Perspectives for Application of RFID on ELV CLSC

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Abstract

The treatment of End-of-Life Vehicle (ELV) and the environmental impact of discarding the resulting residues are subjects of worldwide concern. Moreover, ELV waste flow is a major environmental concern because of its rapidly increasing amount and special composition of hazardous substances.

With the increasing pressure on facilities to manage their ELV processing operations, the availability of information to improve part-processing decisions is becoming crucial. Tagging parts using radio frequency identification (RFID) provides an automated mean of capturing information about collected ELV. In addition, by enabling information availability, the need for further manual identification is eliminated.

In general, this paper provides an insight into how advanced identification technology, such as RFID, could provide the information necessary to improve the quality of decisions made during ELV CLSC management process. Next, it is shown that there are multiple perspectives for RFID application to ELV management process like: enhanced ELV-waste collection, facilitated part sorting, increased recycling and recovery processes efficiency. Finally, an operational view of RFID optimized ELV flow is presented and basic concepts and framework of RFID application on ELV CLSC are introduced.

Keywords: end-of-life vehicle, RFID, closed-loop supply chain.

1. Introduction

Growing concern for environmental problems has led to a range of product-oriented policies that affect various industrial sectors. One of greatly affected is automotive industry, which is currently facing with many challenges in order to accomplish the requirements of Directive 2000/53/EC (EU 2000). Since this policy, participants along the automotive Supply Chain (SC), upstream and downstream, have been moving towards the fulfillment of the EU requirements. Some essential elements of this Directive are the Extended Producer Responsibility (EPR) and waste prevention that oblige manufacturers to guarantee and finance product take-back and recycling.

Waste management is an important topic among environmental issues today. End-of-Life Vehicle (ELV) waste flow is a major environmental concern because of its rapidly increasing amount and special composition of hazardous substances. With the increasing attention to global environment and resource problem, traditional SC has been expanded to Closed-Loop Supply Chain (CLSC). Obviously, as the key phase in the whole ELV CLSC, processing is not only a matter of a company's attitude towards supporting the environment but also a consequence of its intention to make profits.

Radio frequency identification (RFID) is an automatic, wireless identification technology capable of gathering data without human intervention and line of sight requirement. RFID is a technology which allows remote interrogation of vehicle parts using radio waves (Parlikad et al., 2006). This has several advantages, since many tagged components of a single vehicle could be simultaneously identified in an automated manner.

The remainder of the paper is structured as follows: In Section 2, ELV concept is introduced; Section 3 presents a brief description of ELV CLSC; Section 4 deals with a composition of information flow within the ELV CLSC; Section 5 describes an operational view of ELV processing; Basic concepts and framework of RFID application on ELV CLSC are introduced in Section 6; In section 7, some approaches for managing vehicle part information throughout its life cycle, and their pros and cons, are briefly described; Finally, Section 8 gives some concluding remarks.

2. End-of-Life Vehicle

ELV is any vehicle designated as category M_1 (vehicles used for the carriage of passengers and comprising no more than 8 seats in addition to the driver seat) or N_1 (vehicles used for the carriage of goods and having a maximum mass not exceeding 3.5 tones), and three-wheeled vehicles (EU 2000).

In an attempt to reduce waste that originates from ELVs, the European Union (EU) enforced in 2000 the End-of-Life Vehicles Directive (EU 2000). According to the Directive, operators must meet recycling targets of 95% (by an average weight per vehicle and year for all ELVs) by January 2015 (Giannouli et al., 2007).

The prevalent method of treating ELVs consists of removing vehicle components such as tires, batteries, catalytic converters, and large ferrous parts (like the engine, transmission and the doors). The remaining body of the car is then shredded into small pieces. At the end of the shredding process the Automobile Shredder Residue (ASR) remains. At present, most shredder residue is disposed of in landfills or incinerated. The incineration process is harmful to the environment due to the high amount of pollutants emitted, but is often the favored option due to the high cost of landfills.

