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CARDOSO DE OLIVEIRA NETO, GERALDO; SARAIVA DE SOUZA, MARIA TEREZA; DA SILVA, DIRCEU; SILVA, LEONARDO AURELIANO

AVALIAÇÃO DAS VANTAGENS AMBIENTAIS E ECONÔMICAS DA IMPLANTAÇÃO DA LOGÍSTICA REVERSA NO SETOR DE VIDROS IMPRESSOS

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AN ASSESSMENT OF THE ENVIRONMENTAL AND ECONOMIC BENEFITS OF IMPLEMENTING REVERSE LOGISTICS IN THE TEXTURED GLASS SECTOR

GERALDO CARDOSO DE OLIVEIRA NETO[1]
MARIA TEREZA SARAIVA DE SOUZA[2]
DIRCEU DA SILVA[3]
LEONARDO AURELIANO SILVA [4]

Introduction

For many years environmentalists have pointed to the excessive use of natural resources, a fact which has led to the emergence of Non-Governmental Organizations - NGOs - to fight against the likelihood of scarcity of natural resources and against the impacts of their extraction process on the environment.

In view of this, one of the ways to save resources is to implement reverse logistics programmes for the recovery of solid waste and to transform them into raw materials, thus mitigating environmental impacts which are also harmful to human health (CHEMEL *et al.*, 2012 and HATAMI-MARBINI *et al.*, 2013).

Reverse logistics programmes move goods from their disposal sites so as to recover their value or to ensure that they are disposed of appropriately (TIBBEN-LEMBKE, 1998; RLEC, 2013). These operations involve a process of planning, implementing and controlling the efficient and cost-effective flow of raw materials, stock, finished goods and related information from the point of consumption to the point of origin (MEADE, 2007), in order to capture value through proper and safe disposal of resources (SHERIFF *et al.*, 2012).

1. Professor and researcher Doctor of Post-Graduate Program in Engineering of Production. UNINOVE. E-mail: geraldo.prod@ig.com.br
2. Professor and researcher Doctor of Post-Graduate Program in Administration. FEI/SP. E-mail: mariaterezasaraivas@gmail.com
3. Professor and researcher Doctor of Post-Graduate Program in Administration. UNINOVE. E-mail: dirceuds@gmail.com
4. Masters in Administration of Post-Graduate Program in Administration. UNINOVE. E-mail: mkt_academico@yahoo.com.br

Furthermore, reverse flow refers to a set of activities encompassing collection, separation, packaging and dispatching of used, damaged and obsolete items from their points of purchase and/or consumption to reprocessing, recycling, resale or disposal sites (STEVEN, 2004). These activities also involve the reusing and re-manufacturing of goods which can be repaired and put back into circulation (GOVINDAN *et al.*, 2012). Companies, therefore, become responsible for the whole life cycle of their products (DAHER; SILVA; FONSECA, 2006).

More specifically, reverse logistics is a business strategy aligned with the requirements of the Brazilian National Policy on Solid Waste (PNRS) to reduce environmental impact, aiming to promote actions to ensure that the flow of solid waste is directed back into the production chain or the production chains of other producers (Chapter IV, Article I). It is an economic and social development tool whose main purpose is to provide a set of actions to facilitate the collection and restitution of solid waste back to its producers so that it can be treated or re-employed, either in new products within the same cycle or in other productive cycles, and in this way, not generate waste (Article VII) (BRASIL, 2010).

However, there are obstacles to the implementation of reverse logistics such as: (i) a lack of specialists; (ii) a lack of commitment on the part of senior management; (iii) a lack of investment in the system's infrastructure and control; (iv) an absence of governmental control (ABDULRAHMAN *et al.*, 2012); (v) managers' lack of time to plan reverse logistics actions; (vi) a lack of knowledge about the added value of this activity (JINDAL; SANGWAN, 2011; GUNASEKARAN; NGAI, 2012); and (vii) lack of attention given to the implementation of reverse logistics in developing countries (ZHANG *et al.*, 2011; SARKIS *et al.*, 2011; MIAO *et al.* 2012), even though in developed countries its implementation is compulsory in the supply chain of goods and services (ZHANG *et al.*, 2011; SARKIS *et al.*, 2011).

Brazil is a developing country and there is still a lack of governmental incentive to raise the awareness of business people and to set up programmes involving reverse logistics command and control activities. The main gap observed in Brazilian companies relates to the lack of studies to assess, amongst other factors, the economic and environmental benefits of reverse logistics (HERNANDEZ et al., 2012). These benefits are corroborated by other research which points to: a reduction of inventory costs by reusing beer bottles (KO *et al.*, 2012); a reduction in the costs of purchasing raw materials through the recycling and re-manufacturing of broken glass packaging (GOLARA *et al.*, 2012); and, finally, a reduction of 31.7% in logistics costs through cutting down the percentage of unusable tyres and increasing the use of rice husks in the manufacture of rubber, reducing the use of oil derivatives by 10,000 tonnes per year (SELLITO *et al.*, 2013).

