The Recycling of Fire Extinguisher; First Step Toward a Circular Economy

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Abstract

Today, man faces one of the most complex challenges of his existence. Having been able to transform the surrounding environment, he now faces a great dilemma. How to continue to develop, from an economic and social point of view, given the imminent depletion of natural resources? How to maintain accelerated consumption and at the same time stop aggression against the natural environment? From these questions were born new trends such as clean productions and others, somewhat more ambitious, such as the circular economy. These new concepts suggest a change in business and social paradigms aimed at transforming the traditional linear production and consumption model by a circular model.

In those supply chains that already operate in the market, the transformation towards a circular model necessarily goes through several stages. The objective of this work is to present a procedure to gradually transform. Then, the main contribution of this article is the application of a general circular economy transition method that allows gradual

transformation in real life business. The proposed method permits the section of the most adequate circular business strategy and develops the organizational changes into the company.

For future research, it is proposed to test the BCM in other supply chains to demonstrate its generality. Also, a circularity indicator should be introduced to assess the progress in the transformations; to do this; research should be carried out among the different types of indicators that have been developed in the literature.

Keywords

Circular economy, business model, business model design, fire extinguisher

1. Introduction

The economic models in which society has developed follow a linear behavior; man extracts resources from nature, transforms them into consumer goods, uses them and discards them. Today, after more than 20 centuries of proceeding, we discover that the sources of resources are not inexhaustible and that the volumes of waste grow unsustainably. Several sources reveal that in the next 30 years the population density will increase significantly and, as a result, the consumption and extraction of raw materials will grow alarmingly (Ellen MacArthur Foundation, 2013). If the first signs of resource depletion are already notable today, it would be interesting to ask whether in the future we can survive with a linear economic model. As an alternative to the linear economy, circular models emerge.

The CE in not a new concept, and it has several schools of thought as precedents: regenerative design, performance economics, cradle to cradle, industrial ecology, biomimicry and blue economy (Ellen MacArthur Foundation, 2013; Ünal, 2019); all looking for the preservation of natural resources and extending the resources life (Sauvé; Bernard *et al.*, 2016). There are hundreds of Circular Economy (CE) definitions (Kirchherr; Reike *et al.*, 2017; Homrich; Galvão *et al.*, 2018) since it is a multidisciplinary concept and it has received a lot of attention in the last 10 years (Reike; Vermeulen *et al.*, 2018). It is basically a model that seeks an effective product design to work in a four-loop economy: reuse, restore, remanufacture and recycle (Ellen MacArthur Foundation, 2013). It looks for eliminate the garbage that goes to the landfill by separating the treatment of resources in natural and technological cycles, and with a change in the design model; from build to own, to build to consume.

The CE starts from the product design, and this is a fundamental moment that can decide the characteristics of the business (Bocken; Farracho *et al.*, 2014).There are two types of product design strategies the closing and the slowing loops; the last one can be made for long-life products or for product-life extension (Bocken; de Pauw *et al.*, 2016). But, how to transform to slowing or closing loops business when the product is already designed and it has been in the market for a while?

The production and use of fire extinguishers follow a traditional and old commercial model (Sora y De Pascual Ciria, 2007) that, at first glance, does not seem to have prospects for change in the coming years. But nevertheless, innovation, technologies 4.0 and green trends can revolutionize this business, as much as any other in the world. Based on the need to comply with environmental regulations and the emerging of a new formula to produce fertilizers from the wastes of this supply chain, a project arises to transform the fire extinguisher model into a circular economy model.

The EC assume that the application of circular economy arises from a change in the design of the product (Ünal, 2019); however, it can be promoted from solutions that seek to treat the generated waste. In addition, there are few studies to clarify the steps to effectively transform the company's business model to the circular economy, from a practical point of view (Aluchna y Rok, 2019). The aim of this paper is to present a practical method to transform traditional business model into circular economic models. This method was obtained by an empirical research supported in a theoretical review, to solve the case of the fire extinguisher.

The transition to an CE in supply chains has been difficult for several reasons, such as lack of incentives, mutual interest and a unique perception among the actors; also the high uncertainties and risks that represent a great change (Schraven; Bukvić *et al.*, 2019). The CE transformation should be executed on a micro, mezzo and macro-economic levels. The micro level refers to enterprises as center of the transformation; mezzo level is for example an eco-industrial park; and the macro level correspond to regions, cities or countries (Ünal, 2019).

