UNIVERSIDAD SAN FRANCISCO DE QUITO USFQ

Colegio de Ciencias e Ingeniería

Circular Economy in the Plastic Industry: Supply Chain, Business Model, Design Strategies and Methodology Creation and Application in an Ecuadorian Company.

.

Daniela Zambrano Dávalos

Ingeniería Industrial

Trabajo de integración curricular presentado como requisito
para la obtención del título de
Ingeniera Industrial

Quito, 18 de diciembre de 2019

UNIVERSIDAD SAN FRANCISCO DE QUITO USFQ

COLEGIO DE CIENCIAS E INGENIERÍA

HOJA DE CALIFICACIÓN
DE TRABAJO DE INTEGRACIÓN CURRICULAR

Circular Economy in the Plastic Industry: Supply Chain, Business Model, Design Strategies and Methodology Creation and Application in an Ecuadorian Company.

Daniela Zambrano Dávalos

Calificación:

Nombre del profesor, Título académico: **Cristina Camacho, MS**

Firma del profesor: ______________________________

Quito, 18 de diciembre de 2019

DERECHOS DE AUTOR

Firma del estudiante: ____

Nombres y apellidos: Daniela Zambrano Dávalos

Código: 00123775

Cédula de identidad: 1726498320

Lugar y fecha: Quito, 18 de diciembre de 2019

AGRADECIMIENTOS

Gracias a mis padres por el apoyo, esfuerzo, ayuda y dedicación para sacarme adelante e impulsarme para cumplir con mis sueños estando siempre a mi lado celebrando y sufriendo en cada etapa, a mis hermanos que siempre han sido un respaldo para mí. Gracias abuelos Carmen Cecilia y Gonzalo, por ser unos segundos padres para mí y celebrar cada logro en mi vida. A Erick quien me apoyó desde el primer día que decidí estudiar la carrera que me apasiona, quien estuvo ahí para todas mis alegrías y preocupaciones siendo un pilar para mí, a Camila gracias por todas tus palabras y consejos, por ser incondicional. A mis amigos Adrián y Dennise quienes a pesar de la distancia han estado siempre conmigo.

Un especial agradecimiento a Cristina Camacho por todo el tiempo dedicado a mi trabajo y por formarme como profesional hasta los últimos días de la carrera. A Clara Orellana y Carlos Suárez por su aporte invaluable a mi trabajo de titulación. Agradezco también a Pablo Dávila ya que por su clase decidí estudiar Ingeniería Industrial, además por la formación que me ha dado tanto en sus clases así como el año que he sido su asistente de cátedra. Finalmente agradezco al departamento de Ingeniería Industrial, principalmente a los profesores Sonia, Gaby, Galo y Danny quienes impartieron su conocimiento de la mejor manera posible.

Dedicado a mi madre

RESUMEN

En el presente trabajo se desarrolla una nueva metodología de transición a Economía Circular basado en una revisión de literatura, la cual engloba aspectos de Cadena de Suministro, Modelos de negocios, Diseño de Productos y Plástico. En la metodología se encuentra una parte cualitativa, que evalúa la preparación de una empresa para su transición a la Economía Circular, además de una parte cuantitativa que calcula el Índice de Circularidad del Material para productos de una empresa. Con esta metodología se plantea facilitar la transición de empresas a economías circulares, en base a una retroalimentación basada en la revisión de literatura. Además se proveen los resultados de circularidad de un producto para tener un punto de partida en la aplicación de la Economía Circular y de esta manera realizar mediciones futuras que evidencien cómo ha mejorado dicho índice en base a técnicas implementadas de Economía Circular. Además, se realiza la aplicación de la metodología en una empresa ecuatoriana de plástico, obteniendo como resultado cualitativo la necesidad de un modelo de negocios estructurado, de inclusión de más miembros de la Cadena de Suministro y de compartir el riesgo asociado con la transición Adicionalmente, la parte cuantitativa se aplicó en 4 tipos de productos de la empresa, teniendo como resultado que el producto con mayor circularidad es el Plato 6, con un índice de circularidad de 0.59, sin embargo este es el plato con menor producción en la empresa. Por otro lado, el plato con menor índice de circularidad es el Plato Profundo con un índice de circularidad de 0.22.

Palabras clave: Economía Circular, Cadena de Suministro, Modelo de Negocios, Diseño de Productos, Plástico, Índice de Circularidad del Material.

ABSTRACT

In the present work a new methodology of transition to Circular Economy is built based on a literature review, which encompasses aspects of Supply Chain, Business Models, Product Design and Plastic. The methodology includes a qualitative part, which evaluates the preparation of a company for its transition to Circular Economy, as well as a quantitative part that calculates the Material Circularity Index for a company's products. With this methodology it is proposed to facilitate the transition based on the results, with a feedback also based on the literature review, in addition to providing the results of the circularity of a product to have a starting point in the application of the Circular Economy and this way, to carry out future measurements that demonstrate how this index has improved based on techniques implemented in Circular Economy. In addition, the methodology is applied in an Ecuadorian plastic company, obtaining as a qualitative result the need for a structured business model, including more members of the Supply Chain in the transition and sharing the risk associated with the same. Additionally, the quantitative part was applied in 4 types of products of the company, resulting in the product with greater circularity is Plate 6, with a circularity index of 0.59, however this is the dish with lower production in the company. On the other hand, the dish with the lowest circularity index is the Deep Plate with 0.22.

Key words: Circular Economy, Supply Chain. Business Model, Product Design, Plastic, Material Circularity Index.

TABLA DE CONTENIDO

ÍNDICE DE TABLAS

ÍNDICE DE FIGURAS

Circular Economy in the Plastic Industry: Supply Chain, Business Model, Design Strategies and Methodology Creation and Application in an Ecuadorian Company.

Daniela Zambrano

Universidad San Francisco de Quito, Colegio de Ciencia e Ingeniería, Ingeniería Industrial, Campus Cumbayá, Código Postal 17-1200-841. Quito-Ecuador

dzambranod@estud.usfq.edu.ec

1. Introduction

Worldwide exaggerated consumption of resources is a large problem that we are all facing, given the fact that there is a finite number of resources available (Amato, et. al., 2019). Between 1970 and 2010, there was an increase in resource consumption from 23.7 to 70.1 million tons due to population and economic growth (Valenturf, et. al., 2019). According to the Ecuadorian National Institute of Statistics and Censuses (INEC), of a total of 5483 Ecuadorian companies that produce plastic waste, only 17% are aware of the amount of waste they generate, which represents a total of almost 25,000 tons (2016). Furthermore, it is estimated that these 25,000 tons only represent 1.67% of the total amount of plastic waste generated (INEC, 2016). Although the investment of companies in environmental protection initiatives between 2010 and 2016 has significantly increased (INEC, 2016), environmental responsibility is not yet sufficient to have a balance between human beings' consumption, waste generation, and nature.

In the census conducted by INEC in 2010, it was forecasted that by 2017, Ecuador would start generating 5.4 million tons of solid waste per year (Ministerio del Ambiente, s.f.). In the other hand, data corresponding to 2014 shows that of the total solid waste generated in this year, 25% was recyclable, which is equivalent to more than 1.3 million tons (RENAREC, 2015). Within solid waste, 2.6% is glass, 2.2% is scrap, 9.4% is paper and cardboard and 11% is plastic. Of all recyclable waste, in 2014, RENAREC (Ecuadorian National Network of Recyclers) was able to collect only 24% (RENAREC, 2015).

Just as the increase in population generates more waste and at the same time, causes environmental problems, efforts to develop new technologies and philosophies that contribute to environmental care and responsibility are also intensified. One of these efforts is the arise of the study of circular economies (CE), which begins with the idea of performing biological and technical cycles of materials, in other words, reinserting biological waste in nature without any harm and restoring non biological waste through different processes such as recycling, maintenance, reuse, others (Ayres, 1994 Circular economy is a restorative and regenerative industrial system, by intention and design, which replaces the end of life of a product by its restoration (Ellen MacArthur Foundation, 2013). Its beginnings occur in the 90s, however the efforts to apply CE and conduct deeper studies in this subject occur in 2016 (Kirchherr, et. al., 2017).

CE also goes hand in hand with the United Nations' Sustainable Development Goals created in 2015, with goals that should be achieved in the next 11 years (United Nations, 2015). Some of the objectives are closely related to the environment, responsible production and economic growth, which can be achieved through CE techniques for their restorative and regenerative philosophy, in addition to cost savings opportunities (Ellen MacArthur Foundation, 2017).

