# APPLICATION OF ENVIRONMENTAL PRINCIPLES TO REVERSE SUPPLY CHAINS

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## Abstract

*Little attention has been drawn in identifying environmental principles for the planning of both forward and reverse logistics networks. In this paper we deal with this problem. In particular, principles for a company's functions of product design, packaging, collection and transportation, recycling and disposal and marketing are identified and commented upon. We claim that the improvement of both the forward and the reverse channel is essential for the best possible outcome.*

*Keywords: Environmental Management, Reverse Supply Chain, Sustainable Development*

## 1. Introduction

Earth as a resource system has a limited capacity for supporting a growing human population with an intensive exchange of materials and energy with its environment (Karlsson, 1999). Communities, governments, businesses, international agencies, and non-government organizations are increasingly concerned with establishing a means to monitor performance and to assess progress toward sustainable development. The latter is defined as meeting the needs of the current generation without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). The integration of environment and development concerns and greater attention to them will lead to the fulfillment of basic needs, improved living standards for all, better protected and managed ecosystems and a safer, more prosperous future. The key to sustainable development is that it must seek the mutual goals of economic development and environmental protection for the purpose of fulfilling basic needs for all (Conference on Environment and Development, 1992).

Reverse logistics and recovery of used products in particular has received much attention lately due to the above. While traditional logistics is perceived as managing the supply of goods and/or services from the producer to the (end) customer (Cooper et al., 1991), reverse logistics is the process of planning, implementing and controlling the efficient and effective inbound flow and storage of secondary goods and related information opposite to the traditional supply chain direction for the purpose of recovering value or proper disposal (Fleischmann, 2000). Just as economic globalization creates opportunities and poses challenges to our ability to formulate macroeconomic policies, so does environmental globalization. The opportunity for business profit is an additional motive for the companies. Relevant legislations in developed countries derive from the social demand for environmental protection. Nowadays the perspective that the manufacturers should be made responsible for their products "from cradle to grave" tends to dominate. However, it can be claimed that the efforts made so far are rather limited, while nobody would argue against the need for a global approach of the situation. Developed countries or leader firms, mainly, have established environmental policies for product recovery. The issue of how effective these policies are is debatable.

Little work has been done so far in identifying sustainability principles for the planning of both forward and reverse logistics networks, whereas nobody would argue against the necessity for a unified approach. In this paper we deal with such an approach. We claim that in most cases the applied principles, which derive from the demand for sustainability, lead to the improvement of the economic issue as well. We also claim that the improvement of both the forward and the reverse channel is essential for results optimization.

## 2. From cradle to grave

Every product generated, transported, used and discarded within the supply and the reverse chain causes a certain impact on the environment. This impact is a function of the material and energy consumed and of the wastes released in the product's whole life cycle, which in turn depend upon the type of the product and the technology used (Daniel et. al., 1997). Cleaner production is the continuous application of an integrated preventive environmental strategy applied to processes, products, practices and services to increase eco-efficiency and reduce risks for humans and the environment. Cleaner technologies extract and use natural resources more efficiently, generate products with fewer harmful components, minimize pollutant releases to air, water and soil during manufacturing and product use, and design durable goods that can be reused or recycled (OECD, 1995). Rather than, for example, capturing polluting substances after they have been produced (as with the end-of-process technologies), the goal is not to produce the harmful substance at all, or to produce less of it, or a less harmful one (Faucheux and Nicolai, 1998).

Life Cycle Analysis (LCA) has become more widely applied as a tool to analyse the environmental impact from raw material extraction through to post-consumption fate, including intermediate stages of product manufacture, distribution, and use (Fava et al., 1991; Cattanach et al., 1995; Stuart. et al., 1999). Design for the environment (DFE) draws on data from LCA to design products with minimal environmental impact (Allenby, 1996; Fiksel, 1996).

