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Comparison of disposable and returnable packaging: a case study of reverse logistics in Brazil

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ABSTRACT

This article discusses a study on reverse logistics in which a returnable packaging model was developed in order to minimize waste generation and increase the competitiveness of the company studied by reducing costs and resource consumption and minimizing environmental impacts. The objective of this study is to present a case study on reverse flow of returnable packaging to replace a disposable packaging system used by a company located in Joinville, Santa Catarina, Brazil to export machined engine heads to Peterborough, UK. As a result, the returnable packaging model consumed 18.00% less material than the disposable packaging model, reducing costs. Furthermore, the model developed provided greater protection to the products exported and minimized waste generation at the final customer. Other logistic benefits were reduction in the volume occupied and weight of empty packaging during reverse flow and a cycle time of 105 days. Additionally, the unit cost of the returnable packaging was R$ 13.57 per engine head, a satisfactory outcome for the company studied. With regard to environmental performance, the returnable packaging model proved the best alternative since it has less environmental impacts compared to those of the disposable packaging model. The practice of reverse logistics has shown benefits that contribute technically, economically, and environmentally to business sustainability.

1. Introduction

Environmental issues have been hotly debated among the government, researchers, businesses, and society in general. Fraj and Martinez (2007) and D'Souza et al. (2007) suggest that the relationship between society and the environment has evolved from an exploratory view of natural resources to a new concept, in which environmental sustainability should prevail. Therefore, companies must be proactive focusing on improving their image by changing their production practices. A proper way to achieve this is through the environmental improvement of products and processes in which reverse logistics has received increasing attention due to economic reasons, competitiveness, marketing, and environmental requirements (Ravi and Shankar, 2005).

Additionally, legislative issues have increased the importance of reverse logistics in the present scenario, especially for cases on the reverse flow of industrial packaging. González-Torre et al. (2004) cited the European Directive 94/62/EC on packaging and industrial waste materials, which requires manufacturers to recover part of the packaging and waste related to marketed products. Recently, in Brazil, a similar situation has been observed due to the National Policy on Solid Waste – PNRS that has formulated a policy which requires industries to incorporate reverse logistics of post-consumption. In Brazil, industrial packaging has still been focused on disposable models, which generate large and varied amounts of waste. On the other hand, the use of returnable packaging model can reduce costs and resource consumption ensuring better use of space during product transportation, reducing or eliminating waste generation at the final customer resulting in market-share gains.

Based on this current demand for environmental improvements in business performance and considering the recent Brazilian legislation on public policy for solid waste generation in the country, according to PNRS, studies on reverse logistics with emphasis on the industrial packaging application stand out. Thus, this article presents a case study on the reverse flow of packaging used in the export of machined engine heads to replace the conventional system of a company that uses disposable packaging.

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2. Literature review

2.1. Forward and reverse logistics

According to Stock (1992), logistics used to be defined as management of materials from the point of origin to consumption. However, this definition has expanded, and nowadays it includes not only the management of physical flows, but also information flow (Tibben-Lembke and Rogers, 2002). This direct logistic process is known as Forward Logistics. In addition, there is also the reverse logistics process, which is somewhat analogous to the forward logistics process, but it refers only from the point of consumption to the point of origin. This reverse flow is called Reverse Logistics. Fig. 1 shows a flow diagram of forward and reverse logistic processes.

According to Fig.1, the first characteristic that can be observed in adopting reverse logistics is the possible generation of secondary materials that are ready for use as raw materials in the forward logistic process again. The main differences between forward and reverse logistics are the high cost and complexity of reverse logistics. However, direct and reverse logistics can be distinguished based on some key issues, as outlined in Table 1.

Based on Table 1, considering the differences between forward and reverse logistics, the latter seems more difficult to deal with. According to Da et al. (2004) and Parvenov (2005), common issues related to reverse logistics include:

- Work with too small or poorly laid out warehouses;
- Complexity and high degree of uncertainty regarding recovery stream;
- Lack of real time tracking of incoming merchandise does not permit quick put away or cross docking;
- Poor process integration into the warehouse does not allow returned merchandise to be immediately allocated and shipped;
- High costs to establish the reverse logistics process to test and repackage the returned goods (products or packaging) for resale, costs for disposal of unserviceable items, etc.

Although reverse logistics usually has these challenges, they can be overcome and turned into competitive advantage when the reverse logistic system is efficient (Ravi and Shankar, 2005; Bernon and Cullen, 2007). Pokharel and Mutha (2009), for example, indicated briefly significant contributions of reverse logistics to some industrial sectors in which economic and environmental benefits were observed, and they verified the development of reverse logistics on a global scale indicating that it shows a clear tendency to increase visibility and gain support among its potential users.

Compared to forward logistics, reverse logistics concept is a relatively new research topic that has become increasingly discussed due to competitiveness in the global economy. Jayant et al. (2012) presented a literature review on reverse logistics published in the last decades concluding that the number of publications has increased considerably since 2004 demonstrating its growing recognition. Brito and Dekker (2003) believe that the main areas of research on reverse logistics comprise basically studies on quantitative models, case studies, and approaches to new theory construction.

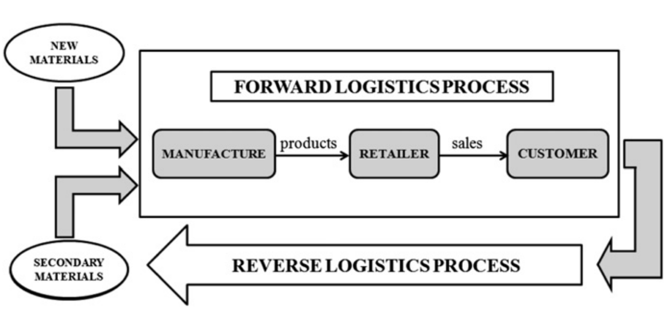

Fig. 1. Forward and reverse logistics processes Source: adapted from Rogers and Tibben-Lembke (1998).

