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Analysis of Circular Economy in a Green Logistics Approach of the Citrus Industry in Mexico

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Abstract—This article addresses essential issues in recent times. However, Green Logistics (GL) is a topic widely used mainly in industrial processes in the primary and secondary sectors in the Asian continent. On the other hand, there are many studies of circular economy in virtually all continents, and a variety of sectors, the addition of both topics is incipient. However, the combination of both topics is complementary because while GL focuses mainly on reducing greenhouse gas emissions, the circular economy implies the reduction of reductions to a minimum. Therefore, concepts such as repairing, renewing, renting, reusing, and recycling materials are addressed, all this added to an industry focused on perishable products for international export that have a 100% reusable waste as compost for citrus plots. An exhaustive literature search and some of its variants were carried out, finding an area of opportunity due to its incipient state. The application in the industry using an intelligent hybrid system under the analysis of variables showed that the combination of both topics in a robust study of variables provides favorable results in economic, sustainable, and social benefits in the Mexican citrus industry.

***Index Terms*—Circular economy, green logistics, citrus industry.**

I. Introduction

A. Logistic

Logistics is an activity performed by man since he began to store and transport goods, that is, since time immemorial, however, although it may seem ironic, it is difficult to find a definition as such until 1985 [1]. Due to the above, we can clarify the term "Supply Chain Management" supply chain management was introduced in the 80's and since that time has been the subject of attention by organizations. By the 1990s it was observed that academics, researchers and even consultants considered Supply Chain Management (SCM) to be the management of logistics outside the company. This position was supported by the definition of logistics proposed at that time by the Council of Logistics Management (CLM): "It is the process of efficiently planning, implementing and controlling the flow and storage of raw materials, in-process inventory, finished goods and related information from the point of origin to the point of consumption, efficiently and at the lowest possible cost, to meet customer requirements" [2].

One of the main objectives of supply chain management is to reduce or eliminate inventory buffering that exists between organizations in a chain by exchanging information on demand and current stock levels [3]. This approach is done with the purpose of providing greater service and better product quality to customers, i.e., a good supply chain management practice starts from the end user and goes all the way back to the procurement of materials for production. To achieve the best results, five basic processes must be taken in to account:

- Demand management: includes market-related activities such as: forecasting methods, customer service, customer order processing and sales.
- Distribution: constitutes the linking process between production and the market, and influences logistics operations through market requirements.
- Production: production and all related processes add value in the flow of products, affect inventory, transportation and delivery times.
- Purchasing: constitutes the procurement link of materials for production.
- Returns: closes the supply chain cycle, receives products that need to be remanufactured, reused or recycled in the production process [4].

B. Citrus Industry

Citrus production is currently the main activity of fruit tree producers in the world (104 million tons) and the countries with the largest production are Brazil, China, India, USA, Mexico and Spain, as well as many other tropical and subtropical regions of the world [5].

Lemon and orange crops, are among those that have had the greatest dynamism in national agriculture in the period between 1980 and 2013, with which they have been configured in the main generators of employment in fruit growing, and are among the 10 most important crops in the generation of employment in Mexico. A region is considered to be the set of municipalities that, at the state level, develop citrus cultivation, around a municipality that is defined as the node or center of the region [6].

In citrus growing regions, as in the production of perennial fruit trees, the cultivated area presents certain conditions that prevent it from being easily reoriented towards the production

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of other crops, especially because it is an activity that is carried out for long-term purposes, and includes a period of several years, in which the plant reaches its development to be able to produce. Thus, it is common to find plantations with a combination of trees of different ages, including, in some cases, trees over 30 years old.

Citrus production, for its development, requires investments that take several years between the development of the plant and fruiting, as well as the period in which they maintain yields in profitable conditions, so that deciding on the reorientation of the productive activity involves the sacrifice of an investment of several years, which substantially affects the farmers' patrimony [7].

There are six groups of citrus fruits of economic interest: sweet orange [Citrus Sinensis (L.) Osb.], common mandarin (Citrus Reticulata Blanco), Satsuma mandarin (Citrus Unshiu Marc), grapefruit (Citrus Paradisi Macf.), lemon (Citrus Lemon Burm. f.) and lime (Citrus Aurantifolia L.) [8].

