Product Return Handling: decision-making and quantitative support

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Product Return Handling:
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Abstract:

In this article we focus on product return handling and warehousing issues. In some businesses return rates can be well over 20% and returns can be especially costly when not handled properly. In spite of this, many managers have handled returns extemporarily. The fact that quantitative methods barely exist to support return handling decisions adds to this. In this article we bridge those issues by 1) going over the key decisions related with return handling; 2) identifying quantitative models to support those decisions. Furthermore, we provide insights on directions for future research.

Keywords: Reverse Logistics, decision-making, quantitative models, retailing and warehousing.

1. Introduction

According to the Material Handling Industry of America, *material handling* is the movement, storage, control and protection of material, goods and products throughout the process of manufacturing, warehousing, consumption and disposal. The focus is on the methods, mechanical equipments, systems and related controls used to achieve these functions, usually internal, within the company (see, for example, Tompkins et al, 1996). In this article we focus primarily on warehousing activities. According to research of ELA (1999), 7.7% of the revenues of the 500 interviewed European companies consists of logistics costs, of which 2% is in warehousing and 3.1% is in transport (1.2% administration and 1.4% inventory costs).

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Return handling is even more costly. In some businesses return rates can be over 20% (for example fashion, mail order) and returns can be especially costly when not handled properly (see Meyer, 1999 and Morphy, 2001). The Reverse Logistics Executive Council has announced that U.S. firms bear losses of the order of billions of dollars on account of return handling (see Rogers and Tibben-Lembke, 1999).

In spite of aforementioned numbers, many managers have disregarded product returns or they handle returns extemporarily (see Meyer, 1999). The fact that quantitative methods barely exist to support return handling decisions adds to this. In this Article we bridge those issues by 1) going over the key decisions related with return handling; 2) identifying quantitative models to support those decisions. Due to the lack of quantitative methods dedicated to return handling, we sometimes depart from existent quantitative models for material handling in general. We review the main findings and remark how such models could be adjusted to support return handling. In these ways we are able to provide insights on directions for future research.

The remainder of the article is organized as follows. Next, we clarify the operations involved with return handling. After that we provide an illustrative example. Subsequently, we consider the decisions to be taken when return handling is at stake. After that, we review the existent models for warehousing and material handling and we identify promising research matters within the topic. We finish with overall conclusions.

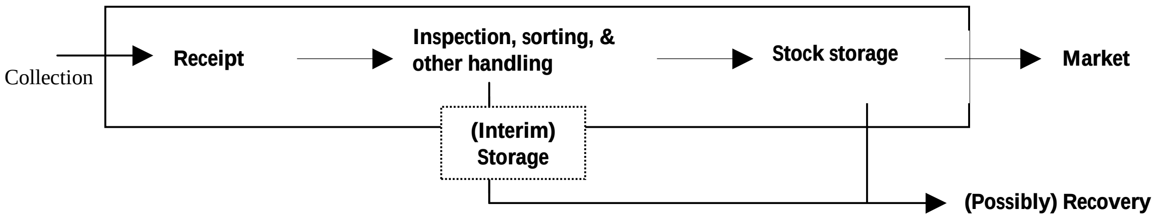
2. Return handling

Different actors in the supply chain face different return flow types (see De Brito and Dekker, 2002). Independent of the return flow type, the following warehousing processes can be distinguished (see Figure 1):

- Receiving;
- Inspection & sorting;
- (Interim/Stock) Storage;
- Internal transport.

Operations' details may differ per return type. For instance products that come back in as-good-as-new state can be restocked to be sold again, while end-of-life products may only need interim storage until they are sold to a third party recycler. Further references to this appear throughout the article.

Figure 1 Return handling in the warehouse.



Material handling is among the most recent research issues within RL, which is a relatively new topic as a whole. Therefore, material handling aspects (e.g. handling, storage) have not been dealt with in great detail. Yet, the coercion of re-use and recycling quotas in Europe (see EUROPA, online) has served as impetus for specific research on subsequent consequences for return handling. For instance, Anderson et al. (1999) have investigated how firms are coping with EU legislation for packaging recovery and Fernie and Hart (2001) have considered the required assets to carry out the European packaging regulations. Very recently, De Koster et al. (2002) discussed in detail retail operations when a diversity of reverse flows are present. In this exploratory study, the handling of product and material returns of nine retailer warehouses are compared. In particular, receipt and storage of returns are analyzed. Furthermore, the aforementioned paper identifies bothersome aspects and slackening procedures for return handling. We come back to specific findings throughout the article.

