The role of ICT in the reverse logistics. A hypothesis of RFID implementation to manage the recovery process.

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Abstract: Traditionally a product was developed to be manufactured and go through the supply chain (e.g. manufacturer-wholesaler-retailer) to be sold to a customer. However, supply chains are steadily integrating more activities than those concerned with supply alone, like including service and product recovery. Here we will focus on the latter, and especially reverse logistics, i.e. the handling of products, components and materials during the recovery process (see Revlog, 1998-). Several forces drive reverse logistics, like, competition and marketing motives, direct economic motives and concerns with the environment. At present, in literature it is not present a model that describes which products can easily be recovered and what are the elements that determine the feasibility of recovery process. This study aims to define the product's characteristics that influence the adoption of reverse logistics and to suggest the use of information technologies to support the recovery process. Information and communication technologies have a main role in the recovery process of electronic devices. In this study we propose a solution with a radio frequency tag (RFID).

1. The reverse logistics processes

Supply chain management (SCM) is the term used to describe the management of the flow of materials, information, and funds across the entire supply chain, from suppliers to component producers to final assemblers to distribution (warehouses and retailers), and ultimately to the consumer. In fact, it often includes after-sales service and returns or recycling [5].

A class of ‘reverse’ goods flows that has been gaining particular importance concerns returns of used products at the end of their normal lifecycle. Companies have been discovering used products as a valuable resource. A scale of recovery options, including refurbishing, remanufacturing, and recycling may allow for recapturing significant shares of the original value added and/or material value, thereby opening the route to extended profits [18].

Though the conception of Reverse Logistics dates from long time ago, the denomination of the term is difficult to trace with precision. Terms like Reverse Channels or Reverse Flow already appear in the scientific literature of the seventies, but consistently related with recycling [7][6]. Kopicky [11] defines Reverse Logistics analogously to Stock [17] (1992) but keeps the sense of direction opposed to traditional distribution flows. In the end of the nineties, Rogers and Tibben-Lembke [15] describe Reverse Logistics including the goal and

the processes (the logistics) involved. The European Working Group on Reverse Logistics [14], puts forward the following definition:
“ The process of planning, implementing and controlling flows of raw materials, in process inventory, and finished goods, from a manufacturing, distribution or use point to a point of recovery or point of proper disposal”
The above definition is more extensive than the one proposed by Rogers and Tibben-Lemke [15]. We do not refer to “ point of consumption” nor do the products need to be returned to their origin, but may be returned to any point of recovery (e.g. collected computer chips do not go back to the original supply chain, but may enter another chain). In this way we incorporate more flows that naturally fit in the definition and which characteristics are the same as of other reverse logistic streams.
The recurrent reverse logistics activities include collection, inspection/separation, reuse, remanufacturing, recycling, re-distribution and disposal. The first stage in the reverse logistic process is collection, that is, all those activities that are necessary for reclaiming returned products, surplus or by-products and transporting them to a place, where they will be subjected to further examination and processing. Locating such products, purchasing, transporting them and storing them at a collection point, are all activities related to collection.
Remanufacturing is a series of steps necessary to transform a part or product that has been used into one that is usable again. Some typical activities in remanufacturing include cleaning, disassembly, replacement and re-assembly. However, remanufacturing is so product dependent that it can barely be characterized by typical activities. For example, restoration for a piece of old furniture may require artistic skill, whereas remanufacturing of a piece of heavy equipment requires advanced industrial infrastructure.
Re-use refers to cases where returned products have such a good quality that they can be re-used almost immediately in the same or an alternative market. This happens for reusable bottles, containers and most leased or rented equipment. It may also happen for surplus goods, e.g. spare parts which are left over after discarding the original equipment.
Finally, re-distribution refers to the logistics activities required to introduce a product into a marketplace and transfer it to the customer. Obviously, this entails storage, sales and transportation. Moreover, efficient marketing of re-usable products requires protocols that support clear and concise communication between interested parties and mechanisms to facilitate matching of offers with requests.