Despite being an interesting technique for contributing to the environment, the implementation of CE has some biophysical limitations, such as very high energy requirements and reduced quality of resources (Valenturf, et. al., 2019). Furthermore, it needs the commitment of all the stakeholders of the company. All these factors contribute to a complex dynamic between parts when the implementation of CE comes to place (Parida et. al., 2019). In addition, it is necessary to understand the fundamentals of CE to determine the strategies that will be used as a company to achieve the objectives of reducing pollution and of increasing resource utilization (Parida, et. al., 2019). To this end, it is proposed to analyze the application of CE in the supply chain (SC) of companies, as well as, a review of the strategies that can be used for the design of products and business models under the standards of the circular economy. Furthermore, it would be ideal to implement CE with all members of the supply chain. In linear economies, products are manufactured, used and disposed; hence, they can work without a full integration of all members of the supply chain. However, in CE products are manufactures, used, restored in order to avoid the final waste, which means that it would be necessary to have a collaboration of the SC members.

Therefore, in order to contribute to the sustainability of companies, the present study focuses on the development of a new methodology for the evaluation of the circularity of a plastics manufacturing company. The project begins with a literature review related to circularity indexes, circular economy, circularity in the supply chain, strategies, sustainability, product and business models. The next step consists on the development of a methodology that measures the level and preparation that a company has to introduce circular economy in its strategic operational objectives. In the literature review, it has been found that although there are already certain methodologies for the evaluation of circularity of companies, there is a need for a methodology that focuses on single-use plastic products used in the food industry, since this material is one of the main problems in the contamination of the planet, given the fact that only 14% of the plastic production is recycled (Ellen MacArthur Foundation, 2017). Therein, the present work proposes a new methodology, based on the methodologies of Circularity Indicators developed by the foundation of Ellen MacArthur, and the methodology of "A two-stage transformation model for large manufacturing companies", developed by Parida, et. to (2019). Finally, the application of the new methodology is carried out in a plastics manufacturing company, which handles 70 tons of plastic plates and 30 tons of plastic cutlery per month. The application of the methodology focuses on determining the circularity index of disposable plates in order to determine and analyze opportunities for improvement.

2. Methods

The following research questions were determined in order to guide and structure the literature review conducted for the present study:

1. What are the different type of business model strategies and product designs that exist to implement circular economy in companies with different types of products?
2. What are the difficulties that companies experience when applying circular economy along the members of their supply chain?

The snowball methodology created by Wohlin (2014), was followed in order to conduct the literature review of the present study (as shown in Figure 1).

As a first step, the inclusion and exclusion criteria of the first group of publications that served as the beginning of the snowball methodology were established. Scopus was used as the search engine, since it is the largest database with peer review citations. Publications between 2010 and 2019 were included. Only publications in English were included. In addition, the areas of Economics, Econometrics and Finance were excluded.

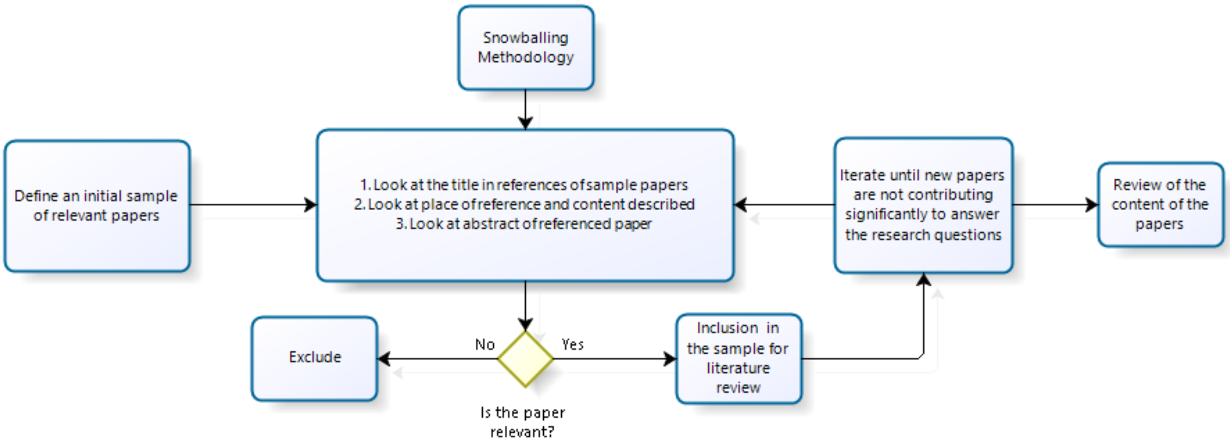

Figure 1 Snowballing Methodology

The terms used for the search were: "circular economy", "circular economy" AND "supply chain", "circular economy" AND strategies, "circular economy" AND sustainability, "circular economy" AND product and "circular economy" AND “business model”. The title, keywords and / or abstract had to contain the search terms mentioned before, in order for the publication to be selected.

Based on the results, a second filter was used, in which it was determined whether the content was aligned with the objectives of the study, which discarded publications that did not answer the research questions in any way.

3. Literature Review

Circular economy (CE) was born in 1994 from the idea, within the company's metabolism, that materials must go through a cycle; as opposed to a linear economy, in which material becomes waste after being extracted, processed and used (Ayres, 1994). Despite being an idea that began more than 20 years ago, the term "circular economy" just started to be mentioned in 2016, being then, a new approach to studies that aim to contribute to the sustainability of companies (Kirchherr, et. Alt., 2017). From that moment on, research began to be carried out on the term circular economy and its implementation in companies. It is only in 2018, that The World Economy Forum takes the initiative to promote CE (Sikdar, 2019).

In most studies, CE is defined as a restorative and regenerative industrial system by intention and design, which replaces the term “end of life” with restoration (Kirchherr, et. al., 2017; Ellen MacArthur Foundation, 2015; Sikdar, 2019). The 4R framework (Reduce, Reuse, Recycle and Recover) is suggested within CE conceptualizations, of which recycling is the most driven technique; however, considering only the recycling of materials is not considered CE, since CE also searches the way of reintroducing the material in the line of production in order to reduce consumption of virgin raw materials (Kirchherr , et. al., 2017).

Currently, the model used by companies is a linear economy, which consists of extracting the resource, manufacturing it, using it and disposing it (Velenturf, et. al., 2019). In the disposal phase, it is considered that the product reached the end of its life cycle, obtaining a waste that can be harmful to the environment (Velenturf, et. al., 2019). On the other hand, circular economy, proposes a strategy of reduction of resource consumption and waste generation, which does not imply that it will harm in any way the growth of the company, on the contrary, it is a growth strategy with environmental responsibility and criteria of sustainability (Soporan, et. al., 2019). The term 'circularity of materials or resources', refers to the fact that the life cycle changes from being: manufacturing, functionality and disposal; to the fact that at the end of the functionality, the resulting material is used in the same or similar process (Soporan, et. al., 2019). In order to ensure that the materials are circular, it is important to consider the two types of loops according to the resources used: technical and biological; to obtain a "cradle to cradle" economy or CE (Bocken, et. al., 2016).

On the other hand, in order to have an adequate and functional application of CE it is important to understand the company's ecosystem, that is, all stakeholders that share environmental responsibility. For this, it is necessary to have an alignment on the objectives of the stakeholders in order to generate CE implementation strategies throughout the entire supply chain (Parida, et. al., 2019). In the past, it was assumed that the business models that are generated based on circular economy had some associated risks, for which companies refused to leave their linear economy supply chain models. However, it is now known that implementing appropriate CE strategies and sharing the risk with stakeholders within the supply chain can lead to economic, sustainable and social benefits (Parida, et. al., 2019).

One of the main restrictions that the application of CE has on the supply chain levels is that a large amount of energy is required to recover materials, as well as biophysical limitations on resources (Velenturf, et. al., 2019). On the other hand, the quality of the resource may decrease, which is an inconvenience to the quality standards of companies (Velenturf, et. al., 2019). In order to deal with these type of difficulties, it is ideal to, from the beginning, design of products and business models with circular strategies. Doing this, facilitates the applicability of CE, without compromising the quality of the product or increasing the cost (Bocken , et. al., 2016).

Product design strategies that take into account CE consider three loops: slowdown, closure and narrowing (Bocken, et. al., 2016). The slowdown loop refers to the creation of products with a longer shelf life. The closure loop refers to the use of materials that can be recycled instead of discarded or in turn, that are biodegradable and can generate new materials. Finally the narrowing loop, proposes the use of fewer resources in order to create a product (Bocken, et. al., 2016).

