ONE AND TWO WAY PACKAGING IN THE DAIRY SECTOR

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Abstract	Choosing packaging material for dairy products and soft drinks is an interesting issue at the moment. Discussions arise on the costs impacts and environmental impacts of both one way packaging and reusable packaging. The aim of this article is to develop an evaluation tool providing costs and environmental impacts of the PC-bottle and the GT-packs in the dairy sector, considering forward and return flows. The evaluation tool enables the user to analyse the costs and environmental impacts of a supply chain with and without return flows using scenario analyses with respect to the use of various carrier types and the number of return loops. It appears that costs differences between PC-bottles and GT-pack are quite small. The PC bottle has a better environmental profile than the GT-pack. Scenario analysis on the carriers results in the advice to use preferably roll-in-containers with direct delivery, secondly roll-in-containers with delivery via distribution centers, thirdly in case of direct delivery either cartons or crates and cartons in case of delivery via distribution centers.	
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One and Two Way Packaging in the Dairy Sector

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Abstract. Choosing packaging material for dairy products and soft drinks is an interesting issue at the moment. Discussions arise on the costs impacts and environmental impacts of both one way packaging and reusable packaging. The aim of this article is to develop an evaluation tool providing costs and environmental impacts of the PC-bottle and the GT-packs in the dairy sector, considering forward and return flows. The evaluation tool enables the user to analyse the costs and environmental impacts of a supply chain with and without return flows using scenario analyses with respect to the use of various carrier types and the number of return loops. It appears that costs differences between PC-bottles and GT-pack are quite small. The PC bottle has a better environmental profile than the GT-pack. Scenario analysis on the carriers results in the advice to use preferably roll-in-containers with direct delivery, secondly roll-in-containers with delivery via distribution centers, thirdly in case of direct delivery either cartons or crates and cartons in case of delivery via distribution centers.

Keywords: reverse logistics, life cycle assessment, environment, pricing, supply chain management

1 Introduction

This paper focuses on the one way and two way packaging of products in the dairy sector[1]. In 1994 EU regulation on packaging enhanced producers to reduce the amount of packaging waste of various branches of industry (EU 94/62/EC, 1994). Targets of 50-65% of packaging waste stream recovered or recycled should be achieved by the year 2001. Based on this regulation Dutch industry agreed in 1997 (www.minvrom.nl) to target for 65% of packaging material either reused or recycled. New one way packaging material can only be introduced if its

[1] This work is part of research carried out recently at the Logistics Center of Expertise of Campina Melkunie B.V.

environmental impact is less than the impact of comparable reusable packaging material.

Campina Melkunie produces fresh milk both in one way packs and reusable bottles. Given the growing interest in the impact of reusable packaging material on economical and environmental performance, Campina Melkunie wants to gain more insights into the costs and environmental impacts of the supply chain of fresh milk. The problem description is as follows:

What should be the role of returnable bottles and carriers in Milk Distribution of Campina?

Looking at decision support models available in the literature, we see on the one hand cost models (e.g. Krikke et al., 1999) and on the other hand environmental (Life Cycle Assessment or analogous) models like (Mekel and Huppes, 1990). The aim of this paper is to describe an evaluation tool that provides the user with cost impacts and environmental impacts of the forward and return flow of a supply chain. The evaluation tool can be used for various scenarios e.g.

- What is the effect of the number of reuse loops on the costs and environmental impacts of reusable packaging material
- What type of carriers is suitable for either one way or reusable packaging material.

Bloemhof et al. (1995) describe a methodology to use environmental information within the decision process of a product mix problem. Using an environmental index it is possible to compare cost-friendly product mixes with environmental friendly mixes with respect to costs and environmental impacts. Bloemhof et al. (1996) attempt to combine life cycle analysis with logistic optimisation while optimising the design of a production network for the pulp and paper industry. Life cycle assessment is used to obtain an environmental performance indicator for each process. These indicators are used in a network flow model to find optimal designs of the pulp and paper network with the lowest environmental impacts. Based on these methodologies the CAMP evaluation tool has been developed. It contains an Activitity Based Costing model combined with a Life Cycle Analysis Tool.