At the macroeconomic level, China and the European Union have more comprehensive policies and programs for economic and social transformation. Although the two regions focus on waste and resource concerns; the discourse of Chinese politics is broader and incorporates pollution and other issues as eco-packing (Homrich; Galvão *et al.*, 2018); and it is framed as a response to the environmental challenges created by rapid growth and industrialization. In contrast, Europe's conception has a narrower environmental scope, focusing more in opportunities for business (McDowall; Geng *et al.*, 2017).

However, both regions are pioneers on regulations and lows proclamation for CE transformation; China have the first regulation on that (National People's Congress, 2008; State Council, 2013) and European Union have completed the

Final Circular Economy Package on March 2019. The Action Plan is fully completed with 54 actions included in the documents package (European Commission, 2011, 2015, 2018, 2019). Although, Germany had been working focused on their program of Resource Efficiency Program (ProgRess) for several years (BMUB, 2015, 2016), Finland presented its roadmap in 2018 (Sitra, 2016; Sitra y Ministry of Enviroment, 2017), France has just published one (Plan Climat Republique Francaise, 2018), and others are working on the building blocks of its roadmap.

In the Cuban case, the closest to a circular economy strategy are the national environmental strategies (CITMA, 2007, 2016) ; however, they do not incorporate the concept of EC or its main bases. This situation makes the strategies at the macro level in the country null; while at the micro level, these are carried out by isolated initiatives of entrepreneurs and managers.

The work of Lewandowski (2016) demonstrates that even when numerous business models for circularity have been developed, there is a need for empirical research on adding value in CE contexts, especially for micro level. Motivated by this lack and in view of the requirements of the fire extinguisher supply chain itself, this work provides an empirical method to achieve circularity gradually.

This paper exposes in the mythologies and method section the Business Circularity Method (BCM) as a path for transforming linear to circular business. The third section sows the results of two application of the BCM on a fire extinguisher supply chain and how the circularity of the business is modified, as well as the increase in the economic results of the company and the supply chain. Final conclusions are presented on the section five.

2. Methodologies and method

In an established business, it is very difficult to go directly to totally closed cycle models, since the transformations tend to be gradual and step by step. Then, even if you have a closed loop as a goal, you will have to go through the slowing loops solutions. For the gradual transformation of business towards a circular economy model, the Business Circularity Method (BCM) in the figure 1 is proposed.

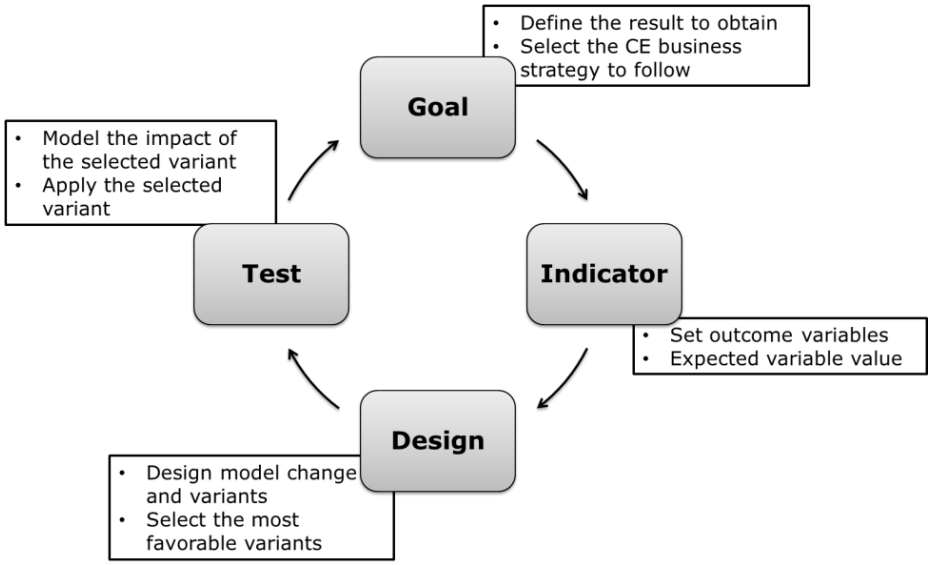

Figure 1 Business Circularity Method (BCM). *Source: own elaboration.*

GOAL: The first step is to have a sustainable objective as resource's utilization reduction, pollution decreasing, new product development or other. It must be selected one or several business model strategies (table 1) to guide the CE objectives.

