The current issue and full text archive of this journal is available at
www.emeraldinsight.com/1355-5855.htm

Received November 2008
Revised November 2009
Accepted December 2009

Design of closed-loop supply chain and product recovery management for fast-moving consumer goods

The case of a single-use camera

David B. Grant
Logistics Institute, Business School, University of Hull, Hull, UK, and
Ruth Banomyong
Department of International Business, Logistics and Transport, Faculty of Commerce and Accountancy, Thammasat University, Bangkok, Thailand

Abstract

Purpose – The purpose of this paper is to qualitatively investigate how product recovery management (PRM) activities affected the strategic design and implementation of a closed-loop supply chain for a fast-moving consumer good.

Design/methodology/approach – The paper employs a case study approach with in-depth interviews and structured observation of PRM processes at the focal company.

Findings – The focal company was able to design an efficient and effective product recovery and recycle manufacturing system by standardizing high-quality raw materials, using a modular structure for the product and maintaining control over the entire process and bypassing the temptation to use third-party collectors and processors.

Research limitations/implications – Primary research relates to the single case study and the focal company; however, the findings may not generally apply to other fast-moving consumer goods (FMCG).

Practical implications – The comparison of the focal company's processes to an extant product recovery model provides firms with a structured way of implementing product recovery and recycling.

Originality/value – This paper adds to our knowledge of PRM and closed-loop supply chain design by investigating its practical application to a fast-moving consumer good; this topic has not previously received much attention by academics and practitioners.

Keywords Cameras, Supply chain management, Fast moving consumer goods, Manufacturing systems

Paper type Case study

Introduction

Reverse logistics forms part of closed-loop supply chain management (SCM) and has gained increased importance as an environmental, profitable, and sustainable business strategy. Both reverse logistics and closed-loop SCM are relatively new concepts with limited empirical research (Rogers and Tibben-Lembke, 2001); however, the pace of interest and research in this area has picked-up considerably.

One aspect of reverse logistics is the product recovery management (PRM) of all used and discarded products, components, and materials that a manufacturer is

The authors would like to acknowledge and thank Mr Kazuhide Rikuta for conducting the fieldwork and Fujifilm and its employees for their support and cooperation during this study.

1355-5855
DOI 10.1108/13555851011026971

responsible for (Thierry *et al.*, 1995). The reverse logistics literature provides various frameworks for developing reverse logistics strategies and subsequent reverse logistics systems; for example Stock (1992, 1998), Carter and Ellram (1998), Rogers and Tibben-Lembke (2001) and Dowlatshahi (2000). However, the literature does not adequately consider the challenges and influences of PRM on production, operations and logistics management, particularly in a supply chain that involves the consumer or end-user as a participant actor and for fast-moving consumer goods (FMCG).

FMCG such as "disposable razors" or plastic bottle packaging for cleaners and detergents are difficult to recover and reuse, or even recycle without some form of consumer incentive in today's "disposable society" with "cash rich and time poor" consumers. However, some FMCG products such as "disposable cameras" may lend themselves more readily to PRM techniques.

The purpose of this paper is to explore how key PRM activities have affected the strategic design and implementation of the closed-loop supply chain for Fujifilm's "Quick-Snap" single-use camera. First, we review the background literature. Then, the case study methodology to study Fujifilm's "inverse manufacturing system" is presented. Next, we present our analysis based on primary interviews and observations at Fujifilm and map their PRM strategy in the context of an extant PRM model by Thierry *et al.* (1995). Finally, conclusions and implications are drawn.

Literature review

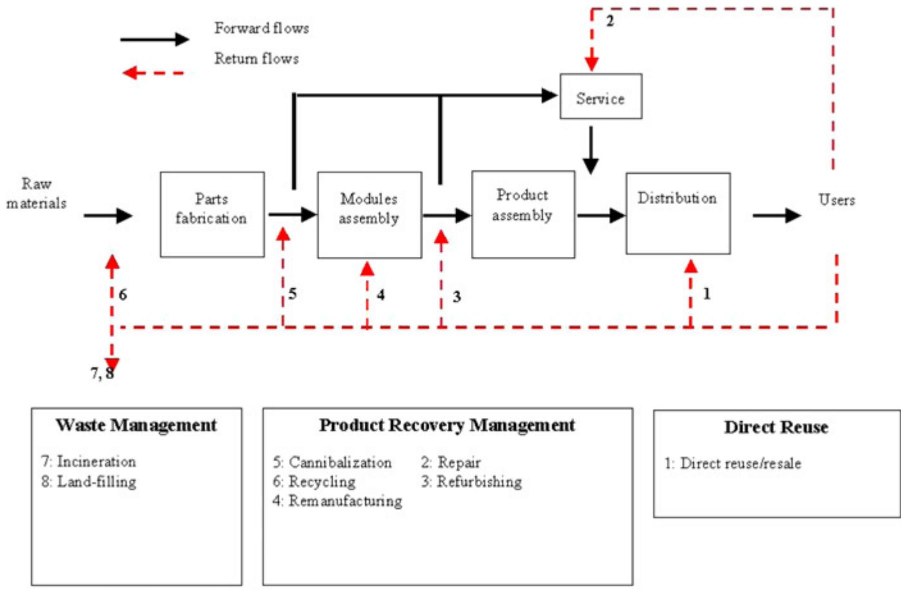
Stock (1992, 1998) and Rogers and Tibben-Lembke (2001) presented reverse logistics as a process in which a manufacturer retrieves previously distributed products from consumption or final destination points in order to recycle and/or remanufacture them for the purpose of capturing value or to properly dispose of them. Thierry *et al.* (1995) proposed PRM as a mechanism to recover as much of the economic and ecological values as reasonably possible, thereby reducing quantities of waste to be disposed. In this context, PRM is considered a subset of reverse logistics that is focussed on recovery as opposed to disposal.