Persian lemon (Citrus latifolia Tanaka) is grown mainly on the Gulf coast of Mexico (Veracruz, Tabasco and Yucatan); this region contributes 30% of the total Mexican production. Its cultivation in Mexico among farmers in the region of Martínez de la Torre, Veracruz, was promoted by the Coca Cola soft drink company to use the citric acid as a raw material for soft drinks; however, the Persian limes harvested did not meet the characteristics specified by the company (too much juice and not enough oil) and the company lost interest in the crop in the region. Consequently, the producers decided to introduce it into the U.S. market through Texas to distribute it in the country under the scheme followed by the Florida producers [9, 10].

C. Circular Economy

Circular economy is the latest products of the research of sustainable development. It has become a trend for the developed countries for the use. At the same time, it is also inevitable choice of our country's economic development. Reverse logistics is a powerful tool to promote economic development. And third-party reverse logistics enterprises are an important carrier to achieve reverse logistics. Thus, construction of third-party reverse logistics based on circular economy can guide the enterprise to develop cycle economy, to improve the efficiency of reverse logistics [10].

Circular economy is generally considered as a normative concept, aiming to achieve a more sustainable future and solve the environment without giving up economic prosperity [11, 12]. Various definitions have been given from different perspectives, such as economic form, comprehensive utilization of resources, environmental protection, or technological paradigm [13]. With the acceleration of urbanization, the populations, energy consumption, and waste discharge from the urban are increasing rapidly. At the same time, the problems caused by environmental pollution, water shortage, and traffic congestion are also becoming increasingly severe, which has an impact on the development of cities, countries, and even the world [14].

D. Green Logistic

In recent years, Green Logistics has received growing interest due to the increase in greenhouse gas emissions from transportation operations. It is a promising approach to manage supply chain decisions to reduce environmental damage.

Many models have been developed in the literature to study the environmental aspects of routing problems. Today there is a growing consensus that GL operations and significant benefits in terms of energy efficiency can be achieved through an appropriate combination of different measures such as: consolidation hubs, optimized urban logistics transport and delivery plans, use of clean vehicles and low emission technologies, a focused regulatory framework, public incentive/qualification policies, integration of city logistics processes into overall urban mobility planning and management.

Sustainable logistics (GL) is based on the improvement of the use of logistic materials, seeking to boost a development of the economy concentrated on raw materials, storage, processes and environmentally friendly transportation; which, combined with the tactics of customers, companies and states, form initiatives for its implementation and a sustainable development.

Environmental issues and government regulations make academic researchers and industry professionals aware of sustainable strategies in the area of logistics and supply chain [15]. For, currently logistics contributes to environmental pollution mainly with: Transportation, Distribution, Warehousing, Loading and unloading, Packaging and to contribute to the mitigation of the negative impact to the environment the following aspects should be considered: Green transportation, Green warehousing, Green loading and unloading, Green distribution, Green packaging, Green information collection and management, Waste recycling.

Green logistics (GL) refers not only to the supply of sustainable products or services to customers, but also to the overall logistical flow of goods as they move through the supply chain. On the other hand, various sustainable activities and operations, such as production scheduling and the construction of distribution networks, have been realized. To improve the performance of sustainable logistics, individual parts of logistics not only have to implement sustainable activities and operations by themselves, but also cooperation and collaboration between different parts of logistics [16]. However, a state of the art study conducted by [17], shows that the application of GL in Mexico is practically null, a review to the current state of the art.

Therefore, GL, aims to make the most of the materials used in storage and reuse the waste obtained in each process, transport processes that minimize or nullify greenhouse gas emissions, to do all this is armed with several techniques such as cleaner production and logistics that help to prolong the environment and generate sustainable development.

II. Methodology

The main goal of this research is to identify the main GL contributions, in order to classify them and subsequently apply them to the case study of the citrus sector in the area of Martínez de la Torre, Veracruz, Mexico.