3. Return Handling: an illustrative case

In this section, we present the Wehkamp case, one of the largest mail order (business-to-consumer) companies in the Netherlands. Wehkamp has about 3.5 million customers, of which 1.5 million order per year about 6 million orders (daily average about 24,000 orders), with on average 1.8 lines per order. The assortment consists mainly of fashion and hardware, in total about 50,000 articles. Sales vary greatly over the days of the week, but also particularly over the season. There are two selling seasons of 26 weeks per year, with different assortments. Sales are largest in the first weeks of the season, after a new catalogue has appeared. Customers are supplied from three warehouses, one for hanging and boxed fashion and small appliances, a warehouse for dry groceries and one for furniture and large appliances. The dry groceries flow is fully integrated with the flow of boxed fashion and small appliances. Return rates in mail order business are large; for Wehkamp they vary from a few percent (mainly warranty returns, for furniture and large appliances) to 15% for small appliances to on average 40% for fashion. The reasons of these returns are, besides warranty returns, partially legislation (it is allowed to return products at no cost within 10 days after the purchase), but accepting returns at no cost to the customer is also seen as an important service element. Telephone operators sometimes stimulate customers to buy more fashion products than they really need, thereby creating a sure return. However, as return transportation and handling costs are free to the customer (this also holds for the delivery cost, unless the customer buys at least one item), this may still lead to lower cost for Wehkamp as compared with the customer placing multiple orders for one unit of which only the last product is bought. Charging a return fee would of course reduce the number of returns, but it would probably reduce the net sales as well.

The home delivery of customer orders is outsourced to a Third Party Logistics Provider (3PL) with a very dense network. Orders are delivered within 24 hours. The 3PL makes use of a hub-and-spoke network to achieve this. When a customer wants to return an item, Wehkamp informs the 3PL, who schedules the pick-up in a route carried out in the area of the customer. If there are no such routes yet, the pick-up is delayed, or the customer can decide to bring it to a close post office himself. In many occasions, pick-ups are within 24 hours, within a time window agreed with the customer. Pick-ups go again via the two sorting centers back with large trucks to Wehkamp. The same trucks are used for pick-ups of the new orders at Wehkamp’s warehouse, thereby achieving efficient use of the trucks and vans in all stages of the network.

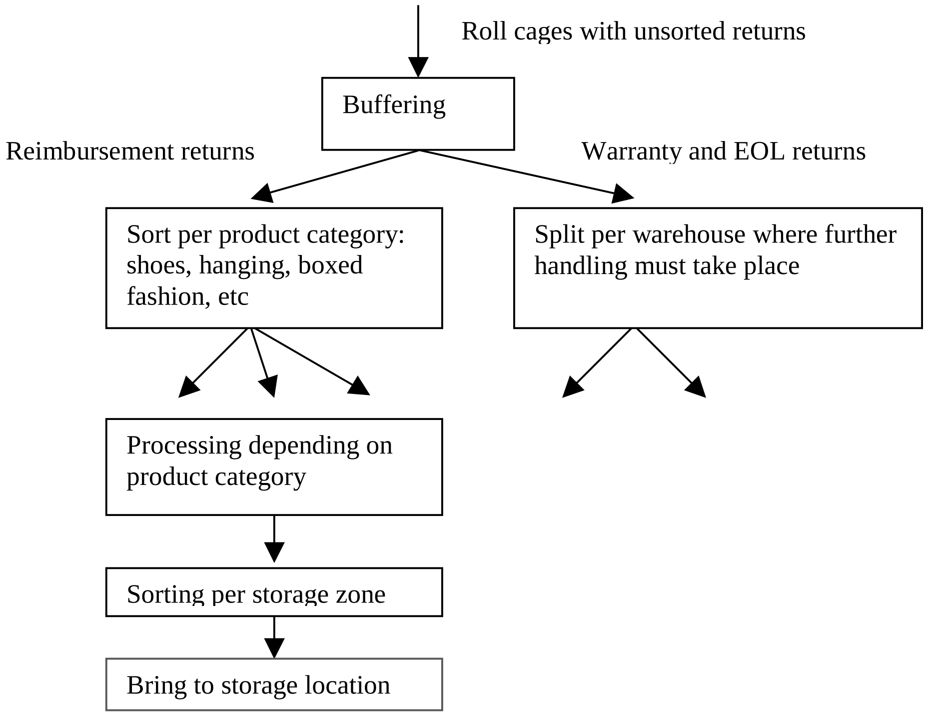
In the further description we focus on the following elements: the receipt of commercial (reimbursement) returns, handling and storage of the returns in the warehouse of fashion and small appliances (where the majority of the stock keeping units is stored). We consider those aspects of reverse flows in relation to forward flows. The average return percentage in this facility is 28%, which corresponds to about 10,000 returns every day.