In view of this, the aim of this study is to assess the economic and environmental benefits of implementing reverse logistics in a Brazilian glass manufacturing company.

Once the main scenario and the object of the research have been described, a review of concepts is carried out which will serve as the basis for structuring this research.

Theoretical Foundations of the Research

Here, two concepts are presented which are fundamental to the theoretical foundations of this research: reverse logistics and glass recycling and reuse.

Reverse Logistics

Terms such as reverse canals or reverse flow were already present in the scientific literature of the 1970s. However, they always referred to recycling (GUILTINAN; NWOKOYE, 1974).

The term reverse logistics was coined by Murphy in 1968 and defined as "... the inverse flow of a product, from the final consumer to the producer in a given distribution channel" (RAVI et al. 2005, p.4).

Reverse logistics is also defined as the process by which companies can improve their environmental performance through recycling, reuse, and by reducing the quantity of materials employed (CARTER; ELLRAM, 1998), so as to transfer goods from their destination to another point, in order to recapture their value (ROSS, 1998).

The wider concept states that "reverse logistics is the process which involves planning, implementing and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin" (Rogers; Tibben-Lembke, 2001). The aim is to generate value or ensure appropriate use of resources to find suitable destinations for material goods (RLEC, 2013), ensuring an economic and environmental gain by recovering, reusing and re-manufacturing goods (SHERIFF et al., 2012).

However, reverse logistics does not only depend on companies. "'Agents' (businesses and individuals) influence logistics through their choices and intentions" (AASTRUP; HALLDÓRSOON, 2008). From this point of view, it can be seen that reverse logistics integrates intentions and actions. Indeed, individuals can also contribute when they dispose of products or reuse faulty products which can be recovered for other purposes. According to Govindan *et al.* (2012), the purpose of reverse logistics is to return faulty goods to their point of origin so they can be repaired, re-manufactured or disposed of.

It is worth highlighting that reverse logistics presupposes the analysis of the distribution channel and the return of packaging, given that goods move along the supply chain to reach the final consumer and are then returned. Thus, it is suggested that the use of trucks is maximized so as to reduce CO_2 emissions and the cost of transport (NEVENS *et al.*, 2008). Another important factor is to implement reverse containers at the supplier's site, the factory and in transportation systems so as to reduce cardboard and plastic packaging (VENDRAMETTO *et al.* 2010).

Reverse logistics activities can be vertically integrated or subcontracted (GOVINDAN *et al.*, 2012). When activities are subcontracted, there are ten criteria that should be taken into account: (i) capacity to avoid wastage; (ii) triage and dismantling sector; (iii) cost remodelling; (iv) recycling costs; (v) available costs; (vi) closed and covered area for storage; (vii) working within a network of companies; (viii) training staff in environmental education; (ix) noise impacts; and (x) pollution impacts (RAVI, 2012).

In reverse logistics, “stages, methods and processes return a percentage of goods - which have little post-sales use, have an extended life cycle or whose life cycle is finished - to the productive cycle, where they re-acquire value in secondary markets either through reuse or the recycling of their components” (LEITE, 2005). Thus, organizations should develop processes to collect, inspect, separate, re-manufacture and dispose of waste in an appropriate manner in order to recover part of its existing value (BARKER; ZABINSKY, 2011).

Companies need to implement clean technologies within the industry itself or at another point in the supply chain in order to put into practice reverse logistics programmes to reduce pollution through reuse and recycling, thus substituting new materials for recycled ones, producing significant savings in energy and reducing pollution (KONG et al., 2012).

Similarly, there are studies which show economic and environmental gains, in addition to showing an improvement in companies’ images vis-à-vis their clients (HERNANDEZ et al., 2010). However, there are still very few studies and some uncertainty with regard to procedures for selecting variables, methodologies and their respective characteristics. Companies which engage in planning and evaluating potential gains from reverse logistics tend to use simple common sense, that is, they assess the more direct factors, such as economic aspects and the relationship with clients and/or the community (HERNANDEZ et al, 2012).

Glass recycling and reuse

The objective of companies is to transform raw materials and energy extracted from the environment in order to produce goods and services for their consumers. Industrial metabolism must be directed so as to delay the return of this flow to the environment, by keeping raw materials circulating within the system and by means of reuse and recycling within a closed cycle (see figure 1), thus reducing the amount of extraction of natural resources (YUKSEL, 2007). Therefore, reverse logistics activities can reduce the amount of materials and waste, and in particular, the amount of toxic products disposed of in the environment (BRAGA JUNIOR et al., 2011). Water and raw materials circulate for a maximum amount of time before being disposed of, resulting in optimization in the use of natural resources.