It was determined to meet some specific objectives of the research in order to successfully carry out the entire process that

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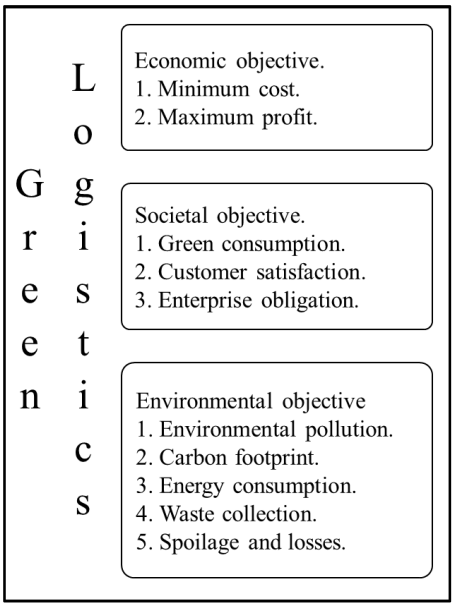

Fig. 1. The objective perspective of GL. Source: Own design adapted from that presented by [17]

the research design entails. These particular objectives are shown below.

A. To identify the state of the art of GL issue.

B. To identify which are the variables previously proposed that influence the development of GL in the citrus industry or similar.

C. To analyze a case study of the area in the citrus industry.

For the documentary development of this research, the methodology used in the research is adapted to that proposed by [36], this case study is divided into 3 steps:

— *Step 1. Sample selection:* An exhaustive and extensive documentary investigation was carried out with a database of different investigations. The search was based on keywords related to "Green Logistic", the publications search was firstly conducted intermso fastructured combination of related keywords. Any “logistics” or “supplychain” related problems involving the concept of “green” or “environmental” or “sustainable” or “closed-loop” or “reverse”. With this consideration, the following data bases were selected for a comprehensive a dextensive review of this interdisciplinary research: IEEE/IEE Electronic Library via IEEE Xplore, ScienceDirect by Elsevier, Scopus, and SpingerLink. In addition to those data bases, Google Scholar was also used to complement the related publications. Once the investigations related to the subject had been identified, they were classified within the same matrix. The process of this bibliographic review follows the four-step process model proposed by [37] and taken up by [17] where the material, the descriptive analysis, the selection of categories and the description of the aforementioned model are mentioned. Thanks to this, the resulting articles were delimited in terms of their impact and relationship with the research, where certain problems of transport, network design, programming and production were found, among others

— *Step 2. Information analysis:* An exhaustive analysis based on the case study was carried out, where we can mention that there is a wide field investigated in the Asian continent over the last 5 years, however, in the case of America or more specifically in Mexico, there is no information reported so far, basically in the area of the case study.

— *Step 3. Report of the results.*

Previous studies such as the one shown in [17] report the state of the art of GL, reporting 115 articles between the years 1990 to 2015, where they mention the history of applications made in GL, since this study has a time cut limited to 2015, an exhaustive documentary review was carried out, of which 64 publications related to the subject were found, and only 16 are related to the present investigation, and as a reference, we can mention that Green Logistics is a subject applied mainly in the Asian continent, and the reported case study has not provided information to the citrus sector so far; that is, there are previous studies that describe research in similar sectors, but still there is a vast area of opportunity in terms of the sector of this case study.

Also, one of the most used variables in terms of GL is the reduction of gas emissions that affect the environment, considering problems of a different nature than logistics. The problems of the publications that have been previously reported are found in figure 1, where the main objectives of GL are shown, the ones that cover three important aspects: the economic, environmental and social issues; which are also known as the triple bottom line, proposed and formulated by [38, 39] and taken up by [17]. Regarding the current publications, we can note that most of these are outlined to inform objectives that follow the previously mentioned trends.

III. Description of the Case Study

This case study focuses on Vela Organic Company, which is a SME, dedicated to the machining process of the citrus production for national and foreign sale. In Figure 2, there is a description of the adaptation made to the case study of the citrus supply chain presented by [40] and taken up for the adaptation of the area of Martínez de la Torre by [41] where the different links are shown from the production in orchards, going through the process of intermediaries, later reaching the processors, where Vela organic company is located; in this section, the process and packaging of several products are carried out so that they can be sent to different markets, where they will finally reach a final consumer.

The following is a brief description of the different supply chain processes in the case study.

— *Production process:* Also called orchard or producer, it refers to citrus growers, where Persian lemon, orange, grapefruit and tangerine stand out, which are the main crops of the study area.

— *Retailers:* This section defines the intermediaries that help the citrus fruits to get to the processing companies, as well as the collection centers where the aforementioned fruits are purchased including collectors in orchards and orchard retailers.