Table 1
Major distinctions between forward logistics and reverse logistics.

Aspects	Forward logistics	Reverse logistics
Product life cycle	Manageable	Complex to manage
Cost of distribution	Easily identifiable	Hardly identifiable
Destination or routing	Clear	Unclear
Packaging of products	Uniform	Depends on several factors
Inventory management	Consistent	Inconsistent
Options of disposal	Clear	Unclear
Distribution outlets	One to many transportation	Many to one transportation
Price	Relatively uniform	Depends on several factors
Forecast	Relatively straightforward	More difficult
Quality of products	Uniform	Depends on several factors
Visibility of process	More transparent	Less transparent

Source: Adaptaded from Tibben-Lembke and Rogers (2002).

2.2. Definition and advantages of reverse logistics

The concept of reverse logistics has evolved over time. In its simplest conception, in the 1980s, it was defined as the movement of goods from the consumer to the producer through a distribution channel (Murphy, 1986). However, in the 1990s, some authors such as Stock (1992) and Carter and Ellram (1998) introduced new approaches defining it as the study of return of materials focusing not only on technical and economic benefits, but also on environmental efficiency enabling the reduction of resource consumption by reusing and recycling industrial goods (products and packaging).

Later, Stock and Lambert (2001) reported that reverse logistics is the field of business logistics that aims to add economic and environmental values to end-of-life industrial goods enabling their reintegration into products' life cycle as secondary materials. However, Nikolaou et al. (in Press) highlighted that there is no consensus regarding the concept of reverse logistics yet, but the most well-known definition is "the process of planning, implementing and controlling flows of raw materials, in process inventory, and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal". This definition was given by the European Working Group on Reverse Logistics and is similar to the concept established by The Council of Supply Chain Management Professionals (CSCMP, 2012), "that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverses flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements".

Moore (2005) states that many benefits can be obtained from an effective reverse logistics program such as:

- Customer retention/satisfaction;
- Reuse of packaging;
- Recycling programs for end-of-life products;
- Asset recovery/restock;
- Reduction of excess inventory of raw materials;
- Obsolete equipment disposition;
- Recalls.

For example, customer satisfaction can be obtained from products that are returned to be recycled or reused without generating waste at the final customer. Other benefits are environmental impact reduction, by reusing and recycling returned goods, and the reduction in inventory of raw materials. Moreover, the savings achieved through recycling/reuse of returned goods can outweigh the costs necessary to maintain the reverse logistic system implemented, which is a great advantage since cost is one of the major barriers to adoption of reverse logistics.

2.3. Typical activities of reverse logistics

According to Leite (2009), studies on reverse logistics consider post-sale and post-consumption flow of goods. Post-sale goods are those with little or no use that return to the supply chain for various reasons including quality and warranty issues, delays in receiving among others. On the other hand, post-consumer goods result from the inability of adequately dispose of products and waste resulting from consumption, which, at the end of life, can be recovered.

According Brito and Dekker (2003), when dealing with reverse logistics companies have to consider some typical activities such as to collect, inspect, select, classify, and define strategies for the recovery of industrial goods. Collection refers to bringing the goods from the customer to a point of recovery, where the goods are inspected and selected and their quality is evaluated to define the type of recovery to be used. The goods are sorted and routed based on typical recovery strategies as follows: direct reuse, reprocessing, and final disposal, as shown in Fig. 2.

According to Fig. 2, with regard to the strategy of direct reuse of goods, Thierry et al. (1995) argue that industrial products can be put back on the market almost immediately by returning them to the supplier to be resold or reused without prior refurbishing. For the strategy of reprocessing, the goods must be reprocessed considering repairing, refurbishing, remanufacturing, cannibalization (reuse of salvageable parts), or recycling. All these alternatives generate secondary materials to be applied in the forward logistics system again. However, when these strategies are not possible, as the last alternative, the goods must be destined for a landfill, incineration, etc.

In order for the reverse logistics process shown in Fig. 2 to function properly, Lacerda (2009) highlights the need for management of some critical factors such as the existence of good information systems (products traceability), cycle time reduction, and properly mapped and formalized logistics processes. Other key factors are product life cycle characteristics, logistic costs, and legislative and environmental aspects. All of them directly influence the efficiency of the reverse logistics process.

With regard to reduced cycle time, Walden (2005) claims that the time to process returned items can potentially increase the time to process routine inbound shipments. Increasing the normal time to process inbound shipments can cause an increase in the time the customer has to wait to get the finished product, resulting in lost sales and customers. Jayaraman and Luo (2007), in a case study on printers, found that delays in typical reverse logistic activities such as transportation, sorting, and selection of printers resulted in market value loss due to the excessive cycle time in the time to process routine inbound shipments. A prime way of reducing cycle time is to change the transport system responsible for the reverse flow of goods since, according to Dowlatshahi (2010), this is a major variable that increases the cycle time.

Regarding the characteristics of the life cycle of products and their relationship with reverse logistics, Tibben-Lembke (2002) emphasizes their importance in the remanufacturing of post-consumer products. In a case study of remanufactured PC monitors, Vasudevan et al. (2012) also pointed out that reverse logistics is a key element for implementation of remanufacturing in companies. Östlin et al. (2009) investigated the influence of the life cycle of post-consumer products in remanufacturing strategies and found that the main factors that directly influence product return rate are the mean product lifetime, rate of technical innovation, and failure rate of components.