The appropriate identification of all life-cycle stages of a product is necessary for the establishment or optimization of environmental policies. Any activity in the supply chain may have an undesired impact on the environmental chain. And vice-versa, any disturbances in the ecological balance may affect production activities and social welfare in the long-term. In this sense, the supply chain is connected in both ends with the environmental chain to establish a perpetual cyclical operation such as that depicted in Fig. 1. The analysis of the cost-effectiveness of schemes for the recovery of products is difficult, however, it is useless to do so without looking at the whole process chain, combining the logistics aspects with the recovery ones (Nagel and Meyer, 1999).

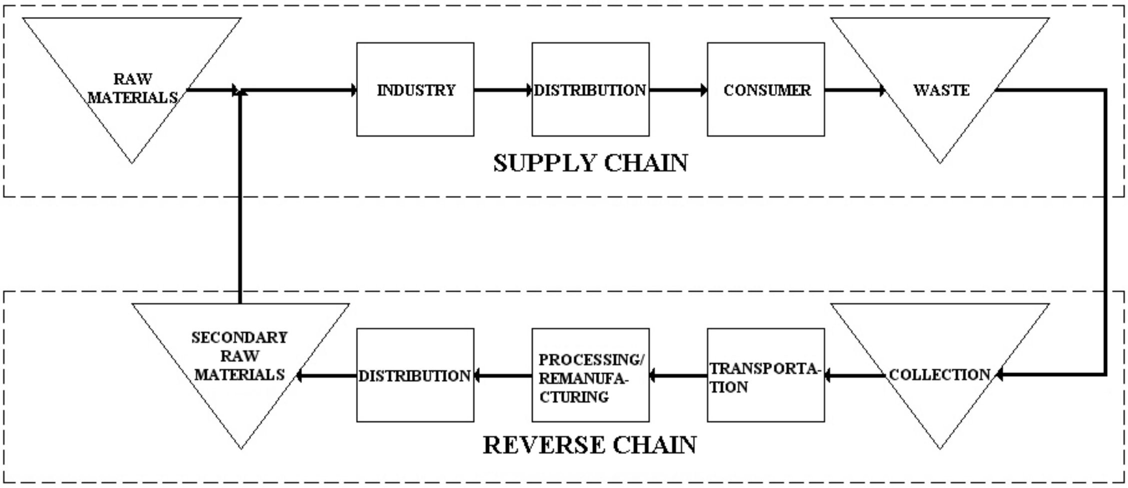


Figure 1

The first stage in the supply chain, including the selection of materials and methods of processing may be regarded as Product design. Product design and process technology typically determine the types of pollutants emitted, solid and hazardous wastes generated, resources harvested and energy consumed (Post, 1991; Sarkis, 1995; Shrivastava, 1995). During the next stage, the forward channel, the materials are processed till the manufacture of the product. The manufactured items are usually packaged and then transported to distributors. Finally the products end in final users-customers. There are cases though, mainly concerning job shop, where the products are directly transported from the producer to the end-user, without the intermediation of a distributor. The reverse channel starts when the product is no longer operable or when the end-user decides that he will not use it anymore. Given that products are not disposed uncontrollably, they are collected and transported to appropriate facilities, where a selection occurs: some of them are reprocessed and the rest are properly disposed. The reprocessed items are finally redistributed and reused. In some cases the separation occurs away from the reprocessing facilities.

## 3. Sustainability Principles applicable to Logistics networks planning

Sustainability principles applicable to Logistics networks planning may originate in social pressure or internally, in corporate planning.

The principles proposed below have been formulated based on the literature, where they may be found either as explicit statements (prescriptions or guidelines) or in treatments of subjects relating logistics to environment, which implicitly suggest such principles. Some of these principles may also be inferred from company practice.