Key facilities engaged in ELV management process include (Staudinger and Keoleian, 2001):

- *Dismantling facilities*, consisting of high-value parts facilities (with quick turnover operations targeting late model vehicles) and salvage/scrap yards (with slow turnover operations accepting most vehicles). The dismantler can be seen as the hub of the vehicle recycling industry (Ferguson and Browne, 2001). Its role is critical in deciding the ELV disposition route and converting ELV comprising parts into a product, which is required for:
    - *Part reuse*: it is the most profitable outcome, both ecologically and economically;
    - *Part remanufacturing*: defined as the practice of cleaning, refurbishing, replacing parts and reassembling a product in such a manner that it is at least as good as or better than new;
    - *Material recycling*: all ELVs will eventually be recycled for their metallic content, which typically makes up 75% (by weight) of the vehicle. They are the most recycled complex product in the world (Ferguson and Browne, 2001); and
    - *Hazardous materials recycling:* have emerged because of increasing legislation.
- *Shredding facilities*;
- *Non-ferrous separation facilities*;
- *Steel mills*; and
- *Landfills*.

3. End-of-Life Vehicle Closed-Loop Supply Chain

The ELV Directive is the first Community Directive that explicitly endorses the EPR principle. It prescribes physical, financial and information responsibilities of a vehicle producer (i.e., manufacturer or a professional dealer). Moreover, by Manomaivibool (2008), EPR is ‘‘a policy principle to promote total life cycle environmental improvements of product systems by extending the responsibilities of the manufacturer of the product to various parts of the entire life cycle of the product, and especially to the take-back, recycling and final disposal of the product’’.

The new set of regulations that ELV Directive established confront the members of automotive industry’s SC with several challenges. Additional participants need to be included in the ELV SC in order to “close the loop” and meet new requirements. The automotive industry has already possessed a reverse logistic system for damaged parts retrieved during repairs, but this return system represents a very small part of closed-loop system, which has to be implemented in order to recycle car waste, particularly the vast masses from ELVs (Simić et al., 2009).

A definite solution for the ELV CLSC has not been settled yet, but the vital actors are identified (Figure 1). Obviously, there are few actor groups representing the ELV CLSC (Ahn et al., 2005). The initial actor is the last owner of ELV. These last owners are to be provided with the possibility of transporting their ELVs to the second actors group usually within a certain radius.

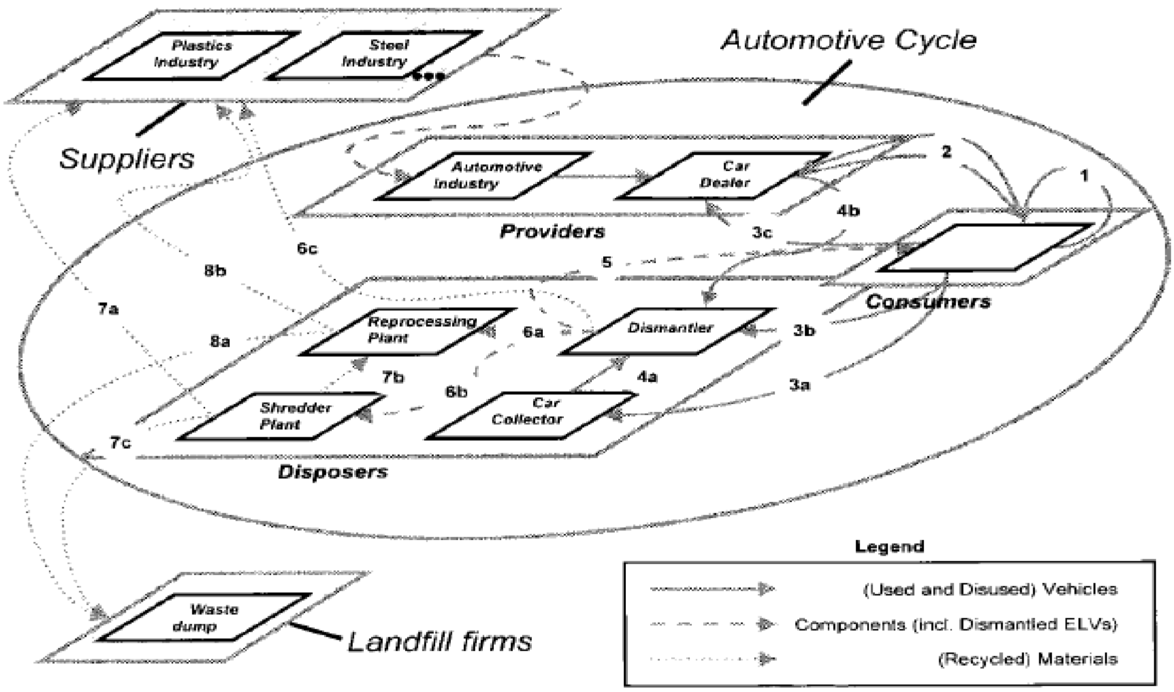

Figure 1. Material flow in the ELV CLSC (Simić et al., 2009)