In terms of environmental issues, reverse logistics should be applied according to a hierarchy of priorities, focusing mainly on minimizing the use of materials and energy. Carter and Ellram (1998) believe that this is possible by maximizing the recovery rate of returned goods. Strategies for the disposal of goods should only be considered as a last resort, for cases in which the recovery of the goods is not possible or feasible.

2.4. Reverse logistics for packaging

Environmental issues are among the main reasons behind promoting reverse logistics in companies, especially for industrial packaging. The use of disposable packaging generates large amount of waste, which contributes to landfill saturation and scarcity of raw materials (González-Torre et al., 2004). Therefore, the use of

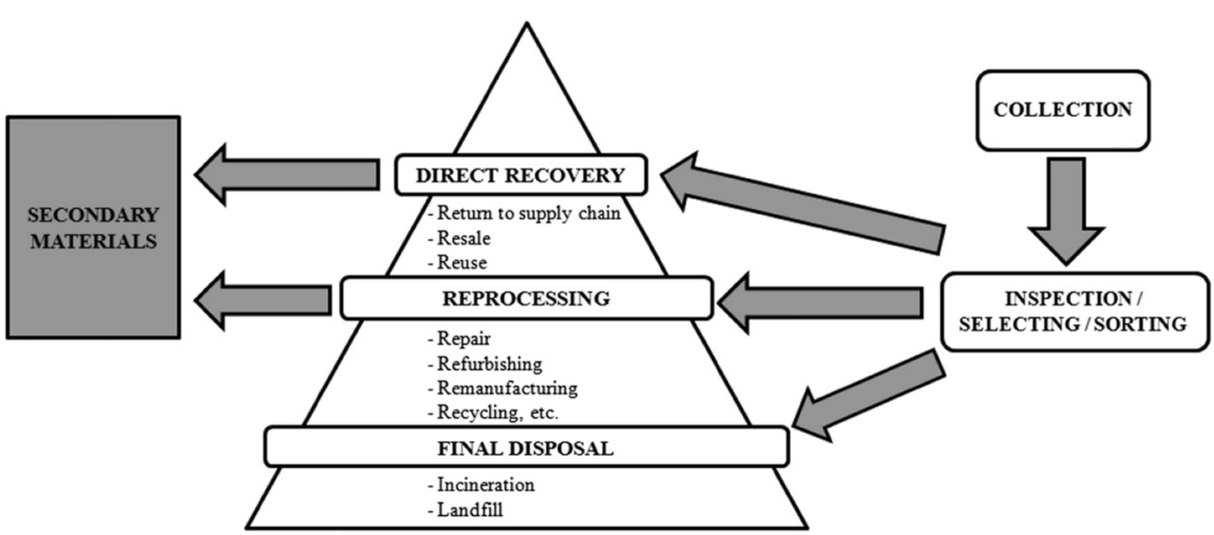

Fig. 2. Typical activities of reverse logistics Source: adapted from Brito and Dekker (2003).

industrial packaging has been the focus of many environmental policies. In the European Community, for example, Directive 94/62/EC regulates the recovery of packaging and makes producers responsible for implementing reverse logistics systems across Extended Producer Responsibility (EPR) programs. According to McKerlie et al. (2006), environmental policies seem to be an effective way to prevent the generation of waste, and EPR programs can stimulate cleaner production practices and more sustainable product designs.

EPR programs have also been prominent in Canada, where the Canadian Council of Ministers of the Environment (CCME) approved the Canadian countrywide Action Plan for Extended Producer Responsibility and the Canadian countrywide Strategy for Sustainable Packaging in 2009 stimulating the reuse, recycling, or any other type of revalorization of post-consumer goods (including packaging). A similar situation has occurred in Brazil with the National Policy on Solid Waste – PNRS, enacted in 2010, which requires the implementation of post-consumer reverse logistics to those involved in supply and production chains for the following industrial sectors: tires, lubricants, batteries, bulbs, electronics, pesticides, and packaging made primarily of plastic, metal, and glass.

With respect to types of industrial packaging, it can be returnable (multi-way packaging) or disposable (one-way packaging) and is a relevant problem in reverse logistics because its value decreases during the consumption of the product, for example, PET or glass bottles. However, industrial packaging can bring technical, environmental, and economic benefits to companies when the best reverse logistic system for packaging is identified. Accordingly, Dae Ko et al. (2011) investigated the standardization of glass bottle packaging and concluded that it brings many benefits due to reduced costs in the reverse logistics system resulting from the reduction in the volume and weight of empty packaging during reverse flow.

There is a global trend to use returnable packaging instead of disposable packaging (Twede and Clarke, 2005). With the adoption of returnable packaging, generation of waste at the final customer can be reduced or eliminated, minimizing risks to the environment, besides presenting a better cost-benefit ratio in terms of industrial applications compared to disposable packaging.

Considering reverse logistics of returnable packaging, it is necessary to create an empty packaging management system to provide return to the manufacturers and its availability at the place and time they are requested. Therefore, Dethloff (2001) highlighted that the management of returnable packaging requires the determination of optimal shipping and return routes since routing problems can arise when both tasks are performed by the same transport infrastructure, for example, an increase in cycle time of returns.

Leite (2009) argues that returnable packaging has disadvantages just like those of disposable packaging, such as transportation costs (direct and reverse), flow management, reception, cleaning, repair, storage, and capital invested. However, returnable packaging can bring benefits that can compensate for these disadvantages including:

- Increased protection for the products;
- Greater flexibility to the consumer in the event of changes in legal requirements;
- The packaging can be returned to the manufacturer as a secondary material and can be used in new types of packaging; and
- Environmental benefits since the packaging is not discarded in the environment like disposable packaging.

