

Chapter 2

M. Repetto

Abstract

In the following paper is proposed a multi-objective model for components allocation in a Green Supply Chain framework. The model builds on the concept of the supply chain as suggested by Porter, and accounts for the costs of production using the Activity Based Cost accounting method (ABC). Such model is organized in blocks related to several moments in the value chain, from the procurement to the end customer. Above each and every one of these blocks, we included a series of environmental constraints that the firm has to comply, with respect to specific country regulation, or in case of a particular Corporate Environmental Responsibility policy...

Da continuare quando il modello ultimato; inserire anche parte sui risultati

1 Introduction

Global Supply Chain Management (GSCM) is probably one of the most used terms when we talk about how the firms are running their business nowadays. GSCM may be defined as the allocation of goods and services along a series of transnational companies' global network to maximize profits and minimize waste. As the Supply Chain Professionals puts it, the goal of GSCM is threefold and focuses on delivering: (a) the right product (b) to the right place (c) at the right time. Inside this very wide paradigm, we can find the concept of logistics which is in charge of the movement of goods, service and last but not least information from the sourcing of raw material, till it reaches the end customer. Along with these two concepts a third one sticks with them, the Green Supply Chain (GSC). This idea, brought to light by a more advanced concern about environmental matters of the developed countries, forced the firms to be accountable for their negative externalities related to the environment in which they operate [8].

However such legislation lacks from a point of view of legal constraints, setting only a few qualitative restriction, poorly measurable by the enterprises or in some cases letting the customers pay for their environmental behavior toward waste disposition. These facts are inevitably leaving some degrees of freedom to the firms, on the other hand, is also important to notice that these are only seeds of legislation that show us how the long-term trend will be about the tolerance given to the behavior of firms with environmental concerns, a trend that in the future may require firms to set particular frameworks to be accountable for their environmental impact. Nowadays such effort is not achieved by the legal frameworks provided by the domestic legislators but by the Corporate Environmental Responsibility (CER), meaning that are the stakeholders to impose the companies to be more responsible on their day to day operations.

Looking at the literature, we can see that there is an emerging branch which deals with the Green Supply Chain Management, a new paradigm of Supply Chain Management whose aim is to keep under control the behavior of the firm during its operations, by applying policies such as Green Manufacturing and Remanufacturing, Green Design etc...

Because of that we propose a Goal Programming model in order to address such problems, following what proposed by literature we try to enhance such model fixing quantitative and qualitative constraints to the pollution generated by the value adding activities, involved in the creation of the good and we also try to implement the benefits of a recycling program enacted by the firm apropos the WEEE directive.

In our case, we chose the networking electronic appliance business (i.e. hub, switch or router). In order to measure such impact, we'll use the framework provided by the Activity Based Costing, in order to assess and address the marginal environmental impact of any additional unit elaborated by the transnational firms.

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2 Green Supply Chain

Green Supply Chain may be defined as the series of interconnected activities across the border of different enterprises that adds value to the goods and services from the sourcing to the market. Its aim is to improve performance in measures of sustainability, cost reduction, emission reduction. Whereas Supply Chain Management sets its objectives to maximize profits and minimize waste, in economic terms, Green Supply Chain sets its objectives even further, posing as its ultimate mission to lower the ecological impact that a firm or a series of them has in their day to day operations. Such operations may involve:

- Green Manufacturing and Remanufacturing: is the process of controlling and reutilizing material in the manufacturing, in order to limit waste creation[10];
- Green Design: is an approach put in place to promote the environmental quality of a certain product or service, by reducing negative impacts on the natural environment; an example could be the automatic switch of the television after a period of idleness[3]; and
- Green Operations in general: by green operation we mean any type of activity which does not fall into the two categories mentioned above but is characterized by a "green" attitude as for example the optimization of the offices consumption through a remote-working policy;

In the market under scope which is the European one, there are several legislation concerning the environmental impact of certain eProducts¹. The most important are:

- Waste Electrical & Electronic Equipment (WEEE);
- Restriction on Hazardous Substances (RoHS); and

¹for eProducts, we intend electrical and electronic equipment such as computers, TV-sets, fridges, cell phones and other electronic appliances

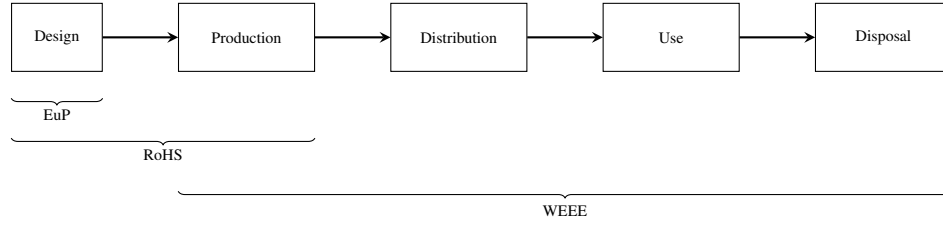


Figure 1: Legislation affection

- Ecodesign Requirement for Energy-using Product (EuP): :

Such legal frameworks act at different levels from the sourcing to the customer involving community member States. The following flowchart illustrates this differences.

