Investigation on Reverse Logistics of End of Life Cars in the UK

By

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Abstract

Global warming is becoming the most significant problem in the world, which generally attributed to the greenhouse effect caused by increased levels of carbon dioxide, CFCs, and other pollutants. This has forced government and business to focus on environmental issues on their initiatives where reverse logistics (RL) practice is described as an initiative that plays an important role for those who seek environmentally responsible solutions to reduce waste, which in turn, reduces carbon emission caused by end-of-life (EoL) products. Among the EoL products, cars are one of the major concerns due to their increasing volume, use of thousands of parts and hazardous materials like CFCs, which cause carbon emission during use, end of life collection, recycling and disposal process. Proper implementation of RL process of EoL cars can slow down the carbon emission by reducing the number of old cars on road, transportation distance for EoL collection and waste for disposal, and by increasing recovery of components, parts and materials.

Therefore, this research investigates RL of EoL cars in terms of its key aspects including the reasons cars become EoL and arrive for disposal, details of the diverse nature of EoL cars and its impact on the EoL RL process; details of the return process and its performance, players involved in the process and their relationship nature, drivers influencing players to become involve and challenges they may face in the RL process. Finally, given that EoL car RL practice understanding would be of limited value unless accompanied by general principles (theories) that inform wider application, the study utilises several established and emerging management/organisational theories (resource and knowledge-based views, resource-dependence theory, stakeholder theory, agency theory and institutional theory) to underpin the multifaceted reality of EoL car RL practice.

Even though a significant amount of RL research has been done, most of the research is generic, addressing issues in a standalone manner, such as cost in RL, technology in RL, or environmental issues. Thus, many important aspects are not known, especially in the automotive industry, particularly in the UK, where managing EoL cars is a key concern now for the automotive industry due to strict law from the UK government to protect the environment by implementing proper EoL car RL solutions. This lack of holistic direction also carries the risk that practitioners and policymakers could mistakenly be addressing the wrong issues and neglecting important aspects that have more significance in reverse logistics practice.

Therefore, an exploratory approach was employed to comprehensively answer the research questions. This exploratory research used a multiple case study method involving semi-structured interviews with the stakeholders who are involved in the EoL car RL practice to explore four research questions within RL key aspects derived for this study.

With regards to the findings, this study contributes a conceptual understanding of EoL car RL practice through operationalising and developing detail of RL key aspects which validates EoL car category (natural, unnatural and abandoned) and the reasons a car becomes EoL (damage due to age, accident or theft); diverse nature of EoL cars and its significant impact on the recovery process due to its design (how components are put together, use of diverse components and materials), components functionality (repairable, nonrepairable) and the source of EoL car (individual consumer, industrial customers or institutions); a systematic EoL car collection process to reduce cost and carbon emission by reducing transportation cost and fuel consumption; use of expertise, processing and equipment to remove and recycle

hazardous components from EoL cars to improve quality and quantity of recovered parts and materials; use of updated shredding technology to increase recovery rate and reduce unrecoverable waste for landfill; diverse relationship nature (acquisition, strategic alliance, arm's length) between players and its impact on the EoL car RL process; factors influencing (legislative pressure, economic gain, stakeholder pressures, competitive pressure, environmental and social awareness) and hindering (costly process, lack of expertise, lack of last car owner support, lack of technology, lack of effective disposal system) involvement of stakeholders in, and the development of, the EoL car RL process.

This study provides practitioners (across all stakeholders) with a potential stock of RL process that they could implement as well as potential performance measures they could operationalise in their respective firms. Also, it helps them to measure the drivers and barriers affecting their RL practices implementation. Overall, given that most of the underlying issues in RL practice are similar within related sectors, the insights from this study can be used as a good starting point for practitioners and policymakers elsewhere in RL practice.

The study is arguably the first comprehensive attempt to understand EoL car RL practice and its importance/relevance in the UK. Also, the application of several established/emerging theories to understand the various RL aspects has not been undertaken previously in the automotive sector and hence constitutes a novelty.

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List of Abbreviations

ABTO	Approved Battery treatment Operator
ASR	Automotive Shredder Residue
ATF	Authorize Treatment facilities
BM	Battery Manufacturer
BSC	Balance Scorecard
CC	Case-Category
CD	Car Dismantler
CFCs	Chlorofluorocarbons
CM	Car Manufacturer
COSHHR	Control of Substances Hazardous to Health Regulations
CPFR	Collaborative Planning, Forecasting, and Replacement
CSR	Corporate Social Responsibility
DSEAR	Dangerous Substances and Explosive Atmospheres Regulations
DVLA	Driving and Vehicle License Authority
EDI	Electric Data Interchange
ELV	End of Life Vehicle
EoL	End of Life
EoU	End of Use
EPR	Extended Producer Responsibility
ERP	Enterprise Resource Planning
FIFO	First in First Out
GA	Government Agency
HRC	Hazardous Recycling Centre
IDIS	International Dismantling Information System
IDS	Integrated Database System
IT	Information Technology
LC	Local Council
LPG	Liquide Petroleum Gas
NF	Non-Ferrous
OSCP	Official Scrap Car partner
QA	Quality Assurer
RBV	Resource-Base View
RFID	Radio Frequency Identifications
RL	Reverse Logistics
ROI	Return on Investment
RQ	Research Question
SCM	Supply Chain Management
SoD	Certificate of Destruction
TBL	Triple Bottom Line
TCT	Transection Cost Theory
WMC	Waste Management Company

CHAPTER 1: INTRODUCTION

This chapter first provides the background and motivation of this thesis and then the settings in with this research is carried out. Finally, this chapter presents the outline of the structure of this thesis.

1.1 Importance of identifying reverse logistics key aspects

Many companies that previously were not engaged with managing return products have begun investing to manage their return (Rogers & Tibben-Lembke, 1998). The key motivation for dealing with returns was found to be value recovery from return products and the environmental protection by proper disposal of the returns, as strict regulation on returns to protect the environment forces companies to manage their returns (Dekker, et al., 2003). It is also evident in the literature that return management is important for achieving economic, environmental and strategic advantages for businesses (James, et al., 2002; Mitsumori 1999; Mukhopadhyay & Setaputra 2006; Roy 2003). Therefore, managing returns during the product life cycle and at the End of Life (EoL) is gaining increased attention in this current age (de Brito & Dekker, 2003; Joshi, 2013).

Managing all these returns for the purpose of capturing value, or proper disposal, is referred to as reverse logistics (RL) (Cater & Ellarm 1998). Practitioners and academics alike increasingly acknowledge the importance of RL, with the latter exploring the application of RL in several sectors, including retail (Rogers & Tibben-Lembke, 2002), electronics (Lau & Wang, 2009), pharmaceuticals (Kumar et al, 2009), construction (Nunes et al, 2009), household (Lee & Breen, 2014) and automotive (Nunes & Bennet, 2010; Chan et al., 2012).

The literature makes evident that returns are increasing and products are returned for different reasons and from different sources, including manufacturers return: raw materials left over or final products that failed quality checks (Fleischmann et al.,1997 ; de Brito & Dekker 2003); distributor return: damaged, unsold and recalled products (de Brito and Dekker, 2003, Khan & Subzwari, 2009); consumer return: warranty return, end of use and end of life return (De Brito and Dekker, 2003; Olorunniwo and Li, 2011; Xie and Breen, 2014). The nature of these return products found cited by literature are composition: how products components are put together and their number; deterioration : functionality of products; use pattern and packaging nature. Therefore, it is important to understand whether all these return reasons and their nature are important or if there are other reasons and nature of return on reverse logistics and whether they are the same or not in different industries.

The literature cites many activities in the RL process, namely gate keeping, collection, inspection and sorting, direct reuse and redistribution, repair/refurbishing and remanufacturing (Rogers & Tibben-Lembke, 1998; de Brito & Dekker, 2003; Yang & Wang, 2007), hazardous product separation, recycling hazardous products (Bai & Sarkis, 2013; Kumar & Putnam, 2008), removal of marketable components, compacting, shredding and disposal (Kumar & Putnam, 2008 ; Xie & Breen, 2014). However, it is not known whether these operations are valid for all types of products or not. Thus, it is imperative to understand operations in the return process for different types of products for better management of returned goods.

The literature highlights that players (who involved in the RL process) are forward chain players (manufacturers, wholesalers and retailers), reverse chain players (recycling specialist companies/third parties) (de Brito & Dekker, 2004; Yang & Wang, 2007), government agencies (organisations responsible for compliance) (Fuller & Allen, 1997;Xie & Breen, 2014), opportunistic players (charity organisations) (de Brito & Dekker, 2003) and senders (who return the products) (Fuller & Allen, 1997). In terms of relationships between players, the literature also cited the total involvement and strategic level collaboration needed to fulfil RL activities. However, the literature provides limited knowledge of which of these players are involved for what types of products and the nature of the relationships in performing these activities. Thus, it is important to explore players RL activities and the nature of the relationships in performing RL activities for better understanding of their contributions.

The literature also highlights some drivers and barriers to the management of RL. These include the following key drivers: legislative pressure (Carter & Ellram, 1998 ; de Brito & Dekker, 2003 ; Xie & Breen, 2014), stakeholder pressure (Carter & Ellram, 1998), competitive pressure (Carter & Ellram, 1998), Corporate Social Responsibility (CSR) pressure (Fleischmann et al., 1997), economic gain (de Brito & Dekker, 2003); and key barriers: Lack of government initiatives, costly processing (Xie & breen, 2014), Lack of top management attention and negative perception of recycling products (Rogers & Tibben-Lembke, 1998). However, knowledge of which of these drivers and barriers are applicable for what types of products/industry/country is limited. Therefore, it is imperative to explore drivers and barriers to identify whether these barriers exist and are similar for different industries/countries.

The following issues discussed above are explored in this research.

- Product return reasons and their natures in reverse logistics
- Key activities in the product return process to recover value and save the environment
- Players' roles and relationship nature in managing reverse logistics activities
- Drivers and barriers influencing reverse logistics activities

1.2 Reasons for choosing the automotive industry as the research context

The harmful consequences on the environment of having increasing numbers of cars and EoL cars in circulation is a global concern. Therefore, the auto sector has become a key sector from a RL perspective (Kumar & Putnam, 2008). Given the huge number of material and energy inputs that go into making an automotive product and the large product volumes involved, this sector's impact on the environment, and where RL could contribute, is significant. From an economic perspective too, RL is relevant for this sector: reuse (after remanufacturing) of components, recycling of material and/or recovery of embodied energy enable lowering of the high input material and energy costs characteristic for this sector.

However, the scope and benefits of RL in the automotive sector have not been sufficiently investigated, with the exception of a few generic studies. Therefore, the purpose of the present study is to explore the above discussed RL issues in the automotive industry context.

More specifically, the present study focuses on the car's End of life (EoL). The car is one of the highest selling and heaviest automotive products, where, therefore, the economic and environment related payoffs from RL can be expected to be significant. It is also one of the most complex in terms of number of parts and variety of materials used, including the large size and unwieldy shape that would tend to cause its RL to be complicated and make it an interesting subject for study. Cars also make an interesting choice because of the applicability of end of life regulations, whose impact on revere logistics is worth investigating. Besides the choice of an automotive product, another consideration is the country setting, as the nature of

RL is seen to vary across countries (Rogers & Tibben-Lembke, 2001). The context of this study is the UK. The UK is one of the largest car markets in the world (and thereby also of returning EoL cars), where, therefore, RL of EoL cars can be expected to be of a significant scale and maturity. A UK-based RL investigation on EoL cars is also not found in the previous literature.

Additionally, given the complexity and importance of the global automotive industry and the limited research on this topic, further investigation into the way automotive companies engage in reverse logistics of EoL cars is needed. Furthermore, it is important to understand the reasons behind the decision for engaging in how to deal with EoL cars in terms of strategic choice decision, especially in the UK, as this automotive industry is currently subject to fulfilling the requirements of European Union End-of-Life Directive (2000/53/EC) regulation, which requires manufacturers to take back, collect and recycle all vehicles of their brand(s) more environmentally, where manufacturers and their contracted partners must also reach strict recycling targets. Many EoL cars are generated each year in the UK. These cars are classified as hazardous waste and must be depolluted to certain standards, where only 75% of the content of cars is reused, recycled, or recovered, with the remaining share referred to Automobile Shredding Residue for further recovery (Nunes et al., 2011), as the recovery rate has to be 95% of the car's total weight. All these make the EoL car RL process very challenging but, as mentioned before, there is limited evidence of academic and practitioner research on the automotive industry and no evidence on EoL car RL practice in the UK context. Therefore, this work develops a systematic approach for EoL car RL practice in the UK automotive industry.

1.3 Reasons for choosing the UK as the research setting

The contexts of majority of the extant literature on RL practices are mainly developing countries, such as India (Ravi & Shankar, 2004), Iran (Mansour & Zarei 2008), Mexico (Cruz-Rivera & Ertel, 2009), China (Zhang et al, 2010; Xiao et al., 2019), Egypt (Harraz & Galal, 2011) and Malaysia (Mohamad-Ali, et al. 2018), where RL practices were not that stabilised compared to the developed countries mentioned by most of these studies. Therefore, for a holistic understanding of reverse logistics practice in terms of what, how, where, when, and why, a developed country perspective was identified as suitable for this study. Thus, the context of the present study is the UK, a more developed country than contexts of previous RL studies. Additionally, with the lack of RL literature in the UK automotive context, the researcher has selected the UK as the geographical region for this thesis due to the essential role of the UK auto industry, as it contributes significantly to global car production. The UK automotive industry is the sixth largest in the world and exports vehicles to over 100 countries. There are 1.6 million cars produced in the UK each year and it is believed that car manufacturing volumes are going to break all-time records by 2020. This means many old cars end up on the scrap heap. In fact, it is estimated that over one million cars are crushed each year in the UK (ICCT, 2016).

In addition to the number of cars, in the UK the average material intensity of vehicles is growing. In spite of efforts to switch to lighter materials and lightweight design, cars have become larger in size and heavier across all vehicle segments. This is partly due to the introduction of new features designed to improve comfort, safety, security and control emissions (Zervas, 2010).

The UK automotive industry is very advanced in terms of RL implementation (Aitken & Harrison, 2013), as this is one of the most environmentally aware manufacturing sectors, as it has moved from the business practice of traditional manufacturing to eco-friendly solutions.

Though the literature states that UK RL has become more and more important, for various reasons including legislative policy regarding environmental and sustainability issues, very few studies have been identified in terms of RL practice in the UK automotive industry. This is surprising as the need for recovery of returning vehicles has been receiving more attention than ever before due to growing environmental concerns.

As a result, the UK presents an ideal research context. This study therefore aims to explore UK RL practices in order to generate an empirically informed and theoretically grounded insight into this phenomenon from the EoL car RL process from different players' perspectives involved in the EoL car RL process to facilitate best practices.

This study focuses on the car manufacturing sector in the UK, as the sector contains the responsible players for the proper disposal of EoL cars and the recycling sector, who are the main operators of the EoL car RL process from collection to disposal. This therefore made both sectors worthy of investigation. In addition, this research also investigates regulatory authority for cross checking data validity and local authority (local council), as they are also involved with the EoL car RL process (senders for abandoned cars). Therefore, empirical data analysed in this study were collected mainly from car manufacturers and ATF companies involved in the EoL car RL operations of their respective organisations, as this study focuses on the automotive industry RL of EoL cars.

