# 3D-Printing based distributed plastic recycling: A conceptual model for closed-loop supply chain design

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***Abstract***

Plastic use and disposal is a major issue that still to be solved on the perspective of a more sustainable development of human activities. Circular economy has been proposed as a potential solution by using materials and energy through multiple phases in a recycling flow. However, most of the studies present in the literature of plastic recycling and other wastes are mainly focused on large centralized networks that try to efficiently carry their costs and / or income. In addition, particularly the centralized plastic recycling networks should face the challenge of collection and transportation for high volume and low weight polymers, affecting its economic feasibility. The emergence and development of Open-source technologies such as 3D printing extrusion and other devices provide an opportunity to explore distributed recycling as an alternative option. Under this distributed model, users will collect domestic plastic waste themselves, which can be recycled at their nearest recycling points, such as FabLabs, in order to produce 3D plastic filament and thus contribute to the Circular Economy by reducing the plastic waste.

On despite its attractiveness, the complexity of this distributed approach represents a limit to this application. Moreover, the environmental and economical effectiveness still needs to be demonstrated. In this article, a conceptual model is developed and proposed for the collection process in a Closed Loop Supply Chain (CLSC) network of local and distributed plastic recycling in order to analyze its economic and environmental feasibility.

***Keywords—*** *Closed Loop Supply Chain, Recycling, Plastic, 3D Printer*

## I. INTRODUCTION

The circular economy is gaining increasing attention in Europe and around the world as a potential way for our society to increase prosperity, while reducing dependence on primary materials and energy. Different definitions of Circular Economy (CE) are given in the literature. For example, the most renowned definition is given by the Ellen MacArthur Foundation, which defines the CE as " an industrial system that is restorative or regenerative by intention and design " [1]. On the other hand, consider the different definitions existing in the literature, Geissdoerfer et al. [2] defines the CE as "a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops ". However, Saidani et al. [3] states that the literature agrees that the CE corresponds to the opposite of the linear model "make-take-waste". The goal of the circular economy concept is to have an integrated process between technical and biological flows and an integrated management by minimizing or eliminating waste [4]. The Circular Economy is characterized by closed loops, promoting maintenance, reuse, remanufacturing and recycling [3].

Plastic materials have a central role in the context of circular economy. One of the main elements is the recycling process for plastic waste. It is possible to distinguish four main recycling processes: primary, secondary, tertiary and quaternary recycling [5]. The primary recycling corresponds to the recycling of decontaminated and single-type plastics, in order to obtain recycled plastic with characteristics similar to virgin plastic. Secondary recycling, corresponds to the recycling of contaminated plastics to obtain recycled plastics with lower performance requirements than the original. Tertiary recycling is related to the recovery of monomers through the depolymerisation of plastic wastes, generally via chemical or thermal recycling. This recycling process is used when it is not possible to perform primary or secondary recycling due to difficulties in identifying and sorting the material into the plastic waste. Finally, when it is not possible to carry out any of the previous recycling processes due to the number of recycling cycles and the loss of properties of the plastic, quaternary recycling is carried out. Quaternary recycling corresponds to the recovery of energy by incineration [5].

The types of primary and secondary recycling are widely applied. These are directly related to the so-called mechanical recycling. In mechanical recycling, the recycling process to produce recycled plastic is carried out by mechanical means involving separation, washing, grinding, remelting and processing polymeric wastes [5], [6].

Historically, plastic recycling has been oriented to centralized facilities in order to take advantage of economies of scale in the production of low-value products. However, this approach must face the challenge of collection and transportation for high volume and low weight polymers, provoking that the recycling of plastic is not so economical in this centralized context [7].

In this centralized context, in the year 2014, of 25.8 million tons of plastic waste gathered in the European Union, 29,7 % was recycled, 39,5 % was used for recovery of energy and 30,8 % was taken to the dump [8]. These numbers demonstrating that the plastic disposal and reuse is an issue that is far from being solved. As a consequence, new ways to realize this recycling should be explored.