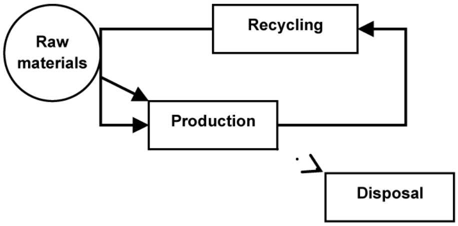

FIGURE 1- Closed Loop
Source: Adapted from Odum (1998)

Similarly, the aim of recycling activities and waste management of different materials (such as metal, glass, paper, plastic and tyres) is to preserve raw materials and save energy within the productive process, as almost all forms of energy production generate significant environmental impacts (HU; SHEU, 2013), and in this way, avoid potential toxic hazards which may be harmful to human life (CHEMEL *et al.* 2012 and HATAMI-MARBINI *et al.*, 2013).

The glass recycling process - which is the object of this study - involves the transformation of waste into small particles in order to make new products. Glass recycling mitigates the extraction of materials from the environment and their final disposal in landfill sites (BLENGINI *et al.*, 2012), resulting in lower costs and environmental gains. Glass residues are used as fill material (GOLARA *et al.*, 2012) and can be reused as glass packaging (KO et al., 2012). Other studies show that glass residues can be used together with polymers for creating new products, improving their mechanical properties (OSMANI, 2012).

Potential benefits of glass recycling include: (i) reducing the consumption of non-renewable natural resources (ii) using waste as a substitute for virgin raw materials, resulting in lower costs; (iii) reducing the size of the areas needed as landfill sites, given that waste can be reused as consumer goods (OSMANI, 2012); (iv) eco-efficient recycling in order to maximize resources and improve the value of waste glass post-use; (v) recycling process within a closed loop (BLENGINI *et al.*, 2012); (vi) economic and environmental benefits (OLIVEIRA NETO *et al.*, 2010).

However, establishing the infrastructure for glass recycling within the productive system requires investing in clean technologies, focusing on prevention. Additional technology is needed at the end of the normal processes so as to reduce toxic environmental emissions, without having to change existing equipment (MOORS *et al.*, 2005; KONG *et al.*, 2012).

Nonetheless, "sustainable levels of consumption" can vary according to the product which is being disposed of. Some products take longer to deteriorate, whilst others not only take longer to deteriorate but end up contaminating the soil. Appropriate treatment of the waste used in the production of new goods of the same category, or used for different purposes, contributes to the conscientious use of finite resources, reducing exploitation of the environment and producing positive results for companies (BRAGA JUNIOR; MERLO e NAGANO, 2008).

According to the PNRS, companies are responsible for the proper management of solid waste. Therefore, they need to provide the means to allow products and packaging to be returned, post-consumption, so that they can adopt appropriate processes and procedures to recover waste, causing the least amount of impact on the environment.

Solid waste, more specifically glass, because of its properties, can be recycled a number of times. It is also an impermeable material which does not often interact chemically with other substances and compounds (CALLISTER; RETHWISCH, 2008; BLENGINI *et al.* 2012; OSMANI, 2012). The properties of glass, together with reverse logistics provides companies with the opportunity for reducing costs, given that reusing glass cuts energy consumption, reducing the environmental impact by preventing the inappropriate disposal of products. In addition, a review of processes and products contributes to improving the image of companies.

Methodological Procedures

In order to check the objectives proposed by this work, a quantitative and qualitative exploratory study was carried out, using a single case study.

According to Yin (2010), the employment of a single case study is justified if it meets the conditions required to test the objectives proposed in the work, and if it is a contemporary and current event.

Moreover, Eisenhardt (1989) explains that a case study is a research strategy which focuses on understanding the dynamic processes of a particular scenario. It usually brings together different methods of data gathering such as documents, interviews, questionnaires and observations. Findings can be either qualitative, quantitative or both. Yin (2010) states that it is thus possible to create the appropriate conditions to understand, contest or confirm a particular theory and that it is a key element in exploratory studies.

As part of the quantitative study, documents from the following departments were collected: waste sorting and recycling, financial, production, and information systems.

In order to collect qualitative information, two techniques were employed: 1. Participant observation, in order to understand how the overall process of reverse logistics is carried out in the company and 2. Semi-structured interviews. These two techniques are used very frequently in qualitative research because they further knowledge through providing more information and can reveal aspects which are apparently concealed (Bogdan e Biklen, 1992).

Furthermore, during participant observations the researcher becomes part of the daily routine in which a particular phenomenon takes place and interacts with the agents of the process to understand how it occurs (MCCRACKEN, 1991). In this case, it was necessary to spend a few hours in the company so as to understand the glass delivery and recycling processes in detail and to devise the open questions for the interviews.

Participant observation indicated that there should be questions on the volume of glass and packaging recycled, processes, costs and profits. In view of this, interviews were conceived regarding the non-explicit aspects of the phenomenon under study (SEIDMAN, 1991).

First, interviews were arranged with the general manager of the company to ask for permission for direct and participant observation with regard to collecting both qualitative and quantitative data on reverse logistics. During this meeting the general manager allowed observation to take place two hours a day for three days in the departments studied. On the first day, the waste sorting and recycling department was observed; on the second, the purchasing department and finally, on the third day, the department of human resources.