Managers should strive for full utilization of current equipment within a PRM strategy in order to minimize total costs and ensure remanufactured products are compatible with the firm's overall product strategy (Dowlatshahi, 2000). When organizations have active resource commitment to reverse logistics programs, operations and supply chain managers may expect superior organization performance through destroying, recycling, refurbishing, and/or remanufacturing products (Skinner *et al.*, 2008).

However, remanufactured products need to provide the same high quality and availability for customers at hopefully a lower cost than new products (Carter and Ellram, 1998). Since customers usually require high-quality products regardless of their lineage, poor quality remanufactured products can affect a firm's reputation and sales. This is particularly important for FMCG where consumers have been conditioned to demand products of high merchantable quality.

Thierry *et al.* (1995) distinguished three categories of activities for consumer returned products in a reverse logistics supply chain: direct reuse or resale without any reprocessing, PRM activities, and waste management or disposal. These activities are presented in an integrated supply chain in Figure 1.

Each PRM option involves the collection of used products and components and the subsequent reprocessing, and redistribution of them. The main difference between each option is the type of reprocessing involved. The purpose of repair is to bring



Source: Thierry *et al*. (1995)

Figure 1.
A model for product recovery management

used products up to working condition and usually only requires limited product disassembly and reassembly. Refurbishing brings used products up to a specified quality, but quality standards are less precise than those of new products. After disassembling used products into discrete modules, critical modules are separated and inspected, and then fixed or replaced as required (Fleischmann *et al.*, 2000; Thierry *et al.*, 1995).

Remanufacturing means bringing used products up to the specified quality standard of new products and is thus more rigorous than refurbishing. Used products are completely disassembled into discrete modules and are extensively inspected. Depleted or outdated modules are replaced with new ones. Repairable components and modules are fixed and extensively checked. Approved parts are sub-assembled into modules and subsequently assembled into remanufactured products (Bylinsky, 1995; Thierry *et al.*, 1995).

Cannibalization involves selective disassembly of used products and inspection of potentially reusable parts. However, cannibalization reuses a smaller proportion of used modules in contrast to a large number of used products re-used during the repair, refurbishing, and re-manufacturing processes (Thierry *et al.*, 1995). Their quality level and the process in which they will be re-used will determine the selection of cannibalized parts.

Although the purpose of these four product recovery options is to retain the functionality of used products and parts as much as possible, the purpose of recycling is to reuse materials from the used products. However, much of the products' functionality is lost in the recycling process. These materials can be re-used in the production of original products if materials quality is maintained (Thierry *et al.*, 1995). Recycling occurs when used products are disassembled into parts, divided into material groups, and the separated materials are re-used in the production of new parts (Kopicki *et al.*, 1993; Pohlen and Farris, 1992).

Contamination makes primary material impure and reduces its recycling value (Pohlen and Farris, 1992). For example, mixed resins introduced into a plastic recycling process can lead to the separation of resins, bubbling, lack of coherence, or damage to the extruder. Contaminants such as oil or paper within the plastic recycling process may become dangerous such as fire and explosions. Maintaining the purity of recyclable products considerably increases costs, therefore material standardization is crucial for manufacturers who recycle used plastic product parts themselves. Material standardization allows manufacturers to recycle plastic materials cheaply and easily over during the recycling process and this will result in the reduction of new resin use and its subsequent environmental impact (Koh and Aoshima, 2001).

Modular production is one measure that eases disassembly and reassembly by decreasing product complexity, lowering the number of parts used in products, and raising the interchangeability and commonality of components (Giuntini and Andel, 1995a, c; Van Hoek and Weken, 1998). This measure uses generic modules that are interchangeable in a number of different finished products and can contribute to more efficient product differentiation in response to customer orders. Modularity also allows for rapid and easy final modification in the distribution channel.

Three logistics advantages of a modular product design include standardization of parts combined with postponed differentiation of products, shortening of total lead time because modules can be manufactured simultaneously and it is easy to isolate potential quality problems (Feitzinger and Lee, 1997). The greater the tolerance between modules for replacing them with different ones, the higher the responsiveness in final assembly for customer needs (Van Hoek and Weken, 1998).

While these PRM techniques are more easily identifiable in durable products, the same considerations may be applicable to FMCG. However, the application of PRM, material standardization, and product modularization to FMCG has not been studied extensively in the literature. Literature regarding PRM and the design of closed-loop supply chains has considered durable or large white goods (Krikke *et al.*, 2001); FMCG products that cannot be recovered such as batteries (Zhou *et al.*, 2007); and network and logistics design parameters such as reverse logistics legality (Banomyong *et al.*, 2008), dynamic modelling for product stocks and flows (Fleischmann *et al.*, 1997; Georgiadis and Vlachos, 2004), network design (Fleischmann *et al.*, 2000; Tan *et al.*, 2003), contingency planning (Guide *et al.*, 2003a), and efficient product returns vs costs (Guide *et al.*, 2003b; Min *et al.*, 2006).

Savaskan *et al.* (2004) also modelled the PRM process to determine the most effective way to collect products and found that the agent, i.e. retailer, closest to the customer provides that effectiveness. They considered the case of Kodak in their modelling, who noted that 67 percent of all returned single-use cameras returned to them are recycled. However, Kodak also takes back cameras from any retailer, unlike Fujifilm who use dedicated retailers for purposes discussed below.

This paper addresses the foregoing gaps by investigating one FMCG product that has the ability to be recovered and re-used. The Fujifilm "QuickSnap" single-use camera cannot be re-used or resold without undergoing some form of PRM due to its design characteristics. Further, waste management is almost non-existent in the QuickSnap "inverse manufacturing system" as an almost 100 percent recycling rate can be achieved, even with components such as packaging for the product, unlike the Kodak situation (Savaskan *et al.*, 2004).

