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Networked RFID Systems in Product Recovery Management

A.G. Kulkarni, A.K.N. Parlikad, D.C. McFarlane and M. Harrison

Cambridge Auto-ID Labs, Institute for Manufacturing,
University of Cambridge, Mill Lane,
Cambridge, United Kingdom CB2 1RX

www.autoidlabs.org

Abstract
Product recovery involves collection, sorting and reprocessing of returned products to recover value from them. The management of product recovery is characterised by a high level of uncertainty in product returns flow due to the lack of information associated with such products. A case study exercise carried out at various electronics product recovery industries in Europe supports this widely accepted fact. The recent emergence of networked RFID (Radio Frequency Identification) systems is a means of connecting a product tagged with an RFID chip to a network and thereby carrying complete information associated with it throughout its lifecycle. This paper examines the benefits of information provided by such systems in decision-making during product recovery stages and consequently, in product recovery management as a whole.

1. Introduction

Radio Frequency Identification (RFID) is receiving considerable attention as an enabling technology that can improve supply chain operations, asset tracking and inventory control. RFID is an automatic identification technology whereby digital data encoded in an RFID tag is captured by a reader using radio waves. The reader can read multiple tags simultaneously without requiring manual scanning of each individual item.

The Auto-ID Center — a collaboration between six of the world's leading universities and over 100 industrial sponsors — developed low cost RFID technology and global standards, to track objects automatically and ubiquitously [1]. The Center's vision is to enable automatic unique identification of an item without manual intervention using RFID, storing all information about the item in a networked database, and ensuring reliable and timely update of information based on physical operations during the item's lifecycle. Such a "networked RFID system" developed by the Auto-ID Center is called as the EPC (Electronic Product Code) Network which can enable a device to scan and identify a product and then, access crucial information about it, such as when and where it was made; where it was shipped from; and how it was handled, used and maintained. This will greatly enhance the quality of strategic, tactical as well as operational level decisions taken along the product lifecycle which are highly dependent on the timeliness and accuracy of the information available[2][3].

One of the possible benefits of the EPC Network is in improving product information quality leading to better product recovery decisions. In particular, we are examining the impact of product information provided by such a network on product dispositioning decisions and product recovery inventory decisions. A product dispositioning decision involves selecting a recovery process such as remanufacturing, or refurbishing or recycling for treating returned products and inventory decisions are concerned with planning of recovery process for returned products.

Product recovery decisions are very complicated due to the lack of information associated with returned products. This is due to the fact that the amount and complexity of data in managing item level information is increasing due to a very high number of variants and customised products [4]. Hence, every single product reaching the product recovery stage is unique in terms of its design, manufacturing, constituent parts and quality. Consequently, extensive information about returned products is required during product recovery stages. A case study exercise carried out at various electronics product recovery industries in Europe revealed that the scarcity of product information during the product recovery stages is a major obstacle in recovering value from returned products.

This paper describes product information availability and requirements in the industry during product recovery decision-making and the role of networked RFID systems in delivering the requisite product information to improve product recovery decisions. The remainder of the paper is organised as below: section II provides a brief overview of the EPC Network describing its various components; section III highlights research scope; section IV examines the availability of product information with respect to different business scenarios and its impact on product recovery decisions; section V elucidates the role of networked RFID systems in product information management; section VI illustrates a networked RFID enabled product recovery scenario with the example of laptops and finally section VII concludes the exposition.

2. Networked RFID Systems

In this section, we will provide a brief overview of the EPC Network—fundamentally networked RFID systems- developed by the Auto-ID Center. For details on the technology, the reader is advised to refer to [5].The EPC Network consists of six technology components as shown in fig. 1.

2.1 The Electronic Product Code (EPC)

The aim of the EPC is to provide a unique identifier for each object. It is designed to be scaleable and extensible.