On the first day of the research, an interview was conducted with the person in charge of the waste sorting and recycling department. The following company documents and indicators were analyzed: the destination and control of waste glass, the reuse of materials for packaging (wood, cardboard and steel cables) and losses in packaging for recycling. During this stage information was collected on the amount of waste glass, packaging and material for packaging which could be reused, as well as the volume of losses in packaging for recycling. All data was measured for monthly periods.

On the second day, based on the information obtained, the purchase manager was interviewed in order to assess the monetary value of amounts of material re-used and the value of losses. Participant observation enhanced the study because the purchasing department did not have analyses on the economic benefits of implementing reverse logistics. Therefore, the authors of the study were able to draw tables to illustrate and measure real data.

On the last day, the human resources manager was interviewed about staff numbers and their salaries and other staff costs. Based on this information, these data were added to the table so as to present the net revenue of the study.

Finally, numerical information regarding Economic Benefits (EcB) and Environmental Benefits (EnB) were analyzed in different ways: EcB were assessed in relation to the information present in the documents collected, looking at the monetary values of the process. Whereas EnB was calculated after the average monthly amount of recycled and re-used materials was established, using the Wuppertal method (2013), developed by the Wuppertal Institute. This method enables the assessment of environmental changes associated to the extraction of resources from their natural ecosystems. It suggests that environmental processes should be divided into four groups or compartments: abiotic, biotic, water and air.

There is interaction between the biotic and abiotic compartments. The biotic compartment is made up of all living organisms such as plants and decomposing organisms and the abiotic compartment is the set of non-living factors within an ecosystem which influence the biotic environment such as temperature, pressure, precipitation and geographical relief (ODUM, 1998).

The total amount of material of each compartment was calculated, providing data known as Material Intensity. In order to determine the Material Intensity, the mass input flow (expressed in corresponding units) is multiplied by the MIF factor (Mass Intensity Factor), corresponding to the amount of material needed to produce a unit of input flow. MIF values used in this work are shown in Table 1.

It is important to highlight that studies about material intensity developed by the Wuppertal Institute are based on the German, European or average world energy mixes.

However, this does not preclude the use of this methodological tool in Brazil, given that according to the Institute, the MIF values of many countries are very similar (WUPPERTAL, 2013).

Table 1 - Mass Intensity Factors by compartment used in this work

	Material Intensity Factors (MIF)			
Items	**Abiotic material**	**Biotic material**	**Water**	**Air**
Wood (g/g)[a]	0,86	5,51	10,0	0,129
Cardboard (g/g)[b]	1,86	0,75	93,6	0,325
Steel (g/g)[c]	9,32	----------------------	81,9	0,772
Glass (g/g)[d]	2,95	----------------------	11,6	0,743

[a] pine, data from Germany; [b] Cardboard, data from Europe; [c] Steel, world data; [d] Broken glass, data from Germany.

Source: Wuppertal (2013).

Finally, the study associated economic aspects to environmental aspects to show that it is possible to gain both economic and environmental benefits by implementing reverse logistics.

Data Presentation and Analysis

This section is divided into two parts: Part one (qualitative): describes the characteristics of the company, the reverse logistics process and technical specifications regarding glass recycling and reuse. Part two (quantitative) presents an assessment of the economic and environmental advantages of the reverse logistics process and of glass recycling and reuse.

Qualitative Analysis: Characteristics of the company

Data was collected in a glass multinational company supplying the Brazilian and the international market. The segment of the contracting company is textured glass. It produces sheets of glass which on average measure 1.70 x 2.20 x 3.8mm and weigh around 20 kg.

The company studied has a sorting department and sends waste to be recycled. Furthermore, appropriately glass waste is sent to the company's own productive system, in case of damage.

The packaging process was previously considered to generate large amounts of wastage as packaging materials are expensive and include wooden boxes, cardboard and steel bands to protect the product from damage during storage and loading/unloading from transport. The company has implemented reverse logistics in order to maximize the use of packaging materials. The reverse flow of glass damaged during transport loading and unloading and during building installation was mapped. Often, it is not possible to use damaged packaging material, as a result of negligence during handling, and these materials are sent to external recycling.

Glass reverse logistics process

The company studied has a department to sort and recycle waste glass which has been damaged during the internal logistics process, as shown in Figure 2 and described in detail further on. However, factors worth highlighting are the sorting and recycling department for waste glass, the crushing machine which has a device for recycling at the end of the process and the fact that reverse logistics is carried out by a Logistics Operator (OPL).

