‘Humansphere’ as the Enabler of Circular Economy in Developing Countries: A Case Study

Abstract
This article is based on a circular economy (CE) case study in Llano Chico - Ecuador. Traditionally and according to Ellen MacArthur Foundation, the CE analyses the flows of matter and energy in order to close the loop of products through the specification of two spheres: biosphere and technosphere. However, this article highlights the importance of the ‘humansphere’, which is explained under the Human Development concept. The humansphere is explored in this case study where end of life tires (ELT) are reused in order to create a retaining wall for vulnerable spaces. Through this construction, the humansphere is analysed and with it, the participation of Llano Chico community as the work force and the receiver of knowledge transfer from academia, the participation of a ministry and a private company in the donation of ELT. This article sustains the importance of considering the humansphere in order to find all the opportunities hidden in the reuse of ELT and the development of inclusive CE business models. The ELT case study also brings to light a new area of debate in current CE academia: that the technological and biological sphere do not always function as independent cycles, but where the humansphere can draw an End of Life Product through one sphere and into the other. This is an eight-shaped figure of CE cycle.

Keywords: participatory circular economy, community driven CE, ‘Humansphere’, ELT management, CE in developing countries.

1. Introduction

The extensive use of natural resources since the rise of industrialization in the mid-eighteenth century has led to environmental degradation and social inequality (Wit et al., 2018). The environment is suffering the effects of accelerated resource consumption as described by a linear economic model following the patterns of take-make-dispose (Ellen MacArthur Foundation, 2013; EC, 2014). Worldwide, 92.8 billion tons of resources are used annually and only 9.1% of this use is circular whilst the lack of material management at end of life (EOL) accounts for 67% of global greenhouse gas emissions (Wit et al., 2018). Additionally, uncontrolled landfilling has negative impacts on population health and the environment (WBCSD 2010). This is evidenced by scrap tires becoming an increasing threat to the environment. For instance, every year an average of one-billion tires reach EOL and nearly four billion are in landfills and stockpiles worldwide (WBCSD 2008).

A circular economy (CE) is essential to promote efficient production and sustainable consumption (EC, 2014; EC, 2015). The Ellen MacArthur Foundation (EMF, 2013) defines a circular economy as “an industrial system that is restorative or regenerative by intention and design” (pp.8). Kirchherr et al. (2017) analyse the concept in the realm of scholars and practitioners. It concludes that the CE is an economic system that reinforces the concepts of recovering, reducing, reusing and finally recycling materials in the different processes of the supply chain: production, distribution and consumption. It also adds that CE can operate in different realms: companies, industries, cities and regions.

Transitioning to CE requires diverse routes of action involving new business and market models, as well as different consumer behaviour (EC, 2014; Wit et al., 2018). For instance, several nations have passed take-back laws that aim to reduce material toxicity, increase availability of recyclable materials and prevent pollution (Preston & Lehne, 2017). Most countries view landfills as an undesirable option, however, in practice in developing regions land-use and disposal regulations are weak and infrastructure for rubbish collection is missing (ETRMA, 2011; Toffel, 2003). The CE model is based on the flows of biological and technical materials. However, it is essential to add to the model the role of humans, and their actions. For instance, especially in underdeveloped countries, the informal sectors play an important role in CE activities, especially in waste management processing. Turning this into a development opportunity would improve environmental, economic and social conditions (Preston & Lehne, 2017).

The objective of this work is to explore the role of the human work force (humansphere) in enabling CE practices related to end of life tires (henceforth ELTs) in developing countries. A case study in Ecuador is analysed in accordance with the current regional framework for its adaptability to community development.

