SUPPLY CHAIN ENVIRONMENTAL ASSESSMENT

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Abstract

Resource depletion, combined with the continued population growth, is pressing legislators and firm managers to take measures that can somehow reverse or at least control the environmental impact of industries. In this context and being supply chains an important system in any organization the design and planning of such systems accounting for these concerns is mandatory. Environmental impact assessment is also of major importance since it allows identifying and prioritizing the most problematic situations. The European Commission has recently released a new methodology for environmental impact assessment called Product Environmental Footprint (PEF), which intends to achieve standardization amongst the pre-existent life cycle approaches. Several studies applying different LCA methodologies have been conducted previously to PEF. Therefore, decisions were taken based on the previous LCA results. Now, it is crucial to verify if the incorporation of PEF will influence the previous decision making processes. In this work we developed a mathematical programming optimization model for the design and planning of supply chains, being the model the basis for a decision process. In the optimization model the environmental impact is assessed both through ReCiPe and PEF in order to compare their results while accounting for the economical aspects. The results are compared regarding the following two issues: 1) assessment of the supply chain structure obtained by the application of the different methods; 2) comparison of the midpoint environmental impact values of the optimized structures.

Keywords

Supply chain, ReCiPe, PEF, decision tool.

1. INTRODUCTION

There is no doubt on the emergency of taking action to reduce the environmental impact of industries. Within this setting the contribution of supply chains that involve the main production, storage and distribution industrial activities requires a deep analysis. The need to develop decision support tools that can help this analysis supporting a strategic change that can reduce the environmental impact of industries has been recently recognised in the literature [1]. More studies are needed focusing on the entire supply chain so as to insure that the reduction in the impact of a given activity is not being achieved at the expense of the environmental impact of another one. Due to that the integration of environmental assessment methodologies plays an important role in such decision tools by accurately helping the assessment and consequently prioritization of intervention. Several methodologies have been proposed in the literature and applied to different industrial case-studies but few studies exist on supply chains. Additionally, on the new method PEF [2] no work has been yet done. The objective of this work is to assess if and how the incorporation of PEF would influence decisions previously made based on other LCA methodologies.

2. METHODOLOGY

A mathematical programming optimization model for supply chain design and planning is developed. This model aims at determining the supply chain structure that minimizes environmental impact, measured both through PEF and ReCiPe. This latter methodology, prior to the release of PEF, had been identified as the most developed one available [3]. For comparison, the determination of the minimum cost structure is also aimed at. The economic performance of the supply chain is measured through facility installation costs and transportation costs (per km travelled). The former includes fixed cost and variable costs varying according to the installed area. If a warehouse is opened at a given location, the cost of a distribution center is incurred at that same location so as to model additional supporting facilities costs (e.g. canteen and daycare costs). The total of these costs are translated into the objective function that measures the economical performance of the supply chain.

Additionally to a cost analysis an environmental impact assessment is also made. This begins with a Life Cycle Analysis being performed on the transportation modes and facilities involved in the supply chain. The ReCiPe and PEF methodologies are applied and the resulting environmental impacts per impact category (and per km and m^2, respectively) are introduced in the model. Within the model impacts are then a function of the distance travelled or of the installed area of each facility, translating in the final environmental impact of transportation and facility installation, respectively. The values are then aggregated into a single score using the normalization factors of ReCiPe and PEF methodologies. This single score acts as the model's objective function that is to be minimized.

In short, given: a) the possible locations for the supply chain entities, and the associated investment costs; b) the distances between each pair of interacting agents; c) transportation and storage capacity constraints; d) costumers demands; and e) the environmental impact factor of each facility (per m^2) and of each transportation unit (per km) for each impact category of both PEF and ReCiPe, the goal is to determine the network structure that minimizes environmental impact, from one side, and minimizes cost, from the other.