Thus, this paper focuses specifically on Fujifilm's PRM strategy activities for QuickSnap, for which there are five options: repair, refurbishing, remanufacturing, cannibalization, and recycling. A case study method (Yin, 1994) was utilized to investigate factors surrounding Fujifilm's PRM and closed-loop supply chain strategies.

Methodology

This study is exploratory and based on a single company case study. The purpose of the case study is to try to understand the rationale behind Fujifilm's PRM and closed-loop supply chain strategies for the QuickSnap single-use camera, an FMCG. Yin (1994) suggested the following framework for case study research, the basis of which is a matter of knowledge acquisition and accumulation through the observation of real events:

- observing new phenomena should occur in a real environment;
- observations should take place when the boundary between the phenomena and the real environment is not expressly clear; and
- observations should be made when data from several sources have been jointly used.

In this case study, investigation triangulation was utilized as the data collected represented different perspectives from several internal managers, engineers, and stakeholders of Fujifilm's PRM program, on-site observations at the Ashigara factory in Japan that produces QuickSnap, and secondary data comprising Fujifilm documents and public reports. This approach was undertaken to try to obtain a better understanding of the most representative or objective reality in the specific research situation.

While the operations management literature discusses case study methods (see Stuart *et al.*, 2002 or Voss *et al.*, 2002 for recent examples), Ellram's (1996) case study method in logistics and SCM was adopted as the operative technique. As suggested by her a letter of introduction and overview of the research was sent to each respondent in the firm to prepare them for the interviews. Even though the conducted interviews were unstructured they followed general themes of PRM and its application at Fujifilm.

Primary interview and observation data were analyzed and combined with secondary data from Fujifilm's archives, documents, and various Fujifilm websites to deduce Fujifilm's PRM and reverse logistics strategies. Content analysis was used to look for themes in the interview and observation transcripts. Content analysis is a technique that uses a set of procedures to make inferences from textual materials; in our case, we categorized words and phrases to develop our themes in an effort to ensure validity of the categorization scheme and the text "units" contained within them (Weber, 1990).

Case analysis of Fujifilm's QuickSnap inverse manufacturing program

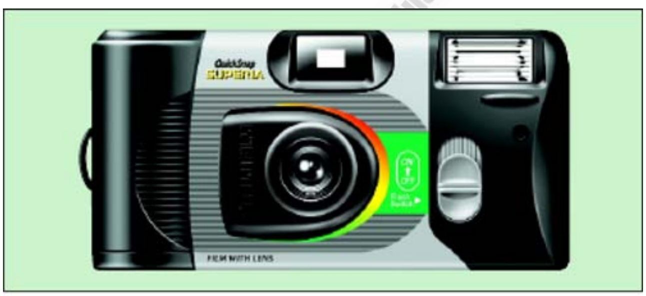
Fujifilm launched single-use cameras in 1986 under the brand name QuickSnap after market research determined that a growing segment of Japanese consumers only wanted to take pictures on an occasional basis. This segment wanted high-quality pictures at a point in time, but they did not necessarily want to own a corresponding piece of photographic equipment. This original concept was a true one-time use device that enabled consumers to have the film processed and images printed while the inexpensive and primarily cardboard camera was disposed of afterwards.

QuickSnap quickly became a popular consumer convenience product and one million cameras were sold in its first six months in the marketplace. Subsequently, the market expanded dramatically and the annual number of cameras sold was over 60 million in 1995. Although the original launching price was around 10 US$, at present selling price range from 7 to 15 US$ depending on product features such as zoom lens, waterproof body, or high-resolution films (Fujifilm, 2009). An example of a current generation QuickSnap Superia camera is shown in Figure 2 (Fujifilm, 2009, p. 2).

At the beginning of the 1990s several stakeholder groups attacked the product's disposable nature that resulted in a negative impact on the brand's image and sales. Consumers began to refer to QuickSnap as "disposables" or "throwaways" and the media reported environmental groups concern regarding their wastefulness. In response to those environmental pressures and as part of its corporate and social responsibility (CSR) posture, Fujifilm initiated a voluntary take-back program and began recycling the cameras by utilizing a highly developed and original recycling program.

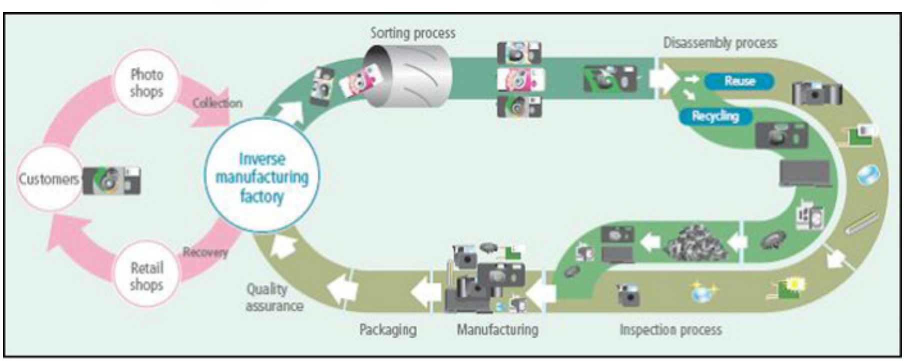
In doing so Fujifilm established one of the first, fully integrated closed-loop or reverse logistics systems for FMCG products and has since negated much of the poor environmental image of the QuickSnap product. Fujifilm calls their reverse system an "inverse manufacturing system" and their view of it is shown in Figure 3. In 2006, this system was awarded the "Inverse Manufacturing Grand Prize, which publicly recognizes achievements from various companies over the past ten years for developing various types of inverse (circulatory) production techniques" (Fujifilm, 2007, p. 21).

As part of our research process, we devised simple process maps (Jones *et al.*, 1997; Hines and Taylor, 2000) for the physical product and information flows in the Fujifilm inverse system that are shown in Figures 4 and 5.