Return receipt, inspection and sorting

Returned items are handled in a large separate area (separated from the receiving area of purchased goods). About 25 people per shift (three shifts) sort and recondition the products. The receiving and handling process is illustrated in Figure 2.

Unsorted returns are received in roll cages and buffered, after which they are first presorted per product category (shoes, media, boxed fashion etc.) People working in small teams process returns per product category: they unpack the fashion products, check them for stains, recondition (for example iron or steam) the product, grade and repack it. After this, products are generally graded as 'new quality' and fit for sale at the original price. The receipt is confirmed in the information system, where it is decided whether the client should be credited or not (based on whether or not it is allowed to return the product – e.g. unsealed cds may not be returned, the condition of the product, payments made, and date of original purchase). The products are labeled, with a label that can be used to trace the number of returns of this particular item, so that items can be monitored individually. Returned items are sorted per storage zone and put in rolling bins, which are regularly brought to the storage area.

Figure 2: Flow scheme of receiving and handling returns in the fashion and small appliance warehouse.



Storage

Bins with returned items are regularly picked up and distributed over the forward pick locations. This is done in a route, visiting multiple storage locations. At the forward location where the product is stored, the returned item's barcode and the location barcode are scanned to confirm the storage and to update the inventory record. In the picking process, no explicit priority is given to returned items over new stock.

Considering the decisions made by Wehkamp to control the returns, we can conclude the following:

- Collection of returns at customers has been integrated with the distribution of products to customers. The same third party logistics company carries out both processes and the route planning is based on both types of orders, although return collection has a slightly lower priority. Even the return drop-offs at Wehkamp are integrated: the truck that brings returned items also collects new orders for distribution. See also Beullens et al., 2003.
- the return handling process is completely separated from the regular receipts of suppliers, with dedicated workstations and handling equipment like conveyors. For administrative handling, a tailor-made software module is used.
- The inbound storage process differs from the regular receipts. For regular receipts, one product carrier (usually a pallet) consists of one product. Returns are consolidated for inbound internal transport in rolling bins.
- Returned products with a "good" status are consolidated with new products on a location in a forward pick area, whereas newly purchased items are stored in a reserve area. Other than 'good' products are either returned to vendors or to brokers.
- In the picking process, no explicit priority is given to returned items.

4. Decisions in Return Handling

The description of the case in the last section served to illustrate some of the decisions to be made when return handling is concerned. We now formally address warehousing decision-making according to long-term, medium-term and short-term decisions (see also Ganeshan et al., 1999). Table I provides an overview. One should notice that the decision topics have many interdependencies. In practice, when deliberating over a decision, the whole set of decisions is to be borne in mind.

Long-term decisions

Facility Layout & Design

Facility layout and design is essentially a long-term decision regarding warehousing. Companies have to ensure that sufficient storage and handling capacity is going to be allowed for return handling and, additionally, how the space in the facility is going to be organized. For instance, whether a dedicated facility to return handling is preferable; or if not, whether returns are handled in a separate area of the facility. By integrating return and forward handling, resources can be shared on the one hand but handling complexity increases on the other. In the illustrative example, returns were handled in the same facility, but in a separate area. Actually, the same was observed in nine retailers of several industries, in a comparative study by De Koster et al. (2002). From the analysis, a threshold on return volume seems to exist that determines whether returns are allocated to a separate area or not: above the threshold it is more efficient to handle returns in a dedicated area. In practice, one even finds companies with a separate facility dedicated for returns, such as Quelle in Germany, Sears and Kmart in the US, which deal with huge amount of returns (Chain Store Age, 2002). Fleischmann et al., (2003) further explains how the decision of settling a separate facility for return handling is affected by the amount and type of returns. An obvious trade off is between investments and capacity for return handling. In addition, the location of a return handling area within a facility affects internal handling systems that can be used and associated cost of internal transport. In the design process future return handling must therefore be taken into account

Long-term decisions
• Facility layout & design Are returns handled in separate facilities? Or, are returns handled in a separate area of the same facility? How to layout these facilities?
Medium-term decisions
• Outsourcing Are warehouse (return handling) operations going to be total/partially outsourced? • Integrating operations (return policy; packaging): Under which conditions are returns accepted at the warehouse (related with return policy/responsibility)? Which returns are to be totally/partially credited by the warehouse? Which responsibility has the warehouse with respect to returns (e.g. collection, sorting)? Specific decisions on reusable vs. one-way packaging; waste reduction/disposal; • Inventory Management Where are products to be stored? E.g. are product returns in condition as-good-as-new to be stored together with new products? • Internal (return) transportation Which type of product carriers should be used? To which extent should the operation be mechanized or automated? Which type of vehicles should be used? • Information systems Which IT systems are to support the return handling? Which information is to be kept and for how long? Will the warehouse make use of dedicated software for return handling?
Short-term decisions
• Inventory, storage and order picking Controlling return storage; Planning returns-storage vs. order picking; • Vehicle planning and scheduling Route selection taking into account reverse and forward flows.