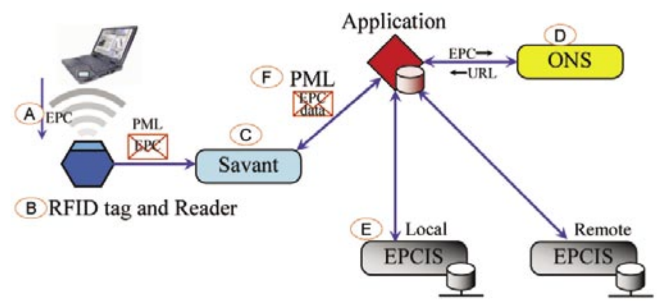

Fig. 1: Architecture of the EPC Network

2.2 RFID tags and readers

RFID is an automatic identification technology whereby digital data encoded in an RFID tag is captured by a reader using radio waves.

2.3 Filtering, collection and reporting of RFID data (Savant)

The role of this technology component is to ensure that only significant “events” and data packets are propagated to application and information systems, rather than individual RFID tag-reads.

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2.4 Object Naming Service (ONS)

The ONS translates an EPC into a number of internet addresses where further information about the given object associated with the EPC can be found.

2.5 The EPC Information Service (EPCIS)

The EPC Information Service is an interface to a networked database which allows trading partners to access and exchange well-defined subsets of their live real-time data, through a standard interface.

2.6 PML (Physical Markup Language)

When data is obtained via ONS and EPCIS, it is necessary that its interpretation is unambiguous and self-describing. PML is developed in the eXtensible Markup Language (XML) format for communicating data directly captured by the EPC network in a structured way.

These building blocks together form the infrastructure of the EPC Network. As shown in fig. 1, the laptop is tagged with an RFID tag which returns its EPC in response to the reader's interrogation. The tag-reads from the laptop are filtered, collected and reported to a software application (e.g. inventory check software). The application will then query the ONS to obtain the URL (Uniform Resource Locator) corresponding to the EPCIS that contains data linked to the EPC. This EPCIS could lie locally or across the Internet. It can then query the appropriate EPCIS to obtain the necessary information.

We are investigating the role of product information provided by such networked RFID systems in decisionmaking during product recovery stages. In the next section, we will take a look at our research scope.

3. Research Scope

In order to obtain a better understanding of prevailing issues in the product recovery industries, a number of case studies were carried out at electronics product recovery facilities in Europe. These case studies corroborated the widelyacknowledged fact that product recovery is characterised by a high level of uncertainty in terms of timing, quantity and quality of product return flows [6] [7]. Uncertainty in recovery of products arises from the fact that a decision-maker does not have information which quantitatively or qualitatively is appropriate to make cost effective decisions during product recovery. Hence, there is a significant potential for information to reduce the uncertainties in product recovery.

Although the research community has recognised that the lack of product information is a major hindrance in efficient product recovery, the link between the decisions taken during product recovery stages and the impact of enhanced information provided by networked RFID systems on these decisions has not received much attention. In view of this, our research is focussed on examining the impact of enhanced product information provided by networked RFID on the following product recovery decisions:

3.1 Product dispositioning decisions

When a product is returned by its last user, there are several ways by which value can be recovered from it - the product can be reused as is, reused after remanufacturing, recycled to recover its material contents or incinerated for engineering recovery. The choice of an appropriate product dispositioning decision greatly depends upon the availability of relevant product information during the decision-making process.

3.2 Product recovery inventory decisions

Inventory decisions during the product recovery stages are highly complex and are not alike in all product recovery scenarios. For example, product remanufacturing done by Original Equipment Manufacturers (OEM) involves decisions on lotsizes of disassemblies and new parts. On the other hand, product refurbishing done by third-party companies involves decisions on identifying and prioritising high value and high quality products for refurbishing to recover as much value as possible from their client's returned products. These product recovery inventory decisions are complicated due to the lack of information associated with returned products. The aim of our research is to provide a quantitative assessment of the impact of enhanced information provided by networked RFID systems on product recovery decisions. In the next section, we will discuss the varied nature of decisionmaking, and the information available to support these decisions in the product recovery industry.

4. Product Information Availibility for Product Recovery Decision-Making: Two Business Cases

A notable finding of the case study exercise is that the nature of product recovery decisions and the availability of product information to support these decisions vary largely across different business scenarios. In this section, we will discuss how different business scenarios govern the availability of product information and consequently, its impact on product recovery decision-making with respect to the two kinds of product recovery industries.