1.1. A Brief Review of ELTs

By 1992 in Europe, 65% of ELTs generated were going to landfill. After a legislative framework adopted by Europe in 2008, this was reduced to 6% of the 3.4 million tonnes generated (Ramos, et al., 2011). ELT recovery through CE has associated opportunities and challenges. Many developed countries have clear legislative frameworks and use three main approaches to ELT collection and recovery. The first approach is Extended Producer Responsibility (EPR), the second includes Governmental responsibility financed through a tax added to the cost of a new tire, while the final approach involves a free market system that makes profits from the recovery and recycling of tires (Ramos et al., 2011; Sienkiewicz, 2012; ERTMA, 2011). EPR is the most popular approach in Europe, with up to a 100% success rate in recovery of used tires by countries where it is implemented. The free market system is less attractive and more difficult to control (Sienkiewicz et al., 2012). Innovative technologies for the management of used tires have progressed in the EU, following restrictive legal regulations. Material recycling and combustion are the most commonly used technologically developed methods (Sienkiewicz et al., 2012). Spanish management of ELT has been successful due to recovery policies, such as door-to-door collection network that brought about a correct handling of nearly all present and previous existing ELTs. In addition, they are promoting new forms of self-supporting recovery and management options to ensure the future of the value chain (Urubunu et al., 2011). Ramos et al. (2011) compared ELT management techniques between the European Union (EU) and Spain, finding that shredding and grinding technologies cover a large part of the market, and not all discretized sizes had a useful application. They mention that another growing market is energy recovery, mainly used in cement kilns, but with a potential for expansion to other sectors. Additionally, pyrolysis and gasification are appropriate applications for synthetic products. In general, the market requires technology expansion to lead in waste management (Ramos et al., 2011).

The main applications of ELTs are in tire-derived fuel (TDF), and tire-derived material (TDM) (Pecnik and Miller 2008). Tires have a high-energy content so TDF is an equal or better source of energy than other fuels (Duggirala, 2009; Singh et al., 2009). Using tires as an alternative fuel source requires little energy and few resources, with lower waste production than recycling, since tires are ground down and used to make new materials (Sienkiewicz et al., 2012). However, energy recovery is not very profitable when analysing the ELT's life cycle. The energy needed for production is 87-115 Mj/kg, while the combustion process only recovers around 35-42 Mj/kg (Duggirala, 2009; Singh et al., 2009; Bajus & Olahová, 2011; Sienkiewicz et al., 2012; Laboy-Nieves, 2014). While energy recovery remains one of the most popular ELT management methods, material recycling is a better approach regarding energy (as less energy is obtained from combustion processes than is required for the manufacturing of a tire) (Sienkiewicz et al., 2012). Within the CE framework, materials turned into energy through incineration is not a circular practice, since they do not return at the same functional equivalence and will have no life after incineration (WBCSD, 2019). To this extent, the main objective of CE processes is to create a valuable raw material for other uses, not merely energy recovery.

Landi et al. (2016) evaluated two different scenarios for ELT processing to create new materials, based on the STECA Company system for ground particle production. In the first scenario was evaluated the current process. In the second scenario a machine for textile cleaning and compaction is used, which increases the environmental impact due to higher energy consumption. In terms of waste generation, the first scenario produces larger amounts of fibrous material ending up in landfills or incineration. Both recovery scenarios have an environmental impact (Landi et al., 2016). To generate new products from used tires, raw materials are recovered using highly complex technological processes to satisfy standards. The component parts of the tire have to be separated from the granules after the grinding procedure, which produces five different types of granules based on size fraction (Sienkiewicz et al., 2012). Whole or shredded tires are used in a variety of civil engineering projects because of their shape, size and other desirable attributes (economical, lightweight, permeable, high elasticity, shock and noise absorption, good insulation and durable) (Oikonomou and Mavridou, 2009; Sienkiewicz et al., 2012; WBCSD, 2018). Tires have a variety of uses in civil engineering projects, such as in embankments, for erosion control and as rainwater runoff barriers, among others, without the need of major equipment (WBCSD, 2008). Oikonomou and Mavridou (2009) studied possibilities for using waste tire rubber in civil engineering, and found that the use of modified concrete with the inclusion of crumb rubber was a good solution when mechanical properties were not a crucial factor. In addition, mixing asphalt with rubber aggregates in wet or dry processes improves its resistance, and has a promising use in geotechnical applications because of its inner properties and low cost (Oikonomou and Mavridou, 2009). The WBCSD (2018) analysed a global representative sample of all geographical regions and demonstrated that two recovery routes recuperated 86% of ELT, of which TDF represented 31%, TDM 55%, Civil Engineering and backfilling represented but 2% of the total.