1.4 Research Objective

The importance of RL in the automotive industry together with the intrinsic gaps in the literature formed the motivation of this research, where a comprehensive RL investigation on the automotive industry covering the implementation of various RL issues across all key aspects. Also, the study tried to develop a higher-level concept of the RL in automotive industry with the use of established/emerging management theories, depending on where and how these theories can, individually and in combination, contribute to providing a deeper, broader and more simplified conceptualization of RL perspectives. The theoretical underpinnings of this study are expected to enhance the practical application of RL in the automotive sector and, in general, contribute significantly towards further theoretical advancement of the field.

The specific objectives of this study are therefore as follows:

1. Investigate the various key return reasons of EoL cars and their natures which have significant impact on RL operations.
2. Investigate various key stages of EoL car RL operations for value recovery and their performance in terms of economic, environmental and social impact.
3. Understand the important nature of relationships between players involved in EoL car RL management operations to understand the best practice of managing RL operations.
4. Investigate the key drivers that drive each player to get involved/to follow a systematic RL process, and the challenges that hinder players to ignore/from improving RL activities for EoL cars.

5. Offer multiple theoretical perspectives in understanding the multifaceted reality of RL practice in the automotive industry.

Furthermore, this research aims to contribute to the improvement of automotive RL practices exploring and identifying the typologies of automotive RL processes/strategies practiced by different players in the car making and recycling sector, identify similarities and differences in their EoL car RL operations, and identify best practice and improvement where necessary. The output of this study will not only facilitate the best practice and improvement of automotive RL processes and standards within and between players, but will also facilitate the proper practice of EoL cars in terms of storage, hazardous components treatment, recovery rate, incineration and landfill process to protect the environment from CO2 emissions.

1.5 Thesis structure

The thesis is divided into nine key chapters (represented in Figure 1.1). Chapter 1 comprises the general introduction of research. Chapter 2 comprises the systematic literature review that underpins this study and the research context adopted. Chapter 3 outlines the research methodology. Chapters 4, 5, 6 and 7 present the empirical research. Chapter 8 presents the discussion of findings and chapter 9 the conclusion.

Chapter 1: Chapter 1 introduces the background and motivation of this research, the scope of this thesis, including specific objectives, and the structure of this research.

Chapter 2: Chapter 2 discusses the themes that underpin this study. This chapter has two phases. Phase one discusses the themes that underpin this study from the generic literature (relevant studies in every industry) and phase two systematically reviews extant empirical studies on automotive RL, systematically confirms gaps in the literature, and reviews core empirical studies which further confirm the validity of research gaps.

Chapter 3: Chapter 3 discusses the research methodology employed for this thesis, where phase one reaffirms the research objectives, and RQs. Then, it discusses the philosophical underpinnings of this research as well as the researcher's philosophical stance. This is followed by the research design for this study, associated research design issues and limitations, as well as details of how the empirical data were collected, displayed and analysed. Phase two describes the research experience in the UK.

Chapter 4: Chapter 4 presents the findings of RQ 1 which explains the reasons for EoL car returns and the nature of EoL cars, including their impact on the EoL car RL process.

Chapter 5: Chapter 5 presents the findings of RQ 2 which explains the process of EoL car RL with all the detailed activities, including location and time related issues in the RL process for EoL cars in the UK.

Chapter 6: Chapter 6 presents the findings of RQ 3 which identifies all the key players involved with RL practice for EoL cars and discusses the relationships between players including collaboration categories on these relationships and their impact.

Chapter 7: Chapter 7 presents the findings of RQ 4 which identifies key drivers and barriers to practicing RL of EoL cars in the UK.

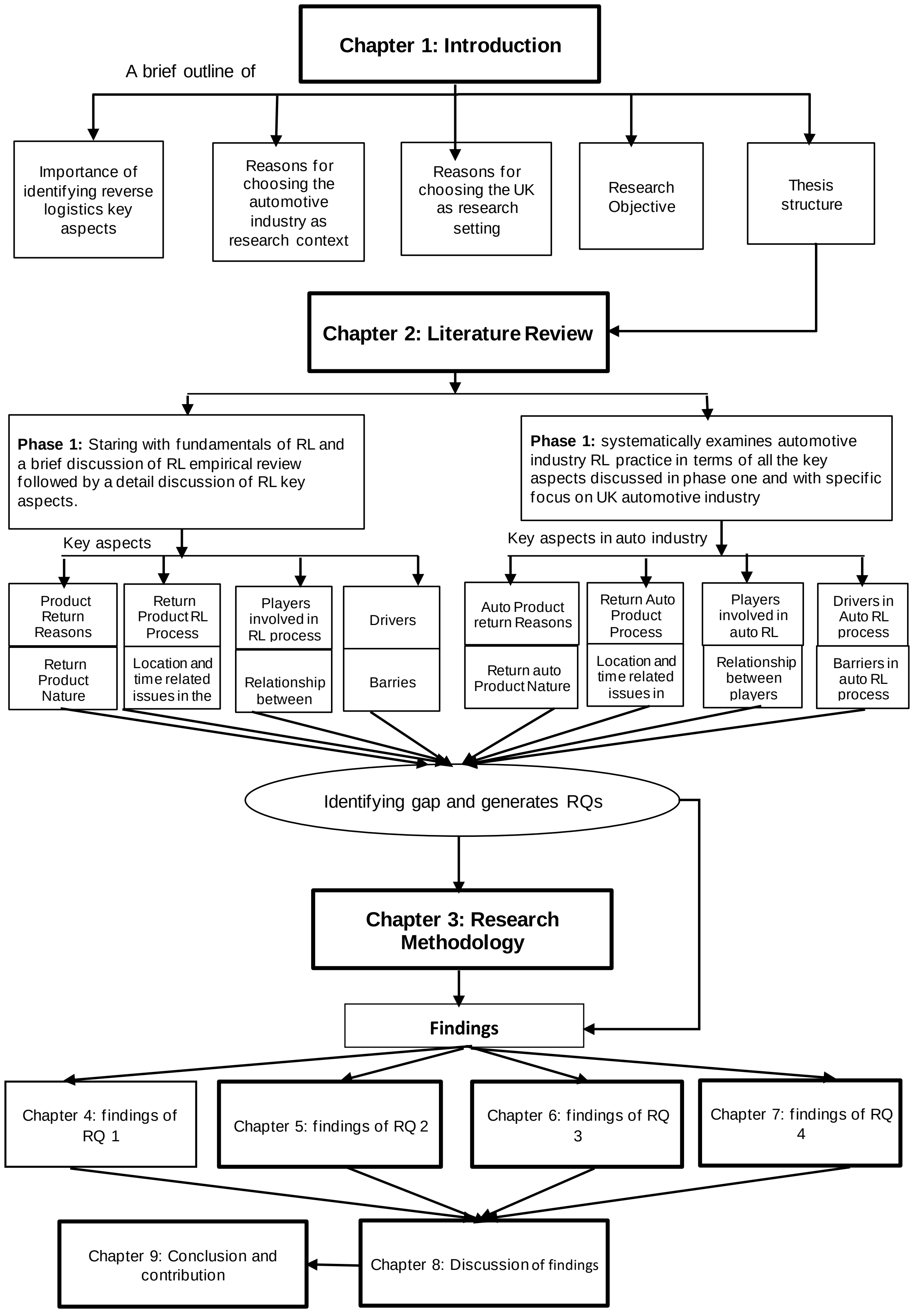


Figure 1. 1 Thesis structure

Chapter 4, 5, 6 and 7 findings are presented by analysing within case which then feeds into the within case-category analysis; this then feeds into the cross case-category analysis. The within case analysis helps to understand the key aspects for each case and clarifies similarities and differences among cases per category and the cross-case category identifies similarities and differences among the categories, as well as patterns in the empirical data.

Chapter 8: Chapter 8 discusses novel insights obtained from the three-phased data analysis processes (Phase One, Two, and Three) by linking them to the extant literature, where possible, to examine the relationships between empirical research and theory. It also considers whether the RL practices employed by the companies investigated in the UK auto industry validate the RL fundamentals described in the extant literature or whether the companies operate on a different RL principle. The chapter also discusses the empirical findings in an integrated and holistic way in order to comprehensively address the research questions. The chapter pulls together empirical evidence to develop an empirically informed and theoretically grounded insight into auto RL practices in the UK, as well as improvement opportunities to achieve best practice. In this chapter, several established/emerging management theories that offer a plausible basis to explain the findings are discussed.

Chapter 9: Chapter 9 is the final chapter of this thesis. The chapter summarises the thesis, presents the conclusion regarding the research questions and highlights the theoretical and the practical contributions of the research, the research limitations, and a guide for future research.

Relevant publications from this work

The full reference of the publication is as follows:

Conference Publication

1. Sorker, F. & Shukla, V. (2015). Reverse logistics of passenger cars in the UK – an examination. Proceedings of the 20th Annual Logistics Research Network Conference and PhD Workshop, University of Derby, UK, 9-11 September 2015

CHAPTER 2: LITERATURE REVIEW

The purpose of this chapter is to establish research questions through a systematic investigation and critical clarification of the literature in the RL area in terms of concepts, methods, theories etc. This chapter also settles the background and reasons for conducting this study and what its contribution is likely be.

2.1. Introduction

This chapter has two phases. Phase one introduces reverse logistics including definitions and its importance. This is then followed by a detailed discussion of reverse logistics key aspects (return reason & nature of returns; process in terms of detail activities, location of activities, time related issues and their impact; details of players and their relationships; drivers and barriers to implementing RL practice) in-general. Phase two examines empirical studies on RL practices in the automotive industry with specific focus on key aspects discussed in phase one, and with a specific focus on UK automotive industry to systematically confirm the gap in the literature and identify the research questions.

2.2 Fundamentals of Reverse logistics

2.2.1 RL Definition

One of the core elements of Supply Chain Management (SCM) is logistics and the real importance of logistics is its ability to give organisations a competitive advantage by providing customers with superior service through inventory availability, speed of delivery and consistency of delivery. However, logistics is not only about delivering goods to customers, but also offers the opportunity for stock to be returned to the supplier via a feedback loop (Ritchie et al., 2000).

Hence, the need or potential for the reuse or recycling of unwanted stock has become a major issue in many industries, and the process of achieving this has been labelled “reverse logistics” (Giuntini & Andel, 1995). Over the years, the concept of reverse logistics has continued to change. In the 1980s, it was taken to be the movement goods from the consumer to the producer through a recognized distribution channel. However, in the 1990s, Stock (1992) approached reverse logistics as returned materials focusing not only on technical and economic benefits, but environmental efficiency as well; however, this approach was quite general and the main focus was only from a waste management perspective (de Brito & Dekker, 2003). It included reverse distribution, which causes goods and information to flow in the opposite direction from normal logistic activities (Pohlen & Farris, 1992). Contrary to the traditional logistics process flows, RL deals with how products are efficiently retrieved from the point of consumption and transported back to the point of origin (Setaputra & Mukhopadhyay, 2010). Forward (outbound) logistics is the main focus of most businesses, while RL (inbound) is traditionally after-sales services with the primary focus of value recovery, cost reduction and regulatory compliance (Khan & Subzwari, 2009). Below, Table 2.1 presents the definitions of reverse logistics that have emerged, as provided by de Brito and Dekker (2003).

Table 2. 1 Reverse logistics definitions

Author	**"Reverse logistics"** Definitions
Stock, 1992	"...the term often used to refer to the role of logistics in recycling, waste disposal, and management of hazardous materials; a broader perspective includes all relating to logistics activities carried out in source reduction, recycling, substitution, reuse of materials and disposal."
Pohlen and Farris, 1992	"...the movement of goods from a consumer towards a producer in a channel of distribution."
Kopicky et al., 1993	"Reverse Logistics is a broad term referring to the logistics management and disposing of hazardous or non-hazardous waste from packaging and products. It includes reverse distribution which causes goods and information to flow in the opposite direction of normal logistics activities."
Rogers and Tibben-Lembke, 1999	"The process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal."
Dowlatshahi, 2000	"RL as a process in which a manufacturer systematically accepts previously shipped products or parts from the point for consumption for possible recycling, remanufacturing, or disposal".
Dekker et al., 2003	"The process of planning, implementing and controlling flows of raw materials, in process inventory, and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal"

Source: de Brto & Dekker,2003

Therefore, researchers proposed definitions for RL as basically the process of moving goods from their designated point of destination back to the point where they were initially produced, for the purpose of recapturing value or proper disposal (Rogers & Tibben-Lembke, 1999; Dowlatshahi, 2000; Dekker et al. 2003). Hence, Reverse logistics is for all operations related to the reuse of products and materials.

2.2.2 Reverse logistics vs forward logistics

RL process is similar to forward logistics process only in that it is concerned with movement of materials from the point of consumption to the point of origin where products are been produced. This reverse order flow is what has been regarded as Reverse Logistics. The known areas of dissimilarities between forward and reverse logistics can be found in the high cost and complexity of reverse logistics. Da, et al., (2004) and Parvenov (2005) identified popular issues connected to reverse logistics, such as:

- Uncertainty in the recovery system
- Incapability of tracking incoming products
- High cost of setting up the reverse logistics process to aid the repackaging of returned goods for resale

- Cost of disposing of unserviceable items and others

However, these problems can be surmounted and converted to competitive advantage if there is a well-organised reverse logistics system (Ravi & Shankar, 2004; Bernon & Cullen, 2007). Therefore, Setaputra and Mukhopadhyay (2010) explain that RL deals with how products are efficiently recovered from the point of consumption and transported back to the point of origin. Forward logistics is the main focus of most businesses, while RL is traditionally an after-sales service with the primary focus of value recovery, cost reduction and regulatory compliance (Khan & Subzwari, 2009). Figure 2.1 below presents the forward and reverse logistics flow difference.

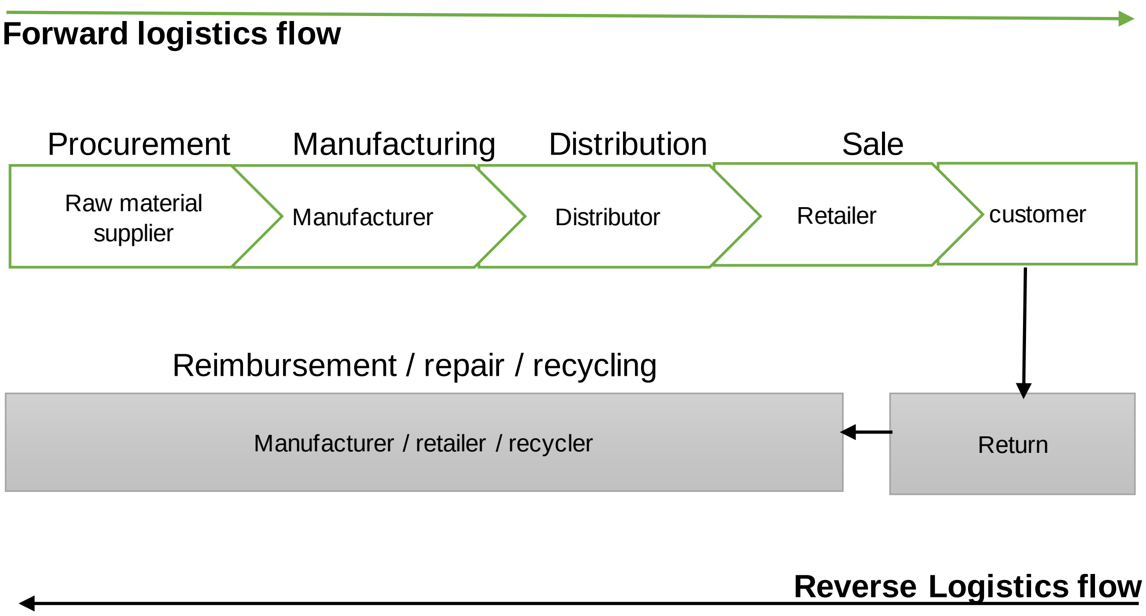


Figure 2. 1 Forward and RL flow

The system used in forward logistics cannot be used to process product return because the reverse supply chain is not a regular image of the forward supply chain due to the differences in material flow and information demanded (De la Fuente et al., 2008). The forecasting and planning in RL also differ from those of the forward supply chain due to the high level of uncertainty associated with product return and waste. Hence, only companies with a high level of collaboration are more efficient and effective in supply chain integration (De la Fuente et al., 2008).