Table 1: Business model strategies to introducing CE into supply chains**.** *Source:* (Bocken; de Pauw *et al.*, 2016)

Business model strategies	Definition
Business model strategies for slowing loops	
Access and performance model	Providing the capability or services to satisfy user needs without needing to own physical products
Extending product value	Exploiting residual value of products – from manufacture, to consumers, and then back to manufacturing – or collection of products between distinct business entities
Classic long-life model	Business models focused on delivering long-product life, supported by design for durability and repair for instance
Encourage sufficiency	Solutions that actively seek to reduce end-user consumption through principles such as durability, upgradability, service, warrantees and reparability and a non-consumerist approach to marketing and sales (e.g. no sales commissions)
Business model strategies for closing loops	
Extending resource value	Exploiting the residual value of resources: collection and sourcing of otherwise wasted" materials or resources to turn these into new forms of value
Industrial Symbiosis	A process- orientated solution, concerned with using residual outputs from one process as feedstock for another process, which benefits from geographical proximity of businesses

INDICATORS: the partners have to define the aim of the project in terms of measure targets and values; for example: increase sales, more reused resources, lest resources from nature, new product design, etc.

DEDIGN: To design the model changes, you can use brainstorming, the Canvas model or another model to generate the new business idea. After that, it is necessary to develop the commercial idea in terms of operational activities and mathematical relationships between the technical variables and the project's objective defined in the previous stage. This phase is developed based on a procedure for the design of customer services (figure 2), all changes must be customer focused. Here you can combine another engineering tool and method to complete the design.

Figure 2: Procedure for Customer Service Design. *Source*: (Acevedo Suárez; Gómez Acosta *et al.*, 2017)

The variants must be organized from the most favorable to the least, so that the partners can select the best variant taking into account the real environment and business scenario.

TEST: The selected variant is the technically developed one and its impact on the business performance variables and the EC indicator is simulated. If the results are suitable for the partners, these new business ideas are implemented. After some time of implementation of the idea, or while continuing, a new cycle of circularity can be generated defining new results and objectives.

3. Results

On the framework of the "Central Innovation Program for Small and Medium-Sized Enterprise" (ZIM) financed by the German Federal Ministry of Economy and Energy (BMWi), the innovation and development project for the enterprise "B & B Feuerloescher- Verwertungs- und Entsorgungs GmbH" (B & B) was carried out. This project resulted in a formation of an inorganic fertilizer made of expired Dry Chemical Powder (DCP), which is patented under the Pflanzovit® brand. In addition, a transfer project is being developed between Technological Havana University "José Antonio Echevarría" (CUJAE), B & B and the Institute of Agricultural and Urban Ecological Projects (IASP), to introduce the technology developed in Cuba. The application of the proposed method to the B&B-IASP-CUJAE transfer project is presented below.

There are several types of fire extinguisher, this project is mainly about the ABC fire extinguishers that can be used on class A (solid combustibles), B (flammable liquids), C (flammable gases) and electrical fires. They are available in a range of sizes from 1 - 9kg and are ideal for application in environments containing mixed fire risks and it is also known as Dry Chemical Powder (DCP) extinguishers.

There are some enterprises that produce and import fire extinguisher, but they meanly give security services. They provide engineering, marketing, installation, technical support and consulting services. The technical support service includes the services of preventive maintenance, corrective maintenance and recharge of fire extinguishers that ensure the sustainability and optimal operation of the systems installed for customers. Customers must hire these services to verify or repair the extinguishers and update the revision card; but the usually do not do it because they forgot the expiration date or they don't have the enough budget to maintenance.

4.1 Fire extinguisher supply chain, first approach

The figure 2 shows the direct and reverse network for the fire extinguisher associated to the security service. They only applied the maintenance/ reuse / refurbish strategy however, with the limitation that not all the installed fire extinguisher receives this treatment. There are many expired extinguishers that remain in customers' facilities for a long time.