In Ecuador, 3.4 million new tires enter the country every year and of all discarded tires, only 18% are properly managed (Cecchin et al., 2019). New companies are focusing on the sustainable development and proper management of ELT. Tractomaq [I] has a recycling plant for the management and treatment of used tires in Ecuador. In this case, the tires are broken down, and the metals separated from the rubber. Next, the rubber is crushed at room temperature, and the collected pieces enter a pyrolysis process that produces a gas similar to propane. However, scholars argue that by promoting energy efficient waste inineration, it conflicts with measures that aim to reduce carbon dioxide emissions (Malinauskatie et al., 2017). Additionally, since it is a down cycling process, it is debatable whether this process enters into the concept of circular economy. In Ecocaucho [II] 95% of the material used comes from recycled ELT. The company processes 900 tires weekly and reuses around 50 thousand tires per year through material recovery. Likewise, Apci-Aliboc [III] produces granulated rubber powder used as an aggregate and mixed with asphalt or concrete to construct roads, create ecological floors and improve the resulting final product quality. However, of the nearly 40 tire recycling companies in Ecuador, only a few produce high quality granulate sizes. Furthermore, limited demand for this material in the country is an impediment to the industries towards operating at their design capacity (Cecchin et al., 2019).

Cecchin et al (2019) described how in 2013, Ecuador implemented an EPR policy for used tires with recycling targets, where the producers and importers were required to provide an annual ELT management report. The authors also highlighted that the results showed a weakness in achieving the recovery targets set by the local authority, leaving one third of tires not properly managed. This was due to a lack of control over tire importers and producers, as well as complex geography for territorial organization. For this reason, in a joint effort from the importers and producers, the SEGINUS group was established in 2018 to improve the management of tires (Cecchin et al. 2019).

Furthermore, the informal workforce in Ecuador plays a key role in the development of CE and EPR policies. The informality rates in Ecuador are one of the highest in Latin America, with over 60% of workers operating in the informal sector (Canelas, 2019). Within the informal sector, several groups work with different types of residential and industrialized common inorganic waste, mostly recovering these resources and selling them to intermediaries or directly to recycling companies. This can be views as an opportunity of employment within the framework of EPR policies and CE. Mishra et al. (2019) identified the “humansphere” as a new dynamic, unique concept to developing countries, which serves as a means of transitioning from a linear to a CE providing opportunities of employment to the informal sector.

1.2. Circular Economy Flows

The CE is largely rooted in similar fields of study, such as Cradle-to-Cradle, Biomimetic and Industrial Ecology. Therefore, it is not a new concept. However, it has had a successful diffusion in recent years. The Ellen MacArthur Foundation (EMF) has propagated the concept of CE in a butterfly diagram (Figure 1), which explains a continuous flow of technological and biological materials through a value chain approach, closing the processes by cascades (Ellen MacArthur Foundation, 2013).