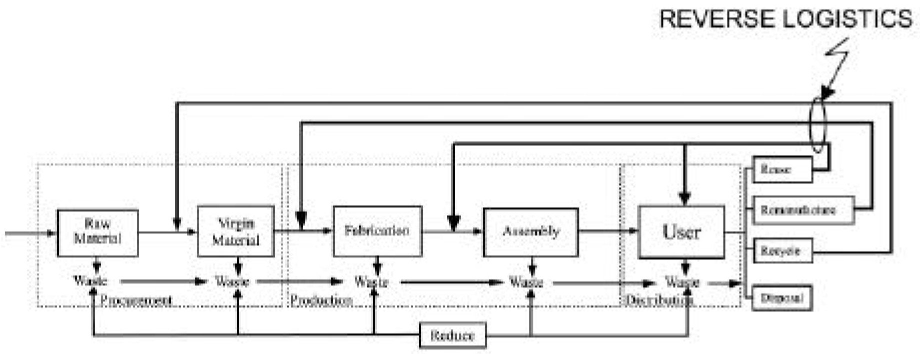


Figura 1: Functional model of an organizational supply chain with environmentally influential practices (Sarkis, 2002)

2. Product characteristics and reverse logistics

Which products are suitable for reverse logistics? In a study of De Brito and Dekker [12], a viewpoint on Reverse Logistics can be obtained by considering what is actually being discarded or returned. Three product characteristics seem to be relevant: composition;

deterioration; use-pattern. As highlighted by Gungor and Gupta [8], product composition in terms of the number of components and of materials is one of the many aspects to keep in mind while designing products for recovery. Not only the number, but also how the materials and components are put together, will affect the easiness of re-processing them and therefore the economics of reverse logistics activities.

The presence of hazardous materials is also of prime relevance, as it demands special treatment. The material heterogeneity of the product can play a role in recovery, where one tries to obtain separate streams of different materials, which are as pure as possible (a problem in case of plastics).

The size of the product has also been pointed out as a significant factor for recovery systems. One can mind e.g. the impact of this aspect on transportation and handling. Tibben-Lembke [19] has studied the way that reverse logistics is impacted by changes in sales over the product's life cycle. In the product life cycle De Brito and Dekker introduce that there are the deterioration characteristics, which eventually cause a non-functioning of the product, but also determine whether there is enough functionality left to make a further use of the product, either as a whole or as parts.

The product use pattern, with respect to location, intensity, and duration of use, is an important group of characteristics as it affects for instance the collection phase. It will make a difference whether the end-user is an individual or an institution (bulk-use), demanding different locations for collection or different degrees of effort from the end-user (e.g. bring to a collection-point). The use can also be less or more intensive. Time is not the only component describing intensity of use, but also the degree of consumption during of use.

The characteristics of the product are related with the type of product in question. Product type in fact gives the first global impression on the potential states of the product when it reaches recovery. Fleischmann [5] distinguish the following types: spare parts; packages; and consumer goods.

In another study, Rose developed a model to forecast End-Of-Life (EOL) product recovery and accurately predicted 86% of 37 case studies based on six technical product characteristics including product durability, rate of technological obsolescence, extent of product complexity, the duration of a design cycle and the reason for redesigns [16]. Further refinements to such theories would extremely beneficial to manufacturers and policy makers [20].

Ammons et al. [1] hypothesize that there are two key features of the product that will help shape the structure of its reverse logistics system: 1) average and variability in frequency of product retirements, and 2) complexity both in materials and manufacture.

The frequency of product retirements is dependent on two further features of the product, the length of use and the number in circulation. However, consumer durable goods and occur in medium numbers, leading to a lower frequency of product retirement. The complexity in manufacture and materials content of products will impact reverse production system.