Implementing these strategies would be ideal in order to achieve circular economy in companies; however, it should be taken into account that, according to Parida, et. al. (2019), there are two important gaps between the aspirations of CE and the ability of the supply chain to achieve these aspirations: changing the business model of the company while encouraging its ecosystem to adopt CE business models to achieve an absolute transformation; and understanding the transition to a greater objective that consists of offering advanced business models based on services or functional results (Parida, et. al., 2019).

3.1. Supply Chain and Circular Economy

Many of the activities conducted along the supply chain of products generate significant impacts on the environment (Cardoso, et. al., 2019), and one of the main problems is dealing with waste at the end of the supply chain processes (Akinade & Oyedele, 2019). This occurs due to the lack of a waste measurement system, which is why companies often use the services of third parties to take care of the final disposal of such materials (Akinade & Oyedele, 2019). According to Farooque, et. al., it is necessary to have a strong network in the supply chain in order to implement a waste management system that achieves economic growth, despite the costs involved in waste management (2019).

As a way of moving towards circular supply chains, there are some approaches that have already been used by companies, such as those of green and sustainable supply chains. Green supply chain (GSC) includes practices that integrate environmental concerns with inter-organizational activities such as product design, materials purchase, manufacturing, product distribution and reverse logistics (Cardoso, et. al., 2019). Among the common practices of a GSC are green design, internal environmental management, investment recovery, eco-design, customer cooperation, purchase from a green supplier, and reverse logistics management (Cardoso, et. al., 2019). On the other hand, sustainable supply chains seek to reduce the negative consequences that its actors may have in order to preserve the environment, without neglecting the economy or society. There are several ways of accomplishing this, such as reducing waste through the supply chain, optimizing the use of energy and resources, among others (Tognato, et. al., 2019).

As mentioned above, one of the practices used in supply chain is the management of reverse logistics, since this is considered crucial to have a certain degree of circularity implemented (Tognato, et. al., 2019). Tognato, et. al., mention that reverse logistics in a circular economy consists of the collection of goods, transportation to a central location, and classification to reuse, recycle or definitely dispose, thus obtaining a reduction in the amount of waste generated (2019). It is also considered that thanks to reverse logistics it is possible to connect customers, suppliers and manufacturing for a better alignment of the supply chain (Tognato et. al., 2019).

In terms of circular economy practices, there are two approaches: circular and closed cycle supply chains (Farooque, et. al., 2019). Farooque, et. al., mention that a circular supply chain (CSC) has a vision of zero waste (2019). In addition, CSC coordinates the supply chain activities in both directions and applies several reverse cycles, in which products are reused, repaired, reconditioned, remanufactured and recycled (Tognato, et. al., 2019). On the other hand, closed loop supply chains (CLSC) are value creation systems derived from product life cycles; in other words, the value creation on the supply chain lies on the restoration of the product with biological or technical cycles (Tognato, et. al., 2019). In both cases mentioned above, what is sought out is a recovery of value through the fundamental tool of the supply chain: reverse logistics (Farooque, et. al., 2019).

In order to correctly implement circular economy in a supply chain, Belc, et. al mention the need of an integrated approach based on the consumer, business, and environmental triangle (2019). On the other hand, one of the crucial elements for a successful network is active cooperation among the members of the supply chain, which ensures that the initiatives of CE are facilitating such cooperation (Cardoso, et. al., 2019). Gupta, et. al., also refer to the need of a collaborative culture in order to optimize the use of natural resources and minimize negative consequences on the environment and society (2018). Farooque, et. al., on the other hand, mention that indicators used to measure a supply chain with integrated CE, must evaluate the economic, environmental, logistic, operational, organizational and marketing performance (2019).

The individual thinking of the parts of the SC does not facilitate the implementation of CE, which is why Gupta, et. al., affirms that a position of support and collaboration by stakeholders must be guaranteed (2018). In addition, Gupta, et. al, also suggest that there must be common sustainability objectives between the parts, fundamentally, to share information throughout the supply chain (2018).

Prior to implementation, the SC should be managed effectively and look for improvements through CE practices (Gupta, et. al., 2018). Farooque, et. al., mention that for an effective transition to CE, it is necessary to have a clear business model, product or service design, production, consumption and waste management practices (2019). If such effectiveness and integration are not accomplished, a difference in policies can be found between the parts, especially in matters of recycling and reuse of resources, resulting in a loss of efficiency in the SC (Gupta, et. al., 2018).

Tognato, et. al. state that circular economy operates on 3 levels: micro, in which there are individual business models; meso, in which the waste of one industry is an input for another in a B2B business model; and macro, in which the functioning of regions that involve the human activity of production and consumption are taken into account in a collective way (2019). Farooque, et. al., agree with the meso configuration, which highlights eco-industrial parks, and additionally mentions 2 more configurations: sustainable and green environmental systems, and closed loop supply chains (2019).

Taking into account the point of view of companies, the approach on SC management generally focuses on the acquisition, consumption and use of materials; however, manufacturing, distribution and sales with circular techniques are rarely mentioned (Farooque, 2019). However, if all parts of the supply chain are integrated into CE practices, positive impacts can be obtained on companies, such as the potential for innovation in all areas (Gupta, et. al., 2018). On the other hand, from the point of view of the consumer, an environmental awareness has to be created, promoting the change of habits and mentalities (Akinade & Oyedele, 2019). Based on this criteria, the client's intention to purchase, how much he/she is willing to pay for the product and the intention to change to products that integrate CE must be evaluated (Russo, et. al., 2019).

Through CE, the utilization of resources and the longevity of the system can be optimized, creating a production technique based on giving circularity to materials and having an excellence in sustainable operations (Sehnem, et. al., 2019). According to Sehnem, et. al., it is important to consider circular designs before the prototype phase of creating a product (2019). In addition, certain fundamental aspects must be considered to have a successful CE implementation, among which are the commitment of stakeholders, an organizational culture of sustainability and the creation of results to make visible the benefits of CE (Sehnem, et. al., 2019). Likewise, some barriers and challenges must be considered when implementing CE. Tognato, et. al., mention that the main challenges that companies face are to reduce transportation costs due to reverse logistics, and maintain product quality (2019). On the other hand, Gupta, et. al., consider that the challenges presented are due to the complexity of the business operations and the stakeholder engagement (2018). Finally, the barriers to the application of CE in companies are closely related to the lack of policies that pressure them to have adequate waste management initiatives; and lack of knowledge, innovation, technology, culture, cooperation, long-term vision, among others (Zhang, et. al., 2019).

3.2. Circular Economy and Business Models

A business model (BM), according to Lüdeke-Freund, et. al., is a representation of how businesses create economic value for a company, by creating value for its consumers (2018). The main characteristic that business models must have is that they must be sustainable and have adequate product and service systems (Lüdeke-Freund, et. al., 2018). Business models are made up of four main approaches based on which decisions and positions are taken: supply chain, customer interface, financial model and value proposition (Diaz, et. al., 2019). Within the four approaches, variations can be made to adapt circular economy with different strategies for each of them (Diaz, et. al., 2019), always taking into account the level at which CE is going to be applied: micro, meso or macro (Lüdeke-Freund, et. al., 2018). The main objective of a business model with CE is to create value using resources in multiple cycles by reducing waste and consumption (Lüdeke-Freund, et. al., 2018).

To have an efficient BM, a process of learning and training in CE technologies and techniques is necessary, since in many cases companies do not know where to start the transition (Ünal, et. al., 2018). However, BMs seeking a transition to CE are viable and changes can be applied throughout the value chain (Ünal, et. al., 2018). Despite the fact that the application of CE in companies can have multiple benefits, one of the main problems mentioned by Ünal et. al., is that there are times when these business models cannot be applied due to a lack of congruence between regulations and dispositions with the waste management carried out by companies (2018). However, there are many practices that can be taken into account for the conformation of these business models.

From a client's point of view, green production practices, product design and green services, service substitutes, services instead of products, functional sales and take-back management can be added to the products they are willing to purchase (Vence & Pereira, 2019). However, Ünal, et. al., mention that it is necessary to carry out practices related to price and promotions that involve circular initiatives with the use of all possible channels in order to promote and communicate the benefits of circularity (2018). This communication is crucial because most of the times, the material managers at the end of their life cycle are the same customers (Ünal, et. al., 2018). The organization must build and maintain this relationship with the customer as it is one of the components that Vence & Pereira consider for a circular BM (2019). Lüdeke-Freund, et. al., affirm that by having a collaborative position of the client, an opportunity is created for the company since clients are facilitators of the action of recovering the waste (2018).