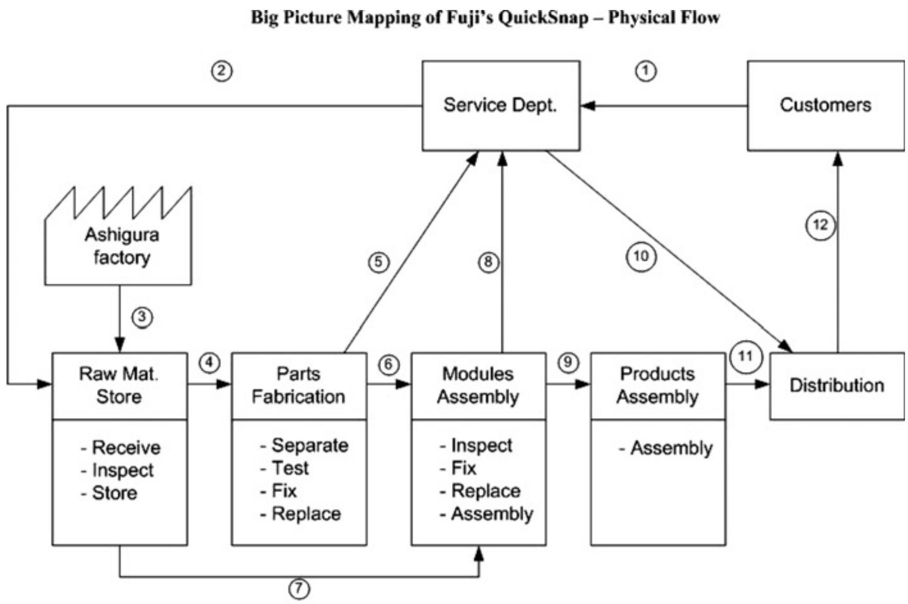
Source: Fujifilm (2009, p. 2)

Figure 2.
Example of current generation QuickSnap camera



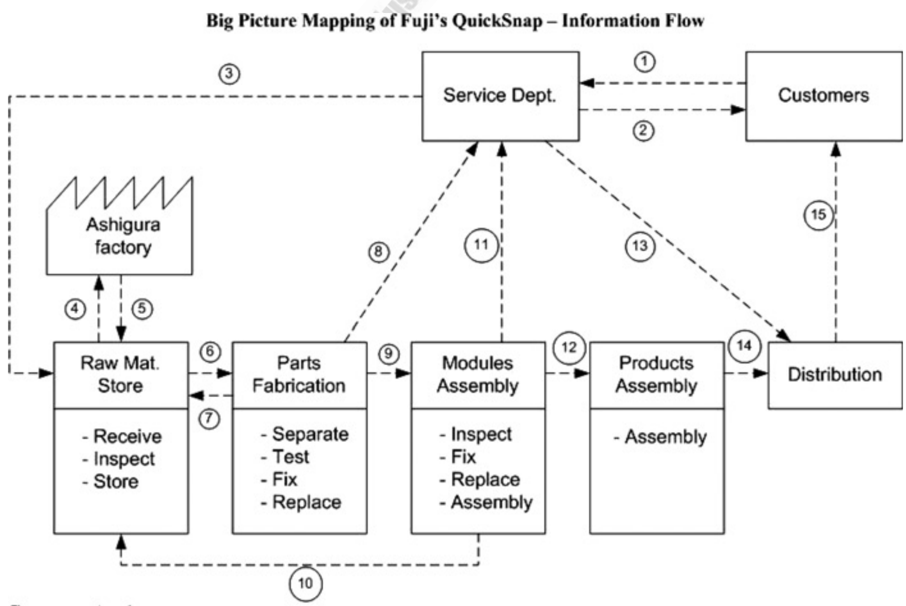
Source: Fujifilm (2007, p. 21)

Figure 3.
Fujifilm's inverse manufacturing system



Source: Authors

Figure 4.
Physical process flow model for Fujifilm's QuickSnap inverse manufacturing system



Source: Authors

Figure 5.
Information process flow model for Fujifilm's QuickSnap inverse manufacturing system

The QuickSnap product concept and structure had two advantages that smoothed the way to recycling. First, the QuickSnap is categorized not as a camera but as "film" in industrial product classification and the silver and chemical base utilized in films already had recycling targets and measures that Fujifilm could draw upon. It was important to reuse high-priced silver from an economic point of view and that also justified the expense of developing an efficient reverse logistics system.

Second, the number of parts utilized in the QuickSnap camera was designed to be as few as possible and cardboard was utilized for outer package. These two features allowed the easy development of product modularization and unitization.

QuickSnap cameras are composed of six units: main body, lens, flash, switch, rear cover, and front cover. Generally, when a functional change is needed the new function is incorporated into all units except for the main body and flash units. There are two main reasons for the QuickSnap modular design according to Fujifilm's manufacturing engineering department. First, it is desirable that products have an easy to disassemble structure in order to be re-used or recycled. Although integration inside each unit or module is very high, the design enabled the interface between units to be simplified. As a result, a high level of dis-assembly efficiency can be realized leading to high efficiency of re-use and recycle.

Second, quality inspection and testing can be conducted specifically on the unit or modular design. It can take a large amount of time to inspect all components of a QuickSnap that has been returned. If constituent components were intricately related to other components, most of the components would have to be inspected in order to guarantee the same specific function. Thus, in order to reduce quality inspection inefficiencies Fujifilm reduced the number of components, integrated some components for discrete functions, and treated those integrating components as a unit. In this manner, each of the six units is a functionally independent unit or module that can be inspected independently.

