public-private investments and cooperation, specific legislation and regulations, cooperation programs between national and local governments and urban planning of cities are fundamental to provide a favorable environment for the implementation of circular economy models and practices. The urban planning needs to invest in city models that regenerate and advance with mistakes and successes, through a holistic view that interconnect the economic, social and environmental dimensions, urban and rural areas, cities and regions (Girard & Nocca 2019).

Participatory public managements have abilities to be and bring together the actors involved in the development of cities, being a catalytic agent for innovative ideas and a conflict manager.

They may conduct the formation of a set of aligned public politics to the transition from the linear to the circular economy, that invest on human necessities in an equitable and inclusive way, that works on a government planning and constitute a State plan. They can conduct the formation of a framework of public policies aligned to the transition from linear models of production to the circular economy, investing in human needs in an equitable and inclusive way, oriented towards the sustainable development of cities.

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