This model is applied to a case study of a Portuguese food distributor, which distributes 5 main aggregated types of products: non perishable, fruits and vegetables, non perishable (in JIT mode), fresh, and frozen products. These different products require different storage conditions and hence 5 types of warehouses are considered. The model can choose out of 18 possible warehouse/distribution center locations, but a maximum of 4 distribution centers is imposed, as requested by the company.

3. RESULTS

3.1 Supply chain network

Figure 1 shows the network obtained when optimizing the supply chain for minimum cost, configuration 1, and for minimum environmental impact, configuration 2. In configuration 1 only one distribution center is composed by all 5 types of warehouses. The remaining distribution centers only include certain warehouses types, in a solution that balances the costs of opening extra warehouses (due to the fixed cost parameter) with the costs of transportation. The environmental impact is measured per m^2. Hence, for the model there is no “fixed” impact of opening a new warehouse, which is however translated in configuration 2 where all distribution centers have all 5 types of warehouses, with smaller areas.

In configuration 2, ReCiPe and PEF return the exact same network, the one that minimizes transportation. In fact, transport is the activity that mostly contributes for the total environmental impact of this supply chain. ReCiPe attributes 90% of the total environmental impact (normalized) to transport, with the remaining 10% coming from facility installation. PEF attributes 99.9% to transport and the remaining 0.01% to facility installation (results not shown).

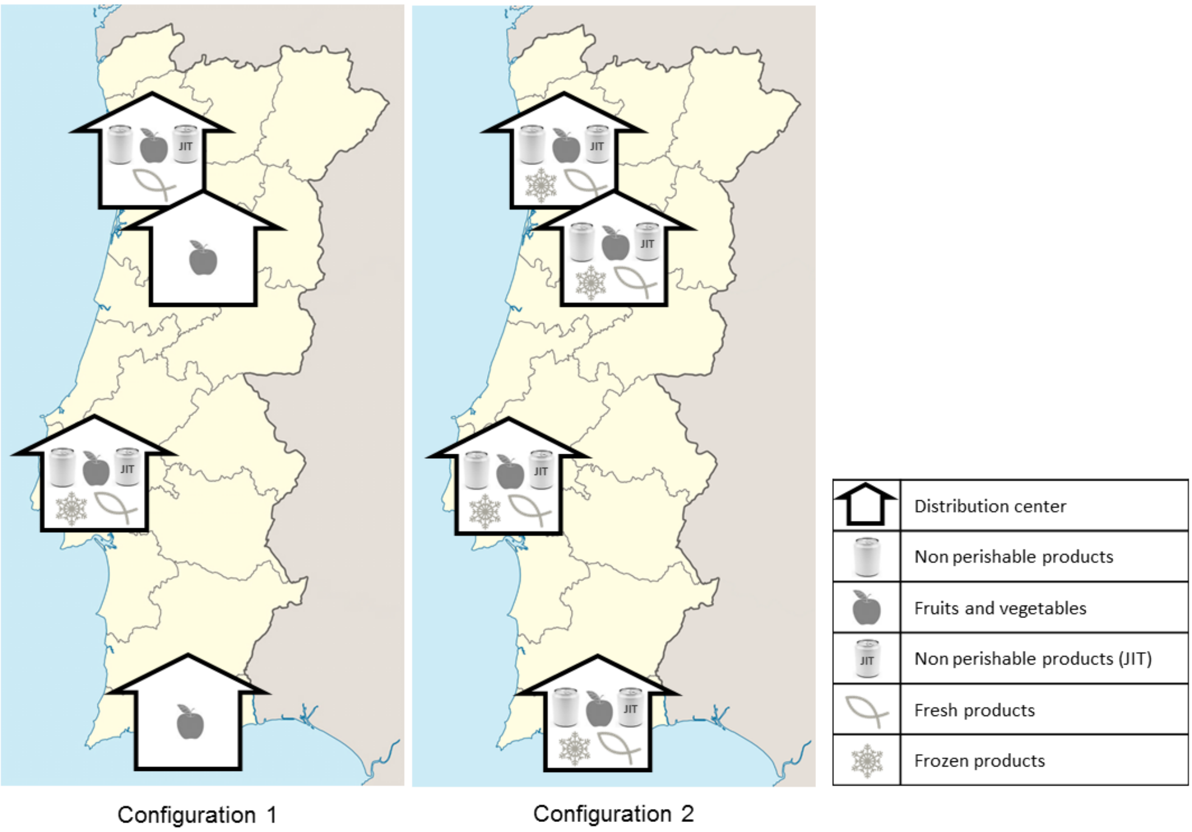
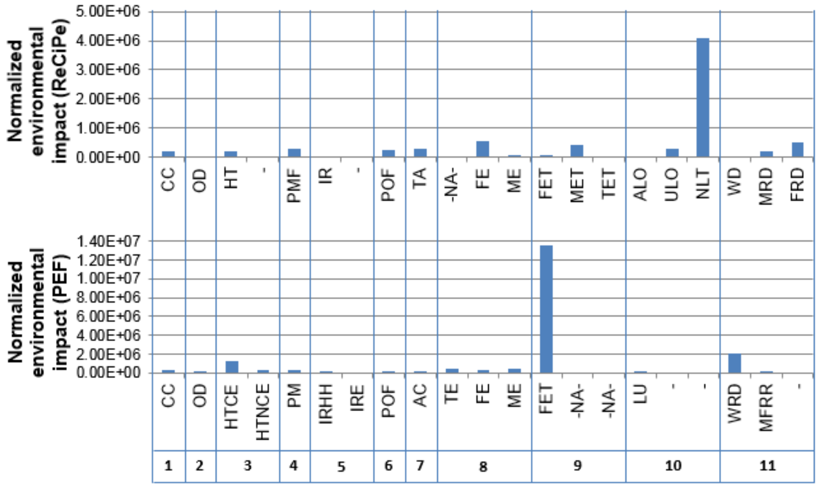