Decomposing the product into several units is determined not only from the standpoint of recycling or reuse but also by a balance of various conditions such as design appeal or production costs. The QuickSnap unit structure has only been slightly changed since 1992 and only to correspond to customer needs. When there is QuickSnap model change and a new module design is required, the external dimensions and each unit's (function module) disposition are examined first. The utilization of three-dimensional computer aided design (CAD) data of the existing product can help design engineers to create the detail of new functional parts which will be added to the product. The CAD data are also sent to the Recycle Engineering Department for comments as both groups will have to carefully examine the CAD data from an assembly and disassembly process point-of-view.

Currently, all QuickSnap products include recycled or re-used parts. Accordingly QuickSnap is considered to be a product that represents "recycle-based manufacturing". The recycle-based or inverse manufacturing system for QuickSnap consists of 11 steps that utilize both recycling and the re-use of components as shown in Figure 3.

From an economic perspective, it is desirable that components are re-used as many times as possible without recycling these components into raw materials (Guide *et al.*, 2003b). However, there are some components that are quite difficult to re-use for such a product. The Recycle Engineering Department Senior Manager noted that:

> Honestly, it is quite difficult to reuse previously recycled products. Although the electrical performance of components is relatively easy to guarantee, but the mechanical performance of components is quite difficult to guarantee because module mechanical function is pretty complicated. For example, the front cover unit has a shutter release button and this unit prevents any light from leaking out. Thus no cracks are allowed on this unit. Consequently, many inspection steps are required to check whether there are any cracks in this unit or not

> and whether the lens is clear. Furthermore it is necessary to check some components with the naked eye. This leads to quite high inspection costs.

Thus, the boundary between reuse and recycle depends on the difficulty of the quality guarantee for each unit or module. The electrical units have relatively uncomplicated functionality so it is not difficult to inspect quality by utilizing mechanical testing. On the other hand, QuickSnap mechanical units include several functions with a high inspection cost incurred to guarantee product quality. The front cover, rear cover, switch, and film advancing knob are always completely recycled into raw materials and reshaped into new components in order to ensure mechanical unit quality. This procedure enables Fujifilm to guarantee reliable quality of every QuickSnap and thus remanufactured products maintain the same quality standards as new products.

In order to realize a satisfactory economic return on the single-use camera, various innovations in design have been developed for the QuickSnap manufacturing process. These innovations are crucial factors in implementing recycle-based manufacturing as well as affecting product quality and costs. Traditionally, recyclable parts were crushed melted and pelletized into recycled materials before being reshaped into new components. "Pelletized" recycled materials enable the manufacture of new parts with approximately one-third of the energy consumption of manufacturing new parts from raw materials.

However, the thermal melting process caused deterioration in material quality. Fujifilm thus developed a new non-pelletized recycling material that avoids such deterioration and ensures that materials are reutilized as much as possible. However, since non-pelletized materials have a different form compared to regular pellets, existing plastics molding machines available on the market could not process them and it was difficult for Fujifilm to sell these materials to external customers in order to further develop this particular aspect of its business.

The volume and weight of the original QuickSnap was approximately twice that of the current QuickSnap product line. More than ten times the energy was used to manufacture plastic parts from raw materials for introductory QuickSnap models compared to current models. This has led to an environmental impact of reduced carbon dioxide emissions resulting from plastic recycling of about 90 percent compared to the original QuickSnap model. Further, the percentage of a QuickSnap camera's weight that is being recycled has increased from 36 percent in 1992 to 95 percent in 2007 (Fujifilm, 2007, p. 21).

Standardized materials are critical for reuse and recycle. If materials are not standardized then it is impossible to warrant the quality of such materials owing to potential impurities. The same-grade polyethylene has been utilized at Fujifilm since 1986 when the first model was introduced. This enabled Fujifilm to recycle QuickSnap easily irrespective of the models and the manufacturing date. Moreover, the use of recycled same-grade resins has led to a reduction in the use of new raw materials. Thus standardized materials have resulted in environmental and cost reductions for QuickSnap production. No screws are used in QuickSnap as all components are fixed by "snap-fits"; QuickSnap cameras can easily be disassembled automatically by a dis-assembly machine.

QuickSnap sales are subject to seasonal fluctuations and it is difficult to forecast demand fluctuations caused by such seasonality. QuickSnap's recycle-based manufacturing assists demand forecasting and factory utilization as the number of QuickSnaps collected from photo finishers also shows seasonal fluctuations. The QuickSnap Marketing and Sales Manager commented:

> It is quite difficult to forecast demand by utilizing only sales data from the number of QuickSnaps sold. However, since the number of collected QuickSnaps in recycle-based manufacturing yields the actual number of cameras that were used by customers, demand forecasting is relatively easy for us.

Thus, the recycle-based manufacturing loop facilitates a balance between forecast accuracy and the ability of manufacturing to adjust production to meet current demands. Fujifilm's inverse manufacturing system allows for both processes, production and recycling, to be carried out in the same facilities. The QuickSnap disassembling process is carried out in reverse order of the new product assembling process and is compatible with the recycling and decomposing processes. For example, one machine which is used only to set the rear unit into the main unit can also take the rear unit off the main unit. This means that other machines can also be utilized for the recycling or dis-assembly process when demand fluctuates and thus efficiency of the inverse manufacturing system is enhanced.

Environmental accounting has allowed Fujifilm to perform calculations and analysis that take into account environmental protection issues in a way that could not adequately be accommodated using conventional corporate financial accounting frameworks. This is done by numerically quantifying the relationship between environmental protection and economic feasibility.

Fujifilm's latest environmental report notes that the fiscal year 2006 economic impact from QuickSnap recovery within the company was 1.7 billion yen out of a total of 37.5 billion yen. Further, the environmental economic impact outside the company, i.e. reductions in sulfur dioxide, carbon dioxide, and volatile organic compounds was 47.2 billion yen (Fujifilm, 2007, p. 84). These calculations are consistent with guidelines from the Ministry of the Environment, Government of Japan (2008) and were vetted and approved by third-party organizations.