On the other hand, from the point of view of the company, the business model must be oriented to processes of transformation in which there are continuous cycles of materials that reduce or completely eliminate waste, for this, the inputs of the line of production must be recycled materials (Lüdeke-Freund, et. al., 2018). Pieroni, et. al., mention that for the business model to be viable, an acceptable profit must be taken into account, that mitigates investment requirements, adjusts to the challenges that arise, has benefits and reduces sacrifices (2019). To do this, support from all stakeholders is needed, creating awareness and developing new skills that allow the transition to a CE to be viable (Ünal, et. al., 2018). Within the communication and logistics activities there must also be a degree of circularity for the transition to be complete (Lüdeke-Freund, et. al., 2018) since pollution reduction practices, waste management, cleaner production, eco-efficiency, and GSCM must be taken into account (Diaz, et. al., 2019). Lüdeke-Freund et. al., also mention cleaner production as one of the practices that should be applied in the BM, being with a systematically organized approach to productive activities that have a positive effect on the environment (2018). Eco-design is also one of the practices mentioned as a design with environmental considerations to obtain sustainable solutions that satisfy the consumer (Lüdeke-Freund, et. al., 2018).

Additional practices, such as energy efficiency management, use of environmentally friendly material and DFX (design for excellence) are mentioned by Ünal, et. as alternatives that companies can use to have circularity in their products (2018). On the other hand, Diaz, et. al., mention that practices that also focus on the life cycle of products, such as cradle to cradle and industrial symbiosis should be implemented (2019). All the options mentioned above help in having benefits such as waste disposal initiatives, creating changes in productivity and maintaining the value proposition that the customer requires, such as quality, cost and availability (Lüdeke-Freund, et. al., 2018).

Finally, the BM mentioned by Vence & Pereira, is a model that takes into account CE as its main objective, mentioning 5 main parts of it: circular supplies, resource recovery, extension of the product's lifetime, sharing platforms and products such as a service (in other words, rent products for the time it is needed for several users, in order to avoid the production of one product for each user) (2019). On the other hand, Lüdeke-Freund et. al. mention that BMs should be oriented to repair, reuse, remodel, recycle, repurpose, and use organic raw materials in the products (2018). Hofmann proposes two types of circular BM, which focus on closed cycles in the use of resources and lower resource cycles, in which he mentions practices of upcycling, downcycling and take-back logistic systems (2019). Lopes, et. al., mention 6 types of BMs: regenerate, share, optimize, loop, virtualize, and exchange (2019). Within these types, the most used one, according to their literature review is the loop, implemented in both product design, planning and control of production, and logistics and supply chain (Lopes, et. al., 2019).

3.3. Circular Economy and Design Strategies

The design of products for a circular economy is essential because even customers with greater environmental awareness are not willing to sacrifice certain attributes of products that prevent their circularity; however, these same customers are willing to sacrifice factors such as price, quality and brand (Sharma & Foropon, 2019). The design of a product or service should allow the application of CE throughout its value chain taking into account environmental, economic and social factors (Farooque, et. al., 2019). The design phase is very important for CE because it will determine factors such as pollution, waste and energy consumption (Franco, 2019).

The design to extend the shelf life of the product is mentioned by Mesa, et. al., which implements repair, reuse, maintenance and upgrading techniques. Mesa, et. al., mention that there should be a robust design process oriented to manufacturing, disassembly, modularity and standardization of components to facilitate removal and reassembly (2019). Bocken, et. al., refer the previous design as a method to slow down the cycles of resources, in addition, the authors refer to the design of products with long life cycles that include attachment, trust, reliability and durability between the product and the user (2016) . The authors also mention another category of resources with closed cycles, in which the design must have biological, technical and disassembly facilitator cycles (Bocken, et. al., 2016). Mesa, et. al., also propose a design for circularity in supplies, which resembles the biological cycles that seek to reinsert the resources that are taken into the environment without causing any damage (2019). Dismantling designs have also been adapted by many industries thanks to technological advances and cost savings offering value throughout the life of the product, even in the end-of-life phase (Farooque, et. al., 2019).

Additionally, it is important to design so that the client can identify that it is a product with CE, which highlights the benefits that it has on the environment, society and economy (Sharma & Foropon, 2019). As mentioned before, the attachment between the product and the user is a technique that can prolong the life time of the product, this objective can be reached by customization in the design. (Sauerwein, et. al., 2019). The circularity design is also mentioned by Farooque, et. al. and Mesa, et. al., who focus on remanufacturing, reuse and recycling, which gives companies an opportunity for innovation (2019). Tam, et. al., mention that it is also possible to perform a redesign to facilitate restorative mechanisms by having efficiency in processes, however it depends on the type of product that is redesigned since it is important to not compromise the most important attributes of the product (2019). Eco-design and design for the environment also propose reuse, recycling and disassembly techniques (Tam, et. al., 2019). Finally, a design for non-renewable materials is also proposed in the event that it cannot be replaced by renewable materials, which can be attained by improving efficiency in the utilization phase to increase the product’s useful life (Tam, et. al., 2019).

3.4. Circular Economy and Plastics Industry

Plastics are one of the fundamental problems in the environment because they are not biodegradable, so their duration on Earth extends to hundreds of years (Paletta, et. al., 2019). Although in Latin America there is only 4% of the world's plastic production, it is necessary to consider that many companies import plastic as raw material or as finished product (Paletta, et. al., 2019). Hahladakis & Iacovidou mention that in many countries, plastic recycling does not have much control and is underdeveloped (2019). On the other hand, Tognato, et. al., propose that the plastic generator should start with its circular flow to improve and encourage the recycling of said material (2019). In spite of the initiatives in the recycling of plastic, the applications of the same are reduced due to the barriers that exist, such as the difficulty in separating the contaminants from the plastic and the costs of the inverse logistics. In addition, the collectors that help with these tasks, usually accept only PET (Polyethylene terephthalate), HDPE (High-Density Polyethylene) and PP (Polypropylene), leaving aside the other types of plastic (Hahladakis & Iacovidou, 2019).

When talking about plastic, there are several types that can be recycled several times, such as PET, PP and PE (Polyethylene); PET being easier to recycle, since it does not require homogenization of the material (Eriksen, et. al., 2019). On the other hand, PP and PE do need a homogenization for the recycling process, so it is difficult to have a circular economy in them; however, this does not mean that closed cycles cannot be achieved, but that a more rigorous classification is needed, especially if the recycled material is in contact with food (Eriksen, et. al., 2019).

According to Faraca & Astrup, plastics should be classified according to several criteria: product application, legislative requirements (quality), polymer, type of product, color, presence of impurities and expected life (2019). Within the application of the product, high quality is needed for items that are in contact with food; medium quality for pharmacists, toys and electronics; and low quality for packaging material that is not in contact with food, cars and construction (Faraca & Astrup, 2019). According to Tognato, et. al., the most recycled plastic is EPS (Expanded polystyrene) and it is mixed with other materials for elements in the construction industry (2019). As for other types of plastic, especially those that are recycled from electronic materials, there are many problems of mixing with other raw materials, quality and complexity in the recycling process, which also makes it difficult to apply circular techniques (Wagner, et. al., 2019).

The difficulties presented by the application of circular economy in the plastics industry are in the collection, classification and mechanical reprocessing phases (Hahladakis & Iacovidou, 2019). On the part of the EPS, the transportation cost is very high due to its low density that makes the inverse logistics costs very high (Tognato, et. al., 2019). The plastic collection centers also represent a viable option to recycle EPS, as long as there is a culture of recycling (Hahladakis & Iacovidou, 2019). Other possible solutions mentioned by Tognato et. al., is a collaboration by the distributors with voluntary delivery points to facilitate the collection of the plastic in a way that materials for recycling are collected in the same route in which the new products are delivered in order to avoid a door to door pickup (2019). In addition to the costs, the difficulty in classifying plastics is complicated, be it manual or automatic, since it cannot be guaranteed that impurities and contaminants are 100% removed (Hahladakis & Iacovidou, 2019). Among the types of impurities that can be found are inks and coatings, additives and aluminum residues, which can lead to cross contamination in mechanical reprocessing (Hahladakis & Iacovidou, 2019).

On the other hand, Paletta et. al., mention micro-scale barriers of the plastics industry for the application of CE, such as: technology, quality, aesthetic implications and economic barriers (2019). Regarding the meso scale, the barriers include the rejection of quality materials and difficulty in disassembly due to mixtures with fiber-based components. The market itself is a barrier because it demands more and more innovation and requirements, which makes techniques such as repair, refurbishment and maintenance difficult (Paletta, et. al., 2019). Finally, Paletta et. al., mention that the increase in costs due to the classification and recycling processes lead to an increase in the price of the product and causes competitiveness problems in companies (2019).