2.2.3 Importance of reverse logistics

RL can be of enormous value in remanufacturing, repair, reconfiguration and recycling, which can be interpreted as profitable business opportunities (Giunti & Andel, 1995; South, 1998). Reverse logistics also affords firms a huge opportunity to distinguish their roles from that of customers and indicates how the handling of a company's returns is often assessed by customers as an important consideration when a future purchase takes place (Daugherty, et al., 2002). To these scholars, a well-planned reverse logistic system can promote long-lasting relationships for mutual benefits (satisfying needs of consumers and profit for the producers).

In like manner, customers are more likely to patronise retailers who perform better than other retailers on the handling of returns. Essentially, logistics is a major factor that enhances a company's achievements in different aspects of business. It is widely acknowledged that reverse logistics plays a key role in a company's performance and customer relations (Daugherty, et al., 2005).

Therefore, a growing interest in reverse logistics activities, including recycling, remanufacturing information technology, warehousing, operations and environmental sustainability, has emerged in academic and in business communities (Huscroft et al., 2013; Dowlatshahi, 2010). Organisations are interested in the return flow of their used products destined for recycling (Souza, 2013; Olugu et al., 2010). Based on the implementation of RL, these organisations develop partnerships with various others in the supply chain to recycle used products. This practice reduces their production cost and incidences; solid waste management costs and the environmental impact of landfill are also reduced, and thus both economic and ecological dividends are realized (Berkowitz et al., 2000).

According to Kinobe et al. (2012), environmental aspects and existing governmental regulations have motivated and induced producers and suppliers of products to take more responsibility for availing their products on the market. This has resulted in an increased interest in reverse flow products and recycling activities. By using RL, companies are able to achieve sustainable development by implementing environmentally friendly supply chain initiatives and optimising profit simultaneously (Dowlatshahi, 2000).

However, as pointed out by Autry, Daugherty and Richey (2001), RL is often under-considered as a strategic option for firms to gain economic and environmental benefits, with its strategic value neglected. Businesses' reluctance in executing reverse logistics programmes can be attributed to the following: The traditional preoccupation of companies with limited logistics and the tendency to hide inventory mistakes are potential factors that can hinder a company from committing substantial resources to reverse logistics.

Another factor is the inability to recognise areas where there are potential benefits (Daugherty et al., 2001; Saccomano, 1997). Moreover, Richey, et al., (2005) state that physical process usually requires "a series of intricate multi layered steps" involving raising returns authorization, printing labels, determining appropriate product handling and disposition, and organising transportation. The unwillingness to commit resources to returns in the chain of supply gives rise to opportunity for companies to establish their business strategies. In regard to this, Stock, et al., (2002) reason that though reverse logistics is often viewed as a "costly sideshow" to regular business operations, it should receive much more awareness than it does now. They also proposed that reverse logistics should "be seen as an opportunity to build competitive advantage".

Similarly, Richey et al. (2005) advise companies to strengthen their competitiveness through operational performance and financial benefits gained from commitment of more resources to reverse logistics. Moore (2005) avers that many benefits can be derived from an effective logistics program. Such benefits include reuse or packaging, reduction of excess inventory of raw materials and old equipment disposal.

In academia, several endeavours focusing on the reverse flow of products have emerged, thereby contributing to the body of knowledge in the relatively new field of RL. The practice of RL has stretched out worldwide, encompassing all layers of the supply chains in various industry sectors including those producing steel, commercial aircraft, computers, automobiles, chemicals, appliances and medical items (Dowlatshahi, 2000).

RL has also gained importance as a profitable and sustainable business strategy (Grant & Banomyong, 2010). The considerable increase in the pace of research in both areas is evident in the increased amount of attention both have received from operations managers and company executives (Dowlatshahi, 2000). While some actors in the supply chain have been forced by regulatory authorities to take products back, others have proactively implemented RL strategy due to the economic potential associated with the practice (de Brito & Dekker, 2003).

2.3. Empirical review of reverse logistics (a brief discussion)

This section provides a brief discussion of RL empirical review to understand the importance of further detailed discussion of the generation of each research question by identifying the gap in the literature.

2.3.1 Reverse Logistics empirical review based on topic

Earlier scholars mainly investigated network structure in RL and focused mainly on recycling (Guiltinan & Nwokoye, 1975; Pohlen & Farris, 1992). Subsequently, more issues, including differences between forward and RL, cost in RL, and other general information have been described by various researchers (Carter & Ellram 1998), including environmental issues to be considered in RL practice (Barry et al.,1993; Kopicki et al., 1993; Webb, 1994). These studies mainly described the role that attention to environmental concerns has in determining the direction of activities of reverse logistics. But these studies lacked empirical evidence in terms of details of RL characteristics (Carter & Ellram, 1998).

Therefore, de Brito and Dekker (2003) identified an important focus of RL key aspects which brought forward a content framework on RL as a whole by bringing structure to the fundamental contents of RL and their interrelations. This was achieved via the answering of four basic questions on RL: Why? What? How? Who? According to de Brito and Dekker (2003), these are the driving forces and return reasons, what type of products are streaming back, how they are being recovered, and who is executing and managing the various operations. de Brito and Dekker (2003) argued that these four basic factors are interrelated, and their combination determines to a large extent the types of issue that arise in implementing, monitoring and managing RL systems. Further scholars also agreed with this and follow these four aspects (what: return reason and nature, how: process, who: players and why: drivers) and added two more key aspects: where: location, why: barriers (Xie & Breen, 2014) and when: time related issues (Salvador, 2017). In this way a general understanding of what RL issues involve was achieved, at the same time capturing the vast categories of matters related to RL. This therefore constitutes a theory of RL. de Brito and Dekker (2003), however, pointed out that the exact influence of the four identified dimensions is still an open question requiring further investigation. It is the intention of this thesis that the application of this framework to explore reverse logistics practice in a different context has the potential to produce empirical findings that can either lead to the extension or the modification of RL key aspects. Hence, this study utilized all the key aspects cited in the literature on return reason and nature in RL, RL process, players in RL, drivers, barriers, location related issues in RL and time related issues in RL to explore the phenomenon.

2.3.2 Reverse Logistics empirical review based on industry

Reverse Logistics has been expanding worldwide, involving all the layers of supply chains in various industries (de Brito & Dekker, 2003), including household (Xie & Breen, 2014); electronic (Agrawal et al., 2016); and retail (Hasiao, 2010). Most studies are from a generic perspective, where the industry is not considered (Carter & Ellram, 1998; Fleischmann et al., 1997; Zhao et al. , 2008; Bai & Sarkis, 2013). In terms of studies that are industry specific, there is literature in related fields that have secondarily added to the theoretical growth of RL. For instance, Thierry et al.'s (1995) report reveals that RL is widely used in the automobile industry; providing automobile firms with far reaching cost and strategic advantages in a highly competitive environment; but here a lack of empirical research has also been identified (Dowlatshashi, 2000). Further academics also supported the above discussion and claimed that the majority of the RL research is generally not industry specific and the automotive industry accounts for 7% of the total publications, followed by the pharmaceutical, electronic and manufacturing industries (6%), medical industry (5%), retail industry (5%), food and beverage industry (4%), electrical industry (3%) and recycling industry (3%) (Salvador, 2017). These findings again indicate the strategic importance and applicability of RL in various industries. In light of these extant empirical studies towards RL theory, this thesis employs the RL key aspects proposed by de Brito and Dekker (2003) and further extended by Xie and Breen (2014) and Salvador (2017) to explore RL practices in a different industry (automotive) context.

2.3.3 Reverse Logistics empirical review based on nation and country

Furthermore, it is important to note that the application of reverse logistics is another area of logistics that is popular in both developed and developing nations (Amole et al., 2018).

The literature shows that in developed nations like Europe, RL processes have a much clearer role in enterprises managing industrial waste. This reveals a fascinating connection between logistics and waste, as well as an interesting element of sustainable development conception for achieving environmental goals (Starostka-Patyk & Grabara, 2010). On the other hand, the procedure of RL and the present state of waste management in developing countries such as Uganda has found that in a relative sense, reverse logistics practice is not established yet (Kinobe, et al., 2012). Therefore, to find stabilised RL practice to present the strength and benefit of RL practice researchers were motivated to conduct research found in developed countries like German, USA and Netherland (Rubio et al., 2008). However, knowledge of trends in the UK was limited, which is an indication of the small quantity of RL research in the UK, though RL practice in the UK was found to be more challenging and advanced than in other developed countries, especially for the automotive industry, due to strict government regulations to reduce the impact on global warming (Aitken & Harrison, 2013). Therefore, the purpose of this study is to investigate the RL practices in the UK.

2.4 Key aspects in reverse logistics

Researchers (de Brito & Dekker, 2003; Xie & Breen 2014; Salvador, 2017) have claimed reverse logistics has eight key aspects: 1. why the product is returned (return reasons), 2. the of nature of returns (return features), 3. the return process, 4. who the players are, 5. why they are involved in RL process (drivers), 6. why they are not involved/barriers faced during the process, 7. where the returns are processed (the location) and 8. when the return process is (time related issues). These eight key aspects are the best practice to characterise and understand RL issues.

de Brito and Dekker (2003) argue that to understand the fundamental components of RL and their interaction, it is necessary to structurally analyse the topic from the first five essential perspectives: why products are returned, what the nature of returned products is, how the products are processed and who the players involved are and why they are involved. Subsequently, other researchers agreed and stressed the importance of analysing these five key aspects (Xie & Breen, 2014).

The five key aspects framework has been expanded further in a recent work by Xie and Breen (2014) by adding key aspects 6 and 7 "why players are not involved in RL activities (barriers)" and "where the location for collection points and distribution centres is in the RL network".

Another key aspect "when" was introduce by Salvador (2017) to provide insight into when key activities such as returning, collection, inspection, sorting, and recovery processes (resale, reuse, redistribution, incineration, or proper disposal) are initiated in the RL network.

The present study has identified, in addition to the above key aspects, the performance of RL process (Olorunniwo & Li, 2011), the relationships between players (Xiao et al., 2019) and product design related issues in RL (Thierry et al., 1995; Schultmann et al., 2006), as these aspects are currently receiving attention to better understand RL issues that are very much related to the above key aspects (Olorunniwo and Li, 2011).

Therefore, with these eight aspects, this research also intends to review, "product design related issues in terms of their impact on the RL process", "the performance of RL process" and "the relationship nature between players". This chapter therefore considers all the aspects below with a detailed discussion of each aspect.

Table 2. 2 Key aspects in reverse logistics practice

Key aspects	Detail
Return Reasons (de Brito & Dekker, 2003; Xie & Breen, 2014; Salvador, 2017)	• What is returning? • Who is returning? • Why are they returning – driver for senders?
Return product nature (de Brito & Dekker, 2003; Xie & Breen, 2014; Salvador, 2017)	• What is the configuration (number of components and materials, how are they put together, materials heterogeneity, presence of hazardous materials, size of product) of return products? • What is the functionality (products age, components/parts age, market value) of return products? • What is the use pattern (single/multiple, duration of use, consumption) of the return products?
The RL process/how (de Brito & Dekker, 2003; Xie & Breen, 2014; Salvador)	• How return products are processed (collection – landfill)
The location/where (Xie & Breen, 2014; Salvador, 2017)	• Where return products are processed
Time related issues/when (Salvador, 2017)	• When the process starts and how long it takes
Players involved/who (de Brito & Dekker, 2003; Xie & Breen, 2014; Salvador, 2017)	• Who is involved in this return product process? • Product, information and other flows between players?
Drivers (de Brito & Dekker, 2003; Xie & Breen, 2014; Salvador, 2017)	• Why players are involved in RL process/drivers influencing payers • What action is taken by players as a result of this influence • Who is taking this action and what is its impact/results
Barriers (Xie & Breen, 2014; Salvador, 2017)	• Why are players not involved yet? • What is hindering more successful RL practice?
Design of products (Thierry et al., 1995; Schultmann et al., 2006)	• Design for new products (thinking of recycling/circular economy)
Performance (Olorunniwo & Li, 2011)	• What is the performance of the RL process?
Relationship nature (Xiao et al., 2019)	• What is the relationship between players and its impact?

Source: de Brito & Dekker, 2003; Xie & Breen, 2014; Salvador, 2017

For a holistic understanding of all the key aspects above, this research attempted to summarise the literature and assembled studies across industries (apart from the auto industry, which is presented in phase 2 of this chapter). Studies considered are not only those focusing on the RL key aspects framework but also other RL studies where at least one key aspect (return reason/return feature/ RL process/players/drivers/barriers/location related issues/time related issues in RL/RL performance/product design thinking of RL/relationship nature in RL) has been considered. Figure 2.2 below presents a clear picture of RL studies collected for this investigation.