There has been a trend towards environmental outsourcing whereby many companies leave a part of the recycling and reuse process to external processors (Van Hoek and Weken, 1998; Knemeyer *et al.*, 2002). The QuickSnap inverse manufacturing system is a truly closed loop as only Fujifilm manages it. Fujifilm does not outsource any part of its recycling and re-use processes for strategic reasons as they consider that their self-sustaining PRM brings out the primary value of their products most effectively and efficiently. The development of Fujifilm's recycle-based manufacturing system has led to a vertically integrated organization. The Manufacturing Engineering Department Manager argued:

> In terms of recycling, there are two ways of thinking. One of them is cascade recycling where all participants such as manufacturers, processors and consumers recycle waste and aim at zero emissions throughout the system. The other is inverse manufacturing where only one participant recycles waste within its system. One of the superior points of inverse manufacturing is that it is relatively easy to add up the value on the collected products. In addition, some dedicated recycle processors do admit that household appliance manufacturers or battery manufacturers are more than unwilling to disclose their know-how including how to manufacture, how to discompose and so on. Hence recycle processors have to analyze ways of decomposition step by step. This point is a typical Japanese industrial characteristic in which manufacturer and recycle processors have been separated. Thus, in order to minimize technical inefficiency and inefficient resource use, manufacturers have developed the recycling of their own products by themselves, because manufacturers understand their products better than anyone else.

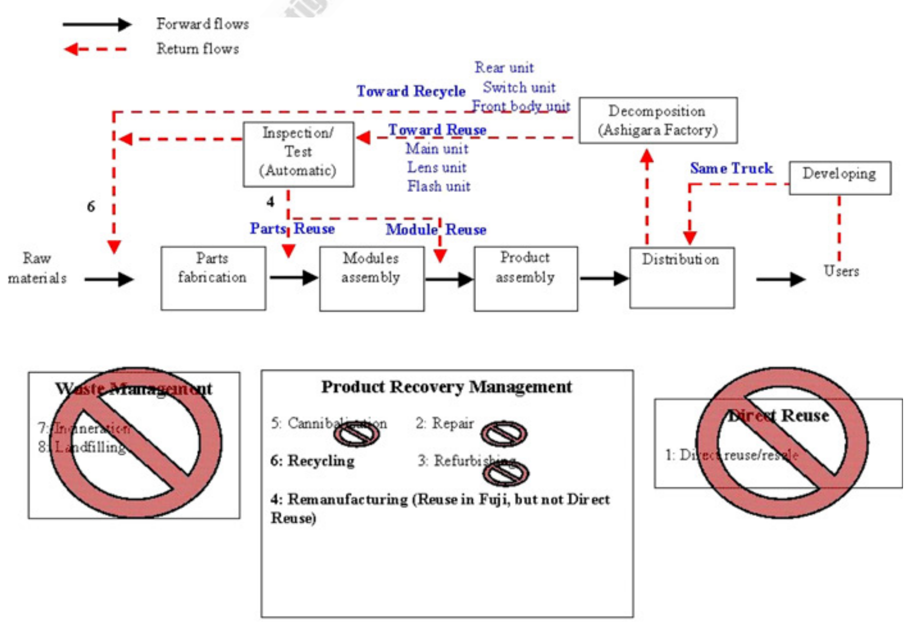
If manufacturers utilize external recycling processors or third-party logistics providers, they will have to provide detailed instructions for them in order to ensure that they understand the required quality standards of the original products (Meade and Sarkis, 2002) and this process is more costly. However, in contrast, inverse manufacturing enables manufacturers to keep a relatively low cost in guaranteeing the quality of the recycled product as well as keeping the technological cost down.

The number of inspections for recycled items is greater than that for new parts manufacturing. This is due to fluctuating manufacturing process conditions that are impossible to maintain in a uniform and homogeneous manners. The recycling condition or the reuse of parts is also subject to consumers' usage and the environment of use. Fujifilm would endanger consumer trust by selling refurbished products as new, especially if they did not have sufficient control over the recycling process.

Comparison of the QuickSnap inverse manufacturing system to a PRM model

Figure 6 shows the structure of Fujifilm's QuickSnap inverse manufacturing system compared to Thierry *et al.*'s (1995) PRM model from Figure 1. Fujifilm's system encompasses recycling, remanufacturing, and some repair operations but has several points of difference with Thierry *et al.*'s model.

First, repair operations usually require only limited product dis-assembly and reassembly and may be performed at a customer's location or at manufacturer-controlled repair centers (Thierry *et al.*, 1995). However, repair operations for QuickSnap are only carried out only when modules need to be fixed after module inspection and thus repairs can only carried out in the main manufacturing factory. If these components do not pass inspection they will be sent to the recycling operation



Source: Authors

Figure 6.
Comparison of Fujifilm's QuickSnap inverse manufacturing system to Thierry *et al.*'s product recovery management model

because the component repair operation is more expensive than the recycling operation in terms of labor cost. Thus the repair operation option given in Thierry's model is not applicable to QuickSnap. Likewise, cannibalization and refurbishing are not extensively carried out in the QuickSnap product recovery operation.

Second, the direct reuse or resale and waste management characteristics are not applicable to QuickSnap as noted above. The QuickSnap PRM process is therefore much more simplified compared to Thierry *et al.*'s model in Figure 1, which was developed to explain PRM for products such as copiers and automobiles. Several recovery options are eliminated from their model regarding Fujifilm as denoted by the "circle and line" graphics shown in Figure 6.

In order to achieve low costs and short time recovery operations and to maintain high quality of recycled products, the QuickSnap inverse manufacturing system is concentrated on re-use and recycling processes by actively introducing automated processing systems and inspection as well as innovative modular design and material standardization. This smaller number of product recovery options enables Fujifilm to achieve a high recycling rate and efficient, low-cost recycle-based manufacturing for the fast-moving consumer QuickSnap product.