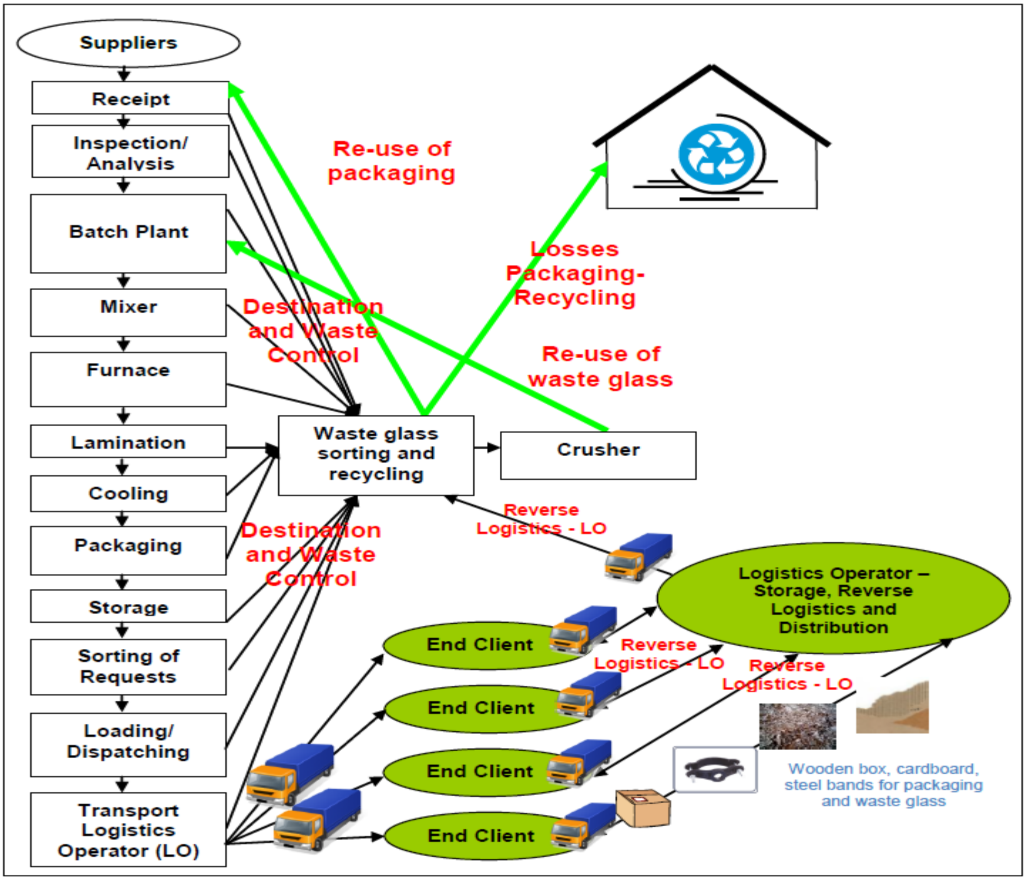

Figure 2 - Internal Logistics: Reuse, Recycling and reverse logistics

Source: Developed by the authors

The collection of material for reuse and recycling is divided into the following stages: receipt, sorting, recycling of waste glass, inspection, analysis, batch plant, mixer, furnace, lamination, cooling, packaging, storage of finished products, sorting of requests, loading and dispatching, transport and logistics operator, crusher.

a) *Receipt -* during this stage, materials are delivered by suppliers, including waste from crushed glass;

b) *Waste Glass Sorting and Recycling -* if damage occurs in the internal departments, glass is sent to this department for sorting. Externally, the OPL takes solid waste from clients because of damage during transport or storage, and sends it for sorting (reuse or recycling). The sorting department defines a sample and analyzes the impurities of the broken glass; if it is over 30%, the batch will initially fail the test until decontamination is carried out. Once the quality of the broken glass is ensured, it is sent for fusion. Another operation carried out in this department is the unitization of packaging (steel bands, wooden boxes covered in cardboard). Packaging which can be reused is sent to the receipt department. Packaging damaged during transport or through inappropriate storage and unpacking is sent to a recycling company;

c) *Inspection and analysis -* of components received prior to processing to assess the physical characteristics of the material;

d) *Batch plant -* it uses advanced technology, the operator follows in real time the operation of the level of raw materials to the furnace, precision sensors and conveyor belts, as well as levels of raw materials in the silos. In this department, there is urgent need for preventive maintenance, but if there are any abnormalities affecting the supply of raw materials to the furnace, the operator is able to identify this and ask for rectification;

e) *Mixer -* the process of bringing together all raw materials, so as to eliminate the likelihood of disproportionate amounts of supplies, for example, more broken glass than sand and vice-versa;

f) *Furnace -* this is a compartment with a capacity for up to 280 tonnes of raw materials, where the temperature can reach 1400ºC. There is continuous need for supplies during this process. Sensors control the levels of raw materials in the furnace which are automatically released if levels drop. Here glass is produced between two cylinders;

g) *Lamination -* the lamination process takes place as the glass leaves the machine, that is, it comes out as a paste between the two cylinders and the machine operators regulate the temperature and thickness of the glass (according to standards, via a control panel);

h) *Cooling -* after the lamination process, the glass is cooled by means of fans which are automatically adjusted according to the type of glass being produced;