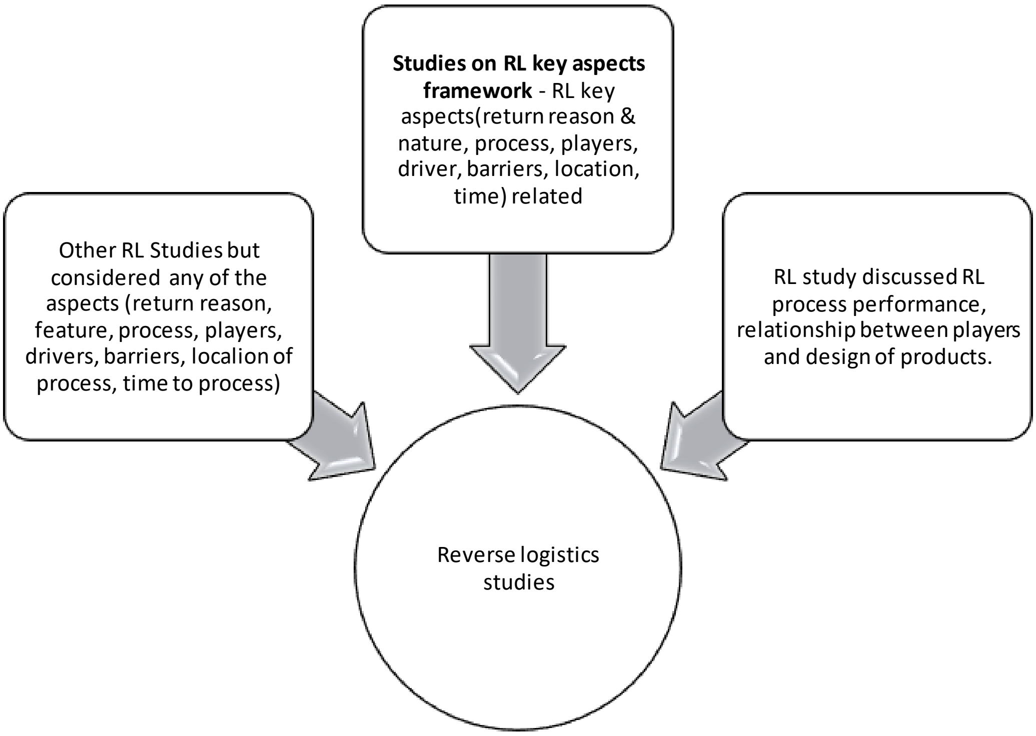


Figure 2. 2 Framework for Reverse Logistics studies collected for this investigation

All these studies are captured in one table presented in appendix 1. Furthermore, for vibrant assessment, each aspect's related knowledge has been presented in separate tables in this chapter where table 2.3 presents RL return reasons, 2.4 presents RL return nature, 2.5 presents RL process in terms of how, 2.7 presents RL process performance, 2.8 presents location related issues in RL process, 2.9 presents time related issues in RL process, 2.10 presents players and their activities in RL process, 2.12 presents drivers influencing involvement in RL and 2.13 presents barriers hindering the RL process.

2.4.1 Products return reasons

The aspect "product return reason" consider why products come back or are returned and who the senders are. Three different senders are identified and discussed in the literature: manufacturers, distributors and consumers. Products are returned by these three senders mainly because the product is defective or no longer required.

1. **Return from Manufacturers**

Three different categories of manufacturing returns have been identified, namely excessive raw material from production (de Brito & Dekker 2003), defective (such as transitional or final products that fail quality checks by manufacturers) (de Brito & Dekker 2003) and production leftover (Fleischmann et al., 1997; de Brito & Dekker 2003).

2. **Return from Distributors**

Six different types of return from distributors are identified in the literature: product defective, damaged, expired, unsold/in excess (which are mainly B2B commercial returns; carrier and packaging; product recalls (de brito & Dekker 2003); stock adjustment for redistributes items between warehouse or stores by distributors due to over stock, slow moving sales and marketing return (Rogers & Tibben-Lembke, 1998; de Brito and Dekker 2003)); product replaced by a new version/product discontinued (Rogers & Tibben-Lembke, 1998); and retailer or distributor going out of business (Rogers & Tibben-Lembke, 1998).

3. **Returns from consumers**

Five different types of product returns are identified in the literature: defective product due to production defect, shipping damaged and quality complaints; unwanted products because of wrong product being ordered (Rogers & Tibben-Lembke, 1998; de Brito & Dekker, 2003; Olorunniwo & Li, 2011); warranty return giving opportunity for customer to return the product if they just change their mind or any other reason (Fleischmann et al. , 1997; Rogers & Tibben-Lembke, 1998; de Brito & Dekker, 2003); end of use, when customers do not want to use the product any more but the product is still functional (Fleischmann et al. ,1997; de Brito & Dekker, 2003, Xie & Breen 2014); and End of Life as product does not function anymore (Rogers & Tibben-Lembke, 1998; de Brito & Dekker, 2003, Xie & Breen 2014).

The key aspect “return reasons” is presented in table 2.3 with details of:

- Where the returns are generated (the source of return products / senders)
- What is returning in terms of the product condition (new / used / unused / damaged)
- Why products return (reason of return) in terms of what happened to the product
- What is driving senders to return the product

The table 2.3 provides a clear understanding of what products are returning in the reverse chain and the reasons and motivations for returning the products. However, there is no discussion identified on “drivers for sender” for manufacturing and distribution reasons and this could be because manufacturing returns are mainly identified as recovered throughout the production phase. These products are usually valuable as new and economically useful and re-usable in production (Teunter et al., 2003). On the other hand, distribution returns are mostly returned to vendors for resale (Rogers & Tibben-Lembke, 1998). Details of this are discussed in the RL process section.

On the other hand, consumers are identified as the main source of return. There is a clear understanding of what products are coming from consumers in the reverse chain and their reasons for returning products.

Table 2. 3 Return reasons in reverse logistics

Source of return	Condition of products	Reason of return	Drivers for senders to return the product	Studies
Manufacturers	• New raw materials	• Left over from production	-	de Brito & Dekker, 2003; Fleischmann et al.,1997
	• New products	• Final product, because it failed quality checks by manufacturers	-	de Brito & Dekker, 2003
Distributor	• New products	• Over stock of products, because of unsold or in excess or slow moving	-	Fleischmann et al., 1997; Rogers & Tibben-Lembke, 1998; De Brito & Dekker, 2003
	• Expired products	• Unsold	-	Fleischmann et al., 1997; Rogers & Tibben-Lembke, 1998; De Brito & Dekker, 2003
	• New but damaged products	• Shipping damaged products	-	Fleischmann et al., 1997; Rogers & Tibben-Lembke, 1998; de Brito & Dekker, 2003
	• Used products	• Recall products, because of production defect	-	Fleischmann et al., 1997; Rogers & Tibben-Lembke, 1998; de Brito & Dekker, 2003, Khan & Subzwari, 2009
	• Product packages	• Because unused or broken •	-	Fleischmann et al., 1997; de Brito & Dekker, 2003
	• New products	• Obsolete product replaced by a new version/product discontinued/ retailer or distributor is going out of business	-	Rogers & Tibben-Lembke, 1998
Consumers	• New but damaged/faulty	• Defective, shipping damaged and quality complaints products	To get refund/exchange the product	Rogers & Tibben-Lembke, 1998; De Brito & Dekker, 2003; Olorunniwo & Li, 2011
	• New products	• Wrong product being ordered	To get right product or refund	Rogers & Tibben-Lembke, 1998; de Brito & Dekker, 2003; Olorunniwo & Li, 2011
	• New products	• Warranty return (customer change their mind)	To get refund	Fleischmann et al., 1997; Rogers & Tibben-Lembke, 1998; De Brito & Dekker, 2003
	• Used	• End of Use/customer does not want to use anymore	To get the product value price	Fleischmann et al. ,1997; de Brito & Dekker, 2003; Xie & Breen, 2014
	• Used and worn	• End of Life	Public awareness	Rogers & Tibben-Lembke, 1998; de Brito & Dekker, 2003 ; Xie & Breen, 2014

Source: Fleischmann et al.,1997; de Brito & Dekker, 2003; Olorunniwo & Li, 2011; Xie & Breen, 2014

Defective, shipping damaged, quality problem, wrong product being ordered, and change of mind are the reasons why products are coming back because companies give customers the opportunity to return products within a certain time frame (around 14 days to 28 days, depending on company policy) and the main motivation here is customers can get a full money refund or can exchange the product. On the other hand, for the return of end of use products, senders are mainly influenced by economic value, as this category of product can still be functional to resell (de Brito & Dekker, 2003). But only End of life return reasons and motivations are not clear, because customers are identified as being less engaged in End of Use or End of life returns, as they are not required to be engaged or do not get significant benefit from it (Xie & Breen, 2014).

Therefore, consumer return reasons, especially end of life and end of use, are identified as the main concern for return reasons to control waste where researchers suggest that to control return and reduce waste, it is important to influence consumers to return end of use and end of life products by enhancing public awareness of environmental protection and conservation, which can have a significant influence on increasing product returns from consumers (Erol et al., 2010; Prahinski & Kocabasoglu, 2006). Setting up an approved compliance scheme has also proven to be successful in enhancing public awareness of the necessity of reducing and recycling waste by bringing back the end of use and end of life product (Xie and Breen 2014).

However, there is very limited knowledge on return reasons for end of life products and how they become end of life. The reasons for end of life products being returned has not been discussed in detail in terms of why senders decide to return the product/ what the individual facts are that influence them to return products instead of just putting them in the bin, especially for consumers. Therefore, it is important to ask the question what drivers influence consumers to return End of Life products, as they may not gain any economic value from them. In addition, the importance of analysing return reasons for improving practice is claimed in the literature but detail of how analysis of return reason can improve RL practice has not yet been discussed.

After having outlined the reasons for product return, the next question that emerges is - what is/are the nature/features of these return products? So, the next key aspect discussed below is “Nature of return products”.

2.4.2 Nature of return product and its impact on the RL process

In the literature, the nature of return products mainly discusses what is actually returning in the reverse flow in terms of product structure/design, functionality and usability. These are categorised into three fundamental product characteristics - composition, deterioration and use pattern (De Brito & Dekker, 2003). Subsequent researchers also added packaging solution (Silvenius et al., 2013). Xie & Breen (2014) also considered three categories (composition, deterioration and packaging solution) and their research not only discussed these in terms of what product is “coming in”, but also in terms of what product is “going out” and its impact (going out mainly focuses on the product leaving the network, which is mainly reuse of the return product, details of this are discussed in the RL process aspects section).

1. **Composition/configuration of products/design of products**

Composition of products is one of the most important features identified in the literature, as it impacts the whole RL process of return products (de Brito & Dekker 2003). Composition of product is categorised based on:

- Number of components and materials contained in the return product (de Brito & Dekker 2003)
- The way components are put together (de Brito & Dekker 2003)
- The presence of hazardous materials (de Brito & Dekker, 2003; Xie & Breen, 2014)
- Material heterogeneity (de Brito & Dekker, 2003)
- The size of the product (de Brito & Dekker, 2003; Goggin & Browne, 2000; Xie & Breen, 2014)

Impact on RL process: Affects the ease of collecting and reprocessing return products and the associated values recovered from them (Goggin & Browne, 2000).

2. Deterioration/functionality of product

Deterioration is another important feature discussed in the literature, which verifies whether there is enough functionality left within a product to make further use or whether recapture of value from its parts/components is feasible —

- Product age elapsed or not during use (de Brito & Dekker, 2003)
- All or few components age elapsed (de Brito & Dekker, 2003)
- Value of the product declines fast (de Brito & Dekker, 2003)
- Market value of the product/product parts decreases due to new product introduced (de Brito & Dekker 2003) or legislation that regulates the usability of the return product (Xie & Breen, 2014)

Impact on RL process: This deterioration/functionality of product has an impact on the RL processing and players. Either products become obsolete because of replacement by a new product, ageing and expiry, or because of legislation restricting reuse of the returned products, which happens with medicines in the UK (Xie & Breen, 2014). Therefore, reuse or resale of medicine is not an option here. In the case of a product like batteries, the product can be dismantled and parts can be retrieved if some of them are still functional.

3. Use pattern of product

This is identified as describing the location, intensity and duration of a used product. It has a strong impact on the collection phase of the reverse logistics process (de Brito & Dekker 2003), as it describes the number of products to collect (single or bulk) from a location. So, it can be categorised into four categories:

- Products coming from a single consumer
- Products coming from an institution
- Product use length
- Product consumed during use

Impact on RL process: Products coming from a single consumer can be one/small amount at a time, whereas products coming from institutions can be returned in bulk and this has a strong impact on transportation and effort to collect products. Some products can be used for a small period of time and can be reused again, such as leased medical equipment (de Brito & Dekker 2003), which has an direct impact on recovery and reuse of product.

4. Packaging of a Product

The packaging of a product is identified as another feature of returned products discussed in the literature which has an influence on RL to process package-related waste, and it concerns package sizes, shapes and materials used (Xie & Breen, 2014).

Impact on RL process: The literature also discusses its impact which can minimise waste generation and help the forward chain to achieve the lowest environmental impact (Silvenius et al., 2013).

Therefore, for return product nature, the review of the literature found limited knowledge of product features (a small group of scholars consider return features in their studies). The literature offers a good understanding of different types of product features and basic knowledge of their impacts and the overall value recovery from RL. Also, features are discussed mostly in general and not in terms of return type. Features can be different for different types of return. The nature of returns was identified as differing between industries, but limited studies were found to focus on this perspective (Goggin & Browne, 2000; Silvenius et al., 2013; Xie & Breen, 2014). Therefore, it is important to ask the question: what are the key features of each category return reason discussed above**?**

After outlining the reasons for product returns and the nature of the returns the following question arises: how are these returns processed? So, the next key aspect discussed below is the “reverse logistics process”.

Table 2. 4 Return nature and its impact on reverse logistics process

Return features	Details	Impact on the RL process	Studies
Compositions /configuration of products	• Number of components and materials contained in the return product	• Impact on recovery process in terms of time and effort required	de Brito & Dekker, 2003
	• The way components are put together	• Impact on recovery process in terms of time and effort required and recovered components quality	de Brito & Dekker, 2003
	• The presence of hazardous materials	• Impact on recovery process in terms of time and effort as they need special treatment	de Brito & Dekker, 2003; Xie & Breen, 2014
	• Material heterogeneity	• Impact on recovery process in terms of time and effort required	de Brito & Dekker, 2003
	• The size of the product	• Impact on collection process in terms of transportation and handling	de Brito & Dekker, 2003; Goggin & Browne, 2000; Xie & Breen, 2014
Deteriorations/functionality of products	• Product age elapsed during use or not	• Impact on assessment process as recovery options depend on functionality of products	de Brito & Dekker, 2003
	• All components age elapsed or few		de Brito & Dekker, 2003; Xie & Breen, 2014
	• Value of the produce declining fast		de Brito & Dekker 2003
	• Market value of the product/product parts due to new product introduced or legislation that regulates the usability of return product		de Brito & Dekker, 2003; Xie and Breen, 2014
Use pattern of product	• Products coming from a single consumer	• Impact on collection process in terms of transportation and handling	de Brito & Dekker, 2003
	• Products coming from an institution		
	• Product use duration	• Impact on recovery process in terms of quantity of recovery	
	• Product consumed during use		
Packaging of product	• Package size/shape	• Impact on minimizing / maximising waste generation	Silvenius et al., 2013; Xie & Breen, 2014
	• Materials used in the packaging		

Source: de Brito & Dekker, 2003; Silvenius et al., 2013; Xie & Breen, 2014

2.4.3 Reverse logistics process

The RL process is identified as the most important phase discussed in the literature, because this phase analyses how value is recovered from returned products and the impact on the environment and society (Xie & Breen, 2014). This process can be different for different types of return reasons discussed below.

2.4.3.1 Return process for manufacturer return

Manufacturing returns are returns recovered during the production phase. They can be raw materials leftover or products that failed in final testing. Raw materials left over often contain valuable material; they are often economically useful and re-usable in production (Teunter et al., 2003). On the other hand, products that failed final testing can be improved and retested (de Brito & Dekker, 2003).