In order to reduce the costs with returnable packaging, it is important to develop light and resistant packaging, given that many shipping costs are associated to the load weight and the need for secure packaging to prevent damage in transit. In this case, the use of standardized returnable packaging is an advantage to optimize the use of space during product transportation and reduce transportation costs (Dae Ko et al., 2011).

Some examples of relevant publications on reverse logistics with emphasis on industrial packaging are: Rosenau et al. (1996), Rogers and Tibben-Lembke (1998), Duhaime et al. (2001), González-Torre et al. (2004), Twede and Clarke (2005), Adlmaier and Sellitto (2007), García-Arca and Prado (2008), Williams et al. (2008) and Dae Ko et al. (2011). Duhaime et al. (2001) carried out a case study to evaluate the system of collection and distribution of returnable packaging for Canada Post and its large mailing customers presenting a model to determine the number of empty containers that should be distributed and returned every month per region and the number of empty containers in stock needed to meet the demand without shipping delays and excess packaging inventory. Adlmaier and Sellitto (2007) proposed the replacement of disposable packaging with a returnable packaging model with benefits by reducing operational costs and resource consumption. However, the environmental performance of the packaging models analyzed was not discussed. With regard to the packaging environmental performance, Williams et al. (2008) studied different ways to reduce environmental impacts of food-packaging systems in a lifecycle perspective applying the Life Cycle Assessment (LCA) technique. With the LCA study, it was possible to develop a new and better packaging model, reducing food losses and environmental impacts considering the packaging design.

Focusing on studying the reverse flow of industrial packaging, this paper presents a case study of reverse logistics of returnable packaging used to transport machined engine heads from a company located in Joinville, Santa Catarina, Brazil, to Peterborough, UK in replacement for its usual disposable packaging system. Hence, a technical and environmental analysis was conducted comparing the two packaging models hoping to demonstrate that the practice of reverse logistic with returnable packaging model can bring important benefits that contribute to the sustainable development of the company.

3. Material and method

In this study, the events of interest are unique within a context of real life and contemporary phenomena, featuring an exploratory character and aiming to raise questions and hypotheses for further top studies. The methodology adopted was the case study, as proposed by Yin (1994). The case study was applied in a company that produces machined engines heads, and its identity was preserved due to strategic issues.

The research team consisted of researchers outside the company and an internal technical team responsible for collecting data in the company. The research methodology used included:

- **Literature review:** databases were searched for publications involving the topic of this research focusing on theoretical and practical studies on reverse logistics in order to gather relevant technical information;
- **Field data collection:** included interviews with company representatives and the analysis of technical documents and standards of the company. Each of these activities is shown in Table 2;
- **Definition of the new concept of returnable packaging:** a returnable packaging model, which was already adopted by the company in the domestic market, was used. In addition, the opportunities for improvements observed during field data collection were included;

Table 2
Main strategies for the data collection and analysis activities.

Collection instruments	Data source
Interview with company representatives	Semi-structured questionnaires with open-ended questions were designed. These questionnaires were sent to the technical team of the company composed of product engineers, logistics, and controllership, and data were collected as follows: – Characteristics of the exported product (volume, dimensions, product weight, etc); – List of materials used and their quantities, disposable packaging assembling instructions, etc; and – Logistics flow mapping of the disposable packaging.
Analysis of standards and documents	Analysis of technical documents and standards of the company: – Technical instructions for assembling the disposable packaging; – Export shipping instructions (weight limit, dimension restrictions, etc.); – Recorded information about costs related to the disposable packaging model such as material consumption, shipping, etc; – Recommendations to ensure product integrity. Since the product is exported, there are some peculiarities that must be evaluated such as care to avoid breaking, corrosion, and scratches in the product among other potential damages.

- **Reverse logistics flow mapping**: the major operations involved in the reverse logistics flow for the model of returnable packaging proposed and material and time flow in each operation were considered. Hence, it was possible to determine the amount of packaging in stock needed for the flow of exported products;
- **Technical analysis:** having defined the type of returnable package, a technical analysis was performed to determine performance characteristics such as total weight transported (packaging and product), packaging weight, cycle time, lifetime of the reusable materials, stock inventory required for returnable packaging, benefits from reduction in the consumption of resources, and the unit cost of returnable packaging per unit of exported product. The data used for the determination of the unit cost of the packaging were provided by the financial sector of the company studied. The technical performance data of the returnable packaging were compared with those of the current model adopted by the company using disposable packaging;
- **Environmental analysis:** This study applied the Life Cycle Assessment (LCA) technique, ISO 14040 standard series, to compare models of returnable and disposable packaging in terms of their environmental potentials impacts. The major considerations for LCA are described in Table 8, in the results and discussion section, based on the technical aspects of each type of packaging.

Table 2 show the strategies defined for the field data collection, as previously discussed.

Based on the methodology steps discussed, this study assesses the logistics system of packaging used to transport machined engine heads from a company located in Joinville, Santa Catarina, Brazil, to Peterborough, UK. The company produces 4 and 6-cylinder engine heads (593 × 323 × 111 mm) (Fig. 3).

Fig. 3. Product assessed in the study of reverse logistics.

The average sales volume is 70,000 exported items/year. The transportation system comprises road and sea, and the product must reach the final customer clean with no scratches, dents, and aesthetic oxidations.

In order to promote better understanding of the returnable packaging model proposed, initially, it was necessary to understand the concept of disposable packaging used by the company in the export of the engine heads.

3.1. The concept of disposable packaging

Through the assembling directions of disposable packaging, it was possible to list all required materials and their quantities consumed, as shown in Table 3.