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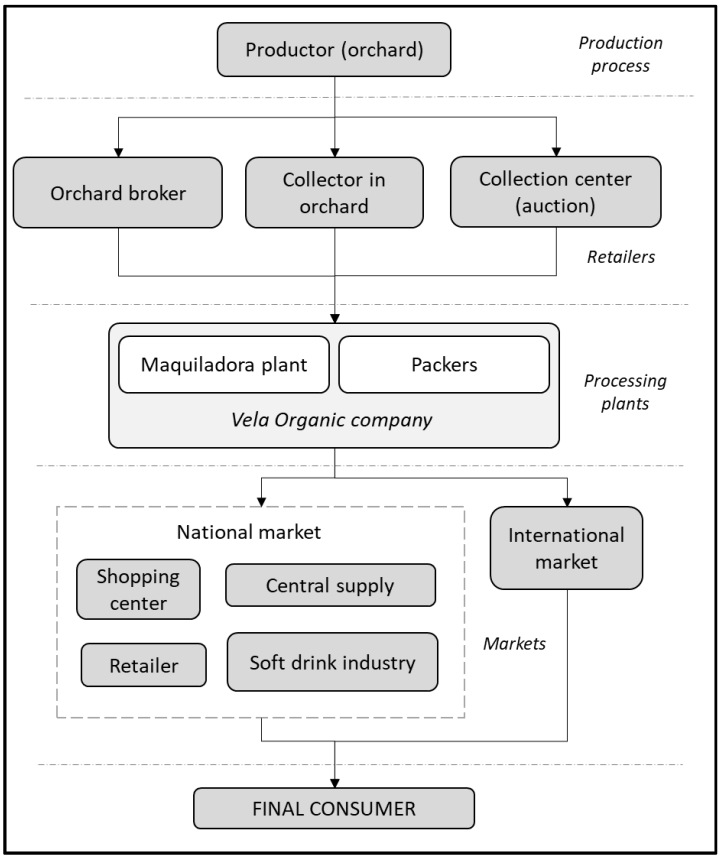

Fig. 2. Contextualization of the supply chain of Vela organic company from Martínez de la Torre, Veracruz, 2021. Source: Owned design adapted from that presented by [41]

TABLE I
SHIPPING MATRIX, SHIPPING TIME, COST, DISTANCE AND REQUIRED CITRUS QUALITY

Destination	Shipping time	Shipping cost	Distance (road)	Quality
Tijuana	12 hours	$90000	3040 km	1st
Matamoros	8 hours	$36000	800 km	1st
Monterrey	7 hours	$30000	817 km	1st y 2nd
CDMX	6 hours	$28000	325 km	1st y 2nd
Veracruz puerto	3 hours	$15000	220 km	1st y 2nd
Guadalajara	9 hours	$45000	825 km	1st y 2nd
Querétaro	6 hours	$30000	495 km	1st y 2nd

— *Processors:* In this section we can find our case study, since it´s the sector where the citrus fruits arrive for the maquila or packaging process.

— *Markets:* Where the citrus fruits will get to, but different factors depend on this, such as from the buyer himself to the quality of the product, the standards with which the company complies for its export or the supply capacity, these are some of the factors that define the national or international destination of the product.

— *Final consumer:* It is the last link in this chain, and who will be the one who acquires and consumes the citrus fruits.

According to data provided by Juan Pastrana in [42], the production process of this case study is carried out in batches, these are normally defined by the client, who sends the product to the company for the machining process, these batches are normally placed on 24 pallets which contain 1,440 boxes of approximately 40 pounds each and which would represent a production of approximately 57,600 pounds per batch.

In addition to this, there is a production in high season of 16 batches per month and in low season 8 batches per month.

Table 1 shows the different destinations, merchandise transfer time and their costs. According to the information provided by the production manager, Juan Pastrana [42], which is worth to take into consideration, the citrus fruit intended for export is sent to the cities of Tijuana, the state of Baja California and Matamoros, Tamaulipas, and from these cities the citrus fruits are also sent to the USA; to important cities like Atlanta, Chicago or Houston, but the latter depends on the foreign buyer.