Certified collecting facilities and dismantlers represent the second group. The third actor group is responsible for the shredding and for transporting the resolving fractions to the different participants of the fourth actor group. The fourth actor group is responsible for the three fractions. The first is the shredder light fraction; it contains foams, plastics, etc. having to be disposed of in landfills. The second leaving the shredder is the nonferrous fraction requiring recycling processes at different reprocessing facilities. The third fraction contains different kinds of ferrous materials, which can be reused by the steel industry.

4. Information flow within the ELV CLSC

With the increasing pressure on facilities to manage their ELV processing operations, the availability of information to improve part-processing decisions is becoming crucial. In fact, a fundamental obstacle in making efficient decisions is the loss of information associated with the vehicle (parts) after the point-of-sale.

The information required for efficient ELV processing can be classified into the following six categories:

1) *Product* information. Examples of such information are parts identification and vehicle dismantling scheme. Product related information is *static* in nature, i.e. the information does not change over the product life cycle;
2) *Location* information, relates to the specific location of the parts and its quantity;
3) *Utilization* information, relates to the use of the vehicle (part) over its entire life cycle (e.g., amount of usage). This information, which is *dynamic* in nature, is required to assess the quality of the part and its potential value. Automatic identification technology, like RFID, is making dynamic data collection possible, where product identification is build into a part, giving it a unique "footprint";
4) *Legislative* information;
5) *Market* information. Finding markets for used products can be very difficult. Product processing critical objective is to receive the highest possible value for every potentially processed part; and
6) *Process* information, generated within ELV processing activity. The two main categories of information generated "internally" are (Ferguson and Browne, 2001): *storage* information (e.g., the availability, quality, part stock currently held) and *sales* information.

5. ELV processing: Operational view

ELV management concerns the processing of vehicle parts (with the objectives of recovering maximum value and acquiring projected EU quotas) after the last owner delivers ELV to collection point. Figure 2 provides a detailed view of involved processing operations. The first thing that should be done when ELV is collected is *booking* into the inventory database and *pre-sorting* of all parts. Essentially, these operations consist of reading life cycle data gathered with RFID tag and determining main part characteristics (e.g. type and physical condition). After inevitable ELV dismantling, we have the first decision point with three options available:

- *Reuse*: if the part has value less than the cost of eventual testing, but can be sold ‘‘as seen’’ in the secondary parts market;
- *Recycle*: if the part is evidently unusable or market demand does not exist; and
- *Part testing*.

If the part is perceived to be valuable enough to warrant further testing before the expected recovery decision is made, additional effort is put in. This involves part testing in order to reveal its functional condition. After the part has undergone thorough testing, a final decision about the choice of recovery option is made by operator's expert opinion. Here, in addition to the options available at the first stage, depending on the quality and condition of the part, it could also be:

- *Reused*: if it is in good condition and there is a demand for it in the secondary parts market;
- *Refurbished*: if it can be sold with minor modifications or component replacement; and
- *Recycled*.