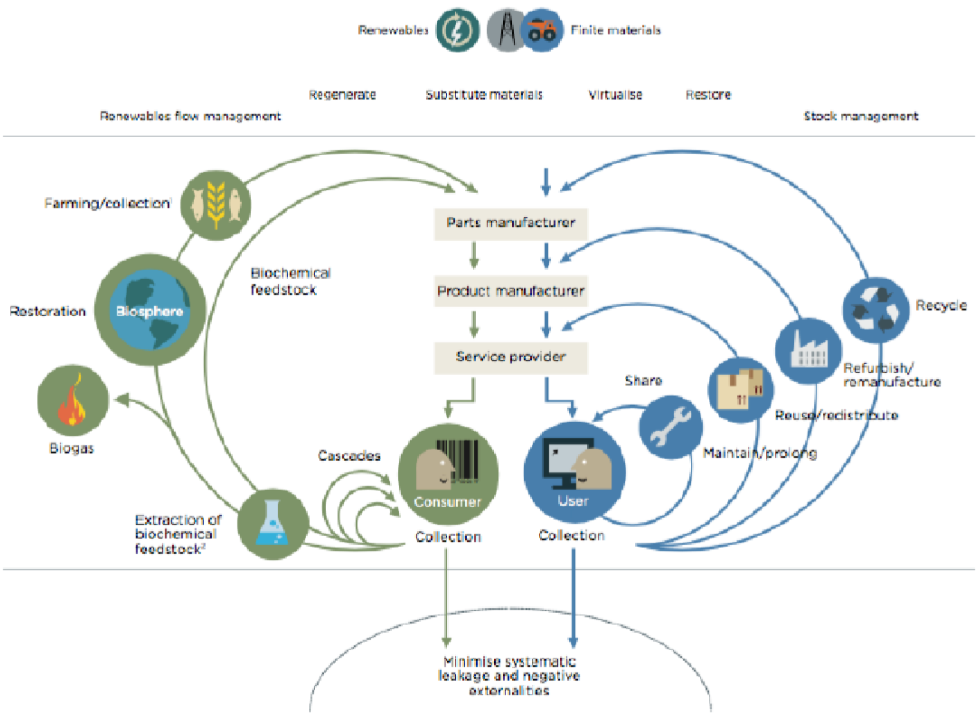

Figure 1. The Circular Economy Butterfly Diagram. Source: Ellen MacArthur Foundation, 2013

The diagram (Figure 1) demonstrates a correlation between two subsystems: the biosphere and technosphere. On one hand (the left side of the diagram), there are flows of biological nutrients from the biosphere, resources that are produced directly by nature and which processes can be used for human use.

At this sphere, natural processes related to ingestion, digestion, excretion and reproduction occur (Van der Voet, 2002). On the other hand, (the right side of the diagram) there are technical flows of the technosphere, which contain the stocks and flows, products and services, which are controlled and caused by humans (Van der Voet, 2002). In a model of CE, these technical flows must be reused in cascades, and recirculate without contaminating. The technosphere in that sense should function and be designed in order to replace the concept of waste, to the one of nutrients that feed new processes. This replicated the processes found in systems of the biosphere.

1.3. Humansphere

It is important to reconsider the model of CE within the butterfly diagram, by adding a specific section that includes the actions of human beings in a system such as CE (Figure 2). As Lemille, 2017a says a "human-embedded circular economy" which looks for the elimination of waste but also for eliminating poverty and inequalities. The drawback of the diagram explained above from the EMF is the "limited role of people as solely being either consumers or users. The circular humansphere concept introduces humans as an integral part of the CE" (Schröder, et al., 2020).

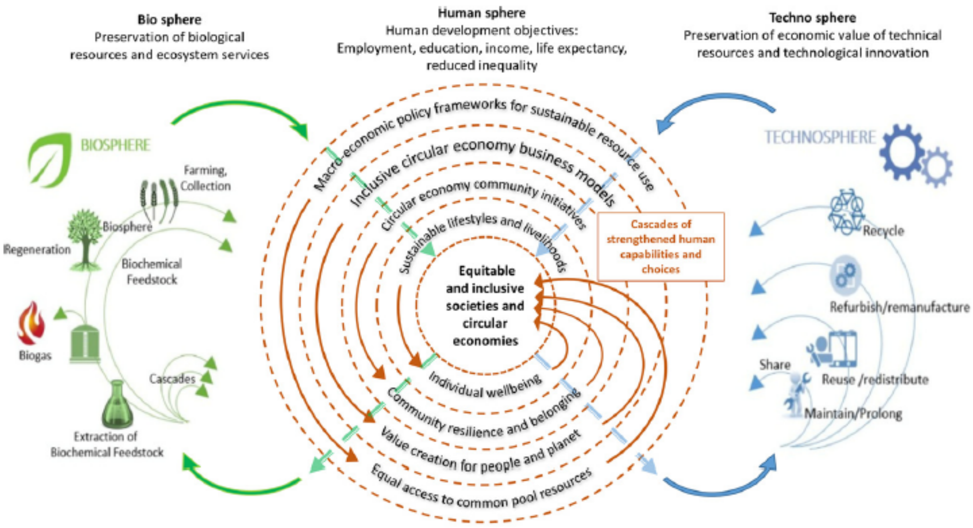

Figure 2. Framework for a Human Development focused Circular Economy (Schröder, et al., 2020)

The humansphere (Schröder, et al., 2020) is explained under the Human Development (HD) concept, which raises finding human wellbeing as an alternative to orthodox welfare economics. It is linked with the Human Development Index (HDI) that combines three fundamental measures of human wellbeing: life expectancy, education, employment and income per capita.