On the other hand, Additive Manufacturing (AM), also known as 3D printing (3DP), is a technology that has had great development in the recent years. The AM is defined as "a process of joining materials to make parts from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing and formative manufacturing methodologies" [9]. This form of manufacturing allows it to fabricate any complex structure, which has allowed its presence in wide range of areas such as aerospace area, medical area and vehicle engine manufacturing [10]. There are five methods of manufacture and seven types of technologies in AM [10], [11]. The five methods of manufacture are [10]: (1) Laser-based processes, (2) Extrusion processes, (3) Material jetting, (4) Adhesive and (5) Electron beam. In Laser-based processes, a medium to low power laser source is used to melt, solidify or cure the material. The Extrusion processes use a heated nozzle to melt the material (usually plastic), which is then deposited through a nozzle to form the figure. The jetting material processes use thin nozzles to spray in a controlled way an adhesive to adhere powder to the solid object and form the figure. In the Adhesive-based processes, a cutter cuts a thin film of paper or plastic according to the corresponding contour. The film is deposited, pressed and adhered to the figure in the printing process by means of a heater that activates an adhesive located at the bottom of the film. Finally, in the Electron beam processes an electron beam is used to melt the material and form the desired part.

The Fused Deposition Modeling (FDM) is one of the seven techniques developed in the AM technology. The FDM uses the extrusion process, where a thermoplastic filament is melted and deposited to generate the product. The simplicity of the process in the FDM makes your equipment relatively inexpensive. In addition, the raw materials used are low cost, non-toxic and odorless, making it ideal for amateurs. The most used materials in FDM are ABS (Acrylonitrile Butadiene Styrene), PLA (polylactic Acid) and PC (polycarbonate) [10], [12].

The patent expiration of the FDM technology in the mid 2000's, allows users the development of this technology in an Open Source (OS) noncommercial way, allowing a decrease in the acquisition costs of this technology and making it accessible to all [13]. An example of this is the RepRap project, which allows users to acquire a 3D printer in the range of $200 to $500 and it is estimated that between 2008 and 2011 the number of RepRaps increased from 4 to 4500 [7]. Moreover, Zhong et al. [14] demonstrated that the coupling of an open source recyclebot (Open source extruder) and RepRap 3-D printer will enable "brings a traditional industrial system into a small single home, business or community center".

In the scientific literature, the notion of *Distributed Manufacturing* and its reciprocal *Distributed Recycling* has been emerged as one conceivable impact of the open-source 3D printing growth.

We could define distributed manufacturing as a form of decentralized local production developed thanks to the synergy among emerging digital fabrication capabilities, the information and communication technologies and the commons-based peer production approach (e.g. the self-selection of tasks by the participants, modularity design) [15], [16]. The main advantages of decentralized production structures are a higher flexibility to reflect local customer, lower logistics costs and shorter delivery times [17].

As OS 3D printers improve progressively in performance, reliability, material options and declining in cost, these devices would play an important role in the deployment of the distributed manufacturing. In fact, Kreiger et al. [18] worked on the environmental impact of distributed manufacturing polymer products made from OS 3D printers. The results showed that distributed manufacturing requires less cumulative energy than conventional (*centralized*) manufacturing. Joining 3D printing capabilities with the photovolaic grid, the impact could be even lesser. From an economical point of view, Wittbrodt et al. [19] proved the attractiveness of this technology for an average US household, until a point that it could become a mass-market mechatronic device.

As a consequence, this growing development and use of 3D printers thanks to its open source nature, makes it possible to think of a new option for recycling plastics by manufacturing 3D printing filaments from recycled plastics [20]. This plastic filament can be supplied to the community, thus forming a plastic Closed Loop Supply Chain that follows one of the objectives of the circular economy helping to reduce plastic waste. Within this cycle additional value can be generated as post-consumer products are reused to produce new products as well as reducing energy consumption and greenhouse gases.

However, as mentioned earlier, the field of polymer recycling is related to large centralized facilities that face the challenge of collection and transportation for high volume, low weight polymers, which results in the study of large and complex logistics networks of plastic recycling. In contrast, the distributed recycling approach is an alternative option.