i) *Packaging -* the packaging system can involve steel bands or end caps wooden boxes to protect the product. Bowersox (2006) provides further elucidation, he states that the main objective of packaging is to be able to move products with due protection without damage, avoiding wastage and making the operation more efficient;

j) *Storage of finished products -* it is important to be able to handle materials in the warehouse, this involves mainly two activities: receiving products from the packaging department and handling them for storage, this process involves moving products in the warehouse and sending them for sorting and storage;

k) *Sorting requests* - after issuing a request for a client the stock-keeper sorts products for dispatching;

l) *Loading and dispatching* - involves checking requests and loading vehicles; and

m) *Logistics Transport and Operator* - the Logistics Operator is the company contracted to handle the distribution process, reverse logistics and storage. During transport, the logistics operator delivers the products to clients and removes the packaging (steel bands and wooden box covered in cardboard) and the glass damaged during transport and storage; broken glass is also taken back from clients and stored. Thus, the transporting truck is always full; it picks up products for delivery, and takes away packaging and broken glass.

n) *Crusher* - a steel funnel fitted with grinding jaws. It is able to receive up to two tonnes of broken glass which is grounded and moved via a conveyor belt to a silo with a storage capacity of up to 80 tonnes.

During the interviews the respondents highlighted other aspects considered important to understand the company's reverse logistics programme:

a) The expected life of metal packaging is ten years, that of wood five years and cardboard one year;

b) The company only follows the life of the product to the level of business-to--business. It only does business with other glass companies;

There is no extra fuel cost for implementing reverse logistics. Negotiations with clients include the exchange of broken glass and the return of packaging after use. During negotiations the client sets a monthly date for packaging removal;

d) Invoices for glass and packaging are issued separately. Packaging is issued with an invoice which receives an Operations and Services Fiscal Code (CFOP) 5949 - for non-specified outputs. The invoice includes the amount of packaging and its pre-tax cost. The same invoice is used for the return of packaging, at no cost to the client;

e) Local delivery routes and their surrounding areas are managed and planned for new requests and for removing packaging and waste glass so as not to generate additional costs. Usually, deliveries are made to the centre of São Paulo or Greater São Paulo, facilitating the scheduling process.

Technical specifications of glass recycling and reuse in the productive process

Recycling is the recovery of the materials that make up waste, either for the same end use or for different end uses, it includes the need to consider recycling integrated to the productive system, thus avoiding reactivity (FURTADO, 2005; BLENGINI *et al.* 2012; GOLARA *et al.* 2012; KO *et al.* 2012; OSMANI, 2012).

The volume of broken pieces as part of the raw material cannot be higher than 35% of the total composition of glass. As the average total consumption for production is 4,630 tonnes/month, the total amount of broken glass cannot exceed 1,650 tonnes/month. If the glass manufacturing company were to reduce the cost of its products by reducing the amount of pure raw materials and increasing the volume of broken glass, the resulting product would present problems. In other words, the greater the amount of broken glass added to the productive process, the more fragile the final product, with an increased risk of breakages during storage, transport and reworking (cutting and refilling for use in glass outlets).

Quantitative Analysis: Assessment of the economic advantages in reusing packaging and recycling waste glass

The reverse logistics operation is subcontracted in order to be able to unitize the wooden packaging covered in cardboard and the steel bands that protect the product. This type of packaging generates a very large volume of waste which can be reused, bringing economic benefits to companies, particularly because the manufacturer can stop purchasing new materials, providing them with a real competitive edge.

Both the economic benefits resulting from the process of reusing waste glass and the economic benefits of the reverse logistics process relating to packaging (steel bands, wooden box covered in cardboard) were estimated.

It can be observed from Table 2 that, on a monthly average, the company reuses 1650 tonnes of waste glass, equivalent to R$ 412,500.00. However, there are some costs (Electricity consumed by the crusher - 925,000 kWh - equivalent to R$ 111,000.00 and an additional R$ 8,400.00 in staff costs). Therefore, the company makes average monthly gains of R$ 293,100.00 which is equivalent to 20.4% of the company's total monthly net revenue from manufacturing textured glass.

Table 2 - Economic benefits from the process of reusing waste glass - average monthly figures

Benefits of reusing waste glass				
Waste	Unit	Quantity	Unit Cost	Total Cost
Waste glass reused	Tonnes	1650	R$ 250,00	R$ 412.500,00
Electricity Costs (EC)				
Machine	Unit	Quantity	Unit Cost	Total Cost
Crusher, 5 CV Engine	KW	925000	R$ 0,12	R$ 111.000,00
Salary Costs (SC)				
Staff	Quantity	Unit cost + Additional costs		Total Cost
Leader	1	R$ 2.200,00		R$ 2.200,00
Fork-lift truck operator	2	R$ 1.600,00		R$ 3.200,00
Assistants	3	R$ 1.000,00		R$ 3.000,00
Total salary costs				R$ 8.400,00
Total costs (EC + SC)				R$ 119.400,00
Net revenue including the re-using process				R$ 293.100,00
Total company net revenue from manufacture of sheet glass				R$ 1.436.170,00
Company percentage share of revenue from manufacturing textured glass				20,4%

Source: data provided by the company.