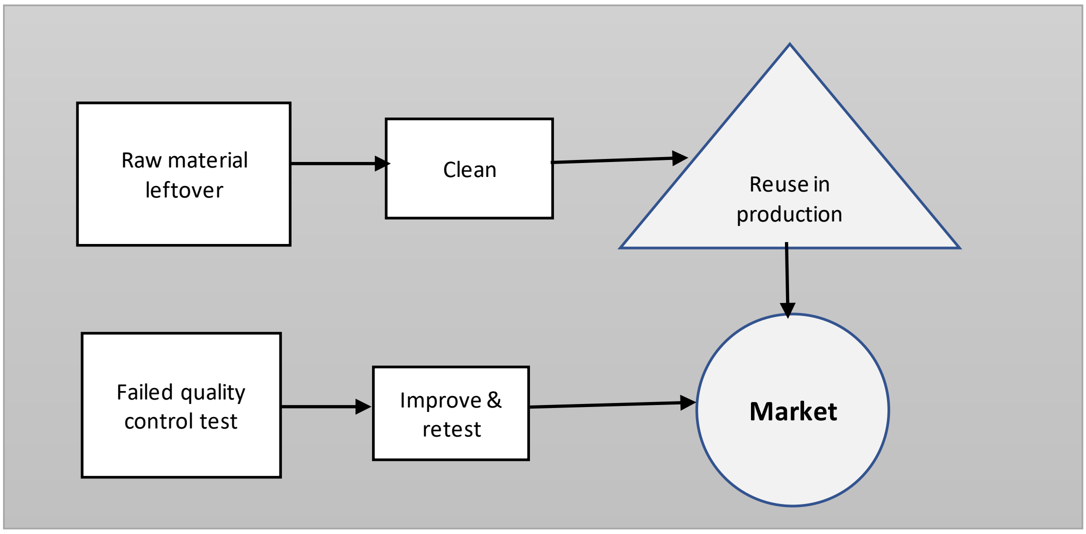


Figure 2. 3 Manufacturing return process

2.4.3.2 Return process for distribution and customer return

The first stage is the gatekeeping stage where an initial checking process engages with mainly products coming back before products become accepted. Once the product is accepted, the collection stage begins, where products are collected from customers and sent to the point of recovery. The second stage is the initial inspection and sorting, whereby the returns will be quality inspected and sorted according to the type of recovery required. If the returned product is new, the product will end up back on the market through re-use, re-sale and re-distribution. If the product is old, the return will be forwarded to the next stage. The next stage is the value recovery stage where the returns will be processed according to the type of recovery activity.

The research classified these recovery options into repair, refurbishing, remanufacturing, recovery, recycling, and disposal (de Brito & Dekker, 2003). Furthermore, these recovery options are discussed in more detail and added to the recovery process, including dismantling of hazardous and non-hazardous parts and the shredding stage to recover materials (Yang & Wang, 2007). Therefore, the common key activity stages identified in literature for the RL process for distribution and consumer return are:

1. Gatekeeping
2. Collection of return product
3. Assessment and sorting for recovery options (options: i) Direct use, ii) Repair/refurbish/remanufacture iii) recycling).
4. Hazardous separation
5. Collection, reuse and recycling of hazardous products
6. Marketable parts removal and reuse
7. Compacting products
8. Shredding products and recovering materials
9. Disposal waste (incineration/landfill)

In the literature different studies considered different stages of the RL process presented in table 2.5; therefore this study tried to present a complete picture of the RL process by integrating the knowledge from the literature which is presented in figure 2.4 and discussed in each stage of RL process below.

Details of each of the stages discussed below and studies considering RL process stages are presented in table 2.5., according to industry and country perspective. As mentioned previously, the RL process's different stages depend on return reasons; therefore, this table tried to capture the return reason for each stage discussed in the literature.

1. Gatekeeping

Gatekeeping (in supply chain terms) refers to the screening of returned goods at the entry point in the reverse flow from the consumer back to the manufacturer/supplier/retailer. Gatekeeping controls the return by deciding which products to allow into the reverse logistics system (Rogers & Tibben-Lembke, 1998). Gatekeeping not only controls return but also helps in assessing customer return reason and feedback about product problems (Yang & Wang, 2007). Gatekeeping can be carried out in the collection stage as well (Yang & Wang, 2007).

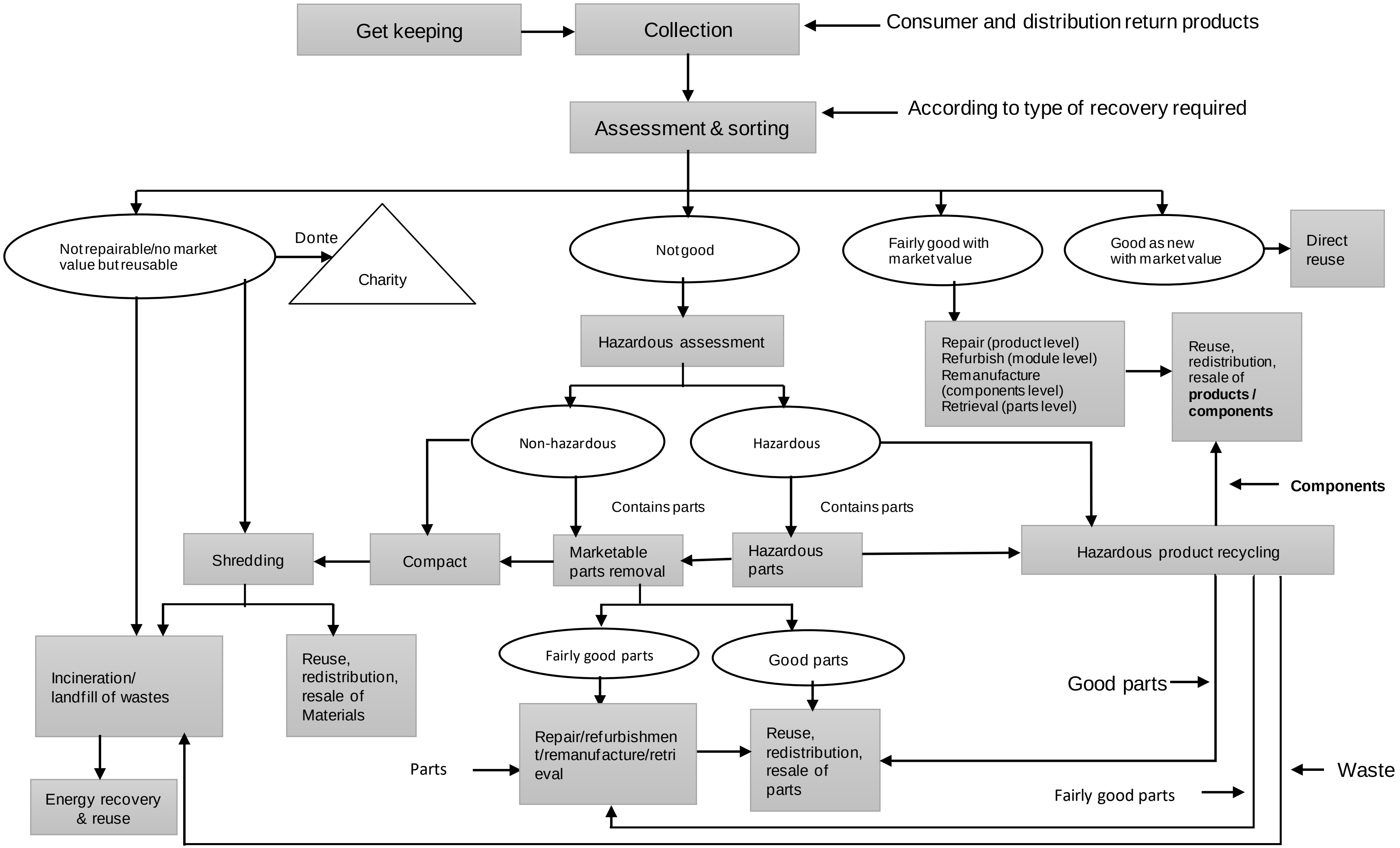


Figure 2. 4 Reverse logistics process for return product

Source: Thierry et al., 1995; Fleischmann et al., 1997; Goggin & Browne, 2000; de Brito & Dekker, 2003; Schultmann et al., 2006; Yang & Wang, 2007; Kumar & Putnam, 2008; Li & Olorunniwo, 2008; Olorunniwo & Li, 2011; Chan et al., 2012; Bai & Sarkis, 2013; Subramanian et al., 2014; Xie & Breen, 2014.

2. Collection

Collection is a very important stage in the reverse logistics process, where product types are selected and products are located, collected, and, if required, transported to facilities for rework and remanufacturing. Used products originate from multiple sources and are brought to a product recovery facility, resulting in a converging process. The collection process is also identified as depending on customers, as the initial transport can be either performed by the consumer/ dropped off by senders or by the receivers (manufacturer/retailer of the product or a third party) (Srivastava & Srivastava, 2006). This depends on the category of return and company policy.

If the return comes for refund/exchange within the time frame (warranty return), the customer will get a refund/exchange and the product can be put back on the shelf directly or may need a little repair or cleaning before being put back on the shelf; if the customer comes for repair, products will be checked and if possible, in terms of company policy and capacity, products will be repaired and sent back to customers (in this case the RL process ends here for repair products); in the case of product returns for recycling purposes, customers may get some rewards and products go to the next stage for inspection and sorting according to recovery options (Yang & Wang, 2007).

Except for recycling purpose/end of use or end of life products, consumers mostly drop off/bring back the return product in the reverse chain to get their money back/exchange/repair and the reverse logistics process mostly ends at the product acceptance stage.

But in the case of End of use and End of life products, return customers as mentioned before can be less engaged, as consumers do not get enough benefit from it and also there is no external force on consumers to return End of Use (EoU) and End of Life (EoL) products (Xie & Breen, 2014). These category products mostly go all the way from collection to he disposal stage. This can be the reason why the main attention on the collection stage is identified as mostly based on end of use and end of life products.

To collect EoL products, the most important focus identified is to have appropriate collection centre networks. The collection centre is the facility where customers bring their products for resolution/exchange. Collection includes inspection, purchase, storage and reselling, if desired (Srivastava & Srivastava, 2006). Inspection denotes all operations determining whether a given product is in fact re-usable and also grading it, which is the 3rd stage of the reverse logistics process, discussed below. Location of an appropriate collection centre near customers can help to reduce uncertainty (Malik et al. 2015) and encourage customers and facilitate the entire RL process (Harraz & Galal, 2011; Xie & Breen, 2014). On the other hand, research suggests integration of forward chain and reverse chain networks for collection of returns can minimise cost and environmental impact (Zarei, et al. 2010). Fleischmann et al. (2003) state that in many countries, companies have a take-back program allowing business customers to return used products in addition to any take-back responsibility. Beullens et al. (2003) present collection as organized by sectors. For some specific hazardous content, the collection (and transportation to destination) should not exceed 12 hours. All these issues make the collection stage very important in the RL process.

3. Assessment and sorting for recovery options

Inspection and sorting may be carried out either at the point/time of collection itself or afterwards at treatment facilities (Srivastava & Srivastava, 2006). Inspection and sorting activities mainly categorise returns for recovery options, presented in figure 2.4.

The literature mentions that these recovery options depend on the product condition and nature, market value, cost benefit analysis and manufacturer requirements. If the product is in good condition, it can be directly reused. If it is in fairly good condition, it can be repaired, refurbished and remanufactured. Whereas, products in bad condition that cannot be repaired can be sent for further treatment. Further treatment refers here to further stages of the RL process: hazardous removal, hazardous recycling, marketable parts recycling, shredding and disposal. These options depend on product type, design of product, type of materials, and nature of materials (hazardous/non-hazardous) (de Brito & Dekker 2003). In terms of market value assessment, this depends on customer demand for the product and regulations for reuse of products (Li & Olorunniwo, 2008). Capabilities as well as the cost benefit analysis are operational cost, landfill and contingent liability cost (de Brito & Dekker 2003). When, for some reason, the firm is prevented from selling the product to the secondary market, and the product cannot be given away, the final option is disposal. As always, the firm's objective is to receive the highest value for the item or dispose of the item at the lowest cost. Some items, such as catalytic converters and printed circuit boards, contain small quantities of valuable materials such as gold or platinum, which can be reclaimed. Such reclamation helps offset the cost of disposing of the item. Other items may be composed of materials that are of some value to scrap dealers, like steel and iron. When the materials are not of value to other companies, the firm may develop ways of using the product to avoid sending it to a landfill. A good example of this is outdoor running tracks made of ground-up athletic shoes. Another example involves sorting damaged retail clothing hangers, melting them, and making new hangers (Rogers & Tibben-Lembke, 1998). It was found that some manufacturers require retailers to dispose of defective products. In this case, the retailer has no choice but to follow manufacturers' instructions and send the product to the landfill or incinerator (Rogers & Tibben-Lembke, 1998).

Therefore, broadly there are three recovery options cited by the literature: direct use, repair/refurbish/remanufacture and further treatment (see details of each options below).

i) Recovery option one: Direct reuse and redistribution of product

Direct reuse options are many:

As a new product: If the returned product is unused and unopened, the retailer may be able to return it to the retail store and resell it as new (Thierry et al., 1995; de Brito & Dekker, 2003). The product may need to be repackaged, so that consumers will not be able to detect that the product is being resold (Olorunniwo & Li, 2011). In some industries, there are restrictions, legal or otherwise, in which products cannot be resold as new once a customer has returned them (Rogers & Tibben-Lembke, 1998), such as return medicines, which cannot be reused directly, even though they are intact and in good condition (Xie & Breen, 2014).

Sell Via Outlet or Discount: If the product has been returned, or if the retailer has too large an inventory, it can be sold via an outlet store. In the clothing industry, because customers will not accept a returned item as new, an outlet store is the retailer's only sales channel (Rogers & Tibben-Lembke, 1998).

Sell to Secondary Market: When firms have not been able to sell a product, and they cannot return it to the manufacturers and are unable to sell it at an outlet store, one of their final options is to sell it via the secondary market. The secondary market consists of firms that specialize in buying close-outs, surplus, and salvage items at low price (Rogers & Tibben-Lembke, 1998).

Donate to Charity: If the product is still serviceable, but perhaps with some slight cosmetic damage, retailers or manufacturers may decide to donate the product to charitable organizations (Li & Olorunniwo, 2008). In this case, the retailer usually does not receive any money for the product. It may, however, be able to gain a tax advantage for the donation, and thus receive some value, while being a good corporate citizen (Rogers & Tibben-Lembke, 1998).

ii) Recovery option two: Repair/refurbish/remanufacturing of product

Products which are not in good enough condition for direct use end up at the stage of repair/refurbish/remanufacturing of product. This stage involves returning used products to working order. These options differ with respect to the degree of upgrading: repair involves the least and remanufacturing the largest (Thierry et al., 1995).

Repair: The purpose of repair is to return used products to "working order". The quality of repaired products is generally lower than the quality of new products. Product repair involves the fixing and/or replacement of broken parts. Other parts are basically not affected. Repair usually requires only limited product disassembly and reassembly.

Refurbishing: The purpose of refurbishing is to bring used products up to specified quality. Quality standards are less accurate than those for new products. Following disassembly of used products into modules, all critical modules are inspected and fixed or replaced. Approved modules are reassembled into refurbished products. Occasionally, refurbishing is combined with technology upgrading by replacing outdated modules and parts with technologically superior ones.

Remanufacturing: The purpose of remanufacturing is to bring used products up to quality standards that are as accurate as those for new products. Used products are completely disassembled and all modules and parts are extensively inspected. Worn-out or outdated parts and modules are replaced with new ones. Repairable parts and modules are fixed and extensively tested. Approved parts are sub-assembled into modules and subsequently assembled into remanufactured products. Remanufacturing can be combined with technological upgrading.