Table I: Decisions for warehousing return handling.

Medium-term decisions

Medium-term decisions concern outsourcing, integrating operations (return policy and type of packaging), inventory management, internal transport and degree of mechanization, and information systems. In what follows we briefly address each of them.

Outsourcing

In the illustrative case, Wehkamp keeps the warehousing operations in-house. In this case outsourcing would be difficult since the activities take place within the warehouse and are closely related with order picking and storage activities. Provided that the return process can be clearly separated from the forward process, return handling may be outsourced. Examples include Albert Heijn (the return warehouse in Pijnacker) and Sears and Kmart in the US, where the returns are handled by Genco (De Koster and Neuteboom, 2001; Chain Store Age, 2002). Other determinant factors are the value and type of product as well as the availability of experienced third parties. At this moment such companies are emerging. Examples include Genco and Universal Solutions Incorporated (see e.g. Chain store Age, 2002).

Integrating Operations

When products are returned, responsibilities for related processes have to be settled. In the case of chain stores for example, either a central facility (often the distribution center) collects and processes the products and waste materials that have been returned to the stores, or the stores take care of it themselves. According to IGD (2002), in the UK all food retailers recycle packaging materials in a central facility: either a distribution center or a separate recycling unit. Actors in the chain also have to establish whether different types of returns incur different levels of accountability. For instance, the manufacturer takes the responsibility for all the processes related with end-of-life returns but no responsibility for reimbursement returns independent of the motive. Another issue to decide upon is the explicit return policy. For instance, stores have to know which products can or must be returned to the warehouse in which situations, or how to grant permission for this. In the illustrative example, the mail-order-company does not have much freedom with respect to the return policy, as it is a legal requirement to allow for returns.

The urge to reduce packaging materials leads to the decision whether packaging materials can be replaced by reusable packages. Reusable packages will demand a higher initial investment, but have the inherent benefit of the repetitive use. Many industries choose to reduce packaging waste by using less and standardized boxes (Schiffeleers, 2001), or replacing packaging materials by other materials involving less material handling. Some retailers opt to start recycling their own packaging materials. Albert Heijn, for example, recycles wrap foil into plastic bags, integrating the forward and reverse flows for a practical purpose. Yet, this demands changes in its operations as follows. Stores have to separate the wrap foil, to put it in roll cages and store it until collection. After recycling by a third party, bags are resent to the warehouse to be integrated with the distribution.

Inventory Management

Returned products may have a quality status that differs from new. Depending on this status and the timing, they may be sold in the same market (e.g. early in the season reimbursement returns, as in the case of Wehkamp) or not (namely leftovers or end-of-life returns). Both newly supplied and (as-good-as-new) returned merchandise are going to be stored for future sales as long as the season runs. The two streams can be stored separated or the merchandise can be consolidated in the same location. In the case of Wehkamp returned items are stored together with new merchandise. De Koster et al. (2002) have also found mixed and hybrid storage policies among the operations of nine different retailers. For instance, one retailer would first store returns at a separate location and consolidate them only when the location's capacity would be exceeded. The analysis led to the conclusion that separate storage policies are mainly found among retailers wishing a high degree of control over returns. Returns can be consolidated if the future market is the same as for newly supplied merchandise. The 'future market' is also a critical factor for other returns than the ones "as-good-as-new." Leftovers are usually consolidated in interim storage locations per vendor or potential 'customer'. A well-known example is of books that go back to the respective publishers. End-of-life returns are also separated and kept together by potential broker.

Internal (return) transport

An important issue in internal transport is the choice of reusable carriers. Choosing the type depends on the willingness of the parties in the chains to adopt one of the available standards. This is usually a complex process, where power plays a major role. Once a standard is in place, the decision that is left is the amount. Product carriers require collection, transportation back to the warehouse, checking and possibly cleaning before being used again. In order to limit the amount of product carriers needed, they should rotate rapidly. Since the timing and quality of such returns are difficult to anticipate, many companies have searched ways to reduce such uncertainty. De Brito et al. (2002) review real applications of incentives to persuade parties behaving in a desired way. A common incentive is to charge a deposit fee between the different parties in the chain, especially if the material has some intrinsic value. Each receiver must pay this fee to its supplier. Often, when multiple companies participate in such networks, there is a central organization that tracks the ownership of carriers and registers financial transactions. The deposit fee not only prevents items from being lost but it also provides a natural mechanism to motivate careful handling and therefore a minimum quality is ensured per returned item, as transactions have to be tracked. Several international pools for pallets exist in Europe, like Deutsche Bahn (DB) and Chep. Many manufacturers supply their products on such pallets. In case the reusable packaging can be shared between different users, the benefits can sometimes be huge, since large savings can be achieved in the numbers needed (Koehorst et al., 1999). For this reason, in the Netherlands and in the UK food retailers have switched to reusable container systems (IGD, 2002). In food retailing, reusable crates are mostly used for product categories such as produce and chilled, where warehouse stocks are small and sales volumes are high. This means the crates are used intensively, reducing the cost per trip. However, wholesalers and retailers with many suppliers and different pallet types have considerable work in handling, sorting and storing pallets returned from their customers (retail organizations or stores). In case of large return volumes, mechanization or automation may become economically attractive. Here there is to choose for example which type of vehicles should be used to load and pick up products from the warehouse shelves.