Section 2 describes the company Campina Melkunie. Campina Melkunie produces about 32 brands of milk, cheese, butter, and yoghurts for direct consumer use and industrial products as protein products and lactose products. The sales area contains over 100 countries. Section 3 describes the supply chains for the PC bottle and the GT pack in more detail. In Section 4 we present the evaluation tool CAMP (Choice of Alternative Material Packaging). The CAMP tool is developed to analyse the costs and environmental impacts of the forward and reverse chain of the packaging material of fresh milk. Section 5 deals with sensitivity analysisis and scenario analysis and Section 6 provides our conclusions.

2 Campina Melkunie

Campina Melkunie is an international cooperation aiming at the development, production, sales and distribution of dairy consumer products and ingredients for the pharmaceutical industries. Apart from fresh milk, also cheese and yoghurts are produced with international brand names like Yogho Yogho, Vifit, Yazoo, Joyvalle, Passendale, Milner, Monchou, Tuffi and Landliebe. Industrial products are sold under the brand names Esprion and Excellion (protein products), Pharmatose (lactose product) and Emser (ingredients).

Campina Melkunie is a cooperation with about 8500 farmers associated. The turnover is 8 billion Euros. The market for Campina contains about 100 countries with a large domestic part in the Netherlands, Germany and Belgium (see Figure 1).

The research focuses on Campina Netherlands, which is a subdivision of Campina Melkunie, mainly producing fresh milk. Production units are in Eindhoven, Hilversum, Maasdam, Rotterdam and Heiloo. These production units also have a distribution center for the delivery of products to buyers in the region. A distribution network between the production units guarantees a full assortment of products in each region. The same networks are used for the collection of reusable packaging material and cargo carriers.

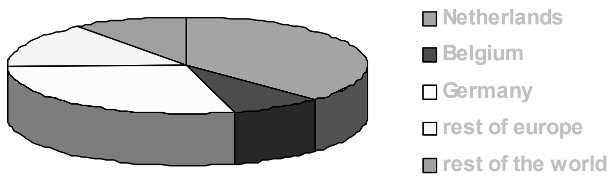

Figure 1. Spread of Turnover

The mission statement of Campina Melkunie is to add value to milk by (i) being entrepreneurial, (ii) making difference in the chain, (iii) focussing on consumer needs and (iv) caring for people, which results in *"a natural caring for the sustainable values of our nature with an environmental responsibility"*.

3 Fresh milk supply chains

Currently Campina uses both one way and two way packaging for their dairy products. Apart from the traditional package, the Gable Top `GT-pack`, a reuseable plastic bottle, the Polycarbonate `PC bottle` is used. The PC bottle returns after use whereas the GT pack is disposed of after use. Data considering the costs and the environmental impacts of both the forward chain and the return chain of the bottles can be used to compose a `cheap and green` strategy in the milk distribution.

Besides direct packaging of the milk in bottles Campina uses crates, boxes, crate containers, pallets and roll-in-containers (RICs) for handling and transportation, Except for boxes, all carriers will be returned to Campina for reuse. Campina can choose between different types of carriers, each with accompanying costs and environmental impacts. Next section gives a description of the primary packaging systems whereas Section 3.2 describes the cargo carriers. Section 3.3 focuses on the logistical processes of a PC bottle and Section 3.4 specifically on the return processes in the fresh milk supply chain.

3.1 Bottles

The Gable Top (GT) is a traditional cardboard box used for fresh milk, yogurts, buttermilk and custards. After use, GT ends up in domestic waste. The supply chain of the GT-pack can be described as follows (see Figure 2). Campina buys the packages from suppliers nearby. At the production locations the packs are filled with milk and stapled in crates, boxes or RICs. The crates and boxes are transported on pallets or crate containers to retailers. At the retailer the packs are sold to the consumer and the carriers are returned to Campina. After use the pack ends up as domestic waste. The cardboard box can be recycled or used for energy recovery by incineration.