As (Schröder, et al., 2020) explains in Fig.2, the humansphere interacts with the bio and the techno spheres, in order to strengthen the objectives of HDI by loops developed in four points. The outer loop is referred to the macro-economic policies that are rooted not only to resource efficiency but also to integral views such as consumption and production systems. The government and its macroeconomic policy formulation is crucial for developing a "human embedded circular economy" by creating economic incentives or changing certain taxation programs towards the use of non-renewable resources. For instance, Sweden was the first country to pass a law that provides preferences to human-based activities such as repairing.

The second outer loop is based on inclusive circular economy business models, viable ventures that embrace the business values with social impact. It considers several areas, especially in emerging economies such as informal workforce, role of female entrepreneurs and others.

The third loop is related to CE community initiatives. This includes bottom-up initiatives in rural and urban areas specially created by communities to incentivize citizen participation in activities such as recycling, repairing or remanufacturing. For instance, the participation of waste-pickers in cities are being recognized by municipalities and citizens as valuable in the creation of jobs, which in turn implies the right to improved working conditions. These initiatives are happening in emerging economies. Adding a sphere that is related to the human action itself, working with the materials that can be avoided ending up in landfill, whilst also providing an environmental, social and economic opportunity.

The fourth loop talks about sustainable lifestyles and livelihoods. CE develops opportunities for consumers to change consumption habits that are rooted in a linear economy. In order for CE to contribute to HD, new business models are required that are driven by flexible production. This is especially true for emerging economies, to avoid the lock-in into linear consumption patterns (Schröder and Anantharaman, 2016). These new business models are designed to enable lifestyle-leapfrogging, taking advantage of the context of emerging economies where small businesses for repairing products for instance still exist. CE will allow opportunities to meet societal needs, rather than simply allowing economic growth. The opportunity lies in finding a new paradigm where human beings are an integrated element with nature (Schröder, et al., 2020). As Lemille (2017b) explains, the humansphere refers to rethinking about the function of the human being as energy and as a resource towards the biosphere. According to Cradle-to-Cradle, all ants weigh more than all humans (McDonough and Braungart, 2008). However, through their functions, they renew the biosphere. It is imperative to talk about the function of humans in the biosphere, not only for environmental remediation but also for regenerative processes that can help nature thrive. Human beings can change their role with adaptive strategies and rebuild the ecosystem.

The development of the human sphere within the CE is essential to combat poverty. It is also a way of bringing the CE concept close to emerging economies, where social inequality and environmental problems abound (Lemille, 2017b). For example: governments can establish laws that support and allow social inclusion; companies can get involved in a manner that informal workers are empowered; industry leaders can ensure that smaller actors are accounted for in all sectors; consumers can give rise to a demand for fairer products; and employers can adopt commercial models of labour integration (Lemille, 2017b).

1.4. Case Study

The Parish of Llano Chico is located northwest of the city of Quito. In 2012, it became a new parish of the Quito canton (PDOT, 2012). It has a concentrated urban nucleus of 13.5 km2 around its main park and its population is approximately 13,734 inhabitants (MDMQ, 2016; PDOT, 2012). It is estimated that its population in 2025 will reach 14 610 inhabitants. Due to the lack of provision of basic services, its neighbourhoods tend to be recursive, giving way to possible circular economy solutions (Cecchin, et al, 2019). Additionally, Llano Chico tends to work as an organized community that incentivizes different social, cultural and economic activities (Criollo et al, 2020). The Llano Chico case study involves a process to put together ELT, people and technology to close the loop of this material. This community driven initiative starts with the participation of academia to design a construction technique that allows the reuse of ELT. The tires that were donated worked as a new material for the formation of a retaining wall that can safeguard the lives and belongings of the most vulnerable people in this parish. Cecchin et al. (2019) highlighted the case study of the retaining wall in their research, and this study builds on their work to show the importance of the humansphere for CE applications in emerging economies and for vulnerable urban populations. Per se, the tires do not become the basis of a circular economy, but rather the engagement of people, their training, their knowledge skills with academia and the opportunity of incorporating reused materials in a novel retaining wall that could reach a large scale.