Different studies in the scientific literature have been carried out about the distributed recycling process in order to show the technical feasibility. For example, Kreiger et al. [7] proved the environmental feasibility in relation to energy use and greenhouse emission of distributed mechanical recycling of HDPE using the RecycleBot, a recycling machine to create 3D printing filament using plastic waste. Likewise, Cruz et al. [21] proves the viability for PLA mechanical recycling using the technology of open-source 3D printing. Furthermore, Cruz Sanchez et al. [13] propose a general methodology to evaluate the recyclability of polymers used as feedstock for 3D printing systems and uses it to prove the feasibility of use recycled PLA for open-source additive manufacturing. Moreover, the environmental and economical effectiveness of this distributed recycling networks using 3D printing Open Source technologies still to be demonstrated.

Based on this background, the contribution of this research is to present a conceptual model with the objective of analyzing the economic and environmental feasibility of the collection phase in a local and distributed recycling of plastics in a Closed Loop Supply Chain network to produce 3D printing filaments.

This article is structured as follows. Section 2 presents the State of the Art related to Reverse and Closed Loop Supply Chain network to the plastic recycling. Section 3 presents the conceptual model elaborated. Section 4 finish with the conclusions and perspectives.

## II. FROM REVERSE LOGISTIC (RL) TO CLOSED LOOP SUPPLY CHAIN NETWORK

In this part, we will first highlight the differences between Reverse Logistic and Closed Loop Supply Chain network concepts. Then we will show the moment at which these concepts appear in the literature, to finish we will focus on CLSC network for both, general purposes and for plastic reuse. Finally, we will show more precisely the optimization models used in these cases.

### *A. Reverse Logistic and Closed Loop Supply Chains network*

Recycling is an activity that can be present in two types of network: Reverse Supply Chain (RSC) (or Reverse Logistic (RL)) and Closed Loop Supply Chain (CLSC). The RSC is the network for the recovery of discarded products for recycling or reuse in other products. On the other hand, the CLSC corresponds to a network that integrates the Forward and Reverse Supply Chain. The flow of goods from the supplier to the client is realized through the Forward Supply Chain, while the Reverse Supply Chain recover the products from the customer for its recycling or reuse. When both types of networks act at the same time, they form one Closed Loop Supply Chain network [22].

### *B. Bibliometric literature review*

We perform a temporary analysis of the Reverse Supply Chain (or Reverse Logistic) and Closed Loop Supply Chain concepts, the search uses the Scopus database. The search is performed considering the logic "Closed Loop Supply Chain OR Reverse Supply Chain OR Reverse Logistics OR CLSC". Title, Abstract and Keyword were considered in the search. A total of 4226 references were found between 2000 and 2018.

References found were analyzed using the VOSviewer software1. VOSviewer is a software developed for the construction and visualization of bibliometric maps [23]. Fig. 1, shows the result obtained from the temporal analysis carried out in the VOSvierwer visualization software considering co-ocurrence of author keywords, with full counting method and an occurrence of 50. From the results obtained, it is possible to conclude that the most frequent concepts in the references dataset correspond to Closed-Loop Supply Chain and Reverse Logistics. However, from the colors associated with both concepts it is possible to conclude that the Closed-Loop Supply Chain concept is more recent than the Reverse Logistics concept, due to its orange and blue colors respectively (Fig. 1). Therefore, the Closed-Loop Supply Chain is a network that has been frequently studied in recent years.

In a general way, there is a relevant review carried out by [24] about Reverse Logistic and Closed Loop Supply Chain literature between 2007 and 2013. In their study, they presented the level of used decision variables which in most of the cases are operational variables (e.g. lot sizing, inventory, etc.) Also, it was found that concerning optimization methods most of the studies used a linear and mixed integer programming (MIP), and that most of them consider only one objective. More specifically, they found that linear programming is the dominant form of modeling for RL/CLSC problems that relate to design and planning, for example, they address decisions such as facility location, facility capacity and flow between facilities.

### *C. Focus on Closed Loop Supply Chain*

In this section the analysis is focused on CLSC-type of networks.

As in the analysis of section 2.1, a search is performed on the Scopus database but this time only in relation to the concept of Closed Loop Supply Chain. The search is carried out under the logics "Closed Loop Supply Chain OR CLSC". Title, Abstract and Keyword were considered in the search. A total of 1546 references were found until 2018.