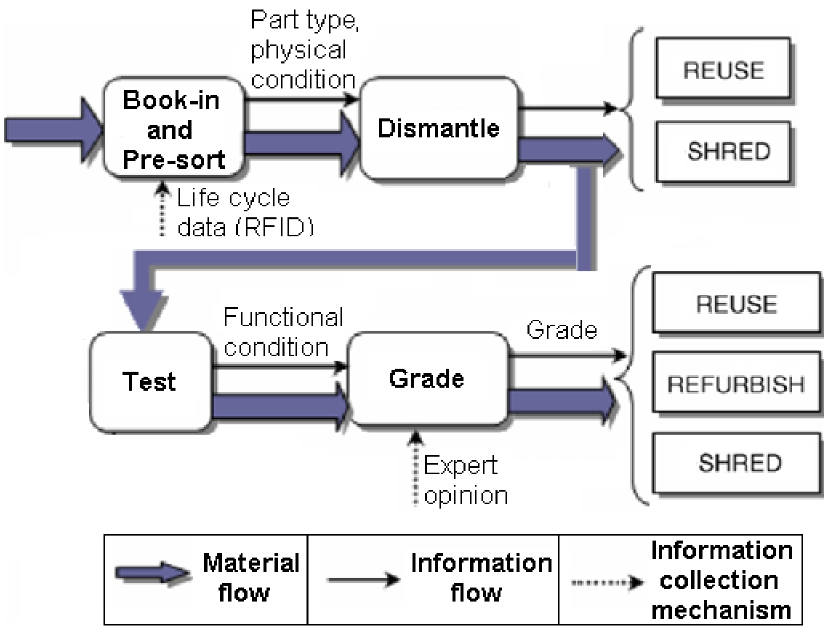

Figure 2. ELV processing operations

6. Application of RFID on ELV CLSC: Basic concepts

ELV processing is characterized by a high variety in the type, quality, and condition of returned ELV parts, and because of the numerous options available, this leads to high levels of uncertainties in determining theirs destiny. Because of such uncertainties associated with content of collected ELV, effective recovery of its value requires extensive information about the part identity and its condition at the time of return. It is expected that application of RFID can provide needed information.

There are multiple advantages of RFID application to ELV management process. RFID is a tool used to *increase traceability* of one vehicle (major) parts throughout complex ELV CLSC. Moreover, hazardous substances in certain components, or even all ELV could be traced and proper treatment could be guaranteed. In this context, application without a transponder on every single part is possible as well. In purpose of *enhancing ELV-waste collection*, uncontrolled treatment of ELV should be avoided whenever possible. One way could be to install automatic points of return (POR) at certified collecting facilities and dismantlers. These points could pre-sort the contained parts and register them in a database. Such automatic points of return will help to decrease the number of abandoned vehicles. The RFID technology could be used to facilitate management of the ELV processing, especially to *enhance* its *sorting*. That will "optimize" the following transport process and lead to an increased efficiency of the recycling and recovery sub-processes. This automated system could function as guidance system for every major ELV part; i.e., it could route every part to the most eligible facility. RFID could also be used to increase the efficiency of the recycling process; i.e., valuable and hazardous substances could be marked to increase recycling percentages and guarantee the right treatment for each part.

6.1 Present RFID applications in automotive industry

There are many examples of using RFID technology into car manufacturing industry. Ford Motor Co. has been using RFID tags in their facilities in Mexico and USA for a number of years (Gaukler and Seifert, 2007). In Ford's implementation, an RFID tag is attached to each car's chassis. The tag indicates via its serial number, which parts and options have to be installed on that particular chassis. BMW equips RFID data carrier in the new conveyor system for assembling bodies for its 3-Series. Each body support is fitted with an RFID data carrier, which stores all the data relevant to the production of the vehicle and makes the body identifiable at any time. At BMW, this is an important factor for production control, documentation, and quality assurance (Bitkom, 2005). Gaukler and Seifert (2007) studied a similar RFID scenario based on an implementation at European car manufacturers. Further analysis of RFID opportunities in the automotive sector is given, for example, in Strassner and Fleisch (2003).

According to numerous car-manufacturing applications of the RFID technology, it is expected that producers will be carriers of its future extensive usage in ELV CLSC.

6.2 Application of RFID on ELV CLSC: Framework

Since the amount of spent vehicles collected in the future is stochastic to a certain extent, the coordination of ELV CLSC requires making decisions under significant amount of uncertainty (Simić et al., 2009). In addition, degree of uncertainty in the ELV case is significantly high, due to its long average lifetime. Because of such uncertainties associated with ELVs, effective recovery of value from these products requires extensive information about the identity and the condition of the product when it is returned.

The advent of RFID-based automated identification has resulted in the ability to enhance the quality of product information that is available to make decisions along the part life cycle. One of the major impact areas of such a capability is in improving the effectiveness of decisions made during End-of-Life (EOL) phase, because "visibility networks" can be built and the additional information can facilitate EOL decisions. Thereby, car producers have started considering new technologies to manage returned and obsolete products in an efficient manner.

It is desirable that information about collected ELV have the following qualities:

- *Unique identification* (individual information trails for each vehicle to enable);
- *Completeness* (plenty of relevant data is available); and
- *Accuracy* (eliminate inaccurate representations of current and historical information).