Furthermore, the economic benefits from reverse logistics in packaging represent 17% of the net revenue, equivalent to R$ 255,088.00 (See Table 3). An aspect worthy of note is that packaging does not always arrive in reusable condition. Negligence occurs during transport and storage, resulting in damage. Damaged packaging is sent to a specialist recycling company. The economic impacts of this loss are not calculated, the manufacturer sends the packaging for recycling for free.

Therefore, the total reverse logistics process is equivalent to R$ 548,188.00 of the net revenue of the company studied, that is, 37.4% of its average total net revenue. Thus, it is possible to achieve better business results when reusing raw materials and practising reverse logistics.

Table 3 - Economic benefits from the process of reusing packaging - average monthly figures

Gains from reusable packaging				
Waste	Unit	Quantity	Unit Cost	Total Cost
Wooden box	Piece	2000	R$ 72,00	R$ 144.000,00
Cardboard	Piece	1572	R$ 18,00	R$ 28.296,00
Steel band	Piece	4918	R$ 22,00	R$ 108.196,00
Total Revenue				**R$ 280.492,00**
Loss from packaging, destined for recycling				
Waste	Unit	Quantity	Unit Cost	Total Cost
Wooden box	Piece	112	R$ 72,00	R$ 8.064,00
Cardboard	Piece	540	R$ 18,00	R$ 9.720,00
Steel band	Piece	10	R$ 22,00	R$ 220,00
Cost from packaging losses				**R$ 18.004,00**
Salary Costs				
Staff	Quantity	Unit cost + Additional costs		Total Cost
Leader	1	R$ 2.200,00		R$ 2.200,00
Fork-lift truck operator	2	R$ 1.600,00		R$ 3.200,00
Assistants	2	R$ 1.000,00		R$ 2.000,00
Total Staff Costs				R$ 7.400,00
Total Monthly Expenditure				R$ 25.404,00
Net revenue including packaging reuse				R$ 255.088,00
Total company net revenue from texture glass manufacturing				R$ 1.436.170,00
Company revenue from reuse in %				17%

Source: data provided by the company.

Assessing the environmental advantages of reuse, recycling and reverse logistics - Wuppertal analysis

Using the Wuppertal method to calculate the total amount of materials, all products which are not disposed of in the environment in a negligent manner are taken into account, including those which are reused and recycled, as this reduces environmental impact. The company provided information on the monthly average Mass of Material (MM) which was appropriately dealt with: 148 tonnes of wood, 39 tonnes of cardboard, 444 tonnes of steel and 1650 tonnes of waste glass. In order to determine the Material

Intensity, the mass input flow (expressed in corresponding units) is multiplied by the MIF factor (Mass Intensity Factor), corresponding to the amount of material needed to produce a unit of input flow. Using the reference values in Table 1, we multiply MM by MIF. Using the steel bands as an example, MIF is 9.32 x 444 tonnes (MM) = 4,138.08. The same principle was applied to calculate the other values.

Table 4 shows the Material Intensity Factors. Reuse and recycling add up to 9,205.40 tonnes of materials in the abiotic compartment. That is, it contributes to sustainability with regard to such events as global warming, the breakdown of the ozone layer and atmospheric pressure. These are directly associated to the biotic compartment, together representing 844.73 tonnes less pollution of vegetation, soil and decomposing organisms. Furthermore, an equivalent of 60,634 tonnes of pollutants was not released in water and 1,600.49 tonnes was not released in the air.

Table 4 - Environmental benefits of the packaging reuse process (in tonnes)

	Mass of Material X Material Intensity Factors			
Items	**Abiotic material**	**Biotic material**	**Water**	**Air**
Wood	127,28	815,48	1480	19,09
Cardboard	72,54	29,25	3650,4	12,68
Steel	4138,08	----------------------	36363,6	342,77
Glass	4867,5	----------------------	19140	1225,95
Total per compartment	**9205,40**	**844,73**	**60634**	**1600,49**

Source: Developed by the authors

Comparing economic benefits with environmental benefits

2,281 tonnes of materials were recovered (the sum of wood, cardboard, steel and waste glass), equivalent to 9,205.40 tonnes of material at the abiotic level; 844.73 tonnes at the biotic level; 60,634 tonnes in water and 1,600.49 tonnes in the atmosphere. The financial benefits of recovering 2,281 tonnes was R$548,188.00, equivalent to 37% of the net revenue of the company (RE).

Thus, the Saved Material through Reuse and Recycling/Gains from Reuse and Recycling (GRR) ratio can vary between 4.16 kg/R$, when considering just the materials recovered, and 131.86 kg/R$ when considering the Materials in all Compartments. In the first case, one Brazilian Real is saved with each 4.16kg of recycled or reused material used. When extrapolating this to the global scale, for each Brazilian Real saved, there is a benefit of 131,86kg of material which is not altered or removed from the environment.