In the following subsection, an additional overview is given to such legislation.

2.1 Waste Electrical & Electronic Equipment

The Waste Electrical & Electronic Equipment also called WEEE is ruled in the European Community by Directive 2002/96/EC now repealed by the Directive 2012/19/EU . The objectives of the policy are, to preserve, protect and improve the quality of the environment, to protect human health and to utilize natural resources prudently and rationally. That policy is based on the precautionary principle meaning that the polluter should pay for its damage. Is important to notice that in the European market such directive is impacting all the community members is not perfectly homogeneous ways because of the implementation which is remitted to the local authorities. This problem may incur in potential elusive behavior as highlighted by the German firms who exploited gaps in the law which have allowed them to move large amounts of WEEE declared for recycling to developing economies including India, China, Nigeria and Eastern Europe [6]. Despite such cases, the overall impact of this directive is mostly positive as highlighted by the Eurostat data here exposed.

The WEEE Directive currently sets a minimum collection target of 4 kg per year per inhabitant for WEEE from households. From 2016, the minimum collection rate shall be 45% calculated on the basis of the total weight of WEEE collected. Where the WEEE is calculated with the following formula:

$$W(n) = \sum t = t_{0n} POM \cdot L^p(t, n)$$

Where $W(n)$ refers to the specific quantity of electrical and electronic waste for a specific year, $POM(n)$ is the quantity of new electrical component injected in the market and L is the discard-based lifespan profile for the electrical component injected in the market. From the graph proposed below we can see how the target of minimum collection of 4 kg per year per inhabitant for WEEE from households was achieved by all the countries in the Eurozone however not all the countries has the same collection rate, meaning that some of them may have introduced legislation that comply only with the

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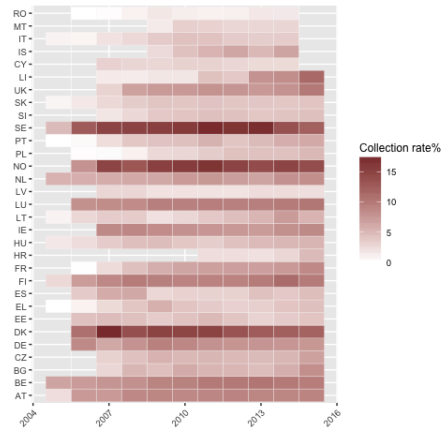


Figure 2: Kilograms of WEEE collected per capita

minimum target of the directive, leaving the households with the freedom to dispose of their WEEE in unconventional manner. Clearly this means for the enterprises less obligation on the collection of eProducts, but at the same time less products to be recycled and less opportunity of remanufacturing.

2.2 Restriction on Hazardous Substances

The Restriction on Hazardous Substances also called RoHS is represented by the Directive 2011/65/EU (RoHS 2 recast). The scope is the restriction on the use of certain hazardous substances in electrical and electronic equipment (EEE) such as lead, mercury, cadmium, hexavalent chromium etc... In such case, as opposed to the WEEE the RoHS directive acts as a barrier to the products containing such minerals and not when they become waste. In considering such regulation is worth noting that there are no differences between the dimension of the distributing entity, meaning that small businesses, as well as large businesses, are equally affected by these restrictions. The only amendment is given to the batteries that may exceed such restriction.

2.3 Ecodesign Requirements for Energy-using Product

The Directive 2009/125/EC is meant to deal with Ecodesign regulations, ecodesign regulations require manufacturers to decrease the energy consumption of their products by establishing minimum energy efficiency standards. In particular, The Ecodesign Directive provides a consistent legal framework for improving the environmental performance of products setting out a minimum mandatory requirement for the energy efficiency of these products. In case of the design of IT networking products such as routers and switches the firms are obliged by such directive to implement some ecodesign features such as the maximum wattage of 1W in case of off mode or a standby maximum consumption of 2W. Such measure per se do not impact in any case the

supply chain since they are just additional features that has to be implemented in theP-products sold in Europe.

3 A state of the art review

As proposed by the Council of Supply Chain Management Professionals, the Supply Chain Management (SCM) is the planning and the management of all activities involved in sourcing and procurement, conversion, and logistics as well as coordination and collaboration with the entities. The problem arising from such activities seems to be well addressed by mathematical modeling, other advantages of such approach are the economic sustainability and the possibility to scale the model in order to address different situations. From the comprehensive review built by Muna et al. [5] we discovered the methods used by the academic world, which are:

- Linear Programming [4];
- Mixed Integer Linear Programming [7];
- Non Linear Programming [2];
- Multi Objective Programming [9];
- Fuzzy Mathematical Programming;
- Stochastic Programming;
- Heuristics Algorithms and Meta-Heuristics; and
- Hybrid Models.