These repaired/refurbished/remanufactured products are mainly redistributed in the secondary market (see below detail of secondary market) (Rogers & Tibben-Lembke, 1998). Fleischmann et al. (1997) argued that repair is to restore failed products to `working order', though possibly with a loss of quality, while refurbishing and remanufacturing conserves the product identity and seeks to bring the product back into an `as new' condition by carrying out the necessary disassembly, overhaul, and replacement operations. However, repair/refurbish/remanufacture options are dependent on customer demands, company policy, and government law on restriction for repair/refurbish and remanufacturing (Li & Olorunniwo, 2008).

iii) Recovery option three: further treatment

As mentioned above, in the case of the product not being reusable directly nor repairable, or able to be refurbished or remanufactured, it goes for further treatment: hazardous materials removal, hazardous recycling, marketable parts recycling, shredding and disposal.

Table 2. 5 Different type of return products RL process stages discussed in literature

(As mentioned before the RL process stages identified depend on product category (return reasons); therefore, in this table column 4 also presents return reasons for all the process stages discussed in the literature)

RL process stages	Details	Product type/return reason	Studies
Gatekeeping	• Controlling the return by deciding which products to allow into the reverse logistics system according to company policy.	• Customer – warranty return	Rogers & Tibben-Lembke, 1998; Yang & Wang, 2007
Collection	• Collection refers to bringing the products from the customer to a point of recovery. • Collection process depends on return category and company policy whether refund or exchange or repair or send for recycling. • the need for the setting up of collection centres near customers was realized because of uncertainty involved in EoL product.	• Distribution return • Customer return -in general; end of use (EoU) and end of life (EoL) product	de Brito & Dekker, 2003; Yang & Wang, 2007; Kumar & Putnam, 2008; Li & Olorunniwo, 2008; Malik et al 2015
Assessment and sorting	• Products are sorted for recovery options (direct use/repair/refurbish/remanufacture/recycling) according to product condition and market value and sometimes manufacturers demand and policy.	• Distribution return • Consumer return	Rogers & Tibben-Lembke, 1998; de Brito & Dekker, 2003; Li & Olorunniwo, 2008
Hazardous separation	• Some product contains toxic or harmful materials which requires separate recycling to protect other products	• Consumer – End of Life (EoL) return	Yang & Wang, 2007; Kumar & Putnam, 2008
Hazardous recycling	• Recycle to recover parts and materials for reuse	• Consumer – End of Life (EoL) return	Kumar & Putnam, 2008
Marketable parts removal and reuse	• If law allows parts get recovered and reuse of those in good condition. Quality standards for parts depend on the process in which they will be reused. Like parts for remanufacturing have to fulfil stricter quality standards than parts for refurbishing or repair	• Consumer – End of Life (EoL) return	Thierry et al., 1995; Kumar & Putnam, 2008; Li & Olorunniwo, 2008; Bai & Sarkis, 2013
Compact product	• Compaction attempts to decrees the recyclable material’s density to reduce transport costs and for ease of transportation to send to shredder	• Consumer – in general	Bai & Sarkis, 2013; Kumar & Putnam, 2008
Shredding product	• Cursing the product and recovering materials for reuse	• Consumer – End of Use (EOU) and End of Life (EoL) return	Fleischmann et al., 1997; Carter & Ellram, 1998; Rogers & Tibben-Lembke, 1998; de Brito & Dekker, 2003; Yang & Wang, 2007; Bai & Sarkis, 2013; Kumar & Putnam, 2008; Goggin & Browne, 2000; Xie & Breen, 2014

Disposal of waste	• Product where recycling is not possible are disposed by incineration/landfill	• Consumer – End of Life (EoL) return	Fleischmann et al., 1997; Carter & Ellram, 1998 ; Rogers & Tibben-Lembke, 1998; de Brito & Dekker, 2003; Yang & Wang, 2007; Bai & Sarkis, 2013; Kumar & Putnam, 2008; Goggin & Browne, 2000; Xie & Breen, 2014

Source: Fleischmann et al., 1997; Carter & Ellram, 1998; Rogers & Tibben-Lembke, 1998; de Brito & Dekker, 2003; Yang & Wang, 2007; Bai & Sarkis, 2013; Kumar & Putnam, 2008; Goggin & Browne, 2000; Xie & Breen, 2014

4. Hazardous product separation

Products which contain hazardous materials (see details in the product nature section 2.4.2 above) are treated differently due to health and safety issues and environmental pollution concern (Kumar & Putnam 2008). After having functionality some of these category products may not be reused as a result of restrictions from governments (Xie & Breen, 2014). So, these category products get separated for special recycling. For some end of life products which contain valuable parts, hazardous components are removed before dismantling valuable parts/shredding to save marketable parts and components (Schultmann et al., 2006). This phase is identified as mainly for End of life products (see the table above).

5. Recycling of hazardous product

There was some very early research conducted on reverse logistics addressing hazardous waste problems (Peirce & Davidson, 1982; Jennings & Scholar, 1984; Zografos & Samara, 1990; Koo et al., 1991; Stowers & Palekar, 1993; Nema & Gupta, 1999). Subsequent to this research, a reverse logistics model for minimising the cost of a multi-time-step, multi-type hazardous waste recovery system was developed and a case study was conducted that considered cost of collection, storage, treatment of hazardous waste and destruction of processed waste (Hu et al. 2002). Wei and Huang (2001) indicated that for hazardous waste reverse logistics systems, it is difficult to coordinate activities for reducing environmental pollution. Apart from environmental issues, Kumar and Putnam (2008) found that hazardous recycling can recover materials from hazardous products and components. These materials can be reused in the production of original parts if the utility of the materials is high, or else in production of other parts (Kumar & Putnam, 2008).

6. Removal marketable parts & reuse

The purpose of dismantling is to recover reusable parts from used products or components (Schultmann et al., 2006). These parts are reused in repair, refurbishing, or remanufacturing of other products and components. Quality standards for dismantled parts depend on the process in which they will be reused. Like products, dismantled parts for remanufacturing have to fulfil stricter quality standards than parts for refurbishing or repair (Thierry et al., 1995). Dismantling involves selective disassembly of mainly end of life products and inspection of potentially reusable parts (Kumar & Purnam, 2008).

7. Compact product

Compaction attempts to increase the recyclable material's density to reduce transport costs and for ease of transportation (Bai & Sarkis, 2013). This stage is mainly applicable for EoL consumer product return. Very limited knowledge was identified from the literature for this stage of RL process.

8. Shredding product

Compacted products and parts come to the shredder for shredding to recover materials. Shredding is the best way to recover materials for reuse (Carter & Ellram, 1998). The shredded metals get recycled and ferrous and nonferrous metals are recovered, and the shredder puff would eventually be disposed of in a landfill (Chan et al., 2012).

9. Disposal of waste

Disposal of products which cannot be reused or parts or materials recovered (due to legal restrictions or product conditions) get disposed by landfill or incineration (Xie & Breen, 2014). This stage of the RL process is believed to be one of the most important stages and mainly applicable for EoL products.

The literature provides a good understanding of the overall reverse logistics process with basic knowledge for each stage. In terms of a detailed understanding of the overall RL process, a common key element that has received attention is use of technology. Common key technologies identified in the RL process, where information technology is used, include computerised return tracing and entry (Jayaraman et al., 2008), use of internet (Li & Olorunniwo, 2008), electronic data interchange (EDI), enterprise resource planning (ERP) and radio frequency identification (RFID) (Li & Olorunniwo, 2008; Jayaraman et al., 2008). EDI is a set of standards for exchanging computer readable information among organizations; ERP is an information system integrating all facets of an organization on a common database; RFID consists of a radio frequency reader/emitter and an active or passive radio frequency tag applied to an inventory (Li & Olorunniwo, 2008). Li and Olorunniwo (2008) identified that each company builds stand-alone customized solutions and database solutions with their own decision rules, with communications through the internet and/or EDI. Some firms use customized solutions integrating with ERP and RFID. The utilization of these types of technologies has been shown to provide net benefits to firms practicing reverse logistics (Hazen et al., 2014).

Now all these stages discussed above are may not be applicable for all return types as different return reasons products found in different conditions which is discussed earlier in this chapter section 2.4.1 and section 2.4.2. therefore, the section bellow discussed RL process in terms of product category.

Each stage of the RL process identified depends on return category. As discussed above, returns are mainly three different types: manufacturing, distribution and consumer return. The RL process for manufacturing returns is mainly identified as recovered throughout the production phase. These products are usually valuable as new and economically useful and re-usable in production (Teunter et al., 2003). Some products may need cleaning and reengineering for final testing, which is done during the production phase. On the other hand, distribution returns are mostly sent back to vendors for resale (Rogers & Tibben-Lembke, 1998). Therefore, the RL process stages above are mainly focused on consumer return products (see the table 2.6). The table 2.6 presents manufacturing and distribution returns mainly processed in the manufacturing and distribution stage and not affecting all the RL stages discussed above. So, for consumer returns, these stages are applicable but here also not all types of consumer returns are affected by all these stages, as most of the consumer returns are sorted in the collection/acceptance stage and some move on to the repair stage. Only EoL return products (highlighted raw in table 2.6) were identified as affected all the way from collection to disposal; as a result, this category was identified as the most complicated to process.

Table 2. 6 Relation between reverse logistics process stages and return reasons

Senders	Return Reason	Reprocess stages											Detail
		Gatekeeping	Collection	Inspection and sorting	Direct reuse	Repair/refurbish/remanufacture	Hazardous removal	Recycling of hazardous products and components	Dismantle	compacting	shredding and sorting	disposal	
Manufacturers	• Raw material left over from production	-	-	-	-	-	-	-	-	-	-	-	Used in production and cleaned or reprocessed if needed Therefore, recovered throughout the production phase (Teunter et al., 2003).
	• Final products fail quality checks by manufacturers	-	-	-	-	-	-	-	-	-	-	-	Fixed, rechecked and sold. So, recovered throughout the production phase (Teunter et al., 2003)
Distributor	• Unsold/in excess/slow moving/over stoke	-	-	-	-	-	-	-	-	-	-	-	Sale with discount so therefore recovered throughout the distribution phase (Rogers and Tibben-Lembke, 1998)
	• Unsold	-	-	-	-	-	-	-	-	-	-	-	Sale with discount so therefore recovered throughout the distribution phase (Rogers and Tibben-Lembke, 1998)
	• Shipping damage	-	-	-	-	-	-	-	-	-	-	-	Sale with discount so therefore recovered throughout the distribution phase (Rogers and Tibben-Lembke, 1998)
	• Production defect (recall product)	-	-	-	-	-	-	-	-	-	-	-	Sale with discount so therefore recovered throughout the distribution phase (Rogers and Tibben-Lembke, 1998)
	• product replaced by a new	-	-	-	-	-	-	-	-	-	-	-	Sale with discount so therefore recovered throughout the distribution phase (Rogers and Tibben-Lembke, 1998)

	version/product discontinued/ Retailer or distributor is going out of business												
Consumers	• production defect, shipping damaged and quality complaints	√	-	√	√	√	-	-	-	-	-	-	This category products identified can only travels to gatekeeping, inspection, direct use and repair stage ((Yang and Wang, 2007). Mostly arrangements on this return products are done in the acceptance stage by refunding/changing the product and product goes to repair stage or producers if production defect.
	• Wrong product being ordered	√	-	√	-	-	-	-	-	-	-	-	
	• Warranty return (customer change their mind/comes for repair)	√	-	√	√	-	-	-	-	-	-	-	
	• End of Use/customer do not want to use anymore	-	√	√	√	√	-	-	-	-	-	-	Mostly this category goes for direct selling as used product, but some also required Repaired/refurbish/remanufactured before resell (de Brito and Dekker, 2003; Xie and Breen, 2014)
	• End of Life	-	√	-	√	√	√	√	√	√	√	√	This category return products goes to all the way from collection to disposal stage as these are mainly End of its useful life (Schultmann et al., 2006)

Source: Author

2.4.4 The performance of RL process

One of the prime issues in the RL context is the evaluation of RL performance. RL and its sustainability performance can be improved if it can be measured and monitored precisely.

According to Song and Hong (2008), performance measurement systems can provide companies with relevant, appropriate, complete and accurate information. Companies have opportunities to monitor and reposition their management and operations to obtain highly competitive environments. Performance evaluation frameworks provide a balanced view between external and internal activity (Keegan et al., 1989) and between results and their determinants (Fitzgerald et al., 1991). Many approaches have been used to develop a RL performance index. Balanced scorecard is one of them and has been utilized by researchers and practitioners frequently in defining goals and performance measures of RL. Yellepeddi et al. (2005) proposed a balanced scorecard approach and utilized the analytic network process technique for the development of an effective RL performance evaluation system. Ravi et al. (2005) used the balanced card approach and analytic network process technique for the selection of alternatives for end-of-life computers. Shaik and Kader (2012) developed an RL performance evaluation framework by using balanced scorecard approach and AHP. In another study, they developed an RL performance evaluation system by integrating balanced scorecard characteristics with the performance prism (Shaik & Kader, 2014). Huang et al. (2012) proposed an RL performance evaluation system for recycled computers from the financial, operational procedure, learning and growth, relationship and flexibility perspectives. Also Bansia et al. (2014) carried out a case study on the design of a performance measurement system for the reverse logistics of a leading battery manufacturing company, using the BSC approach and fuzzy AHP. The balanced scorecard-based performance evaluation systems allow managers to look at the business from four divergent important perspectives: customer, internal business, innovation and learning and finance (Shaik & Abdul-Kader, 2012). The merits of the approach are to integrate strategic, operational and financial measures to consider the balanced key perspectives of performance. However, it does not consider external environment which is important from the perspectives of the players and their satisfaction.

Other approaches have been applied to performance evaluation, such as Biehl et al. (2007), who developed a performance measurement system for carpet recycling by evaluating the system's economic and environmental performance. Paksoy et al. (2011) developed a mathematical model for investigating a number of operational and environmental performance measures, including total transportation costs, total environmental costs, emission rates and customer demand. Recently, Nagalingam et al. (2013) developed a framework for measuring performance in terms of estimated utilization value of a manufactured product, optimizing recovery cost, landfill waste and quality characteristic. Bai and Sarkis (2013) introduced a performance evaluation framework by using the AHP approach for evaluating the economic, environmental and the operational performance. Kannan et al. (2009) proposed a fuzzy multi-criteria decision-making model for the selection of alternative environmental management practices in RL.

There is growing attention on using the Triple Bottom Line (TBL) dimension to measure RL performance where Presley et al. (2007) introduced the relationships of RL to TBL dimensions and developed a strategic sustainability evaluation framework. Govindan et al. (2013) developed a fuzzy multi-criteria decision-making model for measuring sustainability performance of a supplier based on the TBL approach. Nikolaou et al. (2013) developed a framework for evaluating RL social responsibility, based on TBL performance evaluation. The TBL approach, in which performance measures were selected using Global Reporting Initiative guidelines, was comprehensive but difficult to manage practically in real life because of its complexity with the number of indicators. Also, Agrawal et al. (2016) identified that the literature on sustainability aspects of RL is limited and has received limited attention until recently. Therefore, they developed a framework for the economic, environmental and social aspects of RL, including Economic: return on investment, maximum value recapture, logistics cost optimisation, recycle efficiency, annual cost, and disposal cost; Environmental: minimum energy consumption, best use of raw materials, transportation optimization, reduced packaging, use of recycled materials, and waste reduction; Social: employee benefits, stability, customer health & safety, donation to the community, community complaints and stakeholder participation. But the results present that firms (three electronic manufacturers) mainly measure RL performance on recapturing value and return on investment (economic), minimum energy consumption and optimisation of raw materials (environmental), community complaints and customer health and safety (social), and all these studies mainly focused on the development of an RL performance index where actual performance of RL process knowledge was limited.