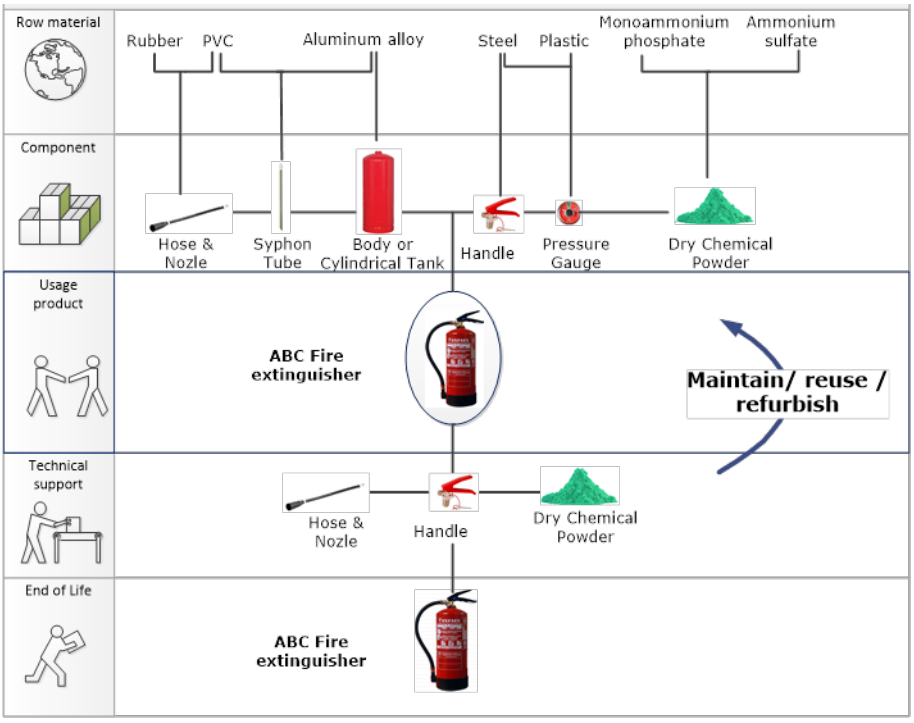

Figure 3: Current direct and reverse network of fire extinguishers. *Source: own elaboration.*

In addition, expired extinguishers that arrive at the recharge workshop of the Security Company, once the end of their useful life is reached, they are returned to the customer or kept in the workshop. Once they pass the workshop property, they are stored for a long time or even end up in the garbage next to the workshop's common garbage. This situation threatens the purpose of obtaining the DCP of expired extinguishers; in addition they are breaking national environmental laws (Consejo de ministros, 1975; Asamblea Nacional del Poder Popular, 1997).

Table 2: Application of the first two phases of the method in the extinguisher business. *Source: own elaboration*

GOAL	
Result to obtain	**CE business strategy**
collect enough expired DCP from fire extinguishers to produce fertilizers	Slogging loop strategy - Access and performance model; **a new closed cycle fire extinguishing service**
INDICATOR	
Outcome variables	**Expected value**
Get some income for DCP sales	More than 1% of the total expenses

DESIGN

To guarantee that all the fire extinguishers receive the preventive and corrective maintenance, an "Access and performance model strategy" is proposed. In this case it is related to a new model for the fire protection service; customers will meet their needs without their own extinguishers, they will do so through a comprehensive extinguishing service. The physical product will be rented and the Security Company will be responsible for maintaining maximum fire detection and extinction capacity.

The new service has as a distinctive feature that preventive maintenance will be mandatory, since its implementation extends the life of the extinguisher. It is proposed that the advice and the preventive maintenance service be contemplated within the installation contract, for a minimum period of one year. In this way, all the expired fire extinguisher will return to the Security Company's workshop for the extraction of the expired DCP.

A. Market segment

The Security Company has a varied portfolio of clients: hotel groups, chain stores and warehouses, ports and airports, fuel supply and storage networks, major industries, telecommunications data centers, banking system and government institutions. In general, all this type of clients can be unified into three market segments: ***wholesaler, companies*** and ***ships***.

B. Segment characterization

- The ***wholesaler*** customers are companies that only buy fire extinguishers, or even other companies that provide security services. This segment represented the 77% of sales to institutions in 2016, which states that the number of customers who prefer to buy only fire extinguishers is greater, instead of requesting all services related to portable extinction. For the new service, this segment includes only the other security service providers.
- The ***companies*** segment consists of all the institutions that request project services, product installation and technical support.
- The ***ships*** segment includes all shipping companies that request a preventive or corrective maintenance service. In 2016, they worked with 14 shipping companies for a total of 117 ships, of which 13% of the Panamanian flag and the rest Cuban.

C. To establish the **characteristics demanded by customers** for the new service, interviews were conducted with them. These interviews showed the following aspects required:

- Fast service execution
- Service reliability
- Meet the agreed deadline
- Delivery of the number of fire extinguishers requested
- After sales service guaranteed

D. Projection of the goal and service level to guarantee

Table 3: Customer service level design. *Source: own elaboration*

Segment	Service level	Formula	Goal
Wholesaler	Perfect order	$\boldsymbol{SLwc} = \left(\frac{\text{delivery on time}}{\text{delivery requested}} * \frac{\text{quantity delivery}}{\text{quantity requested}} * \frac{\text{error-free invoice}}{\text{total invoice}} * \frac{\text{product correct quality}}{\text{quantity requested}}\right)$	95%
Companies	Service reliability	$\boldsymbol{SLc} = \frac{\text{executed maintenance}}{\text{planned maintenance}} * \frac{\text{approved inspection of the fire department}}{\text{fire department inspection}} * \frac{\text{fire events successfully resolved}}{\text{fire events}}$	90%
Ships	Service on time	$\boldsymbol{SLs} = \frac{\text{services performed on time}}{\text{services requested}}$	97%