This project focuses on four pillars to be successful and sustainable. The first pillar involves academic research and user need definition to create low-cost techniques, and solve real community needs. The second pillar includes community participation and training to allow them to take over this process and carry it out autonomously. The third pillar is based on logistics and community organization to get available materials at low cost or free of charge in addition to the volunteer workforce. The final pillar is the implementation of the retaining wall, which involves continuous training of participants to allow them to re-create the cycle and close the loop.

2. From theory to practise: looking at the humansphere through the lens of the case study

On the one hand, Cecchin et al. (2019) described the Llano Chico case study as a reflection on the EOL management of products in Ecuador, with the potential of promoting resistance and social sustainability in informal settlements exposed to natural disasters. The authors explored the possibilities of collaboration with governmental agencies to promote improved EOL management through public policies that could emancipate collaboration with the informal sector. On the other hand, this research takes the Llano Chico case study to establish relationships between the CE in theory (as part of the 'humansphere') and in practice. The objective harnesses this case study, in order to offer a critical examination of the state of the art of circular economy theory through lessons learnt in practice.

There were a number of different materials needed in this project (shown in Table 1), with the main raw material being the ELTs gathered from the private sector as donations. The soil required for the tire infill was also obtained through donation, in relation to excavations being carried out in the area and where the dumper truck drivers were invited to collaborate in the project. The remaining materials were financed with public workshops, carried out to provide training in the construction of retaining walls using ELTs. Additional finance was also obtained through a research project led by the Pontifical Catholic University of Ecuador (PUCE), Faculty of Architecture, Design and the Arts. The installation process is shown in Figure 3.

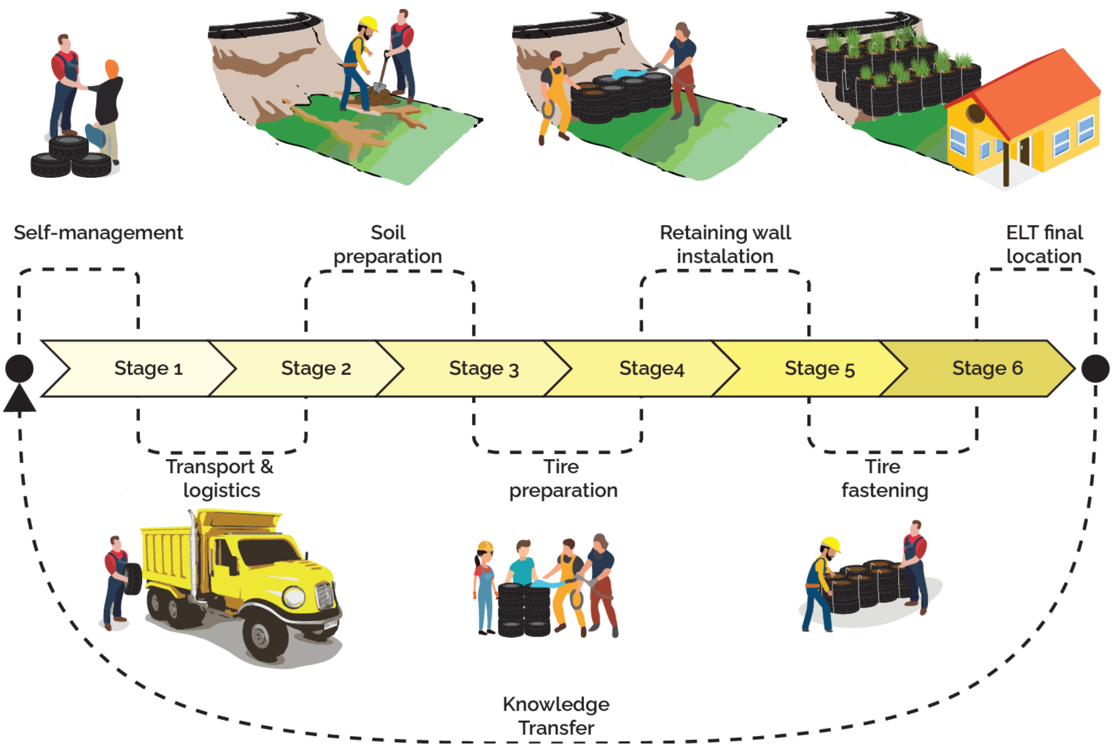

Figure 3. Stages for the construction of a retaining wall based on ELT material in Llano Chico.