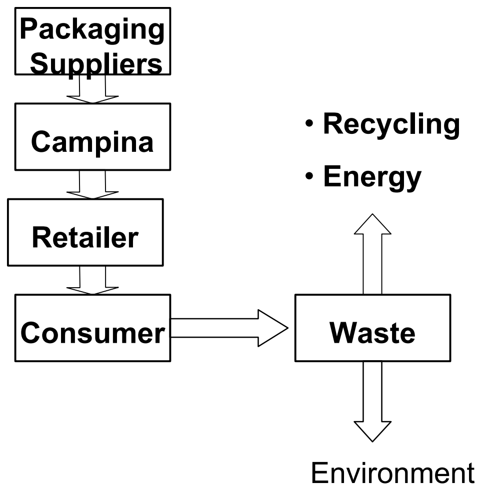

Figure 2: Supply chain of the GT pack

In 1996, the one-litre Poly Carbonate (PC) bottle was introduced, which is lightweight, recloseable and reusable. At the moment a relatively small amount of the milk is sold in PC bottles. Campina cleans all returned bottles before refillment and redistribution. A deposit system of one Dutch guilder for a bottle has to prevent bottles ending up in domestic waste. Campina sells refused bottles to the synthetic industry for recycling in dashboards of cars. In practice, a bottle can be used about 27 times before failing the inspection.

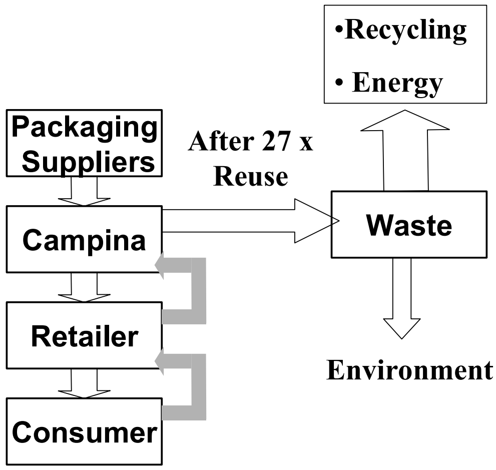

Figure 3. Supply chain of the PC bottle

Most of the milk is filled up in either a GT pack or a PC bottle. Different packageing forms have also been developed. School milk is packed in small cardboard boxes. Campina collects weekly used packaging at the schools. Collected packaging will be recycled and used for toilet paper and tissues. Fresh milk in a PET bottle is a new product and sold in a 33 cl. format at e.g. fuel stations. The PET bottle is lightweight and reclosable, very suitable for take-away purposes. It is a one-way packaging material that ends up in domestic waste.

3.2 Carriers

Campina Melkunie uses crates, boxes, crate containers, RICs and pallets for handling and transportation. Except for the boxes all cargo carriers must be returned to Campina for reuse.

A *crate* consist of synthetic material. It can hold 20 one-litre GT or PC bottles. Crates can be stacked up on pallets or crate containers. After use the crate will be returned to Campina and reused after testing and cleaning. A drawback of crates is the fact that they use as much space filled on the outward journey as empty on the way back, causing relatively high transportation costs as well as sorting and handling costs of empty crates. Crates have a rather long lifetime and can be recycled afterwards to granulate for new crates.

B*oxes* contain six to twelve one-litre GT packs or PC bottles and are used for some DC-customers. A box can be stacked up on pallets or crate containers. PC bottles can be stacked to a higher level than GT packs. After receiving and unpacking, the retailer collects the cardboard for recycling purposes.

A *crate container* is a multiple purpose carrier on wheels, used for direct deliveries of crates. Obviously, the crate container cannot be nested as it contains crates.

A *pallet* is mainly used to deliver crates or boxes to distribution centers. Empty pallets can be stapled easily so it requires less space at the return part of the supply chain. In most logistic chains pallets have been standardized to maximise logistical efficiency at both the suppliers and the buyers (the so-called EURO pallets). For fresh milk products Campina uses a return cycle with specific Melkunie pallets.

A Roll in Container is a moveable carrier that is automatically filled with 160 one-litre packs in the production locations of Campina and used as shelf at the retail shops. Using a RIC makes boxes or crates superfluous saving enormous handling costs and time. Its product-homogenity and a high use of shelfspace are drawbacks of a RIC.