4.1 Case 1: OEM owned product recovery

Many OEMs are sensing long term and economic benefits brought about by recovering value from returned products. They collect their own returned products, restore used parts to like-new condition and use these reconditioned parts for building a new product.

A case study was carried out at a major OEM owned product remanufacturing facility in Ireland. The company is a pioneer in establishing the practice of restoring returned photocopiers and their components to like-new condition. The majority of the company's product returns stem from leased equipment at the end of its lease period. The end-oflease photocopiers returned by customers across Europe are collected at the central collection facility in Venlo, the Netherlands. The collected photocopiers are termed "carcasses." The carcasses are pulled into the remanufacturing facility located in Ireland depending on the demand for new products. Fig. 2 shows a pictorial representation of the OEM owned product remanufacturing operations. When carcasses arrive at the remanufacturing facility, they are stripped to component level. The apparently worn-out components are sent for recycling and the reusable components are cleaned, painted and restored to like-new condition. The reused components are called "donors." New components are procured from external suppliers to make up for the worn-out and non-reusable components. Finally, a new product is built using both new components as well as reusable components. We will now examine the following product recovery decisions and the availability of product information to support these decisions in the context of this product recovery scenario:

1 Product dispositioning decision: This decision typically involves the selection of an appropriate alternative for treating returned products and components. In this company's case, the decision involves whether to remanufacture or recycle products and components. The dispositioning decision at the product level is taken at the collection facility in Venlo. The carcasses are subjected to a visual inspection. This involves checking the overall physical condition of a carcass and identifying any missing components. If the carcass is very old and physically damaged with some major components missing, it is sent for recycling. At this stage, the only information available to aid the decision-making is the product type, model, its physical condition and missing components. This information is shared with the remanufacturing facility to decide which carcasses are required to be pulled into the facility to meet new product demand in the market and which excess carcasses are to be recycled.

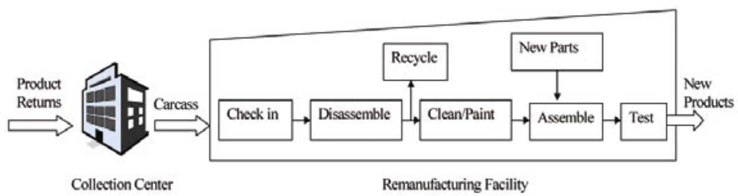

Fig. 2: OEM owned product remanufacturing operations

The dispositioning decision at the component level is taken at the remanufacturing facility in Ireland. A carcass is disassembled to component level and which in turn are dismantled to part level. The worn-out parts are recycled and the deemed remanufacturable parts are sent for cleaning and further reprocessing. Since the company has been involved in product remanufacturing operations for more than a decade, they have built up a failure history for parts and components. The components which can not be given one more usage life are recycled irrespective of their present condition. The company has a practice of updating the failure history of parts and components as and when the need arises. Thus, it can be seen that the decision making is fairly reactive and the company relies highly on the skills of operators and their experience in estimating the residual life of components.

2. Product remanufacturing inventory decisions: An essential issue of remanufacturing planning is inventory management which involves decisions on lotsizes of disassemblies and new parts. Inventory planning in remanufacturing involves two sources of supply as shown in fig. 3. The primary source for components is returned products, each of which yields an uncertain set of reusable parts that constitute a component. The secondary source is the traditional parts supply chain which experiences much lower quality and lead time uncertainty. Thus, in addition to reusable parts, the company has to purchase new parts from external suppliers.

Consider the actual remanufacturing environment in this company. The Supply/Demand team forecasts the number of machines to be produced for a planning horizon (generally one year). The planning horizon is divided into the periods of months. Production planning uses an (Material Requirement Planning) MRP algorithm that indicates the requirements for individual components in the assembly line at different dates. The components can be sourced from carcasses or can be procured from external suppliers. The decisions of when, which and how many carcasses to be pulled into the remanufacturing facility and which excess carcasses are to be recycled are made in the light of the product information such as carcass type, model, physical condition and missing components sent by the collection center. In addition to this, the company depends largely on the component and part failure history to decide the yield from carcasses and consequently, batch sizes of new parts to be procured from external suppliers.