The new references found were analyzed using the VOSviewer software. The obtained map using VOSviewer software and searching for co-ocurrence of author keywords, with full counting method and an occurrence of 5, is shown in Fig. 2. In this figure, the red colored concepts are concepts related to the cluster "network", in other words, in this cluster are found those concepts related to the design and planning of a Closed Loop Supply Chain network. TABLE I shows the concepts of the cluster "network", related to the concept of Closed Loop Supply Chain and her link strength. The link strength can be interpreted (for the full counting method) as the quantity of reference in which both keywords concepts appear in the same reference [25].

TABLE I shows how the most frequent relationship of the closed loop supply chain concept is with the "uncertainty" concept, relating in a total of 25 references. This relationship may be due to the fact that a major problem faced by closed-loop supply chain networks is uncertainty in the number of products or waste available to be recovered. Another concept frequently related to the closed loop supply chain concept is the concept of "network design". From this relationship it is possible to infer that there are many studies related to the design of the closed loop supply chain network.

From a methodological point of view, it is possible to conclude that the most commonly used models in the literature correspond to "robust optimization", "Mixed Integer Linear Programming (MILP)" and "Stochastic programming".

[1] http://www.vosviewer.com/

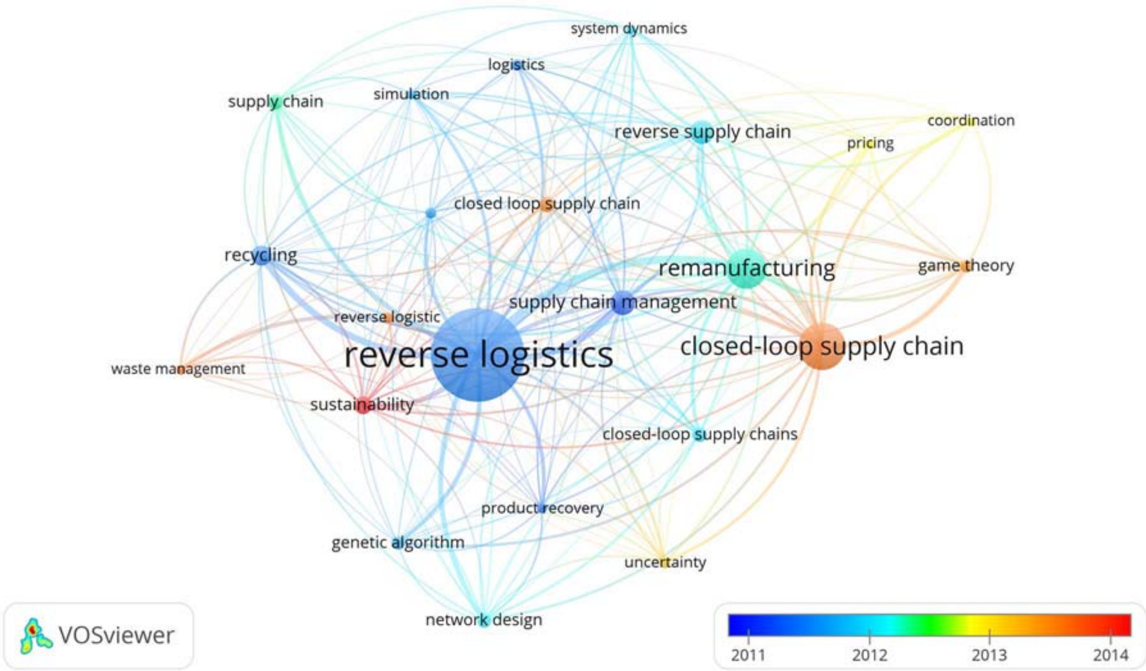



Fig. 1. VOSviewer result obtained from the temporal analysis.