It is important to point out that the proposed principles are not applicable to all cases. This would occur if, for example, the product design was to be launched with no constraints at all. In real cases though, usually not all the parties that contribute in forward and reverse channels meet the necessary conditions for eco-optimization. In such cases total re-design should be applied if feasible. Manufacturers should not only be held responsible for the processes that take place in their facilities, but also for the selection of suppliers and partners.

The sustainability principles applicable to logistics networks design can be classified in 5 groups corresponding to respective company functions:
1. Product design
2. Packaging
3. Collection and transportation
4. Recycling and disposal
5. Marketing

*3.1. Product design*

Product design is a critical phase for ensuring an environmentally sound product profile. R&D directed at process change and product improvement can lead to higher-value products and reduced environmental impacts. Designers, mostly concerned with product performance, must take into account also the effect of design details on energy/material requirements for manufacturing, use and secondary use (repairability, remanufacturability and recyclability). Redesigned products will only be effective if they are able to provide at least the services of the products they replace. By extending the useful life of equipment items, additional raw materials are not needed to produce new items. In some cases, landfill disposal will not be required or that fate is delayed for a few years. A carefully constructed set of economic instruments may provide the incentives needed to lead to design changes that help move towards sustainability. A number of management tools, such as EMS (ISO 14000, EMAS) and LCA, can help business identify and select opportunities for improvement. The following principles may apply in product design:

1. *Design and develop recoverable products, which are technically durable, repeatedly usable, harmlessly recoverable after use and environmentally compatible in disposal (Gotzel et. al., 1999).*

Materials with a high recycling rate and which have the least impact on the environment, both in use and origin, should be preferred. Where possible, environmentally safer substitutes should be used and the abuse of products should be actively prevented (Corbett and Van Wassenhove, 1993).

2. *Produce using minimum energy and materials.*

The misspending of materials and energy either due to inappropriate design, or due to excessive number of defects should be avoided.

3. *Secondary raw materials should be given priority in usage (Gotzel et. al., 1999).*

Primary raw materials should be used only in cases where there would be no stock of secondary ones. Furthermore, in many cases this policy is also money-saving.

4. *Establish flexible manufacturing and management policies (Klassen and Angell, 1998).*

Companies that manipulate materials and energy should be organised in such a way that they could correspond rapidly to changes in management and processes. Sustainable development requires a long-term perspective for planning and policy development. Changing demands for goods and services will also push design changes. The study of alternative design schemes is necessary in order to achieve eco-optimization. ("Do the same but do it better or try to do something different.") (Fleischmann et al., 1999)

5. *Use eco-friendly energy production, reduce water usage and keep control of pollution sources.*

Using less energy is obviously good for the environment. It is also self-evidently good for business because it cuts companies' costs, and eventually avoids potential environmental liabilities. It is, therefore, a prerequisite to the long-term sustainability of business. To replace non-renewable and polluting technologies, it is crucial to support the use of renewable energy resources, as well as to reduce energy consumption. The identification of where great amounts of energy are used could subsequently lead to redesign of the product or its use in order to make significant energy reductions. Major improvements in energy efficiency can often be achieved at little or no cost, even with net savings, through the use of targeted programs. Installed water-saving techniques lead to reduction of water use. In addition, the elimination of the stochastic factors, which affect pollution, may lead to greener production.

6. *Use standardized parts.*

Such a policy ensures that these parts could be re-used by a larger group of producers. For example, automotive companies use standardized screws, speedometers, etc. In most cases this policy is also money saving.

7. *Provide for easy disassembly of the product.*

This would lead to cost, time and energy savings. The opposite case would make the disaggregation of the product unpractical and costly.

8. *Reduce by-products and get the best out of them.*

During the manufacture by-products are also created. Some of them can and should be reduced and/or re-used. The rest must be eliminated and disposed properly.

9. *Impose higher standards on suppliers (Corbett and Van Wassenhove, 1993).*

Adopting specific procurement/purchasing policies requiring suppliers to apply sustainable development practices may help companies avoid buying-in waste and subsequent pollution problems.