Fig. 4 shows the arrangement of the engine heads, the use of fluted plastic divider, and the stretch film. Each packaging holds 16 engine heads arranged in two rows, each with 8 pieces. The parts are separated by a fluted plastic divider to avoid hitting on the machined parts during transportation. Additionally, the engine heads are kept tightly bound for protection by wrapping 4 times a stretch film around the package.

Fig. 5 shows the details of the assembly steps of the disposable packaging. Plastic bags containing VCI (volatile corrosion inhibitors) are used to avoid product corrosion, and raffia bags are wrapped around the outside to prevent the inner package from tearing. The figure also shows the final packaging assembly steps using the wooden pallet and plywood, the placement of the cardboard corners, and the use of polyester binding tape to hold the package together. Finally, the paper label with a corresponding batch of the product is attached for export.

Table 3
Materials used in the disposable packaging.

Description	Amount	Unit
Wooden pallet n° 322 with plywood cover	1	Piece
Fluted plastic divider	1	Kit
Raffia bag type VCI	1	Piece
Plastic bag type VCI	1	Bag
Cardboard corner (length of 1200 mm)	2	Piece
Cardboard corner (length of 930 mm)	2	Piece
Stretch film	0.250	Kilogram (4 laps)
Polyester tape	24	Meters
Paper label	1	Piece

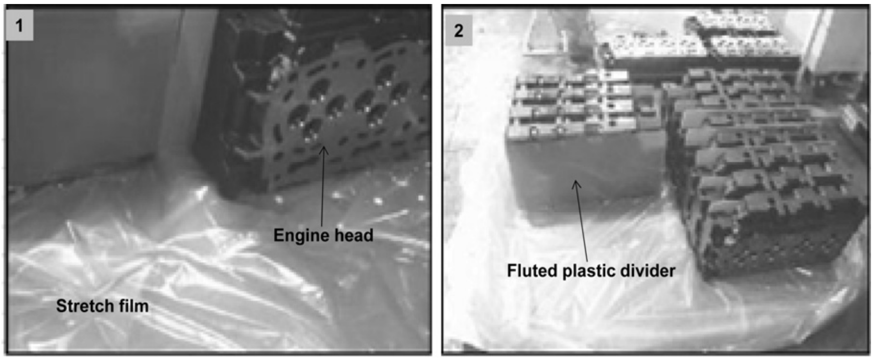

Fig. 4. Arrangement of engine heads during the assembly of the disposable packaging: (1) stretch film and engine head details, (2) overall view of engine heads separated by fluted plastic dividers.

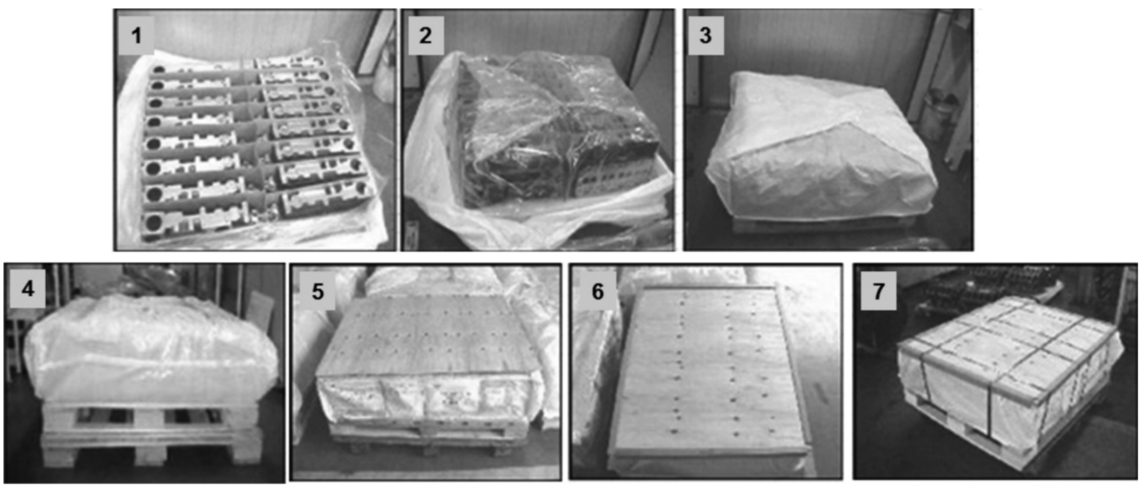

Fig. 5. Disposable packaging assembly steps: (1) engine heads arrangement, (2) VCI plastic bag application, (3) VCI raffia bag application, (4) wooden pallet placement, (5) plywood cover, (6) cardboard corner placement, (7) polyester tape binding.

3.2. The concept of returnable packaging

In order to develop the concept of returnable packaging a benchmarking model for returnable packaging, which was already being used by the company studied, was applied. In that case, the product transported is another type of engine head with similar dimensions and same finish; however, it is not exported. All returnable materials have useful life exceeding five years.

After careful analysis of the returnable packaging that had been adopted by the company in the domestic market, a technical list of specifications for the returnable packaging to be exported was described as follows:

- Packaging with suitable dimensions to hold 416 heads in a 20-foot export container. This type of container had already been used by the company, which chose to keep it in this study;
- A vacuum formed plastic tray was used to arrange the products into two rows with 5 mm spacing between the pieces. This allowed organizing the engine heads according to customer request without requiring the use of stretch film and raffia bags;
- A vacuum formed plastic cover with 50 mm corners, which did not require the use of the plywood and cardboards corners;
- Use of a metallic frame (or rack) with ability to withstand stacking four layers of engine heads without requiring the use of the wooden pallet.