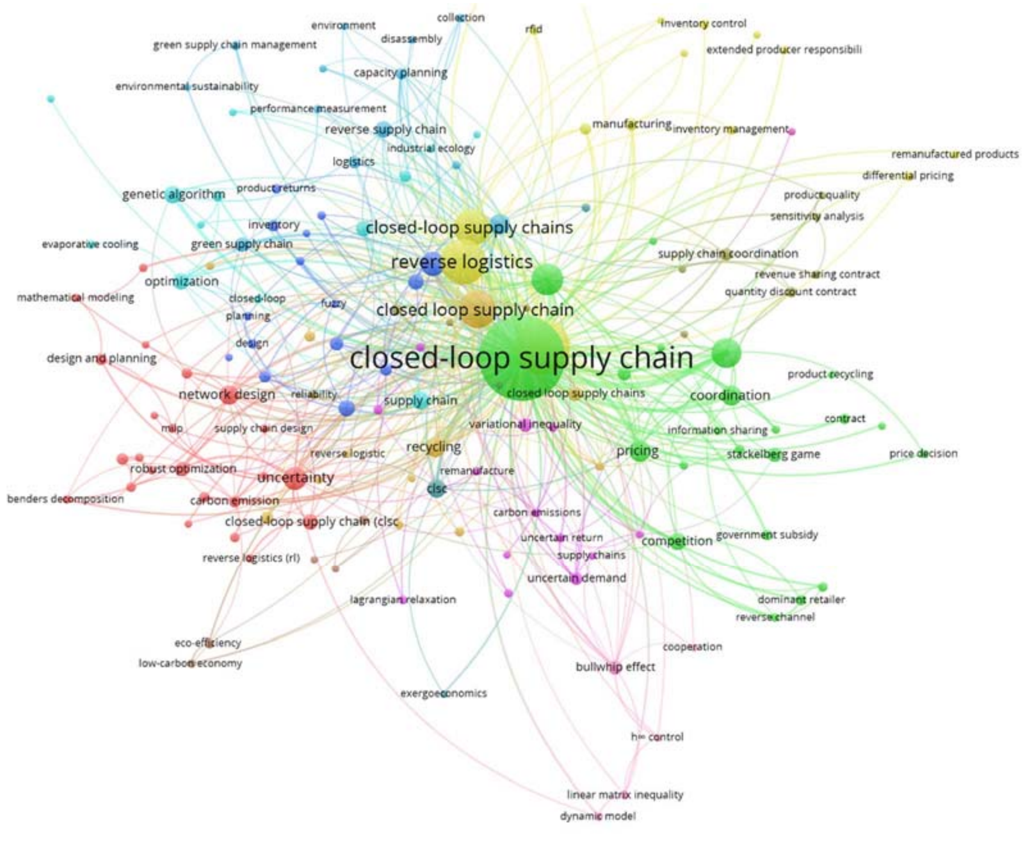



Fig. 2. Map obtained by searching for keywords using the VOSviewer software.

TABLE I. VOSVIEWER RESULTS FOR NETWORK CLUSTER OF CLSC CONCEPT

| Keyword concept 1 | Keyword concept 2 | Link strength |
|---|---|---|
| Closed-Loop Supply Chain | Product design | 7 |
| | Mathematical modeling | 5 |
| | Design and planning | 9 |
| | Facility location | 4 |
| | Network design | 15 |
| | Supply Chain design | 3 |
| | Mixed Integer Linear Programming | 6 |
| | Robust optimization | 9 |
| | Stochastic programming | 3 |
| | Benders decomposition | 5 |
| | Carbon emission | 6 |
| | Multi-objective programming | 2 |
| | Uncertainty | 20 |
| | Supply chain network design | 4 |
| Closed-loop supply chains | Benders decomposition | 1 |
| | Network design | 2 |
| | Supply chain design | 2 |
| | Uncertainty | 2 |
| closed loop supply chain (clsc) | Uncertainty | 3 |
| | Reverse logistics (rl) | 5 |
| Closed loop supply chain | Facility location | 2 |
| | Network design | 4 |
| | Carbon emission | 1 |
| Closed loop supply chain network design | Fuzzy mathematical programming | 2 |
| | Probabilistic programming | 3 |
| | Stochastic programming | 3 |
| | Carbon emission | 1 |
| Closed-loop supply chain network | Robust optimization | 2 |
| | Carbon emission | 1 |
| | uncertainty | 2 |

## D. *Focus on plastics Closed Loop Supply Chain*

In order to focus on the literature related to Closed Loop Supply Chain networks in the plastic area, a search is carried out in SCOPUS under the logic of "(Closed Loop Supply Chain OR CLSC) AND plastic". The search results show eight references related to Closed Loop Supply Chain networks and plastic, of which six were more precisely studied [26]–[31].