E. Organizational design

In practice, the new service only generates changes for the companies' market segment, since the other segments maintain traditional product sales and maintenance services. To define the organizational design to the a new **Closed cycle fire extinguishing service** the model and several matrix proposed by Acevedo Suárez; Gómez Acosta *et al.* (2017) are used. The obtained organizational service model is shown in figure 4.

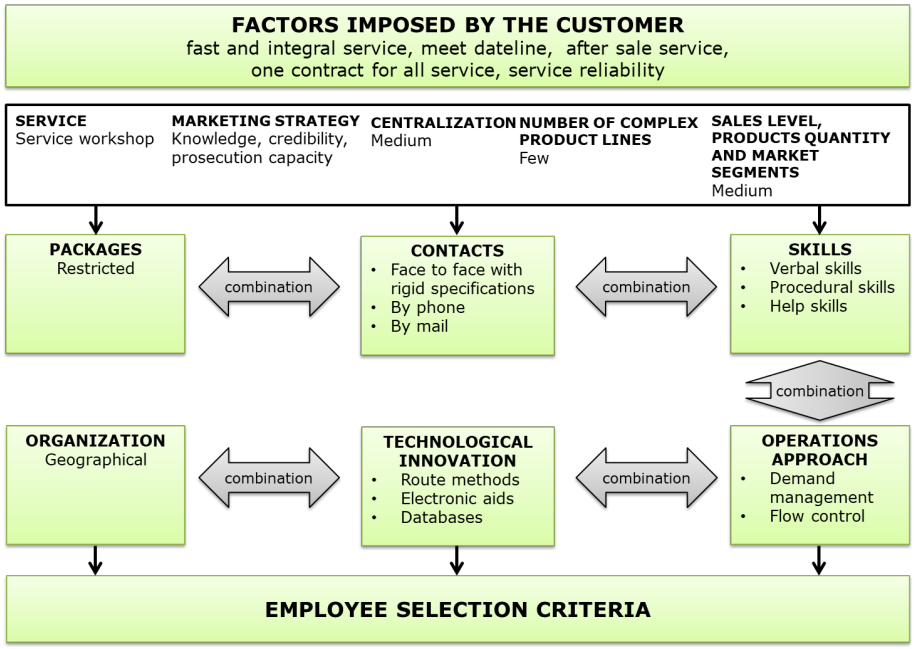

Figure 4 Closed cycle fire extinguishing service organization model.
Source: own elaboration from (Acevedo Suárez; Gómez Acosta *et al.*, 2017) *pp.149-157*

The new service organization defines the criteria for employee selection, and then they have to respond to verbal, procedural and help skill to work in a geographical region offering a restricted package of services on a workshop. Also the will have e restricted demand management and flow control to guarantee the factor demanded by the customer.

F y G. Definition of critical parameters, its content and magnitude

The figure 5 shows the relationship between the client's demands, customer service parameters and logistic system critical parameters.