3.5. Methodology

Based on the literature review, a new methodology was created based on the first part of the model of Parida, et. al. that evaluates, in a qualitative way, the readiness of the company to the transition to CE (2019). Furthermore, this methodology also takes into account a quantitative part, based on Ellen MacArthur Foundation Methodology to measure the Material Circularity Index of a product (2015). These two parts conform the new methodology proposed by the present study; that can be applied in different companies since it is adaptable to several cases, excluding the services industry. In addition, the qualitative section of the methodology also includes a list of questions, that were created based on the criteria listed in the readiness assessment of the qualitative part (Parida, et. al., 2019), and on the literature review conducted for the present study.

Therein, the proposed combined methodology looks as shown in figure 2.

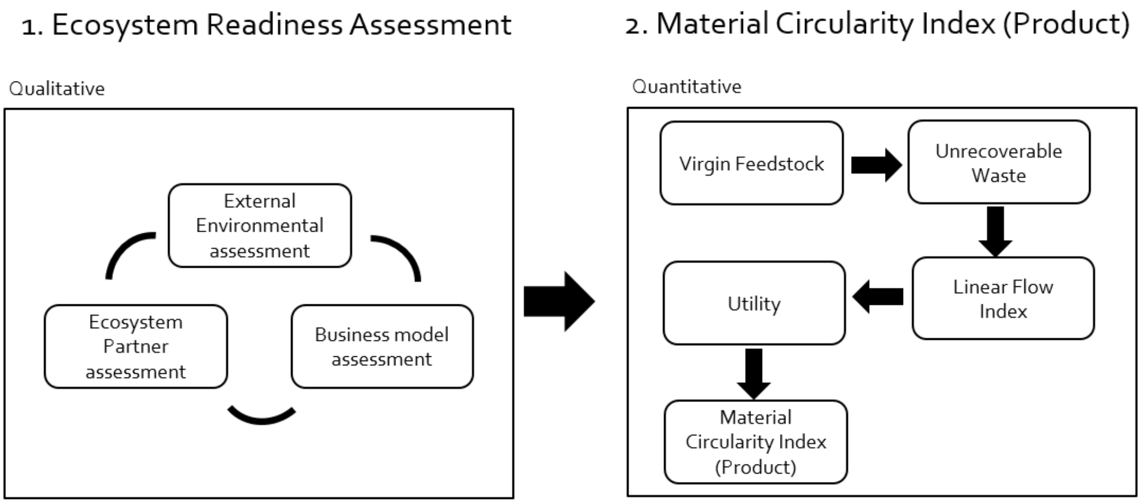

Figure 2 Proposed Methodology

The advantages of the methodology are that it firstly evaluates the readiness of a company and its environment to the transition to CE, and then it complements this with a quantitative indicator that evaluates the circularity of their products.

Ecosystem Readiness Assessment

To carry out the first part of the evaluation, the parameters mentioned by Parida et. al., where taken into account for the creation of qualitative analysis questions (2019). Firstly, there is External Environmental Assessment, which collects information on industry trends, determines what the company's clients ask for, evaluates technological opportunities, analyzes current and upcoming regulations, and estimates overall opportunities and potential threats that can occur in the transition to CE (Parida, et. al., 2019). Secondly, there is Ecosystem Partner assessment, in which an analysis is carried out to determine if the stakeholders are prepared for the transition, taking into account the technology they have and the purchasing power of new technology to implement circular economy (Parida, et. al., 2019). Finally, there is an evaluation of the business model in order to understand the strategies of the business model that would be implemented in line with the objectives of circular economy. For the 3 criterion proposed by Parida et. Al (2019), the present study includes a list of questions that need to be asked in each stage. The questions, listed below, were created based on the literature review conducted for the present study.

What are the economic, social and environmental benefits that, in your opinion, the transition to CE would bring?

Is the company taking into account future trends (environmental policies, environmental regulations, technology, and customer requirements)?

Do you think that **storage**, **digitization** and **data analysis** can help your transition?

What **risks** are associated with this transition?

Do you think that the other parts in your supply chain can **share the risk** with you?

Under what environmental **regulations of solid waste** do you operate, nationally or internationally?

Do you take into account that, given the environmental conditions, it is possible to have more rigorous **changes in environmental regulations**?

Do members of the supply chain **work collaboratively for common goals** (CE or sustainability goals)?

What **goals** (environmental, social and economic) do you have in conjunction with all parts of the SC?

Are all members of the SC aware of the **benefits** of achieving these goals?

How many **suppliers** do you have? Are the majority large, medium or small companies?

To what part of the SC do you have control to be able to **recycle** or **reuse** the materials that are discarded?

What **materials** are possible to **recycle** or **reuse** by the company or the members of the SC?

Is the **technology** available to the members of the SC to recycle or reuse the materials?

Would you be willing to **invest** in technology required to make the transition to CE?

What CE **business model** is planned to be used?

Is it possible to adopt a **business model** that **aligns** with the considerations of the members of the SC and the external ecosystem?

Is the implemented business model considered to last in the **long term**?

Are business models considered to **delay cycle time** or are they **closed cycles**?

In which parts of the company and the SC are these **business models implemented**?

Is there an **alignment** between these business models with the joint goals of the SC?

What **added value** does this business model create for those interested in the company?

Material Circularity Index (Product)

The calculation of the MCIP, is based on the methodology of Ellen MacArthur Foundation (2015), which follows a series of steps and measurements that contribute to the aforementioned indicator.

First, the virgin raw material that is used to manufacture the product is calculated, as shown in equation (1); here, the mass of the product and the fraction of raw material that come from recycling and reuse processes are considered (Ellen MacArthur Foundation, 2015).

$$V = M(1 - F_R - F_U) \qquad (1)$$

Where V is the mass of **virgin feedstock** used in a product, M is the mass of a product, F_R is the fraction of mass of a product's feedstock from recycled sources and F_U is the fraction of mass of a product's feedstock from reused sources (Ellen MacArthur Foundation, 2015).

Subsequently, the **non-recoverable waste** (equation (5)) is calculated, composed of three parts, which are found in equations (2), (3) and (4) (Ellen MacArthur Foundation, 2015).

$$W_0 = M(1 - C_R - C_U) \ (2)$$

Where W_0 is the unrecoverable waste through a product's material, C_R is the fraction of mass of a product being collected to go into a recycling process and C_U is the fraction mass of a product going into component reuse (Ellen MacArthur Foundation, 2015).

$$W_C = M(1 - E_C)C_R \quad (3)$$

Where W_C is the mass of unrecoverable waste generated in the process of recycling parts of a product and E_C is the efficiency of the recycling process used for the portion of a product collected for recycling (Ellen MacArthur Foundation, 2015).

$$W_F = M\frac{(1-E_F)F_R}{E_F} \qquad (4)$$

Where W_F is the mass of unrecoverable waste generated when producing recycled feedstock for a product and E_F is the efficiency of the recycling process used to produce recycled feedstock for a product (Ellen MacArthur Foundation, 2015).

The values obtained in equations 2, 3 and 4 are related in one expression as follows in equation 5.

$$W = W_0 + \frac{W_F+W_C}{2} \qquad (5)$$

Where W is the mass of unrecoverable waste associated with a product (Ellen MacArthur Foundation, 2015).

Once these variables are obtained, it is possible to calculate the **linear flow index** that measures the proportion of material flowing in a linear fashion, from virgin materials to unrecoverable waste (Ellen MacArthur Foundation, 2015).

$$LFI = \frac{V+W}{2M+\frac{W_F-W_C}{2}} \qquad (6)$$

Where LFI is the linear flow index (Ellen MacArthur Foundation, 2015).

Then, to calculate the utility factor (equation (7)), the lifetime or the functional units are taking into account, but not both. With the utility, one can calculate the utility factor F(x) that is built as a function of the utility as follows in equation (8) (Ellen MacArthur Foundation, 2015) The utility takes into account the life time of the product and / or the number of uses of the product, while the utility function is considered to have an impact on the MCI_P based in the utility calculated, but considering, by convention, that if the utility is 1 and the product is fully linear, the MCI_P is 0.1.

$$X = \left(\frac{L}{L_{av}}\right) \cdot \left(\frac{U}{U_{av}}\right) \qquad (7)$$

$$F(X) = \frac{0.9}{X} \qquad (8)$$

Where X is the utility factor, L is the actual average lifetime of a product, L_{av} is the actual average lifetime of an industry average product of the same type, U is the actual average number of functional units achieved during the usage phase of a product and U_{av} is the actual average number of functional units achieved during the use phase of an industry average product of the same type (Ellen MacArthur Foundation, 2015).