The remanufacturing process is subjected to an unknown yield of components. If carcasses are of worse quality than expected, the assembly line is interrupted due to shortages of components. On the other hand, if carcasses are of better quality than expected, more components are recovered than needed. The excess components have to be stocked leading to high inventory. Thus, shortage and holding situations are highly undesirable and can be avoided if one can predict actual yield of carcasses arriving at the remanufacturing facility.

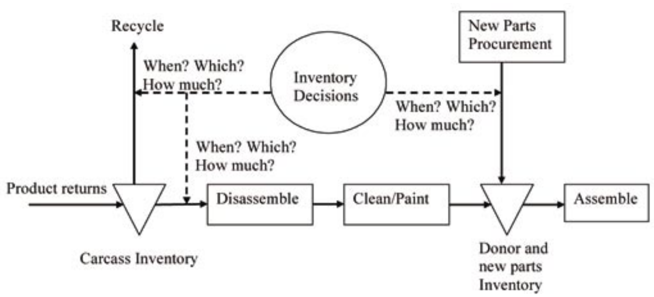

Fig. 3: Remanufacturing inventory decisions

In summary, this case study reflects that a fairly reactive policy is followed for product returns. Product dispositioning decisions as well as inventory decisions are often less informed and largely rely on the experience of managing product returns. We will now discuss these decisions in the perspective of a third-party owned product recovery company.

4.2 Case 2: Third-party owned product recovery

In spite of having economic and other benefits from the recovery of returned products, companies are looking to outsource product recovery activities since these activities are not part of their core competency.

A case study was conducted at a third-party owned product refurbishing facility in the UK. A purpose of refurbishing is to restore returned products to specified quality. Quality standards are less rigorous than those for new products. Frequently, refurbishing is combined with technology upgrading. The company offers asset management solutions which include refurbishment and remarketing of telephones, systems and IT peripherals, and personal computers of clients ranging from OEMs, retailers and distributors.

When a sufficient amount of returned products is collected by a client, they send an advanced shipment notice (ASN) that lists the product type and the corresponding quantity to be sent to the refurbishing company. When products arrive at the facility, they are checked in. The procedure involves matching the actual receipt of products with the ASN.

After check-in of the returned products, they are sent for pre-sorting. The company has a Test/No-Test benchmark which is provided by the sales department to the operations department. The sales department decides which products have a better market value by studying market prices. The products which have a reasonable "Fair Market Value" are tested and the rest of the products are sold without testing.

The products which pass the "Test" criteria are sent for testing. Depending on cosmetic and operational criteria, the company separates the products into different grades. After grading, the products are sent for refurbishing. The refurbished products are resold to brokers, OEMs, retailers and end consumers. The revenues generated from the sales of refurbished products are shared with the company's clients. We will now examine the following product recovery decisions and the availability of product information in the context of this product recovery scenario:

1. Product dispositioning decision: This decision is made in two stages. The first stage involves pre-sorting to separate the products which do not have any market value. The information available at this stage comprises of product brand, manufacturer, type and model. However, this information is not sufficient to make appropriate decisions as products might have undergone various changes during their usage life without decision-maker's knowledge. The products which are above certain threshold specifications are sent for further inspection and testing. This involves disassembling a product to check actual specifications and its physical as well as functional conditions. This information gathering process is very time consuming and labor intensive. Consequently, products lose considerable value due to time delays in treating them.

From this discussion, it is seen that there is a marked lack of product information about products to make quick and better product dispositioning decisions.

2. Product refurbishing inventory decisions: The company receives end-of-life returns, commercial returns and leased returns from their clients within the different product groups. Consequently, each product arriving at the facility is unique in terms of its economic value, intrinsic deterioration and its usage. For example, with a returned PC, the same model may take different forms, each requiring a different action: some PCs are new "factory seals" in which the box has never been opened; some may have only operated a few times; some may need repair; and some can only be recycled. These products can lose value if they are not treated quickly and completely. These losses are particularly substantial for time sensitive consumer electronics where products have very short innovation cycle. Moreover, the company has to sell returned products in the secondary market within stipulated days from the receipt of the products. If it fails to do so, it has to buy the returned products. Therefore, in order to recover as much value as possible from these products, the sales department identifies and prioritises deemed high value products for refurbishing. This decision is based on the type, model and specifications of returned products obtained by the operations department on check-in. Frequently, this information is not up-to-date in the sense that it does not include current specifications of products, usage life, maintenance and parts replacement history. This information is very crucial for laptops and PCs which are highly customised and can be upgraded during its usage period. Surprisingly, it is found that the clients are also not entirely aware of their products' usage and maintenance history and in many situations they do not share all information about products with the company. The consequence of the unavailability of this information is considerable value loss due to misjudgement in treating the products and time delays in recovering value from them. In summary, this case study reveals that the third-party owned product recovery facility faces more uncertainty in handling returned products than that of its OEM counterpart.