In terms of actual performance impact, BSC only covers the impact on internal business, finance and innovation and growth perspectives. On the other hand, TBL covers all three aspects (economic, environmental and social) as follows. Therefore, this study employs TBL to measure RL performance. All the key performance indicators initiated to measure RL performance for the TBL perspective and actual performance with the help of information and knowledge gathered from the literature and experts in the field, are presented in the table 2.7.

Table 2. 7 RL process performance

Indicators to measure RL performance	Actual performance impact	Studies
Economic - Value related		
Return on investment (ROI)	• Use of IT on return tracing and managing allowing more collection with less time which increasing recovery of products and materials from return products improving profit.	Nikolaou et al, 2013; Korchi & Millet, 2011, Somuyiwa & Adebayo, 2014; Agrawal et al., 2016
Recapturing value	• The recovery of the products for remanufacturing, repair, reconfiguration and recycling can lead to profitable business opportunities	Agrawal et al., 2016
RL process efficiency	• Time required, standard operating procedures, recovered product quality/amount, utility uses during recycling process, waste generation/quality of documentation and effectiveness of collection planning schedule are related to RL process efficiency	Agrawal et al., 2016
Customer satisfaction	• Involvement with RL activities enable dealing with return properly in terms of quick response and services which creating satisfied customers.	Yang & Wang, 2007; Yang & Wang, 2007; Somuyiwa & Adebayo, 2014; Agrawal et al., 2016
Economic - Cost related		
Operation/logistics cost	• Collection of products from customers generates a large part of RL cost for manufacturers in electric industry • Distance between RL activities increased transportation cost and time	Korchi & Millet, 2011; Bogataj & Grubbstrom, 2013; Agrawal et al., 2016
Disposal/landfill/incineration cost	• More recovery of product/materials generating less waste which reducing landfill cost	Korchi & Millet, 2011
Compliance cost	• RL practice enable companies to be compliance which minimise noncompliance cost	Somuyiwa & Adebayo, 2014
Environmental		
Waste reduction	• RL process can help to recover more and left Less waste to incinerate/burn and landfill reducing CO2 emissions. (Nikolaou et al, 2013	Nikolaou et al., 2013; Agrawal et al., 2016
Emission impact	• Less waste to incinerate/burn and landfill reducing CO2 emissions • Recovering raw materials and products reducing the use of natural resources	Nikolaou et al., 2013; Agrawal et al., 2016; Korchi & Millet, 2011; Somuyiwa & Adebayo, 2014
Social		
Policy to manage impact on community	• Businesses involved in RL making sure they have the policy to manage impact on community in areas effected by RL activities & preventing customer health and safety and health & safety training, education & policies for human rights for employees as well.	Nikolaou et al., 2013; Agrawal et al., 2016
Local job creation	• RL practice can create local job opportunity to manage return and operate recycling process	Agrawal et al., 2016

Source: Nikolaou et al, 2013; Korchi & Millet, 2011, Somuyiwa & Adebayo, 2014; Agrawal et al., 2016

Though there is growing concern on RL process actual performance, most of the literature focuses on the development of a RL performance index and RL performance improvement and suggests how resources and innovation can help to improve the RL process. Researchers have suggested that resource allocation towards the development of advanced capabilities for the handling of returns can improve RL performance (Richey et al., 2005). Yang and Wang (2007) proposed a framework and the proposed framework identified the use of a sensor agent and a disposal agent as IT system and identified that this can improve reverse logistics performance in terms of repair time and recycling process by increasing information transparency regarding customer feedback, demand, product problems and best possible recovery options. A sensor agent can help to asses customer feedback and product problems, which can control future return and disposal, the agent assessing the product to suggest best possible recovery options. Furthermore, Li and Olorunniwo (2011) also agreed that information technology has a positive impact on speeding up the RL process, decision making, return tracing, flexibility dealing with customer demand, inventory data, warehouse information, and transportation/scheduling data. On the other hand, some researchers also identified that a third-party RL provider can help with successful reverse logistics continuous process by providing flexibility to manage uncertainty (Bai & Sarkis, 2013). Involvement of forward chain players was also identified as playing an important role in reducing the operation cost of the RL network (Korchi & Millet 2011).

Impact on business in terms of economic improvement identified the use of IT on return tracing and managing, allowing more collection with less time, which has a very positive impact on internal business in terms of increasing recovery of products and materials from return products, which also reduces disposal cost for landfill (Nikolaou et al, 2013; Korchi & Millet, 2011, Somuyiwa & Adebayo, 2014). Therefore, a systematic RL practice enables companies to be compliant by reducing waste for landfill, which minimises noncompliance cost (Somuyiwa & Adebayo, 2014). On the other hand, collection of products from customers has a negative impact, as it generates a large part of RL cost for manufacturers (Korchi & Millet, 2011). Further to this, researchers identified the main reason for this cost to be distance between RL activities, which increases transportation cost (Bogataj & Grubbstrom, 2013).

In terms of impact on the environment, this systematic RL process can help to recover more and leave less waste for incineration/burning and landfill, reducing CO_2 emissions (Nikolaou et al, 2013).

Regarding impact on society, businesses involved in RL ensure they have the policies to protect the area and customers (Nikolaou et al, 2013). Also RL practice qualifies companies to develop and implement health and safety and human rights policies (Nikolaou et al, 2013; Korchi & Millet, 2011). On the other hand, available recovered product reduces customer cost (Nikolaou et al, 2013) and increased involvement in the RL process creates jobs for local people (Korchi & Millet, 2011). Therefore, this research intends to use the TBL performance tool to identify the economic, environmental and social performance of the RL process performance and its impact on business, employee, customers and society.

2.4.5 Location related issues in the RL process

The physical network structure is where the players are located and the products are collected and processed. The literature identifies that the locations of players have an impact on the transportation cost and flow of returned products (Korchi & Millet, 2011). RL network designs have been well studied in the quantitative RL literature, with the aim of minimising the total cost (such as investment, processing, transportation, disposal and penalty costs) (Fleischmann et al., 1997; Srivastava, 2008; Yu & Wu, 2010). The location of different RL processes, in terms of where they are located, why they are located in such locations and the impact on RL process and performance across industries is in terms of:

- Location: manufacturers, services, place of purchase/retailers, others (Rogic et al., 2012, Xie & Breen 2014)
- Number: How many collections points/are they sufficient in number (Biehl et al., 2007; Xie & Breen 2014)
- Convenience: how far from consumers, opening hours (Biehl et al., 2007; Xie & Breen 2014)

Biehl et al. (2007) found that the number of collection centres and their locations in terms of convenience to consumers can enhance collection quantity and maximise the return rate (Biehl et al., 2007). Scholars also found that to achieve the target recycling rate, a RL network set up with easily accessible collection points throughout the country can improve the recycling system, as it makes the waste returning system more convenient (Xie & Breen, 2014). To improve convenience and make a positive impact in terms of location, return process exercises can take place in-house, which can make the total cost of managing the RL process relatively low (Salvador, 2017).

Growing attention has been paid to the location of the RL process but there is very limited knowledge and a lack of knowledge of each stage's location, as this is only discussed at the collection stage and the overall RL process (see table 2.8).

Table 2. 8 Location issues in the reverse logistics process at different stages

Location related issues	Detail	RL process stage	Studies
Collection centre number	• increasing the number of collection centres and easily accessible locations providing more convenient opportunities for residents and contractors to turn in their carpet for recycling	Collection stage	Biehl et al., 2007
Collection centre number, distance and operating hours	• Easily accessible to consumers in terms of distance, number and opening ours for battery but not for medicine because pharmacies and GPs are open only weekdays and mostly closed by 5pm.	Collection stage	Xie & Breen 2014
Distance among treatment centres	• Companies dealing with recycling medicine are close to each other and mainly in-housing activities because In-house exercise makes the total cost managing RL operation relatively low.	Recycling stage	Salvador, 2017

Source: Biehl et al., 2007; Xie & Breen 2014; Salvador, 2017

2.4.6 Time related issues in reverse logistics process

This provides insight on when RL key activities such as collection, inspection and sorting and other activities discussed above are begun in the network. Bansia et al. (2014) explain that to recycle battery, the cycle time of a shredding machine is important. The less time it takes, the more battery can be recycled. Also, recent research showed that the duration of time to process returns depends on the product type, expiration date, and date of receipt of the product (medicine). Unusable medicines are stored in quarantined storage for an average of 6 months before demolition commences. Furthermore, the handling process depends on the state and types of drugs in question. Some returned short-dated drugs are usually quality checked and then reduced in price in order to be resold to customers. This is aimed at reducing loss and maximising sales before the drugs completely expire (Salvador, 2017). Though time related issues in the RL process started receiving attention, there still exists very limited knowledge which focuses on time-related issues in the RL process stages. Table 2.9 present the time related issues discussed in the literature in terms of RL process stages.

Table 2. 9 Time related issues in reverse logistics process in different stages

Time related issues	Detail	RL process stage	Studies
Machine cycle time	• Cycle time of each machine, the bottleneck process affects the cycle time of the complete process and reducing the cycle time enhance the productivity	Hazardous product recycling	Bansia et al. 2014
Medicine expiry date	• Unsold medicines are stored for 6 months before disposal. Which get quality checked and resold to customers before it become completely expired.	Hazardous product recycling	Salvador, 2017

Source: Bansia et al. 2014; Salvador, 2017

In summary of the RL process, significant attention has been paid in terms of “how”, but this mainly focuses on the overall process, not any particular stage. However, there is limited attention on particular stages, including the collection stage, which focuses on the collection centre network in terms of location; players; distance; capacity (storage, testing capacity & workforce); cost (worker,transporation,rent); time of collection from transportation to destination; and the separation of collection by sectors. There is still very limited knowledge of this stage despite most research suggesting that collection is one of the important stages of the reverse logistics process and discussing what categories of products are collected (Kumar & Putnam, 2008) and who is collecting them (Bai & Sarkis 2018). In terms of current practice, most of the studies detailing the collection centre networks and their capacity, have focused on developing countries and some of them are generic (Cruz-Rivera & Ertel, 2009; Zarei et al., 2010; Harraz & Galal, 2011; Subramanian et al., 2014; Malik et al., 2015).

In terms of the location of the RL process, there is growing attention on “where” and time of process “when” but very limited knowledge for each stage’s location, as this has only been discussed on the collection stage and the overall RL process, not for other stages separately.

In terms of players, the literature mainly discusses the overall RL process (Srivastava, 2008) and a small group of scholars have also indicated particular stage players, including collection and shredding stage players (Yang & Wang, 2007). Also, the limited discussion of shredders and dismantlers does not adequately answer the questions: who are the shredders? And are they only involved with shredding or other stages as well?

Finally, in terms of RL process performance, most of the literature focuses on the proposed model for the RL process to improve its performance, rather than its actual performance. Also, there is limited knowledge on its actual impact on business, employees, customers, the environment and society. Details of the gap identified for each stage of the RL process is discussed in phase two section 2.6.2.6.

After gathering the knowledge on process, location of process and time related issues in the process, the next question is to know the detail of these players and their relationships to activate the RL process.

2.4.7 Players involved in the different stages of the RL process, their activities and relationship nature

The key players in the RL process include members of the forward supply chain, reverse supply chain companies, such as recycling specialists, third parties and also charitable organizations (Khan & Subzwari, 2009). de Brito and Dekker (2003) identified the group of players involved in RL activities, such as collection, processing and re-distribution to be manufacturers, independent intermediaries, specific recovery companies, RL service providers, municipalities, and public-private foundations. Table 2.10 captures the attention paid by the literature regarding players in the RL process, which presents a number of players in the reverse logistics process from different sectors, and can be grouped into the following five types:

- Forward chain players: Manufacturers, Distributors, Wholesalers, Retailers and third parties
- Reverse chain players: Collectors, Dismantlers, Shredders
- Government/government agencies: organizations responsible for compliance and in some countries for some products also directly involved in disposal process.
- Opportunistic players: charity organizations
- Senders: those who return the products, mainly identified as end users

2.4.7.1 Players responsibilities for RL activities

The different players identified have different roles in the reverse logistics process. Forward chain players are mainly identified as involved in managing and planning return products, as they are not experts in reverse logistics activities where reverse chain actors execute the main activities from collection to disposal (de Brito & Dekker, 2003). Charity organisations also play a role here as opportunistic players, mostly products with no market demand (resell value) are donated to charities (Li & Olorunniwo, 2008). Customers (distributors and consumers) are identified as the main senders of return products (Srivastava, 2008). Engagement of players in the RL chain depends on sectors and countries. In the UK, there are no strong government initiatives for household medicine recycling; on the other hand, in the same country there are successful initiatives identified for household battery recycling, where government agencies also play an important role (Xie & Breen, 2014). In the pharmaceutical sector in Pakistan, manufacturers cannot trust third parties, as medicine is a sensitive product concerning people’s health and safety; therefore, an RL mechanism was set up internally to avoid the risk (Khan & Subzwari, 2009). On the other hand, where products are not as sensitive as medicine and reverse logistics not the core product, third-parties play an important role (Stock, 2001), including retailers hiring third-party providers to implement their reverse logistic process (Meade & Sarkis, 2002). Also in the pharmaceutical industry, distributors are the main senders of return medicine, where manufacturers dispose of medicines in-house together with government agencies and sometimes with distributors (Salvador, 2017).

Table 2. 10 Players and their activities in the RL process

Players	Activities	Studies
Forward chain players		
Manufacturers	• Planning, managing and disposing return products (medicine)	Fuller & Allen, 1997; Fleischmann et al., 1997; de Brito & Dekker, 2004; Yang & Wang, 2007; Li and Olorunniwo, 2008; Morgan et al., 2016; Salvador, 2017
Retailers	• Accepting return products	Fuller & Allen, 1997; Fleischmann et al., 1997; de Brito & Dekker, 2004; Yang & Wang, 2007; Li & Olorunniwo, 2008; Xie & Breen, 2014; Morgan et al., 2016; Salvador, 2017
Reverse chain players		
Recycling companies	• Collecting products, recycling them and redistributing recovered materials	Fuller & Allen, 1997; Fleischmann et al., 1997; de Brito & Dekker, 2004; Yang & Wang, 2007; Li and Olorunniwo, 2008
Others		
Government agencies	• Organisations responsible for compliance	Fuller & Allen, 1997
Charity organisations	• Opportunities players	Fuller & Allen, 1997; de Brito & Dekker, 2003
Senders	• Source of return product	Fuller & Allen, 1997

Source: Fuller & Allen, 1997; Fleischmann et al., 1997; de Brito & Dekker, 2004; Yang & Wang, 2007; Li and Olorunniwo, 2008; Morgan et al., 2016; Salvador, 2017

So, players involved in the RL process and their roles depend on the product type and country policy as well. Therefore, the applicability of this classification for the auto industry will be confirmed during the development of this study.