On the other hand, if the export will be made to Europe, it is sent to the Port of Veracruz for shipment. It should be noted that, for the process of sales abroad, the company that acts as

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TABLE II
INPUTS AND PRODUCTION COSTS

INPUTS	QUANTITY	COST
Maintenance cost	NA	$500
Decomex wax	20 liters	$600
Organic soap	1 liter	$26
13 % sodium hypochlorite	250 ml	$10
Stationery	NA	$100
LP gas	30 liters	$360
Water	1000 liters	$300
Copper wire	90 meters	$900
Strip	15 kilos	$600
Production cost per batch		$3396

buyer is in charge of this process, that is to say, the responsibility of Orgánicos Vela in this situation goes to the destination city.

In this way, when the sale is made in the Mexican market, the company is in charge of delivering the product to the destination city, among which are included the cities of Guadalajara, Tijuana, Matamoros, Monterrey, CDMX, Veracruz port.

A. Production Process

The citrus maquila process focuses on the quality of these, therefore there are two quality decisions throughout the process, although quality is an important aspect, it is not the only relevant one during the process. Figure 3 shows the citrus machining production process diagram of Vela organic company, where it is divided into two specific areas:

1. Dirty area: Named like this because it contains the processes of entry and reception of citrus fruits, for their accommodation in the cellar to begin the process in the rest area where it goes to the first manual selection process, this is carried out by 4 people, where they exclude the waste of the process, which passes to an outlet for its transfer to a defined place for compost.

2. Clean area: Defined this way because it is divided by hygiene and health issues from the previous one, here the washing process with organic soap begins, to reach the disinfection process with Sodium hypochlorite at 13%, where with the help of rollers and water is rinsed off. Then, it comes to the pre-drying process by means of rollers called "draining". After that, it goes to the waxing sub-process, where it goes to the second selection process, this is divided into two selections, the first, where a sorting machine separates by sizes, the so-called first and second quality, which are classified for its export or otherwise, its national sale respectively. Finally, regardless of the category it belongs to, the citrus fruits go to the packaging sub-process, where they are placed in 40-pound boxes and organized on pallets of 40 boxes in order to place them in the exit boxes where they will be loaded in the delivery transport units to be sent to different destinations.

B. Production Costs

As for production costs, a very important factor must be taken into account, basically when the machining process is done, a type of production is carried out per batch, this is something common, as mentioned by [42], moreover, the inputs used are calculated per batch. The following Table 2 describes the input costs for a production batch of 24 pallets with 60 boxes of 40 pounds each.

Carbon dioxide emissions is another important element to take into consideration since it is a fundamental factor that occurs in GL. For the purpose of this case study, these emissions were calculated by using the technique shown in [43].

IV. Circular Economy Model of Reverse Logistics on Electronics Enterprise

The examples of implementation of reverse logistics were not many in electronic enterprises, at present, more and more enterprises rely on logistics providers to set up enterprise logistics system. Enterprises reverse logistics system is the same. According to the analysis of transportation system, the whole recycling transportation system will include recycling points, recycling centers and resources factory. Recycling and transport network chart of reverse logistics is shown in Figure 4.

Recycling program of reverse logistics adopts a different approach due to the characteristics of different products. By waste computers as an example, we designed recycling program of third-party reverse logistics [10].

A. Model of Recycling and Transport System

The costs of the recycling and transport system are calculated by the weight of waste products, the distance between recycling points and recycling center, management costs. The transport cost model is as follows:

$$C = C1 + C2 + C3 = W \times R1 \times Y + W \times R2 \times Y + C3, \quad (1)$$

— C1: Transport cost from recycling points to the recycling center,
— C2: Transport cost from recycling center to the treatment factory,
— C3: The cost of management,
— W: Transport weight,