Therefore, the list of materials used to define the returnable packaging model to export the engine heads is shown in Table 4. The returnable packaging model proposed allowed eliminating the use of some elements such as wooden pallets, cardboard corners, plywood, stretch film, and raffia bags.

The steps to assemble the returnable packaging were similar to those described earlier for the assembly of disposable packaging, which avoided the use of new and more complex activities. Fig. 6 shows the returnable packaging developed and its assembly steps.

As can be seen in Fig. 6, after step 4, four layers of the engine heads were stacked on the metallic rack finalizing the assembly of the returnable package. After placing the last layer, the packaging is covered with the vacuum formed plastic cover (lid), and it is held tightly together using a polyester tape, and the identification tag.

Table 4
Materials used in the returnable packaging model proposed.

Description	Amount	Unit
Fluted plastic divider	1	Kit
Metallic rack	1	Piece
Paper label	1	Piece
Plastic bag type VCI	1	Bag
Vacuum formed plastic cover	1	Piece
Vacuum formed plastic tray	1	Kit
Polyester tape	24	Meters

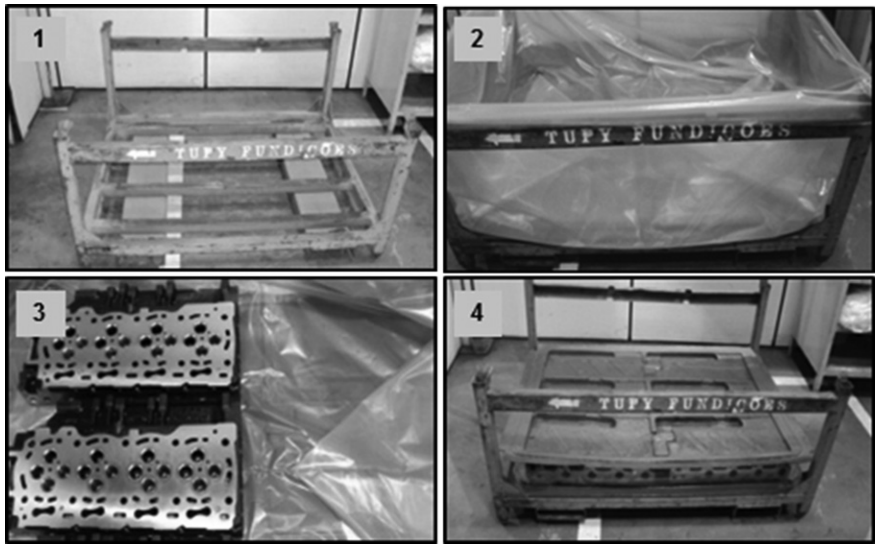

Fig. 6. Returnable packaging assembly steps: (1) metallic rack, (2) VCI plastic bag wrapping, (3) arrangement of engine heads, (4) use of vacuum formed plastic tray.

Fig. 7. Returnable packaging model developed.

Fig. 7 shows the returnable packaging model developed including all components.

4. Results and discussion

Having presented the two packaging models evaluated, the results are shown below considering aspects related to their technical and environmental performance.

4.1. Technical aspects of performance

Table 5 lists the information of weight of the transported material for both types of packaging evaluated.

Considering that the weight of each of empty returnable packaging is 115 kg, and the total weight of the loaded container is 25,766 kg, it was found that for every seven 20-foot containers to be exported, only one container would return with empty packaging. This is due to the criteria established for the development of the returnable packaging model, which allowed the reduction in the volume occupied by the empty packaging during the reverse flow of the packaging to Brazil. As seen in the literature, the reverse logistic system for returnable packaging in general is more expensive due to the reverse load to be returned (Dae Ko et al., 2011). Thus, for an economically viable logistic reverse system, when designing the packaging, it is essential to focus on the standardization to reduce the weight and space occupied by the empty packaging during the reverse flow.

The final weight of the returnable packaging was higher in comparison to that of the disposable packaging. This is due to the fact that the weight of the empty returnable packaging is greater than that of the disposable packaging, and the metallic rack accounts for about 90% of the total weight of the packaging. Further research should be carried out focusing on replacing the metallic rack; however, in the present study this was not done because the metallic rack had already been used by the company, and therefore its replacement could result in an increase in the cost of the returnable packaging model developed.

In order to define the number of packaging units needed for the flow of exported products, the length of time for each step related to the forward and reverse logistics process was considered. The total time in transit or cycle time was of 105 days. This is the time

Table 5
Comparison between disposable and returnable packaging models in terms of transported material weight.

Technical characteristics	Disposable packaging	Returnable packaging
Weight of one engine head	54.75 kg	54.75 kg
Engine heads per packaging	16	16
Weight of one empty packaging	65 kg	115 kg
Weight of loaded packaging	941 kg	991 kg
Transported weight per engine head	58.81 kg	61.94 kg
Engine heads per container	416	416
Weight per container	24,466 kg	25,766 kg

Table 6
Length of time of each step for the transit of the returnable packaging.

Description	Average length of time (days)
Storage in Joinville, Santa Catarina, Brazil	5
Dispatch, Transportation to Port, Customs, Transit, Customs + Transit, Inventory − with products, Inventory − without products.	30
Storage at the final customer	30
Dispatch, Transit, Brazil Customs	20
Safety margin and delivery delays	20
Total (cycle time)	105

between the shipping date from Brazil to UK, the return of the packaging to Brazil, and its reintroduction in the production line of the company. Table 6 shows every step of the logistic process and the average time of each step (in days). All delays were incorporated in a single step with average time of 20 days.

The cycle time was considered good by the company since the product is exported. Therefore, the total time was not a limiting factor because usually very long cycle times add undesirable costs due to cash flow delay.