10. *Use effective accounting systems and management tools.*

The use of accounting systems that account for the full life cycle costing of a product or service, and the environmental impacts it creates, can be expected to provide additional information that will influence the design process. Many companies have discovered that there are economic advantages to changing designs towards being more sustainable, whether because they are easier to market or cheaper to produce.

*3.2. Packaging*

Packaging design is important for attaining a company's environmental objectives. Though it serves certain needs related mainly to the distribution of the product (e.g. safe transportation), it is not part of the actual service offered by the product. In any case, it affects environment in many aspects. This is the reason why regulations concerning packaging constitute an essential part of governmental policies for environmental protection. The following principles may apply concerning packaging:

1. *Limit packaging to the necessary size (Gotzel et. al., 1999).*

The opposite case not only is contrary to environment protection, but it also affects transportation negatively. Furthermore, environmentally safe packaging can be used as a marketing argument (Corbett and Van Wassenhove, 1993).

2. *Design packaging for refilling or recycling (Gotzel et. al., 1999) and use standardized packaging when applicable.*

There are examples of standardized bottles, crates, boxes, pallets and containers, which may be used by different companies.

*3.3. Collection and transportation*

Despite the obvious environmental gain from used products' recovery, collection and transportation of recovered products has an environmental cost. Minimizing such a cost is important in order to increase the total environmental gain from recovery. Principles applicable in this phase of the reverse supply channel are the following:

1. *Formulate a policy for the recovery of used products.*

Such a policy favors the maximum utilization of used products. Companies may decide either to undertake the recovery of used products on their own, or to establish co-operation via local or more extended networks for the collection and recycling of similar products (Gotzel et. al., 1999). United efforts may be more effective and provide higher recycling rates. Also, recovered products often suit more than one manufacturer.

2. *Consider using existing forward chain facilities and transportation system as much as possible for the reverse channel.*

Transportation and the consequent environmental effects can be significantly limited if the recovery of used products can occur at the same time or in combination with the distribution of new products. The theoretical minimal average transportation distances can be determined using a tool for allocation and route planning.

3. *Classify used products as early in the recovery channel as possible.*

This eases the planning of storage of used products and redundant processes are avoided.

4. *Treat hazardous materials safely.*

It is necessary to ensure that the generation of hazardous wastes is reduced and also that adequate disposal facilities are available, for the environmentally sound management of hazardous wastes.

### *3.4. Recycling and disposal*

After its useful life, a used product may be either disposed or recycled (generally recovered). As in the phase of collection and transportation, recycling and disposal may significantly contribute to the total environmental gain and the attainment of the environmental goals of a company. Ideally companies should borrow from natural cycles to design their systems as part of a larger natural cycle, where materials are borrowed from and returned to nature, without negatively affecting its overall balance. The following principles may be applied regarding recycling and disposal:

1. *Close the supply loop by recycling effectively and efficiently.*

Designing for recyclability is essential but recycling becomes unproductive when the energy, materials and pollution used in collecting and processing used products exceeds those used to produce the goods in the first place. Closing the loop by extending responsibility throughout the life cycle chain ensures total product and service stewardship.

2. *Reduce the volume and amount of materials going to landfill (Boks et. al., 1999) and consider alternative uses of used products or wastes.*

Using appropriate techniques one can compact the scrap. In addition, smaller landfills can be used. Alternative uses of used products extend their life cycle. For example, used tires can be used as a protective in seaports, speedways, etc.

3. *Support the development of markets for recovered components and materials.*

The environment can be at the basis of the creation of new markets or of the reorganisation of existing ones for certain (material) flows resulting from the production process. With such a reorganisation, materials that would otherwise end as wastes would turn into useful by-products (Faucheux and Nicolai, 1998).

4. *Locate recycling facilities close to customer markets (Angell and Klassen, 1999).*

Such a policy would ease the direct delivery of used products from end-users. Furthermore, companies can also offer waste disposal services (Corbett and Van Wassenhove, 1993).