Final considerations

The aim of this study was to assess the economic and environmental benefits of implementing reverse logistics in a Brazilian glass manufacturing company. Results show the economic viability of reverse logistics with regard to packaging (wood covered in cardboard and steel bands) and waste glass. Waste glass is 100% reused, whereas with regard to packaging, every month there are losses of around 15%, when packaging is sent to a recycling company with no additional revenue gains.

Results of recovering 2,281 tonnes (total sum of materials) correspond to 9,205.40 of material at the abiotic level, 844.73 at the biotic level, 60,634 tonnes of pollution in water and 1,600.49 tonnes of air pollution. The financial benefits of recovering 2,281 tonnes are R$548,188.00, equivalent to 37% of the company's net revenue. Therefore John's (2000) suppositions are confirmed with regards to gains and savings made through the reverse logistics process. The ratio calculated (Saved Material through Reuse and Recycling (SMRR)/Money Saved (ME)) can range from 4.16 kg, considering only materials recovered, to 131.86 kg, when considering Materials in All Compartments (MAC), that is, glass is 100% recycled. In the first case, each Brazilian Real saved is equivalent to 4.16 kg of material. When extrapolating this to the global scale, for each Brazilian Real, there is a benefit of 131,86kg of material which is not altered or removed from the environment.

Thus, the results corroborate with the findings of other studies (BRAGA JUNIOR, 2011; HERNANDEZ et al., 2013), which clearly indicate that reverse logistics activities should be part of the general strategic plans of companies, given that it can represent a competitive advantage (HERNANDEZ et al, 2012).

The findings of this exploratory study point to the viability and applicability of the Wuppertal method used to assess the environmental gains of glass recycling and the economic gains of implementing a reverse logistics programme. It may lead to new studies so as to assist companies in adopting this method.

Finally, it is suggested that the same methodology is applied to other glass companies so as to have an insight into the economic and environmental benefits of reverse logistics within this sector, using multiple case studies in order to compare results.

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AN ASSESSMENT OF THE ENVIRONMENTAL AND ECONOMIC BENEFITS OF IMPLEMENTING REVERSE LOGISTICS IN THE TEXTURED GLASS SECTOR

Abstract: This research aimed to evaluate the environmental and economic advantages of a reverse logistics process of printed glasses of a large company sector. The company implemented a reverse logistics for solid waste management packaging product protection, consisting of wooden boxes lined with cardboard collar steel and also reuse of broken glass. In this case study of exploratory origin, with data collection through interviews and participant observation, characterized as qualitative and quantitative, measured up the economic and environmental advantages of implementing reverse logistics. For the analysis of the environmental advantage we used the method Wuppertal. The results showed an environmental gain of 131.86 kg of material is not modified and removed from the environment and economic benefit of 37.4% of the average total net revenue from the reuse of packaging and reuse of broken glass.

Key words: Reverse Logistic, Solid Waste Management, Reuse, Recycling.

Resumo: Esta pesquisa teve como objetivo avaliar as vantagens ambientais e econômicas de um processo de Logística Reversa de vidros impressos de uma grande empresa do setor. A empresa implantou a Logística Reversa para a gestão de resíduos sólidos de embalagens de proteção do produto, que consistem em caixas de madeira revestidas de papelão com colar de aço e também, reuso de cacos de vidros. Nesse estudo de caso de origem exploratória, com coleta de dados por meio de entrevista e observação participante, caracterizado como qualitativo e quantitativo, mensurou-se a vantagem econômica e ambiental da implantação da Logística Reversa. Para a análise da vantagem ambiental utilizou-se o método *Wuppertal*. Os resultados mostraram um ganho ambiental de 131,86 kg de material que não é modificado e retirado do meio ambiente e vantagem econômica de 37,4% da sua receita líquida média total com a reutilização de embalagens e reuso dos cacos de vidro.

Palavras-chave: Logística Reversa, Gestão de Resíduos Sólidos, Reuso, Reciclagem.

Resumen: Esta investigación tuvo como objetivo evaluar las ventajas medioambientales y económicas de un proceso de logística inversa de los vidrios impresos de un gran sector de la sociedad. La compañía implementó una logística inversa para la gestión de la protección del producto envasado de residuos sólidos, que consiste en cajas de madera forradas de acero collar de cartón y también la reutilización de los cristales rotos. En este estudio de caso exploratorio de origen, con la recolección de datos a través de entrevistas y observación participante, caracterizada como cualitativa y cuantitativa, a la altura de las ventajas económicas y ambientales de la aplicación de la logística inversa. Para el análisis de la ventaja ambiental se utilizó el método de Wuppertal. Los resultados mostraron un beneficio ambiental de 131,86 kg de material no se modifica y se retira del medio ambiente y el beneficio económico de 37.4% de los ingresos netos promedio total de la reutilización de los envases y la reutilización de los cristales rotos.

Palabras clave: Logística Inversa, Gestión de Desechos Sólidos, Reutilizar, Reciclar.