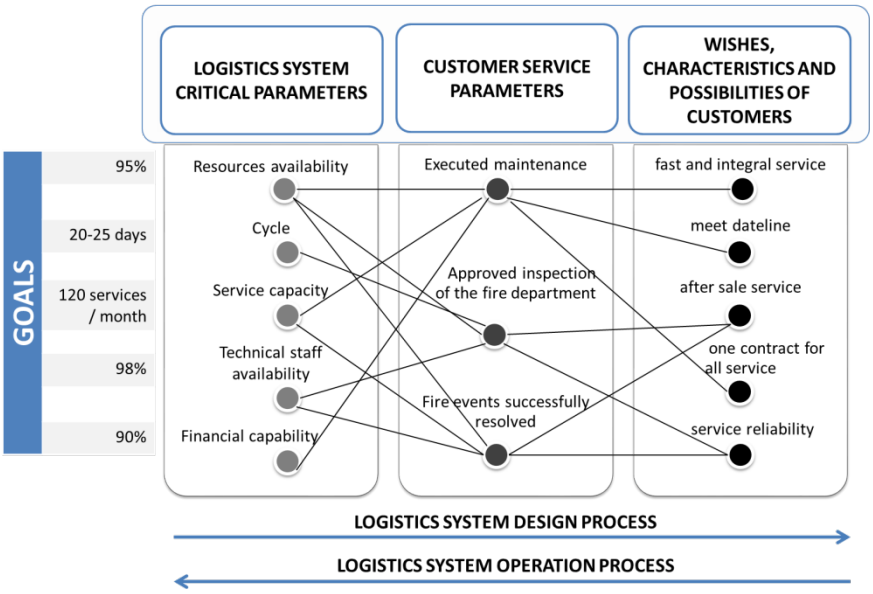

Figure 5: Logistics system critical parameters; it goal and relationship with other system parameters.
Source: own elaboration from (Acevedo Suárez; Gómez Acosta *et al.*, 2017) *pp.158*

H. Offer design and service promotion

The new service works with all types of fire extinguishers, since the integral service requires protection against all the fire risks that exist in the customer. This service includes five faces; and the materials, staff and place to develop it are detailed in the following table.

Table 4 Phases, staff, materials and place for the closed cycle fire extinguishing service. *Source: own elaboration*

Phase	Staff	Materials	Place
Engineering	Designer	Software, white sheets, file, toner	Security Company offices
Rental and Installation	Commercial	Nails, screw gun, hammer, revision card, support for CO_2 and DCP extinguishers	Client installation
Advisory	- Senior security technician - General security technician	CO_2, foam and DCP fire extinguishers	Client installation
Preventive Maintenance	Senior security systems specialist	Review card, support for CO_2 and DCP extinguishers, nails, auger, witness card (hydrostatic test)	Client installation
Corrective Maintenance (Fire extinguisher recharge)	- Senior specialist in security and rescue systems and means - Senior security systems technician - General security systems technician - Security systems operator	Review card, nitrogen, diluent, sandpaper 120, diffuser, seal, paint and all extinguisher components (valve, pressure gauge, label, safety pin, foam, DCP, CO_2, others)	Security Company workshop

Since the new service is designed according to the demands of the customers, it is necessary to offer variants of it that facilitate the decision of the client based on their budget and interests. The defined variants are presented in figure 6.

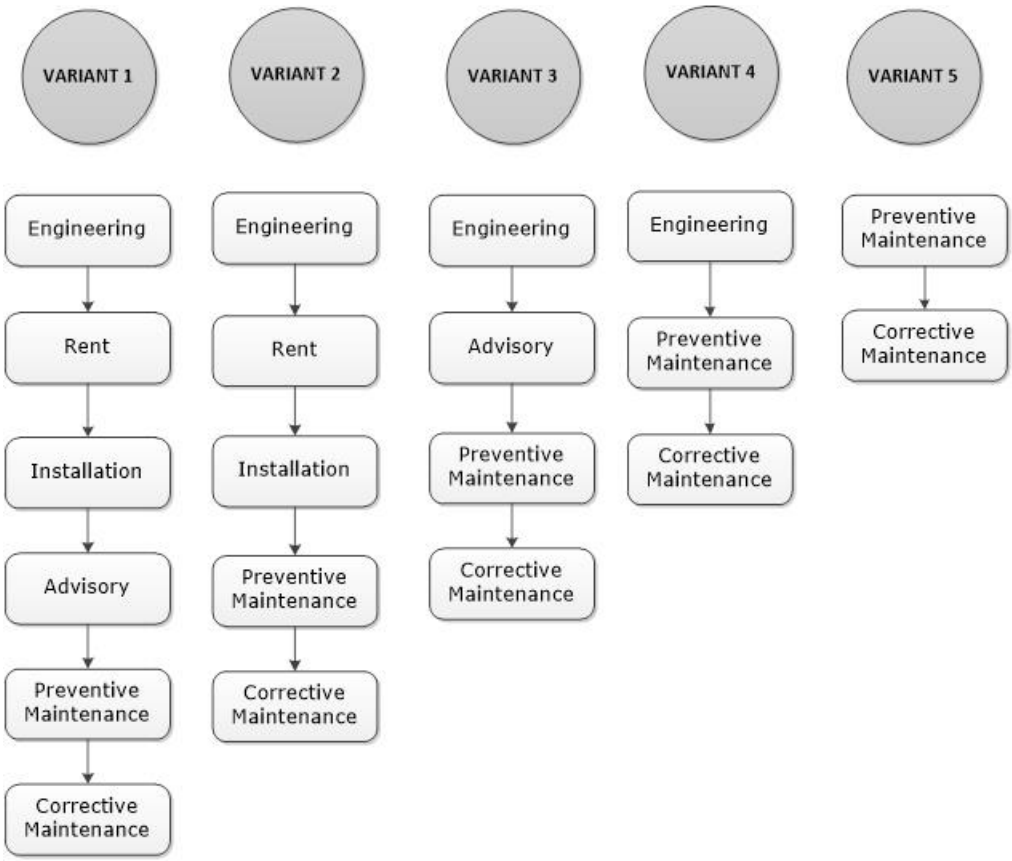

Figure 6: Five variant for applying the new closed cycle fire extinguishing service *Source: own elaboration*