Recycling target of 95% ELV processed becomes easily attainable when foregoing qualities are available. Every actor in ELV CLSC must realize that free information flow between successive actors in the CLSC is significant supplement of mentioned necessities. In addition, complete and accurate information associated with a product will lead to a significant increase in the effectiveness of carried decisions (Parlikad et al., 2006).

Tagging parts using RFID provides an automated mean of capturing information about collected ELV. Moreover, by enabling information availability, the need for further manual identification is eliminated. In addition, it is also possible to monitor critical performance parameters of expensive parts throughout its life cycle by attaching sensors and by linking these sensors to the RFID tag. For example, in the case of the Middle-of-Life (MOL) phase of an engine it could be the following: the number of starts and stops stored and the runtime accumulated; a set of sensor information (such as the motor temperature and consumption in each individual use cycle) recorded, evaluated, and classified; peak and average values of all parameters of interest can be computed and stored (Klausner et al., 1998). The gathered information could help operators to filter vehicle parts that going directly to the reuse from ones that will be send on the refurbishment process. In the case where the part is to be recycled, information could alert the recycler about eventual contained hazardous substances, and could help to identify components that require special reprocessing.

Hence, it is clear that application of RFID technology in the EOL phase is becoming increasingly important. In addition, implementing RFID systems in the ELV CLSC leads to the great improvement of decision support, since it makes accurate, real-time, and complete product processing information (Simić and Dimitrijević, 2010).

7. ELV CLSC Management Information System

In order to make effective ELV processing decisions, it is critical to have access to all information generated throughout the entire vehicle part life cycle. Therefore, in this section, we will briefly describe some approaches for managing vehicle part information throughout its life cycle, and their pros and cons.

ELV CLSC Management Information Systems can roughly be divided into following categories:

- *Design/dismantle data sharing system*;
- *Life cycle data management system*;
- *RFID-based approach* for managing product information.

Design/dismantle data sharing systems are designed to allow automotive producers to share design and dismantle-related information with certified collecting facilities, dismantlers and recyclers. They are only able to capture and share the static information (Parlikad and McFarlane, 2007). Obviously, they are not capable of providing detailed vehicle (part) life cycle information. In general, they have the following characteristics in common:

- Producers provide design data and disassembly instructions to ELV processing facilities; and
- Every authorized ELV CLSC participant is able to access part information through the Internet.

Life cycle data management system is designed to store and share static and dynamic information (Simon et al., 2001), and it displays the following characteristics:

- Enable unique identification of every vehicle (part);
- Provide design data and disassembly instructions (if necessary);
- Monitor and store desired part parameters throughout (whole) life cycle;
- ELV processing facilities are provided access to the information stored with the part and also linked to the static information through the Internet.

RFID-based approach is obviously ideal for EOL applications, because it enables us to track vehicle part in production process, automatically identify, record, transmit and search related information throughout its whole life cycle.

A recent breakthrough in enabling affordable widespread global deployment of RFID is the emergence of approaches connecting a product tagged with an RFID to a network. From ELV CLSC point of view, the possible competitive features of a networked RFID approach for managing product life cycle information can be:

- Unique identification of every vehicle (part);
- Wireless communication between item and networked reader;
- Common database access approach; and
- The information consist all crucial product information during the whole product life cycle.

8. Conclusion

Despite general public perceptions of waste and inefficiency, the ELV management industry today is a relatively efficient process, with 75% of the overall content of an original ELV reclaimed or recycled, including virtually 100% of the iron and steel vehicle content.

RFID technology provides complete and detail information about collected ELV. Moreover, it provides a significant increase in the effectiveness of carried EOL decisions and makes recycling target (of 95% ELV processed) easily attainable.

There are many other causes for application of RFID technology on ELV industry, because it opens up different perspectives for enhanced ELV treatment. RFID is providing the ability to extract ELVs part information in a timely manner. In addition, it brings twofold benefits through: process improvement, that upgrading the efficiency and cost effectiveness of recovery operations, and decision improvement, that leads to higher profit.

It is obvious that implementation of RFID systems in the ELV CLSC will lead to the great improvement of decision support, since it makes accurate, real-time, and complete product processing information available. In addition, this relatively novel technology will clearly provide enhanced ELV-waste collection, facilitated part sorting, increased recycling and recovery processes efficiency.

Overall, the future of implementing RFID technology into ELV CLSC appears to be certain.

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