Finally, one can calculate the **MCI_P** as follows in equation (9), and if it is negative, there is a correction in equation (10) (Ellen MacArthur Foundation, 2015).

$$MCI^*_P = 1 - \mathrm{LFI} \cdot \mathrm{F(X)} \qquad (9)$$

$$MCI_P = \max(0, MCI^*_P) \qquad (10)$$

The obtained value of MCI_P is between 0 and 1, where 0 means that the product is not circular, in other words, it responds to a linear economy, which means that the flow of the product's material is linear: extract the material, manufacture it, use the product and dispose it. On the other hand, 1 means that the product's material is fully restored.

4. Case Study

4.1. Introduction

The present case study is carried out in an Ecuadorian industry that produces plastic cutlery and disposable plates since 2015 (Cubiertplast, 2019). Despite being a relatively new company, they sell approximately 30 tons of plastic cutlery and 70 tons of disposable plates monthly (Cubiertplast, 2019). The type of plastic used in their products is PET, which is up to 7 times recyclable (Carrasco, 2019). Specifically, in terms of disposable plates the company produces them in the form of foam (EPS), which they do not recycle because it is a material with a large number of pores, which hinder the cleaning of impurities in the dish (Carrasco, 2019). Plastic cutlery is also not recycled; however, this is not one of the company's main concerns because the volume of sales of plates exceeds more than double tons of the cutlery (Cubiertplast, 2019) Carrasco has researched several technologies that allow the recycling of the plastic products the company produces, particularly in terms of circular economy techniques, which has led him to find and evaluate several options that could be implemented in the factory (2019).

The objective of the present case study is to determine how ready the company is to make a transition to circular economy, and evaluate the circularity of its plastic plates' production using the new methodology proposed by the present study, which allows us to analyze the current situation of the company in order to promote its transition to a circular economy

4.2. Results

4.2.1. Ecosystem Readiness Assessment

The results obtained after applying the qualitative stage of the proposed Circular Economy methodology in the plastics industry are presented in the sections below.

4.2.1.1 External environmental assessment

Once the assessment was conducted, it is found that there are multiple benefits if the company does the transition. It is noted that there is an economic benefit to the company by reducing imports of raw material. On the other hand, from an environmental point of view, less pollution can be generated especially in rivers and seas, since the material generated is recycled and manufactured again, reducing waste. In terms of a social point of view, clients are having increased awareness of pollution reduction practices, which has an impact not only on the type of plastic that the company produces, but also on other type of plastics used by clients.

In Ecuador, there are two current regulations that regulate single-use plastics in Guayaquil and for political reasons, different regulations were planned for each municipality of the country (Carrasco, 2019). To avoid this, a national law expected to come out in 2020, is being sought, which gives companies 3 years to implement solutions that allow the company abide the new law. That said, the problem with the regulations that arise is that they are not carried out with a technical knowledge, so they have requirements that are still considered unattainable (Carrasco, 2019). On the other hand, these regulations allow the entry of biodegradable plastics that actually have an organic part that degrades, but the plastic becomes micro plastic that generates the same problem as normal plastic pollution to the environment (Carrasco, 2019). Carrasco considers this a very complex issue, since biodegradable plastics allow for an unfair competition because they are inexpensive and accepted as a solution to the exaggerated plastic consumption, but in reality, the technology to create a true solution is much more expensive (2019).

Carrasco believes that if recycling can be implemented properly, with the support of communication campaigns, it can be considered an opportunity for the company. As a technological opportunity, the digitalization of data will allow for comparisons between biodegradable technologies (2019).

The main risks of implementing CE considered by Carrasco, are the cost and competition, since disposable plates are a commodity and people who buy them are price sensitive (2019). If these clients are offered something friendly to the environment that is more expensive, the demand can fall dramatically (2019). Carrasco has carried out extensive research to search for the cheapest solutions (2019). On the other hand, Carrasco considers that there is no possibility of sharing the risk with the members of the supply chain because the market is managed with the most competitive prices, so it is the company's obligation to find a way to maintain the price and remain competitive in the market (2019).

4.2.1.2 Ecosystem partner assessment

Carrasco states that with two large corporate clients they have had an approach to define common objectives with respect to circularity, the main goal being environmental solutions aimed at reducing the pollution generated by the company (2019). The stakeholders are willing to invest in sustainable solutions since they see it as a great opportunity, however they demand profitability (Carrasco, 2019). What the company is looking for is to be the first one to implement circular economy technologies in order to become market leaders. As for the consumer's perspective, their environmental requirements are not rigorous, on the contrary, what they are focused on is a better price. On the other hand, the upper-middle and upper economic class have reduced the consumption of single-use plastic products by 40%; however, this has not affected the company since that is not its market segment (Carrasco, 2019). Carrasco affirms that it is necessary to have some type of contact with the majority of the clients so that the material returns and it can be recycled, so the company aims to have a reverse logistics strategy that allows the recovery of material in order to recycle it (2019). Thanks to the fact that the two products (cutlery and plates) are made of PET, the same machine can be used to recycle the two products, so both products would benefit from circularity. On the other hand, the company’s suppliers are implementing circularity techniques, introducing 30% recycled material into their products without compromising the quality of the raw material.

4.2.1.3 Business model assessment

The business model that Carrasco plans to use is recycling or biodegrading, but if they decide to implement circular economy, the business model will focus on recycling. The business model is implemented in a micro level, in other words, in the company individually. Carrasco calculates that it is required to have this business model for a minimum of 8 to 10 years to recover the investment in the adequate machinery to recycle PET. The company is not considering an extension of the useful life of their products because they are single-use plastics and switching to plastics with greater durability can even change the company´s market segment. The business model is considered to only involve manufacturing, distribution and final customer, but not suppliers. Carrasco says that there is an alignment in this business model with its main client due to the need to comply with the legislation and the final client must accept the changes that the company imposes.

Another risk is that if the cost rises when implementing recycling processes, there is a potential to a return to previous practices in which there was no plastic, but the use of crockery. However, the added value of the company´s products is that it represents a business opportunity since no company has implemented a circular economy technique or business model. Currently, the company has strategic alliances with suppliers that have helped with technical and technological information to boost the business model. Based on this business model, the company expects their sales to grow through new technologies, although the risk is high due to the fact that it is new technology in the market. Currently, there is circularity in the waste in the plant, but in post consumption nothing has been implemented.

4.2.2. Material Circularity Index (Product)

The MCI_P is calculated based on four types of products that the company has according to its composition, all of them are disposable plates, but with different manufacturing formulas, within which there are different percentages of recycled and virgin material. As can be seen in Table 1, the four types of dishes consist of recycled plastic and virgin plastic, in addition to a small percentage of talcum which gives the plate a white color and also provides resistance properties to the plate (Cuenca, 2019).

Table 1. Product Composition

Product	Virgin Feedstock	Recycled Feedstock	Talcum
Deep Plate	80%	19%	1%
Tray Plate	39%	60%	1%
Plate 6	0%	99%	1%
Plate 10 1/4	19%	80%	1%

Based on the composition, it is possible to determine the fraction of raw material that comes from the recycling process (F_R). In addition the mass of each product is obtained from the production data of the months of July, August and September, and the fraction of raw material that comes from reuse (F_U) is 0 since there is no reuse raw material. Table 2 shows the data and also calculates the virgin raw material (equation 1).

Table 2. Virgin Feedstock

Product	F_R	M (kg)	V (kg)
Deep Plate	0.19	38383.70	31090.80
Tray Plate	0.60	72481.75	28992.70
Plate 10 1/4	0.80	16851.25	3370.25
Plate 6	0.99	1185.10	11.85

Subsequently, the mass of unrecoverable waste is calculated (equation 5), for which it is necessary to calculate the non-recoverable waste of product material (equation 2). For this calculation, it is considered that C_R and C_U are 0, because after the use of the product by the customer, there is no recovery fraction. In addition, EC is also considered to be 0 because there is no reuse. Taking into account the above, W_C is 0 (equation 3). Taking into account that E_F is 0.95 (Cubiertplast, 2019), the results of Table 3 are obtained, where the results for W_O, W_F and W are shown.