With the cycle time of 105 days, the annual volume of 70,000 products exported (or 14,000 pieces/week), and the number of engine heads per packaging (16), it was possible to determine the amount of returnable packaging required to meet the flow of products, which was 1313.

Another important returnable packaging feature is the lifetime of each of its materials since the packaging cost is based on it, and it contributes to establish packaging inventory and facilitates the management of waste from end-of-life packaging materials. Table 7 shows the values life expectancy of each returnable packaging material based on the following information:

- Suppliers of reusable materials
- The model of the returnable packaging commonly used by the company to transport the engine heads within the domestic market.

Based on the lifetime shown in Table 7, it can be observed that the metallic rack, the vacuum formed plastic tray, and the vacuum formed plastic cover are the returnable materials. Therefore, they should be seen by the company as the best end-of-life strategy, considering its management should include reuse and/or a proper disposal. Thus, the following procedures are recommended:

- The metallic rack can be reused by the company in internal projects that require parts with similar dimensions, or they can be fully recycled as scrap metal;
- The best alternative for the vacuum formed materials is the disposal for external recycling (sale to other companies).

Table 7
Lifetime of returnable packaging materials.

Description	Lifetime (trips)
Metallic rack	35
Vacuum formed plastic cover	15
Vacuum formed plastic tray	15
Fluted plastic divider	1
VCI Plastic bag	1
Polyester tape	1
Paper label	1

Based on some financial information provided by the company about the costs of the materials that make up the returnable packaging, the costs of acquisition, taxes, shipping, maintenance (packaging washing and cleaning) of each packaging material were considered, and the unit cost of returnable packaging per unit of exported product was calculated. For this purpose, the lifetime of each packaging material was also considered. The cost of the returnable packaging was R$ 13.57 per engine head transported, and the metallic rack was considered the most expensive material used in the packaging system. This cost was higher than that of the disposable packaging, and the company did not disclose detailed information about the cost of each material in this kind of packaging.

Although higher than that of the disposable packaging, the cost of the returnable packaging was considered satisfactory by the company due to the benefits brought by it. Considering the costs of the materials, 18.00% less material was used if compared to the material used in the disposable packaging. Additionally, the use of returnable packaging offered several technical advantages such as greater protection of products transported and reduction of waste generation at the final customer adding greater value next to it. In addition, the 20-foot container that the company used for exporting the products was maintained.

4.2. Environmental aspects of performance

In addition to the gains of 18.00% reduction in material consumption and the lower waste disposal rates at the customer, an environmental performance analysis was conducted based on the LCA technique. The main considerations for this analysis are listed in Table 8 for both packaging models evaluated.

The environmental impact results that are in accordance with the characteristics shown in Table 8 are summarized in Fig. 8. These results were normalized by the “CML2001, Europe” from CML2001 method, which allows the verification of the overall environmental profile of both packaging models in relation to the same reference unit for all categories environmental impact selected.

As can be seen in Fig. 8, disregarding the global warming impact category, an overview of the results shows that the returnable packaging model was the best alternative since it had the lowest levels of environmental impacts compared to those of the disposable packaging model. However, it was found that the returnable packaging model contributed more to the global warming than the disposable model, since it showed greater potential impacts, specially due to the consumption of steel for the production of the metallic rack, which is the main material of the returnable packaging. On the other hand, the disposable packaging showed a negative net contribution to the global warming due to biogenic carbon fixed in wood products, such as the plywood, pallet, and cardboard corner, in their life cycle. Thus, it is important to observe that environmental improvements are required for the returnable packaging model proposed, in particular, in terms of global warming.

However, according to the results, the most important categories of environmental impacts were: GWP, ADP, AP, and POCP, in this order, especially for the disposable packaging, except for the GWP, as explained. This is mainly due to the high levels of consumption of non-renewable resources to produce plywood, wooden pallets, cardboard, and the corner, which are the main materials of the disposable packaging. A lot of non-renewable resources are consumed to produce plywood, pallet, and cardboard corner despite the fact they are derived from wood (renewable resources). Some examples of these non-renewable resources are pesticides and diesel, used in field operations and transport at the forest production stage, and urea formaldehyde resin used in the industrial process of plywood production.

Table 8
Main assumptions adopted for the environmental performance analysis.

Tools	Assumptions
Environmental analysis	The LCA technique was applied according to ISO 14040 standards, considering the life cycle (cradle to grave approach) of the most important materials used in both packaging models studied.
Computational tools	The data related to both packaging models were obtained from LCA database and using computational tools: – GaBi 4.4 Software-Systems and Databases, educational version (PE International, 2012) was used; with this software the life cycle of both packaging models was modeled; – The CML2001 method, according to Guinée (2001), was used to assess the packaging life cycle environmental impact. This method is included in the GaBi software, and it allowed the quantification of the potential environmental impacts related to the packaging models studied; – The following environmental impact categories were considered: global warming potential (GWP), acidification potential (AP), abiotic depletion potential (ADP), eutrophication potential (EP), photochemical ozone creation potential (POCP), ozone layer depletion potential (POCP) and radioactive radiation (RAD). The CML2001 method was used because it takes into consideration relevant environmental issues and also due to the fact that part of the data obtained to evaluate the packaging life cycle was obtained from sources of European technology processes within the GaBi software database.
Data source	Primary data were obtained during the field data collection according Tables 3 and 4. Secondary data were obtained from the GaBi database for most part of disposable and returnable packaging material chain production.
Other modeling approaches	For the disposable packaging, the following assumptions were taken into consideration: – Wooden pallet and plywood cover accounted for 90% of the total weight (65 kg) of the packaging; – The "RER: EUR-flat pallet" processing from GaBi databases was chosen to represent the wooden pallet life cycle, and the "RER: plywood, indoor use, at plant" was chosen to represent the plywood cover life cycle; – Cardboard corner, raffia bag and stretch film accounted for 7% of the packaging total weight (4.5 kg); – The processing "I-25: Corrugated board" from GaBi databases was chosen to represent the cardboard corner. Raffia bag and stretch film were not considered in this analysis, in terms of their life cycles, because they are not available in the GaBi databases; – Polyester tape, paper label, plastic bag, and fluted plastic divider were not considered in this analysis because these materials are also part of returnable packaging model; For the returnable packaging, the following assumptions were taken into consideration: – Metallic rack accounted for 90% of the packaging total weight (103.5 kg); the weight was divided by the material lifetime; – The "DE: Steel sheet PE" processing was chosen to represent the metallic rack life cycle; – The vacuum formed tray and cover accounted for 8% of the total packaging weight (9.2 kg); the weight was divided by the material lifetime; – These plastic materials made from polyethylene terephthalate (PET) were represented by "DE: Polyethylene terephthalate (PET)" processing to characterize the production chain of these materials.