Information Systems

Finally, at this level, one has to determine which information system is going to be used to register product returns. Kokinakki et al., 2003 examines the overall needs and existing supporting technology for managing information in the reverse logistics context. Commercial software particularly designed for supporting return handling is however lacking (Caldwell, 1999). The commonly used ERP packages generally lack the ability to properly deal with returns (De Kool, 2002). At this stage decision-makers may consider the in-house development of dedicated software. This has been the case at Wehkamp and Estée Lauder (see Meyer, 1999). The specialized software system checks returns for expiration date and damages speeding up return handling. Besides this, the software is linked to an automatic sorting system, which has lowered labor costs. In general, it has to be determined the type of information to be registered, for how long and how decisions with respect to returns can be supported. Also attention is given to potential abusive returns (see Schmidt et al, 1999) and how this affects warehousing operations. In the case of Wehkamp, though law enforces accepting returns, returned merchandise is first checked and only then it is decided whether the client should be credited for it.

Short-term decisions

Inventory, Storage, Order Picking and vehicle planning and scheduling

When storing returns, that work has to be planned in coordination with forward operations such as order picking and internal transport. In the case of Wehkamp to put returns back in inventory timely is crucial, to prevent stock outs. Another aspect is the organization of the picking process. In case of Wehkamp no explicit priority is given to returned items over regular stock. There are, however, cases where priority to returns might be given. This was explicitly observed at a mail-order-company as reported by De Koster et al. (2002). The aim is to have quick feedback on returned items. For instance, items that are being returned repeatedly can be identified and proper action can be taken.

We have presented here a framework of long-, medium- and short-term warehousing decisions with respect to return handling. In the remainder of this article we bring into focus the available and potential models to support those types of decisions.

5. Models and research opportunities

Quantitative models on return handling are practically non-existent. Therefore in this section we mainly identify quantitative models on material handling. We will indicate how they can be adapted to accommodate returns and in which areas there are research opportunities in developing quantitative models that aid decision-making. An early overview of the use of OR tools in material handling can be found in Matson and White (1982).

The main research areas in materials handling and warehousing are:

- Facility layout and design;
- Outsourcing;
- Integrating operations: return policy;
- Integrating operations: reusable packaging;
- Inventory Management (see also last item);
- Information systems for return handling (see Kokkinaki et al., 2003);
- Evaluation of equipment types ("vehicles") and determining the number of vehicles;
- Inventory, storage and order picking. This topic includes problems particular within warehouses, such as order batching, order picking, routing pickers in a warehouse, warehouse zoning (dividing a picking area in zones to achieve certain objectives), product storage allocation, forward versus reserve storage area decisions;

- Vehicle planning and scheduling (including dispatch, load assignment), or, more general: planning and control of material handling systems;

We will go over some of these areas in more detail in the remainder of this section.

Facility layout and design

A successful research area is facility layout. A well-known approach is Muther's (1973) Systematic Layout Planning concept, a structured approach leading to a layout. Many algorithms have been produced that may support designers to come to efficient layouts. Classic mixed-integer linear programming algorithms such as CRAFT, ALDEP, CORELAP are described in Tompkins et al. (1996). There also algorithms for multi-storey buildings (MULTIPLE, Bozer et al, 1994) and algorithms for areas which are restricted in length/width ratios (Goetschalckx, 1992). The major objective in the underlying models is to minimize the total cost of daily transport between the different areas in the facility. For some facility types special layout models have been developed with the reduction of travel time as primary objective. These facilities include cross-dock centers, that is centers where goods have to be transported from receiving dock doors to shipping dock doors (Bartholdi and Gue, 2000) and picker-to-parts warehouses where the objective is to find the layout for a given storage capacity that minimizes the order picking travel time (Roodbergen, 2001).