In the next section, we will examine the product information requirements for the two product recovery scenarios in order to be able to reduce uncertainty during product recovery and how networked RFID systems can meet these requirements.

5. Networked RFID Systems in Producrt Information Management

In the previous section, we discussed information availability in two product recovery scenarios and its impact on product recovery decisions. This section will describe how networked RFID systems can help in better management of the requisite information throughout product lifecycle.

5.1 Product information requirements

In order to understand product information needs, semistructured interviews were conducted with various personnel hailing from shop floor to top-level management. The insights gained from these interviews revealed that product recovery decisions require complete and accurate yet timely information about returned products. This information includes:

- *Static product information:* This information includes product attribute data which does not change during product lifecycle. For example, product model, type, bill of material (BOM) during assembly, weight and dimensions etc.
- *Dynamic product information:* This information is temporal which changes along product lifecycle. This includes maintenance history, current BOM, and sensor data etc.

As discussed in the previous section, the ready availability of static and dynamic product information greatly varies across product recovery scenarios. Table 1 shows a representative list of product information requirements for the product recovery decisions. The information requirements may vary from one business scenario to another. The table also indicates the current scenario of ready availability product information in the industry. It is seen that the majority of product information is not readily available. This is due to the fact that information is progressively lost throughout product's lifecycle. Frequently, the information is scattered throughout the company and across companies in the supply chain network. Retrieving information from such supply network requires significant efforts and intervention of different people.

5.2 Product information management: Role of networked RFID

Networked RFID systems, such as the EPC Network described previously, maintain the information at unique product level, updates this information as the product moves along its lifecycle and delivers this information in a timely fashion to the decision support which handles unique requirements of every single product. The information provided by such network has the following characteristics:

- *Uniqueness:* It enables to identify each product uniquely throughout its lifecycle.
- *Completeness:* It ensures all pertinent information is available for decision-making.
- *Timeliness:* It ensures all information can be accessed in a timely fashion for decision-making and execution process.
- *Accuracy:* It reduces discrepancy between actual state of a product and estimated state of the product given by information.

Decisions	Product info.	Product info. requirement	Ready availability of product info.		Network RFID info.
			OEM	Third party	
Dispositioning And Inventory	STATIC	Type	✓	✓	✓
		Model	✓	✓	✓
		BOM	✓	x	✓
		Reliability	✓	x	✓
		Dismantle Instructions	✓	x	✓
	DYNAMIC	Current BOM	x	x	✓
		Maintain History	x	x	✓
		Parts replace history	x	x	✓
		Usage-life (Sensor data)	x	x	✓
		Physical condition	x	x	x
		Functional condition	x	x	x

Table 1: Product Information Requirements and Availibility

There is no doubt that visual inspection and testing of the returned product cannot be avoided even if products are embedded with RFID chips. However, such systems will enable lifecycle usage data to be collected using appropriate sensors and to be linked directly to the product. This will greatly decrease the rigorousness of testing to be performed. We will now illustrate the networked RFID enabled product recovery scenario in the next section.

6. Towards Networked RFID Enabled Product Recovery Management

In this section, we will illustrate with the example of laptops how the information provided by networked RFID systems can bring improvements in product recovery operations.

Consider a laptop with its major components such as hard disk, memory, and motherboard etc. tagged with RFID chips. The information relevant to all these components and the laptop such as type, model, reliability, BOM, disassembly instructions is stored in the networked database. A batch of such laptops moves along retailing and usage stages of the product lifecycle and the pertinent information is maintained and updated along these lifecycle stages as shown in fig. 4.