3.3 Supply chain of a PC bottle

In order to make comparisons of packages and carriers based on costs and environmental impacts a complete description of the fresh milk supply chain is necessary. In Figure 4 we draw a distinction between the forward and the return part of the chain. Figure 4 focuses especially on the logistical process of a PC bottle since the supply chain of the GT bottle has no return part.

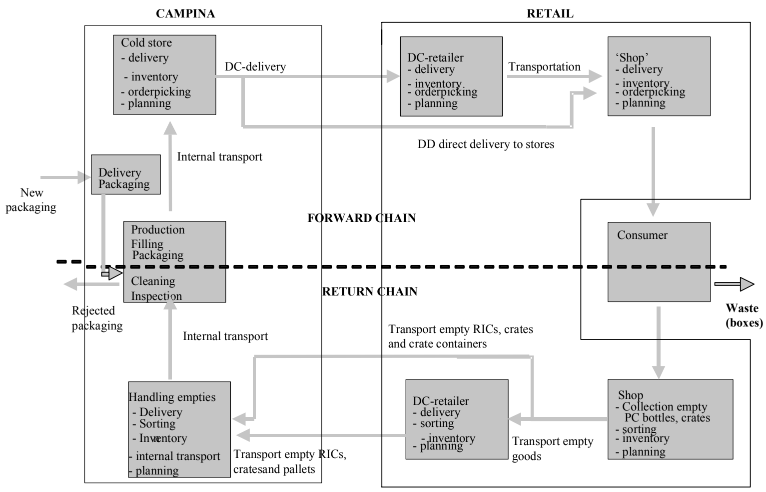

Figure 4. The logistical process of a PC bottle

Campina deliveres filled PC bottles to distribution centers (DC) and directly to shops (DD). In the return part of the chain the empty bottles are also collected in crates, using pallets (DC) and crate containers (DD). This reverse process causes a lot of handling and transportion. On average a PC bottle can be reused about 27 times. A *return loop* starts and ends at the process of filling the bottles with milk. After end-of-use the bottle is sold to the synthetic industry for recycling purposes.

In order to satisfy market demand, it is important for each plant location to have enough empty bottles, crates, pallets and crate containers available. It is difficult to forecast the amount of empty packaging and cargo carriers since the empty bottles are often not returned to the original plant. If the inventory of emply bottles is not high enough, new PC bottles have to be bought by Campina. The necessary amount of external supply depends on the inventory of empty bottles, the historical and forecasted supply of filled PC bottles, the average duration and variation of a return loop and the forecasted return rate and failure rate of empty PC bottles. Both new and returned bottles have to be cleaned.

3.4 The process flow of a returned bottle

The return process of a PC bottle starts when the consumer returns the empty bottle at the retailer. Retailers return crates with empty bottles directly to a Campina production location or via a distribution centre of the retailer following the „full for empty“ rule.

At the production location the process flow of the returned bottles is as follows (Figure 5).