Table 3 Unrecoverable Waste

Product	E_R (%)	Wo (kg)	W_F (kg)	W (kg)
Tray Plate	95%	72481.75	2338.12	73650.81
Deep Plate	95%	38383.70	392.09	38579.75
Plate 10 1/4	95%	16851.25	724.78	17213.64
Plate 6	95%	1185.10	63.08	1216.64

Once the aforementioned data is obtained, LFI, X and F(X) are calculated based on equations 6, 7 and 8. It is considered that in order to obtain L, data was taken in the food court of the Scala Shopping Mall, in which are the restaurants of the principal customer which is the biggest customer of the company. On the other hand, a sample size of 30 was considered (Niebel, 2014). In addition, U and Uav are equal to 1 because they are single-use plastics and

Lav takes a value of 15 minutes since it is mentioned that this type of disposable plate is used on average, between 10 and 20 minutes (Del Valle, 2019). With the above considerations, the results of Table 4 are obtained.

Table 4 Linear Flow Index, Utility

Product	LFI	L (min)	Lav (min)	X	F(X)
Tray Plate	0.91	18.43	15	1.23	0.80
Plate 6	0.70	16.91	15	1.13	0.84
Plate 10 1/4	0.60	16.02	15	1.07	0.73
Deep Plate	0.51	15.72	15	1.05	0.86

Finally, MCI_P is calculated based on equation 9, and due to the results obtained, the application of equation 10 is not necessary, since the indexes are greater than 0. Obtaining as a result that the Plate 6 is the one that has a highest circularity index and Deep Plate the lowest circularity index.

Table 5 Material Circularity Index

Product	MCIP
Plate 6	0.59
Plate 10 1/4	0.49
Tray Plate	0.49
Deep Plate	0.22

5. Conclusions, Limitations and Future Research

5.1. Conclusions

The methodology applied generates a positive impact in the case study company since now the company has qualitative and quantitative data that indicates their current circularity, their readiness for a transition to CE,, limitations, opportunities, benefits and some aspects missing in order to complete the transition. The feedback generated provides ideas to have a better transition as an individual company and also as a part of a supply chain, considering all stakeholders while adapting to the circular economy. Additionally, the MCI_P factor provides a starting point of the circularity of the product and makes possible a future comparison between the actual product and future products made with recycled materials, once Circular Economy initiatives are implemented.

In the qualitative evaluation, it can be observed that the case study company is aware of the industrial trends, such as the use of biodegradable plastic; however, the company has not considered other more environmentally friendly options that do not generate micro plastic. As mentioned by Parida, et. al., it is also necessary to analyze emerging markets (2019), taking this into account, the company in study, must consider other risks such as resources that can substitute plastic, like paperboard based on different organic materials. On the other hand, in terms of regulations, the company is aware and capable of responding to possible internal changes in Ecuador (Carrasco, 2019); however, international regulations that can also affect the company are not considered, such as the UN global commitments to reduce single-use plastics, as well as the roadmap of the same organization to design policies and eliminate the use of these plastics, which would completely affect the company (2019).

The case study company considers the trends of its customers, ensuring that there is no market with rigorous environmental requirements, but if this changes, it would be prepared with adequate technology to reduce its environmental impact. Its stakeholders have also contributed significantly so that Carrasco is aware of emerging technology in terms of plastic, as mentioned by Parida, et. al.(2019). Carrasco is aware of the development of technologies that help the company meet its objectives, and also there is a collaborative culture between the parts of the supply chain that is necessary for the application of the circular economy (Gupta, et. al., 2018). Within the aspects of the methodology is sharing the risk associated with the transition to circular economy, and one of the biggest complications for the company is to find a way to do so. It can be achieved with a future implementation of the second part of the circular economy transition model, as mentioned by Parida, et al., specifically through negotiation. This part is about the mechanisms to orchestrate the company once it has transitioned to Circular Economy.

The methodology also assesses the considerations of the business model that will be used based on Circular Economy. In addition, it was observed that there is no structured business model, but it is clear that the center of it will be recycling. It is recommended to apply a business model scheme as mentioned by Diaz, et. al., Vence & Pereira or Ludeke-Freund, et. al., in which financial issues, customer and company perspectives are deepened, value creation among other aspects considered within business models and not only in its focus.

On the other hand, in the quantitative evaluation, it is obtained that the product with the highest MCIP is Plate 6 with a 0.59; this is attributed to the fact that in its composition there is a 0.99 fraction of raw material that comes from recycling. In addition, the average lifetime for this product is longer than the average life of similar products between companies, which contributes to reducing the linearity of the product (Ellen MacArthur Foundation, 2015), however, its production is the lowest within the plant. On the contrary, the product with the lowest MCIP is Deep Plate with a 0.22, mainly due to its composition, since only 19% of its raw material comes from recycling, in addition to its average lifetime, it is the lowest among the analyzed products. Coincidentally, plate Tray Plate and Plate 10 1/4 have an MCIP of 0.49, on the one hand, Tray Plate has the highest average lifespan while Plate 10 1/4 has a higher recycled raw material composition.

To increase the Material Circularity Index of the products analyzed in the company, there are 3 main approaches that can be worked on. First, in the product design, there is the possibility to obtain a higher percentage of recycled raw material, as mentioned by Mesa et. al., the product can be designed to use the minimum amount of resources (2019). On the other hand, as mentioned by Bocken et. al., the product also can be designed to have closed cycles in resources, specifically decreasing the amount of virgin feedstock (2019). On the other hand, the company can focus on greater efficiency in the recycling process, which is at 95%, however this option would not generate so much impact since the efficiency is quite good today. Finally, there is the possibility of collecting the materials that are currently in waste to be recycled, which is the possibility that is more important for the company due to the willingness to invest in recycling technologies. For this, it is necessary to have a fairly efficient reverse logistics which considers the high transportation costs of low density plastic (Tognato, et. al., 2019) In the same way this is an opportunity to promote a culture of recycling (Carrasco, 2019) to facilitate the recovery of the material.

5.2. Limitations

Among the limitations of this study is the fact that the data collection was done in one place, because access was allowed only in the food court of the Scala Shopping Mall, so only the largest customer was considered. In addition, the data was collected on holidays and with tables available in the restaurants, which may influence the time of use of the dishes. Finally, the questions prepared for the qualitative evaluation are limited to the literature review carried out, so it is possible to extend the number of questions with more content based on more studies.

5.3. Future Research

To continue with the study of Circular Economy in the supply chain, it is suggested that the proposed methodology incorporates the second part of the model proposed by Parida, et. to the. Ecosystem Orchestration Mechanism, which implements negotiation and nutrition techniques for the company's ecosystem. On the other hand, it is proposed to carry out a pilot plan to determine if the final customer can be involved with the Circular Economy transition, creating a recycling campaign supported by advertisement and communication techniques. In addition, it is necessary to carry out a feasibility study of applying reverse logistics to recover the material and recycle it, this together with a financial study that supports the profitability of the Circular Economy initiatives.

6. References

Akinade, O. O., & Oyedele, L. O. (2019). Integrating construction supply chains within a circular economy : An ANFIS-based waste analytics system (A-WAS). *Journal of Cleaner Production*, *229*, 863–873. https://doi.org/10.1016/j.jclepro.2019.04.232

Amato, D. D., Droste, N., Winkler, K. J., & Toppinen, A. (2019). Thinking green , circular or bio : Eliciting researchers ’ perspectives on a sustainable economy with Q method. *Journal of Cleaner Production*, *230*, 460–476. https://doi.org/10.1016/j.jclepro.2019.05.099

Ayres, R. (1994). Industrial metabolism; theory and policy. *The Greening of Industrial Ecosystems.* National Academy Press. Washingtong, DC, 23-37.

Belc, N., Mustatea, G., Apostol, L., Iorga, S., & Vlăduț, V. (2019). Cereal supply chain waste in the context of circular economy. *E3S Web of Conferences, 03031*.

Bocken, N. M. P., Pauw, I. De, Bakker, C., Grinten, B. Van Der, Bocken, N. M. P., Pauw, I. De, Grinten, B. Van Der. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, *1015*, 1–12. https://doi.org/10.1080/21681015.2016.1172124

Cardoso, M., Cardoso, M., Chiappetta, C. J., & Lopes de Sousa, A. (2019). Paving the way for the circular economy and more sustainable supply chains. *Management of Environmental Quality: An International Journal Article information:* https://doi.org/10.1108/MEQ-01-2019-0005).

Carrasco, D. (2019). Personal Interview with David Carrasco.

Cubiertplast. (2019). Sales, product composition, data reports.

Cuenca, S. (2019). Personal Interview with Stalin Cuenca.