Variants 1 and 2 constitute the most complete exemplification of the integral service. Variant 2 does not include advice because, it is for clients who have a certificate to handle protection means. Variants 3 and 4 are applicable to those customers that already have extinguishing systems but have been provided by others. Finally, variants 5 and 6 are for ships and former Security Company customers that already have extinguishing systems; but in that case the maintenance changes the ownership of the extinguisher, of the clients to rent.

To define the cost and earnings in each variant, the programming of the fixed and variable costs of each phase was carried out in an Excel. In this way, each service variant is offered under the restrictions that apply and prices to customers and in that way is reflected on the contracts. Another problem to solve in the new service is the payment methods. As national regulations do not allow paying for services in advance, an equal payment (a fix amount each month for a service that has not yet been received) was established to ensure that the client has financial liquidity to receive the integral service. Also, a customer service letter was prepared to show the objective of the new portable closed cycle extinction; as well as the variants for each type of client, the ways to request it and the service goals established by the company.

TEST

For the test, two types of customers from the company segment were selected, one large (more than 100 fire extinguishers) and one small (less than 50 fire extinguishers). For these two clients, the quantities of recovered DCP and the costs of the service variables were modeled. The amount of DCP recovered is obtained from previous studies that show that 2% can be recovered in the first year of life of the extinguisher and 5% in the following years.

Table 5 shows how the different variant generates revenue for the Security Company and guarantees greater customer service. In addition, the total recovery of DCP that can be generated on companies is guaranteed. All results demonstrated that the new service is more profitable and recover more DCP than the actual service.

Table 5: Input a result for the experimental test for the new service. *Source: own elaboration*

	LARGE ENTERPRISE	SMALL ENTERPRISE
Input data		
Amount of engineering hours	40	30
km to travel	22	10
Number of visits	2	1
Number of extinguishers	440	20
Number of people to advise	50	50
Number of days	2	2
Number of hours	4	4
Extinguishers type	- 10 CO_2 5kg - 60 PQS 9kg - 50 PQS 1kg - 20 PQS 25kg - 300 PQS 3kg	- 4 CO2 2kg - 8 PQS 6kg - 2 CO2 5kg - 5 Espuma 9Lts - 1CO2 10kg
Result		
Actual service	*$8 600*	*$340*
Variant 1 (price)	$35 943	$2 214
Variant 2 (price)	$35 819	$2 098
Variant 3 (price)	$15 655	$919
Variant 4 (price)	$15 530	$803
Variant 5 (price)	$15 356	$681
Variant 6 (price)	$15 840	$797
DCP recovered (quantity and incomes)	139, 30 Kg /	10, 71 Kg /

4.2 Fire extinguisher supply chain, second approach

The next year after the proposal for the new service, the purpose of finding a destination for each of the extinguisher components is suggested. The second application of the Business Circularity Method is summarized below.

Table 6: Application of the first two phases of the method in the extinguisher business (second time). *Source: own elaboration*

GOAL	
Result to obtain	**CE business strategy**
Find a destination for the extinguisher components	A closing loop strategy - Extending resource value & Industrial symbiosis; **new product from the new waste extinguisher management service**
INDICATOR	
Outcome variables	**Expected value**
- Quantity of new products from waste - Quantity of treated waste (Kg, l, etc.)	- 2 new product - 98% of total amount

All the waste generated from the fire extinguishers are classified according Hevia Lanier y Urquiaga Rodríguez (2007) morphological characterization of industrial waste. A treatment strategy is search for each one in correspondence with the Reverse Logistic Reference Model developed by Hevia Lanier; Urquiaga Rodríguez *et al.* (2011).

The figure shows how the network of direct and reverse fire extinguishers finally turned out, where each waste received a strategy for recovery, reuse, recycling and design of new products. Among the new products is the inorganic fertilizer already defined in the first stage, but at this stage the feasibility study for the construction of the production plant is developed. The other product that is developed is the exhaust pipes from the 9 kg extinguishing cylinders. This production was previously carried out by individual producers, but they obtained the cylinders in the landfill, now it is commercialized directly from the Security Company workshop.