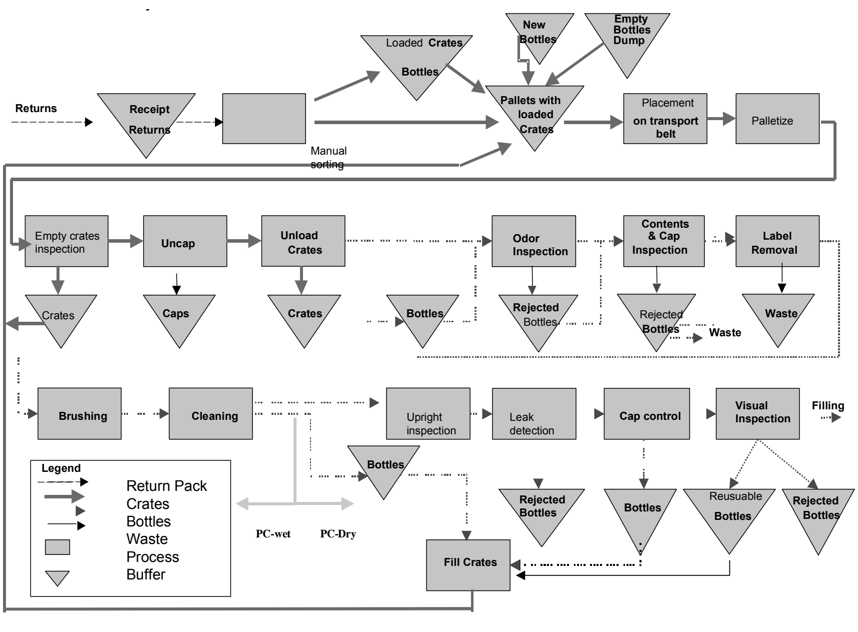

Figure 5. Process flow of empty PC bottle

After delivery the returned bottles are sorted by hand. Crates full with empty bottles are stapled on pallets and collected at the start of the PC-assembly line. The bottles are uncapped and the caps are collected for external recycling. Then the bottles are put one by one at the assembly line. First the odor check is carried out (is the bottle a milk bottle or not). Then the emptiness control takes place (is the bottle empty) followed by the cap control (is the cap removed succesfully). Next phase is the cleaning phase consisting of removing the labels, brushing the inner side of the bottle and rinse the bottle completely. This process takes about 20 minutes per bottle. After the rinsing process a leackage check is followed by a visual inspection. If the bottle endures the inspection it can be refilled.

4 CAMP

The evaluation tool Choice of Alternative Material Packaging (CAMP) is developed to compare one way and returnable bottles and carriers based on costs and environmental impacts (Kraal, 2000). CAMP is based on the following assumptions:

- All PC bottles contain low fat milk.
- The production and sales quantity of PC bottles and GT packs are the same (in order to compare costs and environmental impacts).
- The PC bottle has on average 27 return loops before end of lifetime.
- Full truck load for delivery of new bottles, caps and labels.
- If a PC bottle is not returned it ends up in domestic waste.
- About 10% of the returned bottles has no cap. These caps are part of domestic waste.
- Incineration of domestic waste takes place in a closed installation.

Table 1 illustrates the various steps in the CAMP tool. Both the cost part and the environmental part consist of three steps. First step is the inventory of the processes and activities within the supply chain. Next step is the determination of the relevant cost drivers and environmental issues. Thirdly, costs and environmental effects are assigned to products. The result is either a cost component or an environmental impact for both the PC bottle and the GT pack.

Table 1. The CAMP evaluation tool

Choice of Alternative Material Packaging	
ABC	LCA
1. Inventory of activities 2. Determination of cost drivers 3. Assignment of cost to products	1. Inventory environmental impacts 2. Determination of relevant environmental problems 3. Assignment weights to problems
COST COMPONENTS	*ENVIRONMENTAL IMPACT*

4.1 Costs of packaging

The cost part of CAMP is based on Activity Based Costing (Cooper and Kaplan, 1988). The ABC method is used in a dynamic environemnt with bad predictable demand, short product lifecycles and a broad assortment. The method is based on finding the activities that cause the costs and describe the way they are linked with a product. The ABC method consists of the following steps:

- Inventory of the important activities

- Determine the cost drivers for each activity
- Assign costs of activities to products.

The PC bottle goes through a forward chain and a reverse chain. The GT-pack only has a forward chain but the crates, crate containers and pallets used for the transportation of GT-packs do have a reverse chain.

The total costs can be divided into three cost components:

- Costs of the packaging material itself: These costs including purchasing costs of bottles, labels, caps and glue, transportation costs of the material and a negative cost component of deposit fees;
- Internal costs of the forward chain: These costs include the costs of the filling process, packaging, internal distribution, salaries, energy, distribution from production location to distribution center, distribution from distribution center (DC) to retailer and the activities at the DCs and the retailers.
- Costs of the reverse chain: These costs are both external (activities at the retailer and the DCs, distribution from retailer to DCs and from DCs to Campinas production location and the transportation of waste) and internal (fixed costs for the PC reassembly line, internal distribution, salaries, energy and packaging material).

Table 2 shows the results of the integral cost comparison between PC and GT bottles assuming direct delivery to retail stores with crates on crate containers as carriers.

Table 2: Cost components as percentage of the consumer price (direct delivery)

	PC	GT
Consumer price	1,59	1,25
Packaging	8%	21%
Forward chain	68%	71%
Reverse chain	24%	8%

The difference in costs between one way and returnable packaging systems appears to be limited. The PC bottle has higher costs in the reverse flow but these costs are compensated by low material costs per unit as the bottle can be used about 27 times.