The studies found cover different aspects of a CLSC network. French & Laforge [27] conduct an exploratory analysis of the reuse practices of the process industry in a CLSC network, in order to find research questions that can guide future research in this area. On the other hand, Chavez & Sharma [26] evaluate and compares the profitability and environmental friendliness of a CLSC chemical PET recycling network. To carry out his work he takes as a case study the Mexican automotive market, which evaluates from the point of view of cost, energy consumed and CO2 emissions considering a PESTEL analysis. Comparing its results with a forward network, it shows that the proposed CLSC network is more profitable and environmentally friendly. Pati, Vrat, & Kumar [30] measure the bullwhip effect in a closed loop supply chain network, i.e. the effect of demand variability in a CLSC network. Ma & Chen [29] model and analyze the play of three oligarchs retailer in a CLSC network by means of Nash equilibrium, bifurcation and chaos of e.g. the recycling price.

Only two of the six studies focus on the design and planning of a CLSC network. Kannan, Noorul Haq, & Devika [28] propose a closed loop multi-echelon distribution inventory supply chain model, which solves by means of a genetic algorithm and particle swarm optimization. The model is applied in the cases of tire manufacturing industry and plastic goods manufacturing industry. On the other hand, Sheriff, Nachiappan, & Min [31] propose a mathematical model for reverse logistics, which minimizes costs and decides the location of facilities, allocation of facilities and routes of the means of transport. The model is applied to the case of the plastics industry in India.

As shown in the TABLE II, studies of CLSC network in plastic area, consist only of centralized networks of industrial scale. Furthermore, the two articles related to optimization in design and planning area of the plastic recycling CLSC network, correspond to studies of a centralized network, with industrial orientation and country level (India) [28], [31].

TABLE II. ANALYSIS OF WORKS IN THE AREA OF PLASTICS CLOSED LOOP SUPPLY CHAIN

| Author | Area of study of the network | Orientation | Network type |
|---|---|---|---|
| Kannan, Noorul Haq, & Devika (2009) | Design and planning | Industrial | Centralized |
| Sheriff, Nachiappan, & Min (2014) | Design and planning | Industrial | Centralized |
| French & Laforge (2006) | Issues and practices | Industrial | Centralized |
| Chavez & Sharma (2017) | Network evaluation | Industrial | Centralized |
| Ma & Chen (2014) | Uncertainty | Industrial | Centralized |
| Pati, Vrat, & Kumar (2010) | Uncertainty | Industrial | Centralized |

## E. *State of the art conclusion*

From the literature review analysis, it could be concluded that the research works found related to logistics network design of CLSC plastic recycling, consider only a centralized network and at an industrial scale, that is, to the best of our knowledge there is no studies of a CLSC network of distributed and local plastic recycling.

From a methodological point of view, it could be inferred that this local and distributed plastic recycling networks can be modeled by means of a MILP model, robust optimization or stochastic programming.