Figure 1: Network configuration 1: obtained when minimizing cost. Network configuration 2: obtained when minimizing environmental impact through ReCiPe and PEF.

3.2 Midpoint comparison

Even though the exact same configuration is obtained when minimizing environmental impact measured through ReCiPe and PEF, Figure 2 shows that the midpoint categories impact distribution is quite different. In ReCiPe, Natural Land Transformation (NLT), from the Land Use midpoint impact category, is considered to be the main source of concern in this supply chain. However, through PEF, Freshwater Ecotoxicity (FET) is the highest contributor to the total supply chain environmental impact, followed by Water Resource Depletion (WRD) and Human Toxicity, cancer effects (HTCE).



	Midpoint Impact Category
1	Climate change
2	Ozone depletion
3	Human toxicity
4	Particulate matter/Respiratory inorganics
5	Ionizing radiation
6	Photochemical ozone formation
7	Acidification
8	Eutrophication
9	Ecotoxicity
10	Land use
11	Resource depletion

Figure 2: Midpoint impact categories comparison measured through ReCiPe and PEF. The categories of each methodology are grouped into 11 categories according to the legend on the right. “-NA-“: Non-Available method. “-“: non-existent category.

4. CONCLUSIONS

The design and planning of supply chains accounting for both economical and environmental impacts have been addressed. A mathematical programming optimization model was developed. This model was applied to a case study and optimized for minimum cost and minimum environmental impact, measured through ReCiPe and through PEF.

Both LCA methodologies returned the exact same network configuration, which means that PEF and ReCiPe led to the same strategic decision. However, from the midpoint categories analysis it was concluded that the impact categories of main concern are different when measured with the different LCA methodologies. This fact might imply that decisions undertaken in supply chains covering production facilities will be influenced by the method selection. Therefore it is possible to verify that PEF can bring some changes in the previous assessments conducted in previous methods using ReCiPe.

Future work should include studies of different supply chain networks so that stronger conclusions can be taken regarding PEF’s influence.

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