3. The product characteristics model

Literature propose several characteristics that identify the "level" of recovery of a product. The precedent studies consider product characteristics and process characteristics at the same manner. In this study we divide product characteristics and process characteristics and we suggest an approach concentrated on the product. Following studies will take in consideration the processes related to the recovery of products.

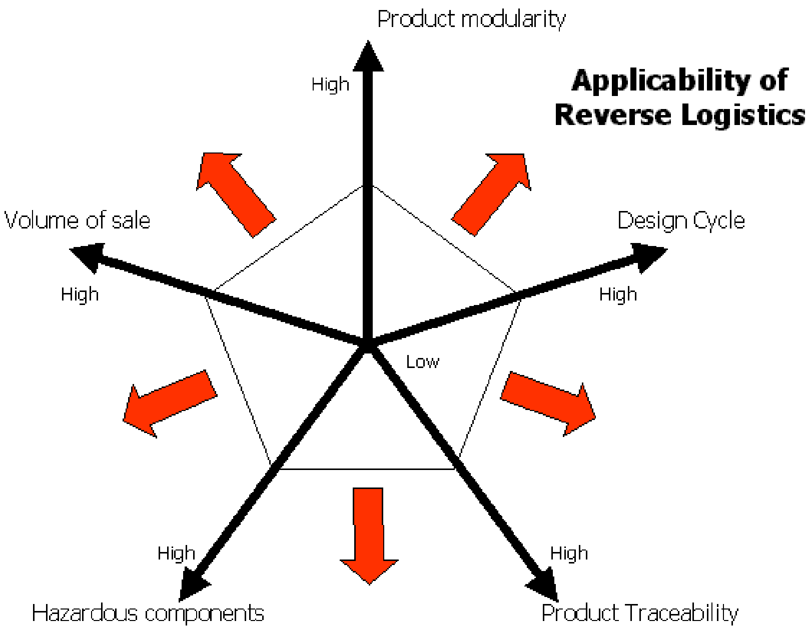
The model we propose define the product characteristics for the recovery as a group of seven parameters:

- The product size
- Volume of sale of products

- Hazardous components
- Design cycle and product life cycle
- Product traceability
- Product modularity

Product size

The size is the approximate dimensions of the product and its weight. Large dimensions are a bound in the recovery processes. Consumer can not transport the product to the collection center and the handling is very difficult. A product with small size is suitable for the recovery process.



Product traceability

The traceability systems are record keeping procedures that show the path of a particular unit or batch of product or component from supplier(s), through all the intermediate steps which process and assemble components into new products and through the supply chain to customers and perhaps ultimately to consumers. A high-level of traceability allows to identify the consumer and to stimulate him to the updating of its product. This type of controll allows to increase the services of marketing and create an high level of fidelity through up-selling activities.

Volume of sale

This parameter represents the number of products sold. A high number of products sold (mass product) facilitates the procedures of recovery and we can achieve some economies of scale. In fact it can be organized some centers of harvest in the territory. An inferior level of products sold can be recovered through the collaboration of the retailers. Finally, to recover little diffused products becomes more complex because it needs to define one-to-one connections with the consumer.

Hazardous components

A product contain hazardous components when it has a large environmental impact at end-of-life (Spicer and Johnson, 2003). Computers and other electronics are comprised of a large number of different materials, which makes disassembly and recycling difficult. Additionally, there are considerable amounts of toxic and potentially hazardous waste material in electronics [9]. The hazardous elements found in electronics require that the processing of recovered electronics be responsibly managed in order to protect the health and safety of the workers and to protect the environment where the processing occurs. A product with a high percentage of hazardous components must be recovered.