Based on these methods, commercial software has been developed to graphically aid designers in interactively developing designs. An important shortcoming in the models is that in reality many other restrictions and objectives are important as well, such as congestion reduction. The models and solution methods can be applied straightforwardly to facilities with return flows and handling areas. Departments where returns have to be received or sorted do not change the models fundamentally. However, it is important to incorporate returns operations from the start in layout decisions, since the solutions may change dramatically, compared to the situation without returns (think of crossing flows, or travel distances). It may be interesting to study how return flows impact such changes in layout. This is a topic that did not receive attention from researchers so far.

Outsourcing

Literature on process outsourcing is mostly of a qualitative or quantitative empirical nature. Although much literature deals with outsourcing of warehousing and transport to logistics service providers (see for example Rabinovich et al., 1999; Van Laarhoven et al., 2000), academics have not specifically addressed the outsourcing decision of return handling so far.

Integrating operations: return policy

Distant sellers and other retailers usually accept merchandised back up to a number of weeks after delivery or purchase. Wekhamp puts the threshold at about two weeks and does not charge the client in case of return. In reality we find various charging schemes including partial refundable costs. Schemes to charge returns and some of the associated dilemmas have been studied in the literature, like how to control opportunistic returns (see Hess et al., 1996). Researchers have established relations between return policies and a number of elements, among which: salvage value (Davis et al., 1995 and 1998; Emmons et al., 1998); mismatching probabilities (Davis et al., 1995; Hess et al., 1996); speed of consumption (Davis et al., 1998); product's value to the consumer (Davis et al., 1995; Hess et al., 1996); product's quality (Moorthy and Srinivasan, 1995; Wood, 2001).

However, return handling costs have been kept out of the discussion. We present here a model to explicitly include return handling costs. The model below is in fact a holistic approach to return policies as it gives plenty of room for the incorporation of multiple critical factors.

Let Ur be the utility function of a retailer. Ur is a function of factors, like:

- t, return period
- p, price of the product
- x, quantity sold
- y, quantity returned
- c_h handling/warehousing costs
- c_{rh} return handling costs

Customers i= 1, …, m have respectively utility functions u_i. Each u_i is a function of factors as

- p, price
- t, return period
- q, quality of the product
- c_{rc} return charges

All the actors involved intend to maximize their utility function. The retailer is the leader as (s)he sets *a priori* some of the parameters, like t and p. In turn, customers will react to the values of these parameters and maximize their utilities.

The problem can be written as follows:

Max Ur

s.t.:

$\max u_i$, i=1, …, m

The problem is in the form of a Mathematical Programming problem with Equilibrium Constraints (MPEC problem, see Luo et al, 1996).

The previously mentioned literature on return policies can be used to estimate the utility functions. Furthermore experiences similarly to the ones described by Wood (2001) can be conducted to tune the parameters' relations.

Integrating operations: reusable packaging

Several authors have paid attention to the evaluation of durable versus one-way packaging. Organizational, technical, economical and environmental aspects play a role in this evaluation. Organizational aspects concern responsibilities of different actors in the supply chain with respect to the handling, return and storage of the packaging, including the financial set-up. Technical aspects involve investments needed in equipment to properly handle the packaging.

In order to determine economic benefits, the needed number of reusable packages and the distribution over the network has to be determined. In order to do this, quantitative models can be used. Kroon and Vrijens (1995) use a location-allocation model to determine the locations of empty container depots and to allocate stocks of empty containers in the different depots to the users of the containers. The objective is to minimize empty container transport cost and the fixed costs of the container depots. Duhaime et al. (2001) use a minimum-cost-flow model to determine the number of empty containers that should be returned to the central hub of Canada Post each month and the distribution over the network. To determine the environmental impact of reusable crates, Life Cycle Analysis (LCA) can be used (see Pappis et al., 2003; and Bloemhof-Ruwaard et al., 2003). For every process (production, handling, transport) or material usage the impact on the environment (for example global warming or acidification) can be established by calculating the emissions of different components. It is still necessary to trade-off the different impacts. Furthermore, different methods exist to calculate these emissions. The best method depends on production and transport technologies used, on the country, etcetera. Gradually standard tools become available to do such analysis.

Inventory Management

If return rates are high, such as in distant selling business, it becomes necessary to manage return stocks explicitly. One can also look at this from a completely different perspective: remote sellers are overselling to customers that return merchandise (and therefore underselling to customers that do not return merchandise). One can actually fit customers that (systematically) return merchandise versus not, in two classes: less- and more- profitable customers. Mail order companies are a good example as these companies carry large amounts of historical customer data, which can be employed to draw the profile of each customer class. Return-handling costs can be explicitly utilized to draw the line between the two classes. Existent inventory models with priority customers can be stretched to this new application (see Kleijn and Dekker, 1999). Research has showed that "… in some cases it is optimal to … reserve inventory for possible orders from higher-margin customers" (Cattani and Souza, 2001). In other words, it may be optimal to reserve inventory for customers that do not systematically return merchandise. This nurtures confidence in the opportunities that this sort of models can offer to retailers like mail order companies. Moreover, return-handling costs can be plugged in explicitly, bringing realism to inventory management with product returns.