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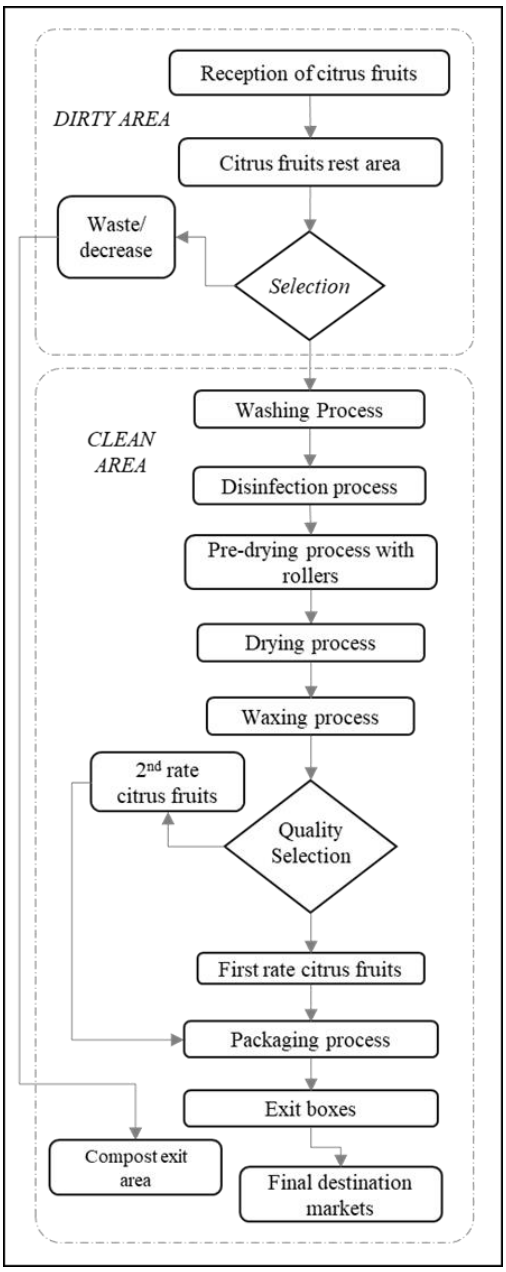

Fig. 3. Citrus machining production process diagram of Vela organic company from Martínez de la Torre company, Veracruz, 2021. Source: Own design made from [42]

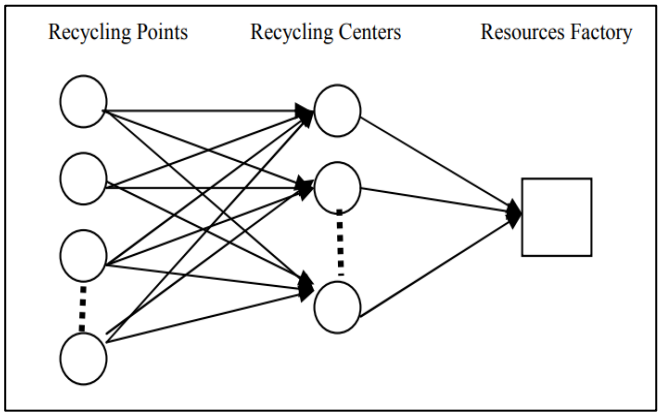

Fig. 4. Recycling and transport network chart of reverse logistics. Source: [10]

— R1: Transport price from recycling points to the recycling center.
— R2: Transport price from recycling center to the treatment factory,
— Y: Transport distance.

Logistics performance of enterprise is as the overall evaluation goal, by fully considered the requirements of circular economy, combined with basic characteristics of reverse logistics enterprise. Performance evaluation system will be divided into six subsystems, namely, the subsystem of technical strength, the subsystem of transport capacity, the subsystem of recycling capacity, the subsystem of service level, the subsystem of social benefits and the cost subsystem. [10]

V. Conclusions

The selection of an optimal route is a complex problem that generally involves particular criteria related to the interests of the decision maker, however, this information is also often a problem due to its scarcity, outdatedness or absence. In the review of the information, it was observed that there are a large number of models and solution methods, but these vary according to the needs or the approach that the author wishes to express and the solution of the method used.

By considering both environmental factors and the evaluation of cost variables makes that for this case study it is taken into account that the company Vela organic should make its sales to its closest markets, as this will ensure to minimize shipping costs and CO2 emissions produced by shipping the goods at the same time. In addition, the circular economy made it possible to identify and quantify the waste and shrinkage produced throughout the process described. Consequently, it can be stated that the use of both concepts is mutually complementary, which will allow future work to be focused on projects where closer criteria are established between Green Logistics and circular economy.

Companies should not only be valued in economic terms, but also in social and environmental terms, and there is a growing conviction that the valuation of companies should include these three dimensions, as can be seen in the text, the three dimensions where the circular economy is broadly contemplated, these are within the objectives of GL, the transformation of institutions and companies into entities with the dual purpose of ensuring the maximization of their results in terms of sustainability, highlighting a global trend that will continue to grow in the coming years.

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