Product modularity

In broadest terms, modularity is an approach for organizing complex products and processes efficiently [2], by decomposing complex tasks into simpler portions so they can be managed independently and yet operate together as a whole. From a system's perspective, modularity can be viewed as a continuum describing the degree to which a system's components can be separated and recombined, and it refers both to the tightness of coupling between components and the degree to which the "rules" of the system architecture enable (or prohibit) the mixing-and-matching of components.
To enhance component reuse and material recycle, engineers must embed strategic modularity into the product and reduce the cost to the recycling organizations. Such effort will lead to overall improvement of industrial ecology through reduction of raw material use, energy use throughout the product life-cycle, and solid waste [13]. In this study we consider the modularity like the ratio between the number of modules present in the product and the total number of its components. A product with a modularity near to one is suitable for the reverse logistics because we can reuse the modules in the forward logistics. [10].

Design Cycle and product life cycle

The design cycle is the length of time between successive generations of the product. The design cycle is the frequency that a design team redesigns the product or designs a new product thus making the original product obsolete. A long life cycle permit to recovery the product, dis-assemble and check the components, and re-insert them in new products. If there is a short life cycle, the manufacturer introduces with high frequency in the market new products . This compel to innovate the components and this cause an high obsolescence.

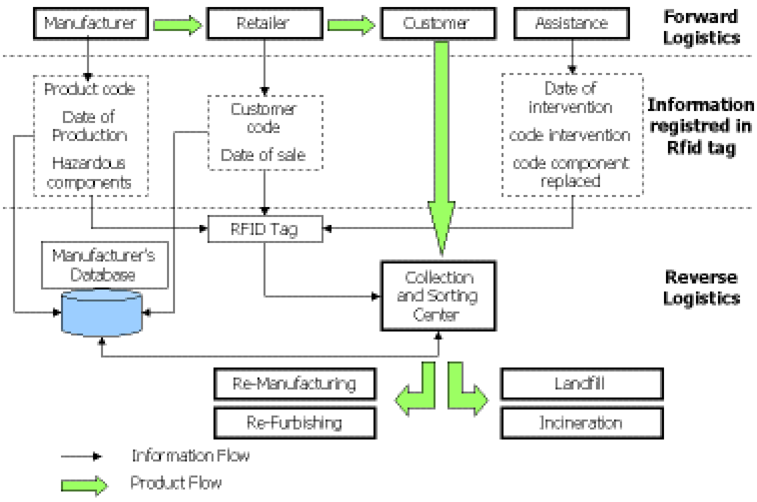
4. The RFID support the recovery process

The characteristics object of this study can be gathered together in three clusters: aspects relate to the structure of the product (dimensions and weight); aspects relate to the market (volume of sale and life cycle); aspects relate to recovery (modularity, toxicity and traceability). While the physical characteristics of product and the typology of market cannot be changed by the manufacturer, the firm has to implement some solutions to improve the aspects related to recovery. First, the firm has to increase the modularity, developing the Design-for-Disassembly.
The products designed for disassembly and remanufacturing can deliver much greater savings than can be achieved through the remanufacturing of a product that was not designed with this intention. This finding supports the argument that design plays a key role in determining economic and environmental benefits of remanufacturing [3] [21].

The research and development needs many years to develop products with low level of hazardous components. We can think about the lubricants in the cars, the batteries in the cellular phones or in the PCs, the refrigerant liquids in the air conditioning systems, etc.
At present, the firms can only develop the traceability of product to simplify the recovery processes.
Some products have a very long cycle of life (i.e. refrigerators), in some cases from the eight to ten years. This means that an individual will purchase on average 8 refrigerators during his existence. The manufacturing firm must estimate the value of a durable customer relationship management and must follows the product during all the life cycle phases until the end-of-life. If the firm loses the knowledge of the product when the product exit from the retailer, the firm loses many strategic information about the period of use, like the malfunctions. Therefore the firm must know what will happen to the product during its life. Otherwise, the company will can not apply any direct marketing initiatives and therefore will lose competitiveness.
It becomes strategic for the manufacturers to manage in an opportune way all the phases that follow the sale of the product to the final customer. To follow the goods during their life will involve many advantages:

- to increase the services to the customer;
- to trace the life of the product and to gather information related to the life of the product (use behaviours, malfunctions, etc.) ;
- to maintain the contact with the customer, and increase the fidelity to the brand;
- to manage the activities of recovery in definite periods;
- to stimulate the up-selling;
- to check the defectiveness of the product;
- to check the state of the sales in real time.