4.2 Environmental Aspects

The environmental impact of the use of one way bottles or reuseable bottles is determined by a Life Cycle Analysis (LCA). According to SETAC (1993) *Life cycle assessment (LCA) aims to evaluate the environmental burdens associated with a product, process or activity by identifying and quantifying energy and material used and wastes released to the environment; to assess the impact of energy and material used and wastes released to the environment and to identify and evaluate opportunities to affect environmental improvements.* LCA can be defined as an input-output analysis of resources or materials and energy requirements in each phase of the life cycle of a product. Usually it is composed of four parts:

- The definition of the scope and the boundaries of the study.
- The inventory quantifying the necessary data in an objective and consistent way using an input-output database.
- The impact assessment classifying the inventory results by environmental indices and their valuation concerning the environmental impact.
- The improvement assessment focussing on the reduction of environmental impacts associated with the system under study.

With the inventory one can identify opportunities for reducing material use, energy requirements or emissions. The impact assessment helps to become aware of the different types of environmental impacts whereas the improvement assessment aims especially in identifying potential reduction strategies. Figure 6 represents the process tree of PC bottles and GT bottles.

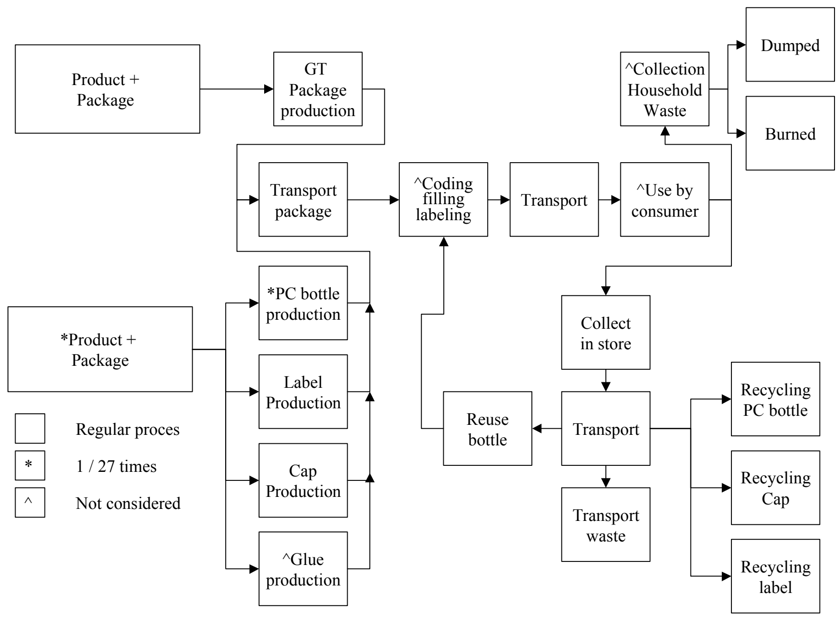

Figure 6. Process Tree

Assumptions for the environmental part of CAMP are:

- Filling, coding, labelling and using either a PC bottle or a GT bottle makes no difference in environmental impact.
- Domestic waste will be disposed of for 10% and incinerated for 90%.

For each process an ecobalance is made, based on research from Mekel and Huppes (1990). Updating to 1999 has taken place where necessary. The ecobalances are classified based on the contribution to the various environmental problems, resulting in an environmental profile (Table 3).

Table 3. The environmental profile of PC and GT bottles

(in kg/year)	PC bottle	GT bottle
Greenhouse effect	-175	-572
Smog	1.44	2.43
Acidification	7.43	33.5
Nutrification	1.44	2.03
Human Toxicity	11.37	20.85

After normalisation the environmental impact of a PC bottle can be compared to a GT bottle as follows (Table 4)

Table 4. Relative environmental impact of PC and GT bottles

	PC bottle	GT bottle
Greenhouse effect	-1	-3.18
Smog	1	1.69
Acidification	1	4.52
Nutrification	1	1.40
Human Toxicity	1	2.00
Environmental Impact	1	2.82

The Life Cycle Analysis shows that the GT bottle has about three times higher contribution to the environment than the PC bottle.