Conclusions

We have presented the Fujifilm QuickSnap PRM process for FMCG as an application of Thierry *et al.*'s (1995) PRM model. Based on Fujifilm's experience, other FMCG manufacturers may be able to achieve efficient and more economical recycling options as well as being environmentally friendly to manufacture by reducing the number of product recovery options.

Pohlen and Farris (1992) emphasized that plastic material standardization is crucial to improve part recyclability, heighten material value, and reduce manufacturing risks. Material standardization idea has been introduced in the QuickSnap design and this has positively affected several aspects of the QuickSnap recycle-based manufacturing process. QuickSnap's standard polyethylene plastic has been utilized since product inception and this has enabled Fujifilm to recycle QuickSnap easily irrespective of models and manufacturing dates.

The use of same-grade resins has also led to a reduction in new raw material use. This application supports Koh and Aoshima (2001) and Di Marco *et al.* (1994) who suggested that same-grade plastic applications allow manufacturers to recycle plastic material economically. Plastic material standardization has been used in the automobile industry (Ferrer, 1996; Giuntini and Andel, 1995a); however, the QuickSnap recycle-based process achieves a plastic recyclability level of almost 100 percent compared to the automobile industry where the best is about 80 percent at BMW (Giuntini and Andel, 1995c).

Material standardization has led Fujifilm to develop their own original non-pelletized plastic recycling process that is characterized by no material deterioration caused by thermal treatment, and CO_2 emissions being reduced by 90 percent. The polyethylene material standard and non-pelletized plastic recycling process are unique to Fujifilm and thus this closed loop prohibits the use of external recyclers. This means that economies of scale in recycling this material are limited to a certain extent.

Just as with material standardization, modular structure is one of the crucial factors affecting QuickSnap's reverse logistics. Modular design decreases product complexity by lowering the number of parts a product is composed of, and increases the varieties of products available (Giuntini and Andel, 1995a; van Hoek and Weken, 1998). The

QuickSnap design of six modules accomplishes those objectives to produce many product variations with a small number of common modules. This minimizes product costs and reduces the cost of assembly and disassembly (Aoki and Ando, 2002; Giuntini and Andel, 1995a, 1995b; Van Hoek and Weken, 1998).

By introducing a modular structure, Fujifilm has developed its own unique closed loop, inverse manufacturing system, and consequently third-party recycling processors are not considered an option for them. However, Van Hoek and Weken (1998) and Knemeyer *et al.* (2002) argued that modularity encourages suppliers to engage in original equipment manufacturer recycling, especially for automobiles and end of line computers. The difference here comes from product complexity and the number of modules in the final product; Fujifilm can effectively and efficiently bypass recycling processing traders due to the simplicity of the QuickSnap design and its unique and non-transferable manufacturing techniques as well as Fujifilm's own quality control concerns.

This case study suggests that Fujifilm's QuickSnap single-use camera has established itself as an environmentally friendly yet profitable product. It supports the use of some of Thierry *et al.*'s (1995) model for PRM for Fujifilm due to its closed-loop recycle manufacturing system and the nature of the QuickSnap being a fast-moving consumer product. The case study approach used by the authors was important in the understanding of the rationale behind Fujifilm's close-loop supply chain for its QuickSnap product.

Future research should apply the Thierry *et al.* (1995) model in other FMCG contexts and industries to determine whether the results of this case study can be replicated and whether Fujifilm exemplifies, as the authors believe, best practice in this area. Another objective of such future research should be the establishment of more simplified PRM models for different contexts and industrial supply chains such as food, services, and other FMCG.

References

Aoki, M. and Ando, H. (2002), *Modularity: New Industry Architecture*, Toyo Keizai, Tokyo.

Banomyong, R., Veerakachen, V. and Supatn, N. (2008), "Implementing legaility in reverse logistics channels", *International Journal of Logistics: Research and Applications*, Vol. 11 No. 1, pp. 31-47.

Bylinsky, G. (1995), "Manufacturing for reuse", *Fortune*, February 6, pp. 60-5.

Carter, C.R. and Ellram, L.M. (1998), "Reverse logistics: a review of the literature and framework for further investigation", *Journal of Business Logistics*, Vol. 19 No. 1, pp. 85-102.

Di Marco, P., Eubanks, C.F. and Ishii, K. (1994), "Compatibility analysis of product design for recyclability and reuse", *Proceedings of the Computers in Engineering International Conference, New York, NY*, pp. 105-12.

Dowlatshahi, S. (2000), "Developing a theory of reverse logistics", *Interfaces*, Vol. 30 No. 3, pp. 143-55.

Ellram, L.M. (1996), "The use of the case study method in logistics research", *Journal of Business Logistics*, Vol. 17 No. 2, pp. 93-138.

Feitzinger, E. and Lee, H.L. (1997), "Mass customization at Hewlett-Packard: the power of postponement", *Harvard Business Review*, Vol. 75 (Jan-Feb), pp. 116-21.

Ferrer, G. (1996), "Product recovery management industry practice and research issues", Working Paper No. 96/95/TM, INSEAD, Fontainebleau.

Fleischmann, M., Krikke, H.R., Dekker, R. and Flapper, S.D.P. (2000), "A characterisation of logistics networks for product recovery", *Omega*, Vol. 28, pp. 653-66.

Fleischmann, M., Bloemhof-Ruwaard, J.M., Dekker, R., van der Laan, E., van Nunen, J.A.E.E. and van Wassenhove, L.N. (1997), "Quantitative models for reverse logistics: a review", *European Journal of Operational Research*, Vol. 103 No. 1, pp. 1-17.

Fujifilm (2007), *Fujifilm Sustainability Report*, available at: www.fujifilm.com/pdf/about/sustainability/ff_sr_2007_001.pdf (accessed 30 September 2008).

Fujifilm (2009), "Fujifilm product information bulletin: FujiColor QuickSnap superia", available at: www.fujifilm.com/products/quicksnap/pdf/quicksnap_superia.pdf (accessed 17 December).