The new designed circular network for fire extinguishers (figure 7) allows handling six of the seven types of waste, only painting residues are not yet treated. This represents 1.5% of the waste generated in the network, and then the expected value for the amount of waste treated is reached. In addition, two new products are produced; the inorganic fertilizer and the exhaust pipe of the car, both generating small entrepreneurial companies. All this results are the effect of the development of a new **waste extinguisher management** service.

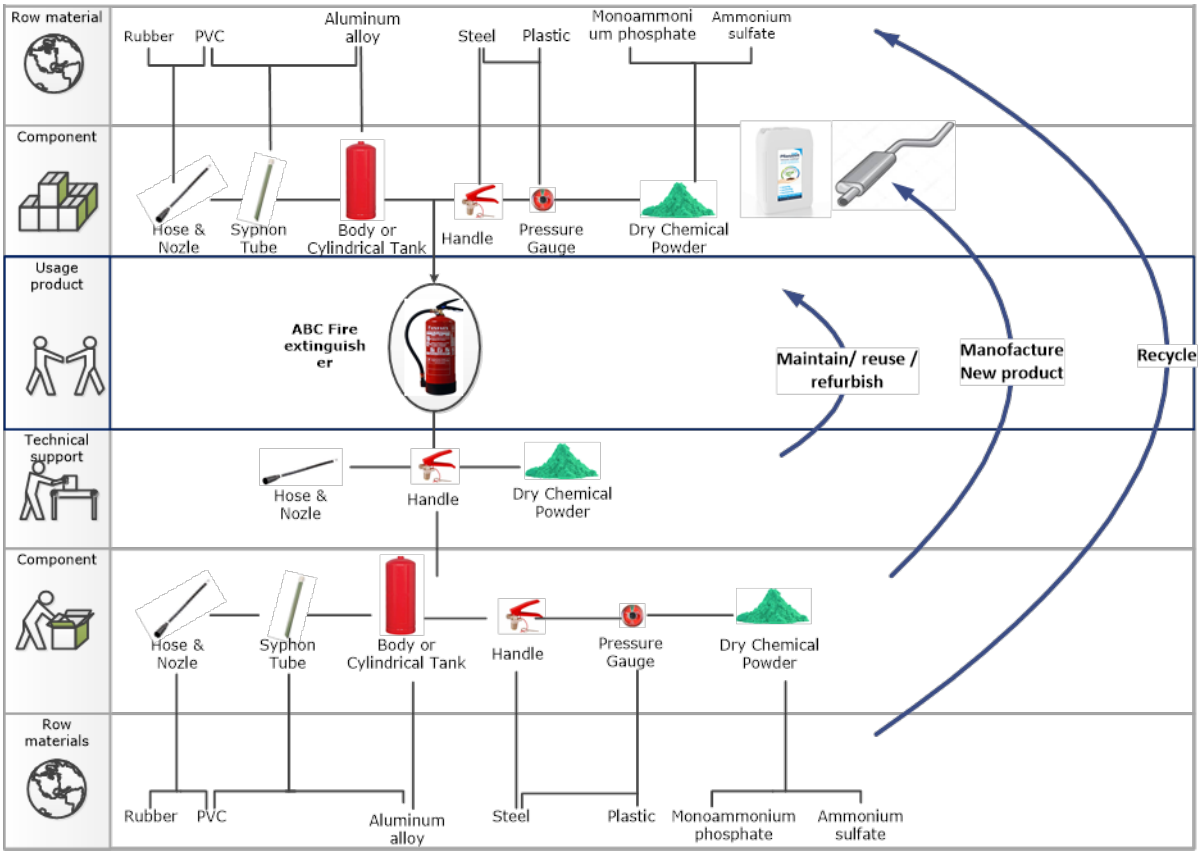

Figure 7: New circular network of fire extinguishers. *Source: own elaboration.*

The next steps in this supply chain are to treat or eliminate paint residues. Also, the following iteration of the BCM should focus on obtaining natural raw materials and developing new components and product from them (new product design).

4. Conclusions

The transformation of business towards the circular economy brings not only new strategic and commercial models, but also the redefinition of supply chains. Above all, it takes the transformations or creation of logistics systems for the businesses operation. Moving towards a circular business model should generates new services, products, supply networks, businesses and workers skills.

The proposed model to transform the fire extinguisher business proved its validity in two applications that generated organizational transformations into companies and supply chains. The first application generates a new service that improves the value delivered to the client and the company income. The second application creates new business and supplies to other businesses; in this way, the largest amount of waste generated are treated.

5. Acknowledgements

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