Is worth noting how the majority of the models pertain to the category of Mixed Integer Linear Programming, this may be due to the fact that is probably one of the simplest and most reliable methods that can be used to solve such problems, however, this simplicity comes with some costs such as the focus on a single linear objective function with linear constraints whereas we may face different objective functions as for example the manager preferences toward greener choices. Another interesting topic brought into light by Aouni [1] is that such models are generally deterministic, where in reality such assumption does not hold most of the time, for example, the demand forecast can't be deterministic at all and derives from a stochastic process. This lack of deterministic variable lies also in case of the procurement where the price of a commodity is said to follow a sort of stochastic process and an order may be placed several days after the decision make it.

4 Model formulation

The model we developed is based on what formulated by Porter on the concept of value chain [] plus the mathematical formulation adopted by Santoso in solving the strategic

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problem of supply chain allocation in a stochastic fashion. The model proposed by Santoso is formulated as follow:

$$\begin{aligned}
& \min \sum_{i=1}^P c_i y_i + \sum_{k=1}^K \sum_{(i,j)=1,1}^A q_{ij}^k x_{ij}^k \\
& \text{Subject to} \\
& \sum_{i=1}^N x_{ij}^k - \sum_{l=1}^N x_{jl}^k = 0 \forall j \in P, \forall k \in K \\
& \sum_{i=1}^N x_{ij}^k \geq d_j^k \forall j \in C, \forall k \in K, \\
& \sum_{j=1}^N x_{ij}^k \leq s_i^k \forall i \in L, \forall k \in K, \\
& \sum_{k=i}^K r_j^k \cdot \sum_{i=1}^N \leq m_j y_i \forall j \in P, \\
& x \in \mathbb{R}^+ \\
& y \in Y[0, 1]
\end{aligned}$$

Where...

It's worth noting that such model do not implement any support activities, whereas the Porter model mention them. Such activities are a fundamental part on the supply chain that serves as glue with the supply chain steps to the deliver the value to the end-customer. Therefore the hibrid model will looks like this:

$$\begin{aligned}
& \min \sum_{i=1}^P c_i y_i + \sum_{k=1}^K \sum_{(i,j)=1,1}^A q_{ij}^k x_{ij}^k \\
& \text{Subject to} \\
& \sum_{i=1}^N x_{ij}^k - \sum_{l=1}^N x_{jl}^k = 0 \forall j \in P, \forall k \in K \\
& \sum_{i=1}^N x_{ij}^k \geq d_j^k \forall j \in C, \forall k \in K, \\
& \sum_{j=1}^N x_{ij}^k \leq s_i^k \forall i \in L, \forall k \in K, \\
& \sum_{k=i}^K r_j^k \cdot \sum_{i=1}^N \leq m_j y_i \forall j \in P, \\
& x \in \mathbb{R}^+ \\
& y \in Y[0, 1]
\end{aligned}$$

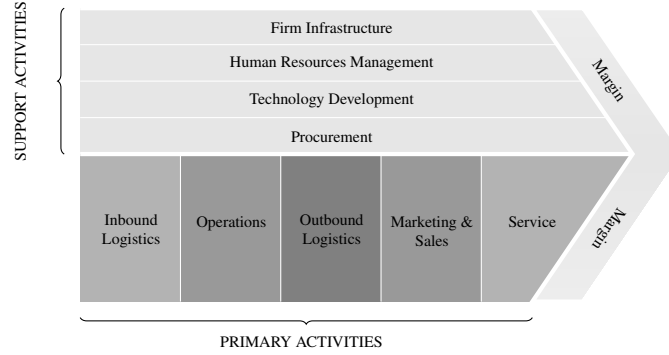


Figure 3: Porter's Value Chain

Finally we wanted to implement the concept of green supply chain from a point of view of the legislations activated by the EU countries. However since such legislations, especially the WEEE does not impose any quantifiable level to be collected by the firms but is intended to be for the ultimate polluters (meaning the end customers) we need a way to proxy the potential of collection of each country in order to forecast the collected quantity that the firm expect to receive each year on the base of what is sold today. Because the electronic waste turns out to be a resource for the firm we need to model the fuzziness of such desire expressed by the DM, and therefore we implemented a Fuzzy set[] defined as:

$$\mu[f_q(x)] = \begin{cases} 1 & f_q(x) \geq b_q \\ 1 - \frac{b_q - f_q(x)}{n_{max}} & b_q - n_{max} \leq f_q(x) \leq b_q \\ 0 & f_q(x) \leq b_q - n_{max} \end{cases}$$

Such set penalized the negative deviations from the target demanded by the decision maker, the *ratio* behind this is given by the fact that a very low amount of collected electronical waste may turn out as higher cost of production because of the additional cost of buying new material. Conversely is also important to take

4.1 Objectives

4.2 Constraints

4.3 The Goal Programming model

5 Results and Conclusion

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