Internal (return) transportation: vehicle evaluation

OR models (stochastic models, mixed-integer linear programming models or simulation) can be applied successfully in the evaluation of material handling systems, in particular estimating the number and type of vehicles needed. By comparing multiple scenarios, with multiple types of material handling systems, an evaluation of the best system can be made. The underlying models try to determine the number of vehicles of a certain type in a certain facility. Examples are the evaluation of single-load versus multiple load vehicles (Van der Meer, 2000), or lifting versus non-lifting vehicles (Vis, 2002). Other, related, design areas are vehicle transport track design, choice of pick-up and delivery points, design of deadlock-free tracks, track claim design, or design of battery loading areas. The paper by Goetz and Egbelu (1990) is an example. Material handling systems used for both forward and return flows may have to meet different requirements. Depending on the return volume, separate systems may be needed, that are better fit for return handling.

Inventory, storage and order picking models

Many papers deal with warehouse planning and control. There are many overview papers in this area; recent ones are by Van den Berg (1999), Rouwenhorst et al. (2000) and Wäscher (2002). The following topics have been addressed in OR literature in particular:

- Product to storage allocation
- Order batching, wave picking
- Routing order pickers in a warehouse
- Warehouse zoning, worker balancing
- Forward – reserve problem
- Pallet or container loading

Product to storage allocation tries to allocate products to locations such that the order picking process (sometimes also the storage process) is optimized. The objective is usually to minimize the worker's travel time. Well known methods for storage allocation are: closest open location storage, the cube-per-order index method (Heskett, 1963), class-based storage, random storage, full-turnover based storage, or family grouping.

Order batching and wave picking is concerned with grouping customer orders and releasing them to pickers as a group, in order to reduce the processing time. By combining orders in a pick route, the routes may become more efficient. This is often at the expense that the picker has to sort the orders while picking. De Koster et al. (1999) present a performance evaluation of different order batching methods.

Routing order pickers is the problem of finding efficient routes within a warehouse to pick all orders. Objective is the minimization of travel time. The models depend on restrictions that play a role, the warehouse layout (for example: the length and number of aisles, the presence of cross aisles), start and finish locations (these may be free or variable), the type of material handling equipment used. Roodbergen (2001) presents an extensive literature overview on this topic.

The problems of *worker balancing* and *zoning* have been addressed, among others, by De Koster (1994), Bartholdi and Eisenstein (1996) and Bartholdi et al. (1999). The latter papers show that the throughput can be increased substantially if workers have free, rather than fixed, working zones.

The *forward-reserve* problem is concerned with the storage of small (daily or weekly) pick quantities of some items in a forward pick zone and the storage of bulk quantities in a larger reserve zone. The forward zone is replenished from the reserve zone. Some items may be stored exclusively in the reserve zone and have to be picked there. The objective is usually minimization of cost or of total work. Literature includes Hackman and Platzman (1990).

The *pallet (or container) loading* problem is closely related to the bin-packing problem (Coffman et al., 2000). A tactical problem is to determine the right container sizes to be used. At the operational level, a choice must be made from the available sizes and a stacking scheme must be developed.

There is some literature on combinations of these above-mentioned problems, but due to the complexity of such problems, this is not abundant. Gademann et al. (2001) combine batching and routing, Roodbergen (2001) combines routing and layout design. Recently storage and routing received some more attention (see, for example, Dekker et al. 2002).

Currently, no models exist that explicitly include return flows. In our view, creating models is most interesting for the following decision areas.

- An important decision is to set-up separate storage areas for returns (for example storage of multiple products per location), or to consolidate them with existing stock. The trade-off is in storage and order pick travel time, but also in the cost of a warehouse of increased size. Storing returns on separate locations may save time in storage, but potentially requires more space, which in turn increases pick times.
- With respect to put back returned products in stock, a further point to investigate is how long to buffer product returns before consolidating them on stock. Important factors that play a role in such decision are the quantity, variety and timing of the returned items.

- Another decision area is in the sequencing and routing of pickers that have to store returns on location in a route, but also have to pick orders in routes. In many occasions, return job scheduling issues play a role, since picks can only be carried out when the (returned) products are at their location (this is the case at Wehkamp, see section 3). On the other hand picks are much more urgent, because of due times for shipment. This problem has received no attention from researchers so far.