A laptop enters into the product recovery channel when the end user returns the laptop to the collection center. A retailer can act as an initial collection point or even the OEM can set up its own collection center. The collected laptops can be presorted into different categories based on their market value and their present condition such as current specification, maintenance and parts replacement history. The returned products which are in working condition can be repacked and restocked. The end-of-life laptops can be directly sent for recycling and the deemed recoverable laptops can be sent to

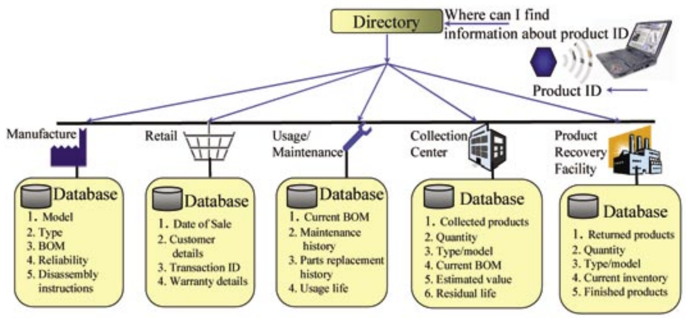

Fig. 4: Networked RFID enabled product recovery

a product recovery facility for further reprocessing and remarketing in secondary markets. The early sorting of products will reduce delays for processing the time sensitive products with high economic value. This is because the returned products can lose up to 10-20% of their value simply due to time delays in processing [8]. Also, as the information about the products is available immediately after arrival at the collection center, there is less uncertainty about their intrinsic condition. This information can be shared with the product recovery facility to take appropriate decisions of when, which and how many laptops to be pulled into the facility depending upon the demand in the market. If the quantity of collected products is more than the immediate need, low quality and low economic value products can be sent to recycling facility.

Networked RFID systems not only bring decision improvements but also process improvements to product recovery operations. For example as shown in fig. 5, the sorting process at theproduct recovery facility can be automated with the help of RFID technology. The products can be quickly categorised into different groups based on a preset criteria and can be treated as per their requirements. The sales department will have better visibility over the shop-floor and can identify and prioritise high value and high quality products for recovery process. This will also aid in initiating sales actions for seemingly good products and components. From the above discussion, it is clear that networked RFID systems have the potential to bring substantial benefits to product recovery decision-making and to product recovery management as a whole.

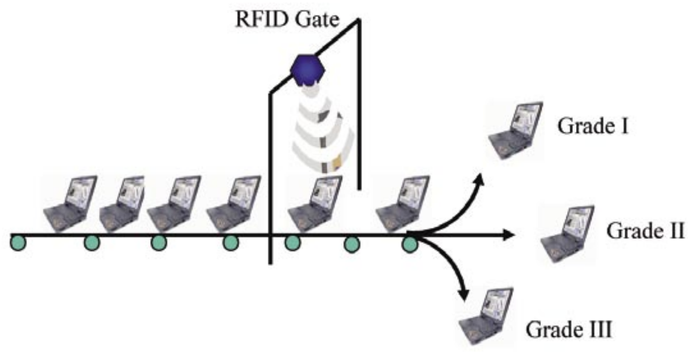

Fig. 5: Automated sorting with RFID

However, the information provided by such systems is not without costs. Therefore, the question is how much the information is worth and under what conditions it is more valuable. As part of this research, mathematical models, that quantitatively evaluate benefits of networked RFID systems in product recovery management, are being developed which in conjunction with simulation techniques will provide a methodology for a quantitative assessment of the availability of product information in product recovery management.

7. Conclusions

The lack of information about returned products is often cited as a major barrier to efficient recovery of returned products. The case study exercise carried out at various electronics product recovery facilities not only corroborated this widely acknowledged fact but also revealed that the availability of product information in the industry largely varies across different business scenarios.

Networked RFID systems can provide an automated and efficient approach for capturing and delivering complete itemlevel product information in an accurate and timely manner thereby bringing both decision as well as process improvements during product recovery stages. Nevertheless, the information provided by such systems is not costless. Therefore, it is necessary to analyze the economic benefits vis-à- vis investments in such product identification technologies.

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