Table1. List of materials and their use in the retaining wall

Material	Use
Tires	retaining wall
Soil	tire infill
PVC pipe	drainage system
Gravel	drainage system
Wire or rope	tire fastening
Industrial plastic sheeting	Interlayer drainage system

The four loops of the humansphere can be analysed in this context. The outer loop called "macroeconomic policy framework for sustainable resource use" was present in the EOL legislation of the Ministry of the Environment, which enabled the private sector to donate ELTs to the project. Additionally, as this paper is being written, a formal CE law is being debated by the Ecuadorian government (Pichincha Comunicaciones, 2020). Its main objective is to incentivize and control the activities of the enterprises in order to manage their waste properly and reinforce CE opportunities. The CE law includes opportunities to recognize waste pickers as formal employees and an important part of the whole chain of waste management in cities.

The second loop is based on inclusive circular economy business models. In this case Llano Chico showed the potential for ELTs to become a raw construction material led by the informal sector. Additionally, the workshop served as a link with the community, not only to teach good constructive practices but also to create a social fabric that can serve to replicate this type of initiatives in the place. The mentorship and the "know how" of how to build a wall with EOL can become a novel business model that can be applied in different communities

The third outer loop is related to CE community initiatives. The Llano Chico retaining wall is an initiative in an emerging economy (the informal sector). Moreover, it works with ELTs that are not subsequently dumped in landfill or otherwise. The final retaining wall mitigates negative environmental effects, whilst the construction of the wall and ELTs as a raw construction material open social and economic opportunities.

The fourth loop is about sustainable lifestyles and livelihoods. A change in behaviour can be seen in relation to environmental services. The retaining wall is being built with EOL tires, this material was perceived in the area as low quality and cement was mostly preferred. However, through the workshop, design and construction with the population, it was demonstrated that this material suits the need for specific construction elements. Once the retaining wall was built as a final product, it was guaranteed that it had a long life use. Additionally, it is possible to repair it with local resources. Taking into account Figure 2 and from Schröder, et al. (2020), this case is based on circular economy community initiative, therefore it is linked with community resilience and belonging. This takes into account equitable and inclusive societies and circular economies.

2.1. From loops to figures of eight

An interesting overall point to note is how the case study offers a new perspective regarding CE cycles. The state of the art of the CE describes two cycles that act either in the technological sphere or in the biological sphere. These cycles are facilitated through the loops of the humansphere. Let us consider paper for example. Paper use can be maintained in the technological sphere: people use the paper; it is cleaned, shredded and reduced to a raw material; new, fresh paper is made; people use the paper. It can also be fed into the biological sphere: people use the paper; it is cleaned, shredded and reduced to a compostable material; the paper becomes a nutrient source that is re-incorporated into Mother Nature. However, the ELT retaining wall flows through both the technological and biological cycles, more in a figure of eight with the humansphere at its centre, than in a 'loop'. The ELTs are transformed in the technological sphere from being a waste product that has no further use in the automotive industry, to being a raw material for the construction industry and civil engineering works (the retaining wall). This does not occur through a technical transformation of the tire, but through an innovative perception of the potential of ELTs in the humansphere. This change of perception leads to the reuse of the tire as raw material for the construction of a retaining wall. Once completed, the tire retaining wall acts as a matrix that not only retains the soil slope, but also provides a structure that can be populated by a range of local flora (from plants to trees). In this aspect, there is a stark difference between a traditional reinforced concrete retaining wall and those built from ELTs. A reinforced concrete retaining wall has little post-construction ecological value; it merely completes its function of slope stability. In contrast, the gravity retaining wall of Llano Chico has an ecological value following construction. In this manner, the ELTs come out of the technological cycle, and become an element of the biological cycle. The end point of the ELT retaining wall is a matrix for local flora, in addition to its function as a retaining wall. This combined series of cycles can be represented as a figure of eight, which starts in the technological cycle, has the humansphere at its centre, and ends in a biological cycle.