## III. PROPOSITION OF A CONCEPTUAL MODEL

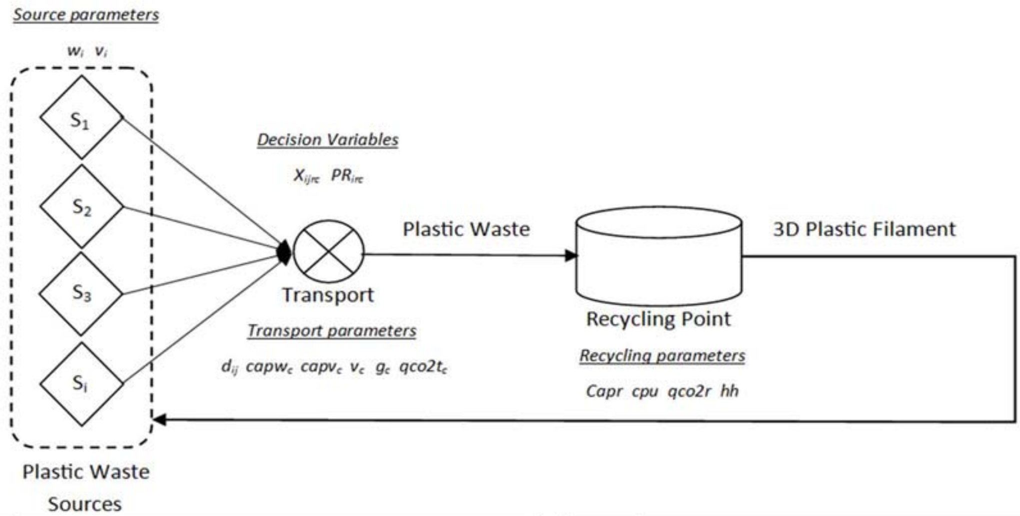
From the analysis of the state of the art, it was found that a CLSC network of distributed and local plastic recycling has not been studied, which according to our approach, might be possible under the open source 3D printing technologies. However, it is necessary to analyze the feasibility of this recycling approach by trying to use the resources of the recycling point in an optimal way and also contribute to the environment. According to the state of the art, this analysis may be possible by means of an optimization model, so we propose conceptually one according to this recycling approach.

The aim of the proposed model is to identify the optimal configuration of the plastic closed loop supply chain network taking into account a particular context. By context, we understand a set of geographical distributed sources of polymers to be recovered and processed in a recycling point with a limited production capacity. So the main question to the decision maker is to deal with: the means of transport to use, the route sequence and the number of collection points that allows simultaneously, to maximize the economic benefit as well as minimize the ecological impact.

The model will be developed for the following CLSC type scenario shown in Fig. 3: only one type of plastic waste is collected locally from different plastic waste sources, which is transported and recycled to a recycling point to produce 3D plastic filaments, which will finally be reused.

The objective function of the model could be represented by both, minimizing economic and environmental costs, or maximizing economic and environmental benefits associated with the entire process. As the intention is to analyze viability of local and distributed plastic recycling, the objective function will be represented as a maximization of the economic and environmental benefit of implementing local and distributed recycling for 3D printers in comparison to a context without local recycling and distributed for 3D printer. Formally, the objective function can be represented as the economic and environmental benefit of manufacturing plastic filament from recycling a certain amount of plastic, compared to buying that amount of plastic filament in the market. In other words, it would be a difference in the economic and environmental costs between the plastic filament purchasing process (if the amount of plastic to be recycled is purchased in the market) and the process of recycling the amount of plastic (represented in Fig. 3).

The decision variables of the model correspond to $X_{ijrc}$ and $PR_{irc}$. $X_{ijrc}$ represents a particular ordered trajectory. It is a binary variable that will be one if the means of transport $c$ is associated with route r and makes a trip between points i and j ($i$ and $j$ represent the collection points and the recycling point),




| Symbol | Meaning |
|---|---|
| $w_i$ | Weight of the amount of plastic waste available in source point i |
| $v_i$ | Volume of the amount of plastic waste available in source point i |
| $X_{ijrc}$ | Binary variable that will be one if the means of transport $c$ is associated with route $r$ and makes a trip between points $i$ and $j$. |
| $PR_{irc}$ | Binary variable that will be one if source point $i$ is associated with the route $r$ and means of transport $c$. |
| $d_{ij}$ | Distance between points $i$ and $j$ |
| $capw_c$ | Capacity (as weight) of means of transport $c$ |

| Symbol | Meaning |
|---|---|
| $v_c$ | Speed of the means of transport $c$ |
| $g_c$ | Fuel cost of the means of transport $c$ |
| $qco2t_c$ | Amount of CO2 emitted per unit of distance traveled of the |
| $Capr$ | Recycling capacity of the recycling point |
| $cpu$ | Cost of the recycling step of a plastic unit |
| $qco2r$ | Amount of $CO_2$ emitted when recycling a certain unit of |
| [illegible] | [illegible] |