The traceability of the product is possible with the radio frequency identification (RFID). In order to handle reverse logistics better, firms will need to improve their reverse logistics information systems.
Automation of those processes is difficult because reverse logistics processes have so many exceptions. Reverse logistics is typically a boundary-spanning process between firms or business units of the same company. Developing systems that have to work across boundaries add additional complexity to the problem. To work well, a reverse logistics information system has to be flexible. Information systems should include detailed information programs about important reverse logistics measurements, such as store compliance, return rates, recovery rates, and returns inventory turnover. Some of the systems for controlling returns will obviously require significantly expanded and improved information systems.



The RFID is a technology similar in theory to bar code identification. With RFID, the electromagnetic or electrostatic coupling in the RF portion of the electromagnetic spectrum is used to transmit signals. An RFID system consists of an antenna and a transceiver, which read the radio frequency and transfer the information to a processing device, and a transponder, or tag, which is an integrated circuit containing the RF circuitry and information to be transmitted. One of the key differences between RFID and bar code technology is RFID eliminates the need for line-of-sight reading that bar coding depends on. Also, RFID scanning can be done at greater distances than bar code scanning. High frequency RFID systems (850 MHz to 950 MHz and 2.4 GHz to 2.5 GHz) offer transmission ranges of more than 90 feet, although wavelengths in the 2.4 GHz range are absorbed by water and therefore has limitations

A very small, very low powered radio transmitter is installed in each product, broadcasting a very faint signal. The signal is strong enough, that it can be picked up by receivers in a warehouse. Each product can send a different signal. You could build 10 million computers, and install an RFID “tag” in each one, and each one could have a different signal.

Using RFID to assist in the management of returned refrigerators might be a good option. Placing an RFID tag on the machine at the time of manufacturing would take away the errors in the paper chain and assist in the life cycle management of the refrigerators.

RFID has the potential to aid reverse logistics operations in a number of ways. As mentioned, it may be helpful in keeping track of products inside the warehouse and outside in the collection phases of the recovery processes. The other way it may be beneficial is in gatekeeping. RF tags may be used in recording the ID of products when they are sold, and this information can be useful in determining which products to accept for return.

If we consider a medium size product (i.e. refrigerator) with a long lifecycle, we can develop a reverse logistics model based on the RFID technology.

The information system needs a unique central database that collects the products code and the technical characteristics of goods. This database is updated when the product is sold via a Web-portal or using a GSM system. During the life, if the product needs assistance, the technicians up-date information in the tag with the Personal Digital Assistant (PDS) endowed with RF transmitter. At end-of-life the product is brought to the Collection and Sorting Center (CSC). At the CSC the tag is read. The Center can query the manufacturer database via an Internet application. At this time, the center can know the modules that can be remanufactured or refurbished, the demand for remanufacturing of the firm, the toxicity of product and eventually the instruction for disassembly. The manufacturer update its database with the information contained in the tag and sent by the CSC. Finally, the

Collecting and Sorting Center decides if the product will be remanufactured, refurbished or send to landfill on incinerator.

The strengths of RFID system are:

- to increase the recovered products
- to simplify the operations of collecting and sorting
- to simplify the operations of disassembling
- to reduce the quantity of toxic components scattered in the environment.

The weakness for RFID system:

- unique identification system is needed;
- the system of coding has to be shared among all the manufacturers of a particular good;
- the firm need an organizational change;
- products with an high level of modularity are needed.

Conclusions

Currently we are estimating to apply the presented model in an Italian firm. The main problem to the realization of the project is the organizational change needed. However the presented model is suited for products with long cycles of life, with an elevated level of modularity and with middle or small dimensions. New studies will be done for analyzing with precision the processes related to the recovery of products with different characteristics

References

[1] Ammons J.C., Realff M.J., Newton D. Reverse production system design and operation for carpet recycling, Submitted for publication consideration to European Journal of Operational Research, 1997.