5 Sensitivity analysis

The previous sections gave some insight in the costs and environmental aspects of one way and reusable packaging materials in the dairy sector. In order to draw conclusions, it is very important to investigate the sensitivity of the results if some of the input variables change. We give an account of four scenarios.

- Fixed costs at the production location differ with up to 25%. The results of the CAMP model change between 5-7 %, being not decisive.
- Costs of activities in the distribution centre differ with up to 25%. Again results differ with less than 6%.
- Energy use for cleaning PC bottles differs with up to 25%. Environmental impact differs with about 5%.
- Energy use for the production of PC bottles differs with up to 25%. Results of the model change with less than 1%.

Furthermore we carried out sensitivity analysis on *(i)* the number of return loops and *(ii)* the type of carriers.

(i) Changing the assumed number of return loops has a large influence on the purchase costs of PC bottles. If the number of return loops increases, the purchase costs per bottle decrease as well as the costs of buying new bottles. The CAMP model gives the following results: costs of the PC bottle decrease with an

increasing number of return loops whereas the environmental impact of the PC bottle slightly increases.
(ii) If the PC bottles and GT packs are stapled in boxes instead of crates, this has the opportunity to get around deposit fee issues. Possible drawbacks are an increased amount of waste and less space in the DC.
Using the RIC instead of crates gives considerable cost savings due to less activities at the retailer and the external distribution. The environmental impacts of RIC and crates in crate containers are about the same. If the PC bottle is transported in RIC, crates are still necessary for returning the PC bottle to Campina.

6 Conclusions

Comparing the costs of the PC bottle and the GT pack in crates gives the following results. Costs for the forward chain are almost the same for PC bottles and GT packs. The return chain for PC bottles is more expensive than for GT packs which is rather obvious. However, the total cost difference based on equal quantities is only limited. The PC bottle has a significantly better impact to the environment than the GT pack.

Given the results of this research the following recommendations hold;

- Increase the sales volume of PC bottles.
- Use a RIC for large volumes of PC bottles and GT packs.
- In case of direct delivery (DD) crates and boxes are equaally attractive.
- In case of delivery via distribution centres (DC) boxes are preferred above crates. Crates however are still necessary for the return chain.

References

Bloemhof-Ruwaard, J.M., Koudijs, H.G., and Vis, J.C. (1995) Environmental impacts of fat blends: a methodological study combining life cycle analysis, miltiple criteria decision making and linear programming, *Environmental and Resource Economics* 6:371-387.

Bloemhof-Ruwaard, J.M., Van Wassenhove, L.N., Gabel, H.L., and Weaver, P.M. (1996), An environmental life cycle optimization model for the european pulp and paper industry, *Omega, International Journal of Management Science* 24:615-629.

Cooper, R. / Kaplan, R.S. (1988): Measure costs right: make the right decisions. *Harvard Business Review* sept/oct: 96-103.

Ellram, L.M. (1991): Supply chain management: the industrial organisation perspective, *International journal of physical distribution and logistics management* 32(1): 13-22.

EU 94/62/EC (1994) European Parliament and Council Directive of 20 December 1994 on packaging and packaging waste, *Official Journal L365*, 31-12-1994:0010-0023.

Horngren, C.T. / Foster, G. / Datar, S.M. (1996) *Cost Accounting*, London: Prentice-Hall International.

Kraal, A. (2000) ***PAK (e)en FLES,*** master thesis Faculty of Business Administration, Erasmus University Rotterdam.

Krikke, H.R., Van Harten, A., and Schuur, P.C. (1999), Business case Oce: reverse logistic network re-design for copiers, *OR Spektrum* 21-3:381-409.

Kroon, L. / Vrijens, G. (1995) Returnable containers: an example of reverse logistics. *International journal of physical distribution and logistics management* 25(2): 56-68.

Mekel, O.C.L., Huppes, G. (1990) Environmental effects of different package systems for fresh milk, Leiden, Center of Environmental Studies.

SETAC (1993) Guidelines for life-cycle assessment – a code of practice, Brussels.

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