Georgiadis, P. and Vlachos, D. (2004), "The effect of environmental parameters on product recovery", *European Journal of Operational Research*, Vol. 157, pp. 449-64.

Giuntini, R. and Andel, T. (1995a), "Advance with reverse logistics", *Transportation and Distribution*, Vol. 36 No. 2, pp. 73-7.

Giuntini, R. and Andel, T. (1995b), "Master the six R's of reverse logistics", *Transportation and Distribution*, Vol. 36 No. 3, pp. 93-8.

Giuntini, R. and Andel, T. (1995c), "Reverse logistics role models", *Transportation and Distribution*, Vol. 36 No. 4, pp. 97-8.

Guide, V.D.R., Jayaraman, V. and Linton, J.D. (2003a), "Building contingency planning for closed-loop supply chains with product recovery", *Journal of Operations Management*, Vol. 21, pp. 259-79.

Guide, V.D.R., Teunter, R.H. and van Wassenhove, L.N. (2003b), "Matching demand and supply to maximize profits from remanufacturing", Working Paper No. 2003/53/TM, INSEAD, Fontainebleau.

Hines, P. and Taylor, D. (2000), *Going Lean: A Guide to Implementation*, Lean Enterprise Research Centre, Cardiff Business School, Cardiff.

Jones, D.T., Hines, P. and Rich, N. (1997), "Lean logistics", *International Journal of Physical Distribution and Logistics Management*, Vol. 27 Nos 3/4, pp. 153-73.

Knemeyer, A.M., Ponzurick, T.G. and Logar, C.M. (2002), "A qualitative examination of factors affecting reverse logistics system for end-of-life computers", *International Journal of Physical Distribution and Logistics Management*, Vol. 32 No. 6, pp. 455-79.

Koh, Y. and Aoshima, Y. (2001), "Recycle and reuse", *Hitotsubashi Business Review*, Vol. 49 No. 3, pp. 144-58.

Kopicki, R., Berg, M., Legg, L., Dasappa, V. and Maggioni, C. (1993), *Reuse and Recycling – Reverse Logistics Opportunities*, Council of Logistics Management, Oak Brook, IL.

Krikke, H., Bloemhof-Ruwaard, J. and van Wassenhove, L. (2001), "Design of closed loop supply chains: a production and return network for refrigerators", CIMSO Working Paper No. 2001/67/TM/CIMSO 19, INSEAD, Fontainebleau.

Meade, L. and Sarkis, J. (2002), "A conceptual model for selecting and evaluating third-party reverse logistics providers", *Supply Chain Management: An International Journal*, Vol. 7 No. 5, pp. 283-95.

Min, H., Ko, H.J. and Ko, C.S. (2006), "A genetic algorithm approach to developing the multi-echelon reverse logistics network for product returns", *Omega*, Vol. 34, pp. 56-69.

Ministry of the Environment, Government of Japan (2008), Available at: www.env.go.jp/en/recycle/ (accessed 30 September).

Pohlen, T.L. and Farris, M.T. (1992), "Reverse logistics in plastic recycling", *International Journal of Physical Distribution and Logistics Management*, Vol. 22 No. 7, pp. 35-47.

Rogers, D.S. and Tibben-Lembke, R. (2001), "An examination of reverse logistics practices", *Journal of Business Logistics*, Vol. 22 No. 2, pp. 129-48.

Savaskan, R.C., Bhattacharya, S. and van Wassenhove, L.N. (2004), "Closed-loop supply chain models with product remanufacturing", *Management Science*, Vol. 50 No. 2, pp. 239-52.

Skinner, L.R., Bryant, P.T. and Richey, R.G. (2008), "Examining the impact of reverse logistics disposition strategies", *International Journal of Physical Distribution and Logistics Management*, Vol. 38 No. 7, pp. 518-39.

Stock, J.R. (1992), *Reverse Logistics Programs*, Council of Logistics Management, Oak Brook, IL.

Stock, J.R. (1998), *Development and Implementation of Reverse Logistics Programs*, Council of Logistics Management, Oak Brook, IL.

Stuart, I., McCutcheon, D., Handfield, R., McLachlin, R. and Samson, D. (2002), "Effective case research in operations management: a process perspective", *Journal of Operations Management*, Vol. 20 No. 5, pp. 419-33.

Tan, A.W.K., Yu, W.S. and Arun, K. (2003), "Improving the performance of a computer company in supporting its reverse logistics operations in the Asia-Pacific region", *International Journal of Physical Distribution and Logistics Management*, Vol. 33 No. 1, pp. 59-74.

Thierry, M., Salomon, M., Van Nunen, J. and Van Wassenhove, L. (1995), "Strategic issues in product recovery management", *California Management Review*, Vol. 37 No. 2, pp. 114-35.

Van Hoek, R.I. and Weken, H.A.M. (1998), "Integrating the supply chain using modular production", *International Journal of Logistics: Research and Applications*, Vol. 1 No. 1, pp. 39-56.

Voss, C., Tsikriktsis, N. and Frohlich, M. (2002), "Case research in operations management", *International Journal of Operations and Production Management*, Vol. 22 No. 2, pp. 195-219.

Weber, R.P. (1990), *Basic Content Analysis*, 2nd ed., *Sage University Paper Series on Quantitative Applications in the Social Sciences*, 04-049, Sage, Newbury Park, CA.

Yin, R.K. (1994), *Case Study Research: Design and Methods*, 2nd ed., Sage, Thousand Oaks, CA.

Zhou, L., Naim, M. and Wang, Y. (2007), "Soft systems analysis of reverse logistics battery recycling in China", *International Journal of Logistics: Research and Applications*, Vol. 10 No. 1, pp. 57-70.

Corresponding author
David B. Grant can be contacted at: d.grant@hull.ac.uk