Diaz, F. J., Bastein, T., & Tukker, A. (2018). Business Model Innovation for Resource-efficiency, Circularity and Cleaner Production : What 143 Cases Tell Us. *Ecological Economics*, (March), 0–1. https://doi.org/10.1016/j.ecolecon.2018.03.009

Del Valle, G. (2019). Día Mundial del Medio Ambiente: ´Sigue prohibir el unicel para proteger al planeta´

Ellen MacArthur Foundation. (2013). Towards the Circular Economy.

Ellen MacArthur Foundation. (2015). Circularity Indicators An Approach to Measuring Circularity. Methodology, 1–98.

Ellen MacArthur Foundation. (2017). New Plastics Economy. Recuperado de: https://www.ellenmacarthurfoundation.org/our-work/activities/new-plastics-economy

Ellen MacArthur Foundation. (2017). What is the Circular Economy. Recuperado de: https://www.ellenmacarthurfoundation.org/circular-economy/what-is-the-circular-economy

Eriksen, M. K., Christiansen, J. D., Daugaard, A. E., & Astrup, T. F. (2019). Closing the loop for PET , PE and PP waste from households : Influence of material properties and product design for plastic recycling. *Waste Management*, *96*, 75–85. https://doi.org/10.1016/j.wasman.2019.07.005

Faraca, G., & Astrup, T. (2019). Plastic waste from recycling centres : Characterisation and evaluation of plastic recyclability. *Waste Management*, *95*, 388–398. https://doi.org/10.1016/j.wasman.2019.06.038

Farooque, M., Zhang, A., Thurer, M., Qu, T., & Huisingh, D. (2019). Circular Supply Chain Management: A Definition and Structured Literature Review. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2019.04.303

Franco, M. A. (2019). A system dynamics approach to product design and business model strategies for the circular economy. *Journal of Cleaner Production*, *241*, 118327. https://doi.org/10.1016/j.jclepro.2019.118327

Gupta, S., Chen, H., Hazen, B. T., Kaur, S., & Santibañez, E. D. R. (2018). Circular economy and big data analytics : A stakeholder perspective. *Technological Forecasting & Social Change*, (October 2017), 0–1. https://doi.org/10.1016/j.techfore.2018.06.030

Hahladakis, J. N., & Iacovidou, E. (2019). An overview of the challenges and trade-offs in closing the loop of post- consumer plastic waste (PCPW): Focus on recycling. *Journal of Hazardous Materials*, *380*(July), 120887. https://doi.org/10.1016/j.jhazmat.2019.120887

Hofmann, F. (2019). Circular Business Models: Business approach as driver or obstructer of sustainability transitions? *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2019.03.115

INEC. (2016). Módulo de Información Ambiental Económica en Empresas 2016. Recuperado de: https://www.ecuadorencifras.gob.ec/documentos/web-inec/Encuestas_Ambientales/EMPRESAS/Empresas_2016/PRIN_RESUL_MOD_AMB_EMP_2016.pdf

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Resources, Conservation & Recycling Conceptualizing the circular economy : An analysis of 114 definitions, *127*(September), 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

Lopes, A., Rojas, J., Rojas, O., Chiappetta, J., Oly, N., Caldeira, J., & Horneaux, F. (2019). Circular economy business models and operations management. *Journal of Cleaner Production*, *235*, 1525–1539. https://doi.org/10.1016/j.jclepro.2019.06.349

Lüdeke-Freund, F., Gold, S., & Bocken, N. M. P. (2018). A Review and Typology of Circular Economy Business Model Patterns. *Journal of Industrial Ecology*, *00*(0), 1–26. https://doi.org/10.1111/jiec.12763

Mesa, J. A., Esparragoza, I., & Maury, H. (2019). Trends and Perspectives of Sustainable Product Design for Open Architecture Products : Facing the Circular Economy Model. *International Journal of Precision Engineering and Manufacturing-Green Technology*. https://doi.org/10.1007/s40684-019-00052-1

Ministerio del ambiente. (s.f.). Programa "PGNIDS" Ecuador. Recuperado de: http://www.ambiente.gob.ec/programa-pngids-ecuador/#

Naciones Unidas. (2015). Objetivos de Desarrollo Sostenible. Recuperado de: https://www.un.org/sustainabledevelopment/es/objetivos-de-desarrollo-sostenible/

Niebel, B. (2014). Ingeniería industrial de Niebel: métodos, estándares y diseño del trabajo. McGraw Hill

Paletta, A., Leal, W., Balogun, A., Foschi, E., & Bonoli, A. (2019). Barriers and challenges to plastics valorisation in the context of a circular economy : Case studies from Italy. *Journal of Cleaner Production*, *241*.

Parida, V., Burström, T., Visnjic, I., & Wincent, J. (2019). Orchestrating industrial ecosystem in circular economy : A two-stage transformation model for large manufacturing companies. *Journal of Business Research*, (June 2018), 0–1. https://doi.org/10.1016/j.jbusres.2019.01.006

Pieroni, M. P. P., Mcaloone, T. C., & Pigosso, D. C. A. (2019). Configuring New Business Models for Circular Economy through Product – Service Systems. *Sustainability*.

RENAREC. (2015). Datos sobre reciclaje. Recuperado de: https://renarec.com/cambiamos-el-mundo-2/

Russo, I., Confente, I., Scarpi, D., & Hazen, B. (2019). From trash to treasure: the impact of consumer perception of bio-waste products in closedloop supply chains. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2019.02.044

Sauerwein, M., Balkenende, R., Doubrovski, Z., & Bakker, C. (2019). Exploring the potential of additive manufacturing for product design in a circular economy. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2019.04.108

Sehnem, S., Jose, C., Jabbour, C., Carla, S., Pereira, F., Beatriz, A., & Sousa, L. De. (2019). Improving sustainable supply chains performance through operational excellence : circular economy approach. *Resources, Conservation & Recycling*, *149*(May), 236–248. https://doi.org/10.1016/j.resconrec.2019.05.021

Sharma, A. & Foropon, C. (2019). Green product attributes and green purchase behavior A theory of planned behavior perspective. *Management Decision*. https://doi.org/10.1108/MD-10-2018-1092

Sikdar, S. (2019). Circular economy : Is there anything new in this concept ? *Clean Technologies and Environmental Policy*, *21*(6), 1173–1175. https://doi.org/10.1007/s10098-019-01722-z

Soporan, F., Lehene, V. Paduretu, T. & Gabor, T. (2019). Engineering of circular economy and good management of industrial material resources. IOP Conference Series: Materials Science and Engineering. 572. 012086. 10.1088/1757-899X/572/1/012086.

Tam, E., Soulliere, K., & Sawyer-beaulieu, S. (2019). Resources , Conservation & Recycling Managing complex products to support the circular economy. *Resources, Conservation & Recycling*, *145*(December 2018), 124–125. https://doi.org/10.1016/j.resconrec.2018.12.030

Tognato, C., Luna, M., & Campos, L. (2019). Understanding the Brazilian expanded polystyrene supply chain and its reverse logistics towards circular economy. *Journal of Cleaner Production*, *235*, 562–573. https://doi.org/10.1016/j.jclepro.2019.06.319

Ünal, E., Urbinati, A., Chiaroni, D., Cattaneo, U. C., & Chiaroni, D. (2018). Managerial practices for designing circular economy business models The case of an Italian SME in the. *Journal of Manufacturing Technology Management*. https://doi.org/10.1108/JMTM-02-2018-0061

Velenturf, A. P. M., Archer, S. A., Gomes, H. I., Christgen, B., Lag-brotons, A. J., & Purnell, P. (2019). Science of the Total Environment Circular economy and the matter of integrated resources. *Science of the Total Environment*, *689*, 963–969. https://doi.org/10.1016/j.scitotenv.2019.06.449

Vence, X., & Pereira, Á. (2019). Eco-innovation and Circular Business Models as drivers for a circular economy. *Contaduría y Administración 64 (1) Especial Innovación*, *64*(1), 1–19.

Wagner, F., Peeters, J. R., Keyzer, J. De, Janssens, K., Duflou, J. R., & Dewulf, W. (2019). Towards a more circular economy for WEEE plastics – Part A : Development of innovative recycling strategies. *Waste Management*, *100*, 269–277. https://doi.org/10.1016/j.wasman.2019.09.026

Wohlin, C., 2014. Guidelines for snowballing in systematic literature studies and a replication in software engineering. In: EASE'14 Proc. 18th Int. Conf. Eval. Assess

Zhang, A., Venkatesh, V. G., Liu, Y., Wan, M., & Qu, T. (2019). Barriers to smart waste management for a circular economy in China. *Journal of Cleaner Production*, *240*, 118198. https://doi.org/10.1016/j.jclepro.2019.118198