[2] Baldwin, C.Y. and Clark, K.B. Managing in an Age of Modularity, Harvard Business Review, (September-October), 1997, pp.84-93.

[3] Clegg A, and Williams D. Production planning for companies with remanufacturing capability. In: Proceedings of the IEEE International Symposium on Electronics and Environment. IEEE, May, 1995.

[4] Commission of the European Communities. Proposal for a Directive of the European Parliament and of the Council on waste electrical and electronic equipment. June 13, 2000.

[5] Fleischmann M., Krikke H.R. , Dekker R. and Flapper S.D.P. A characterisation of logistics networks for product recovery, Omega, Vol. 28, No. 6, 2000, pp.653-666.

[6] Ginter P.M. and Starling J.M. Reverse distribution channels for recycling, California Management Review, Vol. 20, No. 3, 1978, pp.72-81.

[7] Guiltinan J. and Nwokoye N. “ Reverse channels for recycling: an analysis for alternatives and public policy implications” in R. G. Curhan (ed.), New marketing for social and economic progress, Combined Proceedings, American Marketing Association, 1974.

[8] Gungor A., and Gupta S.M. Issues in environmentally conscious manufacturing and product recovery: a survey. Computers & Industrial Engineering, Vol. 36, 1998, pp.811-853.

[9] Industry Canada Environmental Affairs Branch. Computer Recycling Infrastructure in Canada. March 2001.

[10] Kerr W. and Ryan C. Eco-efficiency gains from remanufacturing. A case study of photocopier remanufacturing at Fuji Xerox Australia, Journal of Cleaner Production, Vol.9, 2001, pp.75-81

[11] Kopicky R.J., Berg M.J., Legg L., Dasappa V. and Maggioni C. Reuse and Recycling: Reverse Logistics Opportunities, Council of Logistics Management, Oak Brook, IL, 1993.

[12] Marisa P. de Brito M.P. and Dekker R. Reverse Logistics – a framework, Econometric Institute Report EI 2002-38, Erasmus University Rotterdam, 2002.

[13] Mikkola J.H. Modularity assessment of product architecture: Implications for substitutability and interface management, Paper prepared for DRUID's Nelson and Winter Conference Aalborg, Denmark June 12-15, 2001.

[14] RevLog, the European Working group on Reverse Logistics. http://www.fbk.eur.nl/OZ/REVLOG/, 1998.

[15] Rogers D.S. and Tibben-Lembke R.S. Going Backwards: reverse logistics trends and practices, Reverse Logistics Executive Council, Pittsburgh, PA, 1999.

[16] Rose C.M. Design For Environment: A Method for Formulating Product End-of-Life Strategies., Dissertation, Stanford University, 2000.

[17] Stock J.R. Reverse Logistics, Council of Logistics Management, Oak Brook, IL, 1992.

[18] Thierry M.C., Salomon M., Van Nunen J., Van Wassenhove L. Strategic issues in product recovery management, California Management Review, Vol. 37, No.2, 1995, pp.114-135.

[19] Tibben-Lembke R.S. Life after death: reverse logistics and the product life cycle. International Journal of Physical Distribution & Logistics Management, Vol. 32 No. 3, 2002, pp. 223-244.

[20] Toffel M.W. End-of-life Product Recovery: Drivers, Prior Research, and Future Directions, Conference on European Electronics Take-back Legislation: Impacts on Business Strategy and Global Trade Center for the Management of Environmental Resources, INSEAD, Fontainebleau, Oct. 17-18, 2002.

[21] Umeda Y. Key design elements for the inverse manufacturing. In: Proceedings of the IEEE International Symposium on Environmentally Conscious Design and Inverse Manufacturing. IEEE, February, 1999.