### *3.5. Marketing*

Appropriate marketing policies may also add value to a product, particularly by providing as much information as possible regarding recovery possibilities, thus involving customers in the recovery effort. Principles relevant to marketing are the following:

1. *Indicate the return, reuse and recovery possibilities (Gotzel et. al., 1999), make available the necessary information of your products concerning recycling and provide adequate safety instructions (Corbett and Van Wassenhove, 1993).*

The end users should be aware of what they could do after the product has completed its life cycle. Thus customers can make educated decisions about what products to buy and how they should treat them after the end of their life cycle. Since it is difficult to predetermine where the products would end in, it should be easy for everyone to identify the product. An easy solution could be the use of labels with serial numbers or barcodes and the storing of the relevant information in a database (Nagel and Meyer, 1999).

2. *Motivate customers and keep records of where they deliver used products or packages.*

Motivation is important in order to maximize return volumes. On the other hand, keeping records of where records used products and packages end in may lead to a better planning of collection and transportation networks.

3. *Extend service and enhance product function at the usage phase to improve eco-efficiency.*

Extended service and functionality increase the value of a product with positive consequences for the company.

4. *Establish product update policies.*

Several companies, e.g. those dealing with computers and other electronics, can adopt such a policy. As a result, recovery practices are enhanced, while an up-to-date recycling schedule may be formulated.

5. *Introduce the eco-objectives to the personnel.*

Key to recovery success is the involvement of employees at every level in order for them to promote the concept of eco-efficiency. Researchers outside the field of operations management have considered the role of culture (Wehrmeyer and Parker, 1996), training and education (Dechant and Altman, 1994) and the importance of measurement systems (Brown and Dray, 1996) for encouraging environmental activities of the work force. Corbett and Van Wassenhove (1993) mention that it is possible to organise and supervise "green groups" to encourage employees to find and discuss ways of reducing pollution.

## 4. Conclusions

Companies are in a continuous worldwide interaction with society. Consequently, the legislations and the streams should be taken under consideration. Manufacturers share responsibility for products from cradle to grave along with suppliers, consumers and others in the life cycle chain. Manufacturers, suppliers, users and disposers of products all have a role to play in minimising the negative environmental effects of products and waste streams. Sharing responsibility for environmental effects will yield a more efficient use of resources, cleaner products and technologies, improved relations between companies and communities and responsible consumer choices.

Industrial practices, individual habits, and the laws produced by governing bodies all need to bring consumption of non-renewable resources and production of harmful pollutants into line with what such bodies and ecosystems consider healthy. Until lately, industry only paid for the initial production of a product, while consumers and the taxpaying public had to pick up the tab for the harmful side effects of the pollution generated by that production. Industries are more and more held accountable for the clean-up costs of their pollution and for the long-term damage to the health of humans and the ecosystem. Increasing acceptance by producers of responsibility for their products after sale may ensure that post-sale management of these products will increasingly come into the design equation. If the producer has no responsibility for reuse, recycling or disposal, there is little incentive to design products that are durable, easily disassembled for recycling, or biodegradable.

Businesses have many bottom-line incentives to adopt sustainable development. Many firms take the view that, rather than maximizing profits within a fixed set of environmental constraints, it is better to modify these constraints in order to gain a competitive advantage. Environment is introduced as a new criterion for differentiating among products extending to the development of environmental standards or labels (Faucheux and Nicolai, 1998). For starters, a sustainable approach can lead to internal cost savings from using energy more efficiently, producing less waste and recycling materials. Second, sustainability can open new markets, as consumers are attracted to companies that have invested in green technologies. Third, opportunities abound to assist other companies and communities -both at home and in emerging markets- to use energy, water and by-products more efficiently and to find beneficial uses for wastes (International Institute for Sustainable Development, 2000).

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