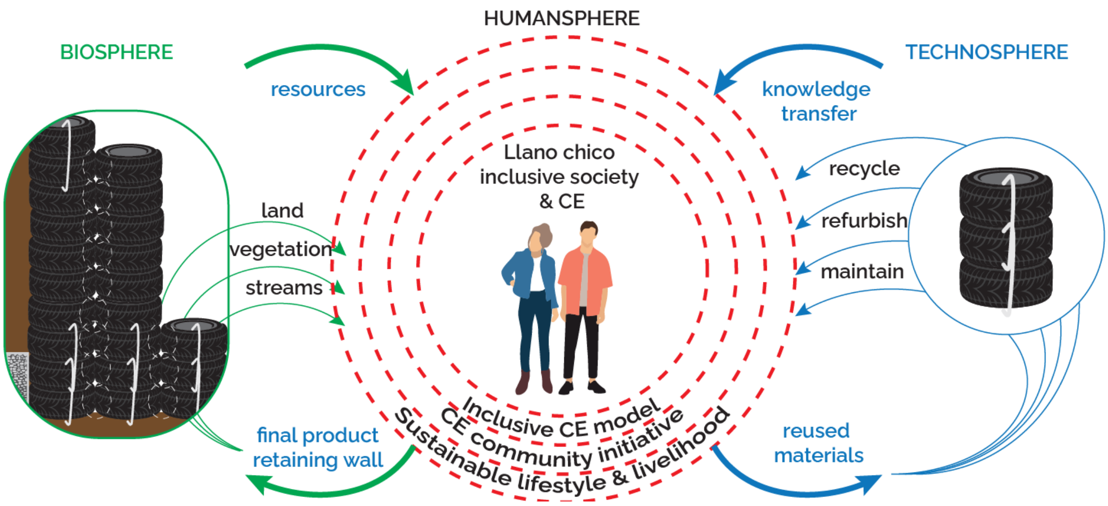

Figure 4. Loops and cascades of the humansphere in Llano Chico.

3. Conclusions and recommendations

Circular Economy (CE) models offer a powerful alternative against linear production processes that lead to resource depletion, waste management problems and environmental degradation. This is particularly true for End of Life Tires (ELTs), which at the end of their use in the automobile industry are generally burnt or dumped. CE innovation includes the breakdown of ELTs to being a granulated rubber, or even to their core materials. However, this entails a high-energy expenditure and certain environmental impacts. As an alternative, the use of whole ELTs in civil engineering applications can be a successful, low cost alternative. This is especially relevant for emerging economies, and in this context a case study was carried out through the construction of a gravity retaining in Llano Chico, a low-income urban area of Quito, the capital of Ecuador.

The transformation of whole ELTs into a raw material for civil engineering works required nothing more than human ingenuity, looking at the ELTs from a different perspective regarding their inherent base mechanical properties. In this sense, the humansphere currently at the frontier of CE thinking was highlighted. In addition, the loops of the technical and biological spheres of the common CE "butterfly diagram" were critically assessed. In the case study, the ELTs were cycled through the technical sphere in a recollection and recycling process. The humansphere processes transformed the ELTs from being a waste product into a retaining wall. However, once constructed, the retaining wall from ELTs serves as a matrix for local flora to take root. This is in stark comparison to a traditional concrete retaining wall, which has little ecological value. The end point of the ELT wall is its incorporation into the environment, where its cycle ends in the biological sphere.

Overall, the case study invokes the need for further research into CE practical applications in low-income communities in emerging economies. Additionally, it calls us to critically assess the loops of the technological and biological spheres in current academic debate surrounding CE. This article argues that the case study highlighted the importance of the human sphere in drawing out the potential of End of Life Products (ELP), without necessarily having to radically change those products through energy intensive industrial processes. Furthermore, the observation is raised that the technological and biological spheres do not always function as two independent cycles. The humansphere can link the two loops, drawing an ELP through one cycle and into the other. This is a newly defined, "figure of eight" cycle.

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