Vehicle planning and scheduling

A large part of the literature on material handling equipment covers planning and control issues of unit-load automated storage and retrieval systems (AS/RS). This has yielded some important results, such as:

- The optimal length-height ratio of storage systems, with respect to crane cycle times (Bozer and White, 1984).

- Calculation of crane cycle times using different storage or retrieval strategies. Initial papers are by Bozer and White (1984, 1990) and Hausman et al. (1976).

These initial papers have led to a large number of papers on cycle time calculation for AS/RS systems with slightly different layout, behavior, location usage, interleaving policies and storage strategies.

Another large group of papers is on planning and control of automated guided vehicle (AGV) systems. The nature of such internal transport systems is that the environment they work in is highly dynamic, that is the horizon over which information is available of loads that need transportation is usually short. On a slightly longer horizon, information may be known in advance, but is uncertain. Load arrivals are stochastic and also transportation times are stochastic, due to congestion and intersection control policies. The following activities have to be carried out by a controller of the system:

- Dispatching of vehicles to pick up certain loads
- Route selection
- Vehicle scheduling
- Dispatching vehicles to parking positions

Most literature addresses one or at most two topics simultaneously. Many heuristic rules have been evaluated for vehicle dispatching, with or without prior load arrival information. Overviews can be found in Van der Meer (2000) and Vis (2002). Vehicle routing and scheduling problems are often modeled as mixed integer programming problems, which may have mixed pick ups and deliveries, time windows for the deliveries, dynamic versions of the problem and different objective functions (like makespan, average load waiting time). Overviews have been given by Desrochers et al. (1988), Solomon and Desrosiers (1988) and Savelsbergh and Sol (1995).

Quantitative research on planning and control of other material handling equipment is not abundant. There is some literature on conveyors and sorting systems (Meller, 1997; De Koster 1994), carousels (Rouwenhorst et al., 1996), compact storage and other systems.

When returns are involved, the planning and scheduling of such material handling equipment will change. Returns can be modeled as another type of (storage or transport) job that has to be carried out. However, particular-sequencing restrictions will apply. For example storage jobs resulting form returns must be carried out prior to retrieval jobs. Or, for unit load handling machines, it must be attempted to combine jobs in a double play to increase machine utilization. The above type of models can be applied to situations with returns as well.

In conclusion, there is a shortage of both models and empirical research for handling return processes. Presumably, quantitative models are not straightforward and more has to be learned on the processes themselves before they can be developed and implemented successfully. Besides such quantitative models, also more qualitative, or empirical approaches are needed. For example, research towards best practices may help decision makers to come up with solutions for sorting, buffering and storage.

6. Summary and final remarks

The handling of return flows is not as the usual handling of forward flows coming into the warehouse. As illustrated in Section 3 and discussed in Section 4, handling return flows additionally involves collection, inspection, grouping, splitting and recovery. This demands that decisions in a larger number of issues are taken.

We have presented a decision-making framework for return handling from long- to short-term decisions: 1) facility layout & design; 2) outsourcing; 3) integrating operations (return policy and reusable packaging); 4) inventory management; 5) internal (return) transport; 6) information systems; 7) inventory, storage and order picking control and 8) vehicle planning and scheduling. We have stressed that the whole set of decisions has to be taken account for every single decision because of the many interdependencies. Some of the known results on efficient material handling were reviewed. In short, when high volume of returns is present, receipt and sorting is likely to be in a dedicated area of the warehouse. With respect to storing of returned products, the future market of returns and the desired degree of control on returns are the influencing factors (see De Koster et al., 2002).

Though available quantitative models can be adapted to support warehousing return handling, this has been up to now largely ignored. For a vast number of research areas, we have in Section 5 highlighted how forward models can be extended or new models can be launched to include return handling. We brought to attention several research holes, which can be turned in a research agenda: What is the impact of return flows have on 1) the warehouse layout; 2) material handling systems (e.g., whether dedicated return handling systems do pay off); 3) vehicle planning and scheduling (mind sequencing restrictions); 4) storage and picking procedures (ex. route combination of returns' storage and pick ups). Furthermore we suggested the innovative use of MPEC formulation to e.g. help retailers deciding upon the return policy. A new direction to inventory modeling was also put forward by categorizing customers in two classes, i.e. less- and more- profitable depending on whether the customer (systematically) returns, or not, merchandize.

Most likely some of the ideas for future research laid down here are not straightforwardly carried out. We believe that learning more about the practice of return handling can subtract some of the latent modeling difficulties. Not only quantitative models are needed, but in order to implement it successfully more qualitative, or empirical approaches are necessary. For example, research towards best practices may help decision makers to come up with solutions for sorting, buffering and storage. By conducting simultaneous desk and field research, quantitative models will plausibly aid on real return handling decision-making.

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