Despite being the best alternative in terms of environmental performance, the returnable packaging model needs some technical improvements. Considering the ecodesign, a viable alternative could be to replace the metallic rack with some other equivalent material that would serve the same function and present less potential impacts, especially in terms of GWP, since this was the component that contributed the most to the potential impacts assessed for the returnable package model proposed.

A limitation related to the environmental performance results is the databases used to model the packaging models life cycle, because of the life cycle dataset of the materials that make up each type of packaging were meant for European technological processes (available in GaBi databases) and not for Brazilian processes. Nevertheless, it is important to mention that there are no well-known LCA databases available in Brazil (Cavalcanti, 2010), and that the approach of LCA was adopted to better understand the

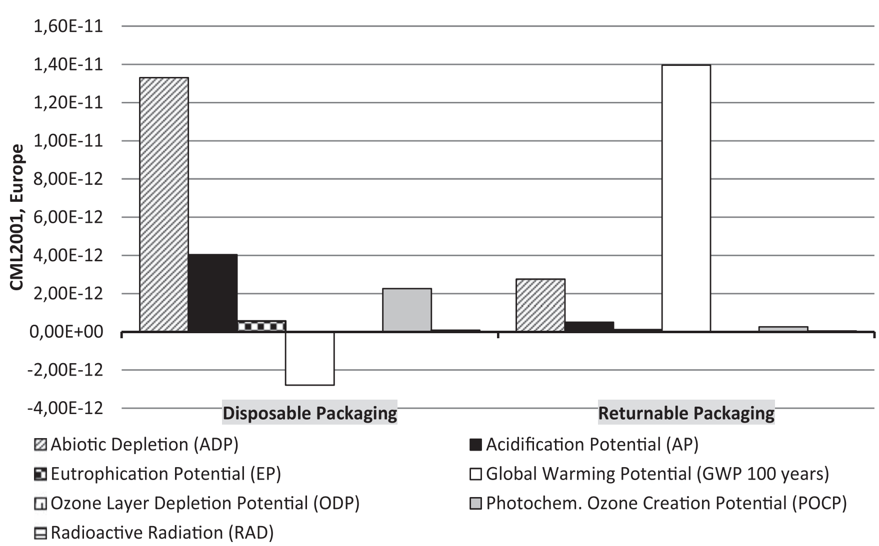

Fig. 8. Overall environmental impact assessment results.

benefits of the returnable packaging model suggested to replace the disposable packaging model from the perspective of the environmental impacts related to the packaging life cycle.

5. Conclusions

The major contribution of this research is to show that the practice of reverse logistics concerning the use of returnable packaging can bring important results for the logistic process in terms of technical, economic, and environmental benefits.

We attempted to standardize a returnable packaging model to replace the disposable packaging, the current model used by the company studied. Using the returnable packaging model proposed, it was possible to reduce the amount of disposable materials consumed resulting in cost reduction, greater protection for the products exported, reduction of waste generation at the final customer, and logistical benefits such as reduction in volume occupied by the empty packaging during the reverse flow of empty packaging, which allowed that for every seven containers of products shipped for export, only one container would return with empty packaging.

The cycle time was 105 days, and the amount of returnable packaging required to meet the flow of products was 1313. Within the context of this study, the company considered these characteristics satisfactory.

All relevant costs related to the returnable packaging model proposed were considered, and the unit cost of the returnable packaging was R$ 13.57 per engine head exported. This value was presented to the company for more studies, and it expressed interest in adopting the model developed in its logistics system.

The returnable packaging model resulted in the use of 18.00% less material when compared to the disposable packaging model, presenting economic and environmental gains by reducing material consumption and waste generation.

With regard to the environmental performance assessment using the LCA technique, the returnable packaging model was the best alternative since it had the lowest levels of environmental impacts compared to those of the model of disposable packaging. The most important categories of environmental impacts were GWP, ADP, AP, and POCP, in this order, being GWP especially more relevant for the returnable packaging, while all other impact categories were most significant for the disposable packaging model. Therefore, the returnable packaging model developed was the most feasible alternative presenting less impact on the environment. However, improvements in the proposed model are necessary, especially in terms of reducing the GWP.

Suggestions for further studies include:

- Study the process of traceability of returnable packaging since it is an important issue that could compromise the operational integrity of the logistics process
- Modify or replace the metallic rack with a similar material since it was the factor that contributes the most to the majority of environmental impacts related to the returnable packaging model, especially for the GWP. Furthermore, this material was responsible for most of the total weight of the empty packaging (90%) during packaging reverse flow, which results in an increase in transportation costs.

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