Fig. 3. CLSC type scenario for local and distributed recycling of plastic.

so with this variable it is possible to decide to have a set of points of origin, destination points, routes and means of transport. $PR_{irc}$ is a binary variable that represents whether the collection point $i$ is associated with the route $r$ and means of transport $c$. The idea of the $PR_{irc}$ variable allows the model to decide which points to go to collect and which not, associating the points to a route $r$ and means of transport $c$ to obtain the maximum possible benefit. In order to represent the economic benefit, a comparison must be made between the purchase costs and the costs of the proposed recycling process. As purchase costs should be considered the cost of purchase in the market of the amount of plastic to collect and also its cost of shipment. On the side of recycling costs, transportation and recycling costs should be considered. In the transport process, parameters such as the following are involved: $d_{ij}$ (distance between points $i$ and $j$), $v_c$ (speed of the means of transport $c$ for collecting) and $g_c$ (fuel cost of the means of transport $c$), which are used to calculate the total cost of transport for collecting. Finally, in the recycling process, parameters such as *cpu* (representing the cost of the recycling step of a plastic unit) must be considered, which must be used to calculate the total cost of the recycling stage of the amount collected.

The environmental benefit can be economically represented by knowing the cost of a $CO_2$ unit. Therefore, in order to calculate the environmental benefit, it is necessary to make a comparison between the amount of $CO_2$ emitted by the purchase process and the amount of $CO_2$ emitted by the proposed recycling process. By obtaining these quantities, the environmental benefit can be represented economically by knowing the cost of a $CO_2$ unit. In order to know the quantity of $CO_2$ due to the purchase process, it is necessary to take into account the $CO_2$ emitted by the manufacturing process of virgin plastic filament and its transport to the place where it was demanded (since it is a local recycling, it must correspond to the same sector where it is planned to recycle). On the other hand, in order to know the amount of emitted $CO_2$ by the recycling process, it is necessary to take into account the amount of emitted $CO_2$ when transporting the collected quantity and the amount of emitted $CO_2$ during the recycling process at the recycling point. When calculating the amount of emitted $CO_2$ during transport steps, it is necessary to know parameters such as the distance between two points ($d_{ij}$) and the amount of $CO_2$ emitted per unit of distance traveled of the means of transport $c$ ($qco2t_c$). To calculate the amount of emitted $CO_2$ in the recycling process, it is necessary to know the amount of emitted $CO_2$ when recycling a certain unit of plastic (*qco2r*), which allows us to determine the amount of emitted $CO_2$ in this process based on the amount of plastic collected.

As restrictions of the model, it is necessary to consider the restrictions of the means of transport, the recycling point and route conditions. As a restriction of the means of transport, the means of transport $c$ used for collection cannot collect more than its transport capacity, either as weight ($capw_c$) or volume ($capv_c$). In addition to determining this, of each source point i should know the weight ($w_i$) and volume ($v_i$) of the amount of plastic waste available. In the case of recycling point restrictions, it cannot recycle more than its recycling capacity in a given time period (*capr*). It should also be considered as a restriction of the recycling point, that the duration of the collection should not last longer than the established number of hours of work in recycling point (*hh*). Finally, as route conditions, it is necessary to establish restrictions such as, for example, that the established route must begin and end at the recycling point, that it must be passed only once by a source or collection point and that each route must have only one means of transport associated with it.

## IV. Conclusion and Perspectives

In this work, a literature review was conducted in relation to plastic recycling networks concluding that there is no optimization model devoted to local and distributed recycling network type CLSC for small-scale plastic waste.

Based on results of the literature review, a conceptual model was proposed considering economic and environmental aspects of the collection phase in a CLSC network of distributed and local plastic recycling to produce 3D printing filaments.

As future work, it is suggested to formalize the conceptual model proposed as a model of optimization MILP or other in order to analyze the economic and environmental feasibility of this type of network. It is also suggested to carry out research for plastic recycling with this type of application considering more stages than just the collection and the simultaneous collection of more than one type of plastic.

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