The next section discusses the relationship nature between players in the RL process to understand their roles in detail.

2.4.7.2 Relationship nature between players in the practice of RL

Surprisingly, there is very limited evidence on current practice on relationships between players in RL. Therefore, for a clear understanding of the relationships between players, this research considered some of the relevant generic supply chain and logistics management literature before discussing the relationships identified between players in RL practice.

In the different literature of supply chain and logistics management, different terms with a variety of levels and strength have been used to describe relationships between players in the chain. Based on Lambert and Stock (2001), relationships between organizations in the supply chain can range from arm's length relationships to partnerships and finally to vertical integration.
A partnership relationship is not the same as vertical integration, where a company owns all the operations in the chain, nor is it the same as arm's length relationships, which involve a limited type of relationship. The term partnership is used when a closer, more integrated relationship is in place. (Harrison et al., 2008).

Figure 2. 4 Relationship between players in SCM perspective

Arm's length	Partnership	Vertical integration
• Price-based negotiations	• Joint planning • Technology sharing	• Company owns all the operation in the chain

Source: Lambert and Stock (2001) – relationships between players from the supply chain management perspective

Based on Lambert and Stock (2001), the majority of relationships between supply chain partners are normally arm's length associations. Arm's length relationships are more transactional in nature. In economics, a transaction cost is a cost incurred in making an economic exchange. Therefore, relationships in this level are like a simple contract. For instance, a seller provides a product (service) for several buyers which it normally provides in a standard format. While this kind of relationship might be proper in many cases, there are situations where parties need to work more closely, especially when they move towards their core competencies. Generally, an organization is involved in several business areas, like manufacturing, marketing and distributing, where some or at least one of them is its core competency. Depending on the company's specific policy, some fields of its job are more important than others and in the case of partnerships, decisions must be considered more carefully. Whereas some insignificant relationships could be achieved through arm's length relations, those relationships closer to the core competency of the company are understood to be achieved with some kind of partnership where a collaborative approach is considered as one of the best practices for this purpose.

According to Levi et al. (2003), as with any business function, there are four basic relationship categories for a firm to ensure that logistics-related business functions are completed. These are:

Internal activities, when a company has resources and expertise available, logistics activity can be performed internally, especially if the logistics are one of the firm's core competencies, as this may be the best way to perform the activity. If not, this may not be a logical option, since logistics activity requires huge amounts of investment including infrastructure, resources and expertise. Most importantly, these assets should be updated periodically, causing more and unnecessary consideration, which will then cause the company to disregard other important and essential activities in its system.

Acquisitions, if a firm does not have resources available internally, another firm could be acquired to perform the task. An example is a joint venture that involves shared ownership between the two parties. Although this method will give full control over the acquired company and might be useful in some circumstances, still it has its drawbacks. Generally, it is very expensive and difficult to obtain a suitable company. Furthermore, normally, acquired companies do not have the same culture and organizational structure. Therefore, adjusting the acquired company's structure to the desired condition may impose additional cost.

Arm's length transactions, most of the relationships between organizations are of this type, where a seller typically offers standard products or services to a variety of customers. Normally this kind of arrangement does not exceed a specific and short period of time. While this method is suitable in many situations, still there are areas in which a company in its logistics activity needs a closer and integrated kind of relationship with either the supplier or customer.

Strategic alliance, this kind of fulfilment is not the same as acquisition, which involves shared ownership between the partners, nor is the same as arm's length transactions which does not entail any kind of responsibility between the two parties. Based on Levi et al. (2003), these are typically multifaceted, goal oriented, long term partnerships between two companies in which both risks and rewards are shared. While parties remain separate from an ownership perspective, a well-managed partnership can provide benefits similar to acquisition or vertical integration. Regardless of the strategy which a company selects in this way, collaboration and cooperation with partner(s) in terms of resources, information, knowledge etc. is essential.

Figure 2. 5 Relationship between players from a logistics management perspective

Internal activities	Acquisitions	strategic alliance	Arm's length
• Logistics is one of the core competencies • Available resources • Performing logistics activities internally	• Unavailable resources • Joint venture with another company • Ownership sharing	• Not sharing ownership • Collaboration and coordination with partner • Long term • Goal oriented • Share risk and	• Buyer and seller relationship • short term

Source : Levi et al., 2003

2.4.7.3 Collaboration type for each relationship nature

Recent attention on the supply chain and logistics management relationship has focussed on collaboration. The objective is to reduce or eliminate inefficiencies in the SCM and logistics process through collaboration, in order to bring benefit to all trading partners. This approach leads to assets such as facilities and capital equipment being used to the fullness of their capacity and economies of scale being maximized. This involves information and process flow whereby suppliers and buyers collaborate jointly with carriers or third party logistics providers (3PLs) to provide effective and efficient shipment delivery.

The fundamental rationale behind collaboration is that a single company cannot successfully compete by itself and to do this it must share information, knowledge, risk and profits with other parties involved. Furthermore, collaboration occurs when companies work together for mutual benefit (Langley, 2000), which otherwise would not be accomplished. That is, every entity must guarantee that this partnership will increase total system effectiveness and its rewards be shared among all parties. Simatupang and Sirdharan (2003) also defined collaboration in a supply chain as occurring when "two or more independent companies work jointly to plan and execute supply chain operations with greater success than when acting in isolation". Collaboration can also be defined as a relationship between independent firms "characterized by openness and trust where risks, rewards, and costs are shared between parties" (Sandberg, 2007). Ganesan (1994) posited that trust alludes to the extent to which supply chain partners perceive each other to be credible (i.e. partners have expertise to perform effectively) and benevolent (i.e. partners have intentions and motives that will benefit the relationship). Information exchange on the other hand is the extent to which data is accessible to partner firms through mutually agreed exchange infrastructure.

Whipple and Russell (2007) presented three types of collaborative relationships in supply chains, namely: Type I, Type II, and Type III. Type I refers to collaborative transaction management characterized by high-volume data exchange (e.g. use of EDI for VMI and scorecard collaborative initiatives) and task alignment centred on operational tasks.

Type I relationships focus on transaction management with emphasis on IT tools, building data integrity, and standardising the information that is exchanged.

Type II refers to collaborative event management characterised by joint planning and decision-making activities, such as in new product introductions/new store openings, new business plans, and sales promotions, where there are more interpersonal interactions across collaborating firms. Type II activities involve both initial collaborative planning, forecasting, and replenishment (CPFR) activities and event collaboration, requiring non transactional data.

Type III, collaborative process management, involves joint problem solving, long-term process planning, and more fully integrated supply chain processes, such as manufacturing scheduling, truckload utilisation, warehouse management and order forecasts/ replenishment. Here, collaborative process management requires building trust, setting joint business goals, and designing inter-enterprise processes to meet those goals (Whipple and Russell, 2007).

Among all the activities in the supply chain, collaboration in the logistics area is seen to be more logical and reasonable. Due to the huge amount of investment and regular reinvestment that this business requires, outsourcing decisions is common for those whom logistics is not their core competencies. Logistics collaboration is a result of logistics outsourcing decisions (Visser, 2007). While a number of outsourcing strategies exist, based on Lynch (2001), collaborative logistics is driven by a changing corporate vision that views competition and suppliers as potential collaborative partners in logistics. According to Czaplewski and Soin (2002), “collaborative logistics is defined as mutually beneficial cooperative problem solving and opportunity exploitation beyond traditional, predefined trading partners, to foster new different and innovative ways to solve business problems and capture new business.”

Basically, companies have a variety of options when they want to join a partnership. Depending on the level to which they want to be involved, they can select the intensity which is more appropriate to their situation. In the above section, three types of collaboration (partnership) in the supply chain were mentioned. The exact classification is recognised from the literature for types of logistics collaboration as well. Based on Visser (2007), the three types of logistics collaboration are:

Type 1, Operational collaboration: deploy activities more efficiently within the existing logistic structure. Partners collaborate at an operational level with a short term horizon.

Type 2, Coordination collaboration: achieve savings by coordination between parties. Partners exchange information and planning together with a midterm horizon.

Type 3, Strategic collaboration: accomplish structural savings as a result of restructuring of the shared logistic structure. Partners investing together and collaboration has a long term horizon.

As mentioned, an effective logistics network requires a cooperative relationship between shippers and carriers. However, the above classification starts with coordination in activities which is the lowest level when two companies would like to run any kind of partnership practice. Coordination means organising or harmonising efforts. Here, organisations recognise each other as the partners coordinating on a limited base that could eliminate any duplication in work, for instance when a shipper and carrier agree on doing an assignment together. Alternatively, the term used to describe types 2 and 3 is “integration”, which is a more powerful expression in defining a relationship. Integration means incorporation and joining together. This is more than just simple supporting and typically many functions within the organisations are involved. Normally, companies create partnership on business rather than on one or several assignments, especially in type 3, where the organisations view each other as an extension of their own firm. The important point in consideration of each type is the period in which the two organisations plan to work with each other. It is recognisable that as the level of integration increases, the time that the relation extends will increases as well. The reason is that developing and maintaining such a relationship, particularly under stress, requires considerable time and effort from the involved parties. Moreover, the responsibilities and expectations vary in the selection of each type.

2.4.7.4 Relationship between players in reverse logistics

Different kinds of relationships between different players are identified in RL practice. Hence, it is imperative to emphasise the roles of different players, such as manufacturers, retailers, senders and regulatory bodies, engaged on the RL system implementation of a firm (Álvarez-Gil et al., 2007). The survival and success of a firm depends on its capability to establish and maintain a relationship with its stakeholders (Post et al., 2002) **to** reduce risk of inappropriate disposal systems, in some industry firms found in literature where manufacturers are involved with RL activities internally and disposing medicines (Salvador, 2017). But this case is rare in literature, as and mostly recycling, and disposal activities were found to be carried out with the help of third party. As reverse logistics concerns itself with how to effectively manage the flow of return products and its associated information flow (Ferguson & Browne, 2001), this requires efficient information and technology systems for facilitating reverse logistics during various product life cycles (Daugherty, Meyers, & Richey, 2002; Ravi & Shanker, 2005). Therefore, reverse logistics service requirements firms require transportation, warehousing management capabilities and advanced IT, where strategic alliance with strategic level collaboration in relationship is needed from all the players in the RL systems, to reduce and recycle waste (Xie & Breen 2014). It is also evident in literature that many manufacturing firms that lack either the resources or capabilities to manage RL activities, effectively outsource all or a portion of their reverse logistics to third party logistics providers (reverse chain players) to ensure an efficient reverse logistics process (Krumwiede & Sheu, 2002). The extant literature reveals that high-tech companies have reduced inventories and increased field engineering productivity by as much as 40% through appropriate handling of reverse logistics (Minahan, 1998). Therefore, strategic alliance relationships between players with close collaboration are identified as appropriate decisions for manufacturing firms to achieve a competitive advantage (Espino- Rodriguez & Padron-Robaina, 2006) in a reverse logistics system.

2.4.7.5 Collaboration level in relationships between players for reverse logistics practice

Considerable attention has been identified in the literature focusing on collaboration between partners to manage RL activities. In terms of types of collaboration, a very limited number of studies were found that categorise collaboration type. Carter and Ellram (1998) identified a need for greater collaboration for logistics managers to work with supply chain members to ensure quality of environmentally friendly input/design to enhance RL activities. The greater the relationship, the higher the level of RL activities in terms of reducing uncertainty between demand and supply. Furthermore, Xie and Breen (2014) identified total involvement and cross section strategic level collaboration needed to fulfil RL duties to comply with the RL system. Morgan et al. (2016) also stated that where firms do not have IT expertise, they need strategic level collaboration relationships with IT expertise to manage returns by increasing information support between partners, which empowers the partners to be more responsive to each other to achieve RL competency. This indicates that close collaboration in relationships between partners is important in the RL process.

2.4.7.6 Relationship Drivers in reverse logistics practice

Referring to table 2.11, a number of studies focused on relationship drivers and suggested that organisations find a third party and partner with them to manage RL uncertainty in return rate to manage uncertain higher returns (Serrato et al., 2007). Most businesses, where RL activities are not their expertise, as they are expert in making and selling products not recycling and managing return, prefer to hire third-party reverse logistics activities expertise and collaborate with them (Ordoobadi, 2009) to manage the RL process. The costs associated with returns are another driver identified here for collaboration. The costs include warehouse, customer service associates, shipping, storage and inventory space, packaging for disposition, disposal fees and other direct costs (Li and Olorunniwo, 2008). Value recovery from returns has been identified as significant as well as including customer satisfaction. Some drivers were identified as interlinked and related to both cost and value including focusing on core.

Table 2. 11 Relationship drivers in RL practice

Drivers	Detail	Studies
Focus on core	• Firms who are making and selling products are do not want to be involved with a new market which is recycling of their return product therefore they look for an expertise in RL to collaborate with so they can focus on making and selling products not recycling them.	Logozar, 2008; Ordoobadi, 2009; Li & Olorunniwo, 2008; Badenhorst, 2015; Tavana et al., 2016
Critical process of RL process	• Uneven, unpredictable and critical nature of RL process drives organisations towards close collaborative relationship, so they can share and plan for higher return rate and other hidden costs	Daugherty et al., 2002; Serrato et al., 2007
Lack of resources	• IT expertise needed for information support to manage returns, as retailers do not have IT expertise. Strategic level collaboration with IT expertise minimise product tracking and return authorisation process time enable to serve customer quicker than before.	Olorunniwo & Li, 2010; Morgan et al., 2016
Saving investment	• Avoiding huge capital expenditures in facilities for transportation and technology and relying on 3PL's expertise, technology, and IS.	Li & Olorunniwo, 2008
Access to new market	• Close collaboration can allow firms to access in each other technology and resources.	Badenhorst, 2015
Reducing operation cost	• Relationship between firms can reduce operation cost by sharing transportation and storage to manage return	Badenhorst, 2015

Source: Logozar, 2008; Ordoobadi, 2009; Li & Olorunniwo, 2008; Badenhorst, 2015; Tavana et al., 2016

The literature cited "Focus on core" as one of the key relationship drivers (Logozar, 2008; Ordoobadi, 2009; Li & Olorunniwo, 2008; Badenhorst, 2015; Tavana et al., 2016). Manufacturers and retailers want to concentrate on product making and selling and look for partnerships with RL process expertise to deal with their returns. Li and Olorunniwo (2008) identified a consumer electronics manufacturer wanting to concentrate on manufacturing only, which drove them to go for a close strategic alliance relationship with close collaboration level (strategic level) to deal with their returns. A recent study also suggested focus on core as a most important criterion in order to take collaboration decisions for RL activities (Tavana et al., 2016). The Critical process of te RL process was also cited by the literature as another important relationship driver (Daugherty et al., 2002; Serrato et al., 2007).

Lower investment and operational cost were found to be relationship drivers where researchers suggest that finding a third-party RL provider and partnering with them brings financial benefits by reducing RL operation cost (Badenhorst, 2015), as the relationship between partners allows organisations to share transportation, warehouse/storage and other operational costs between partners, which helps to lower the overall operation cost. Partnering with an expert third party RL provider (3PRLP) helps firms to reduce the need for initial investments for recycling and remanufacturing facilities (Logozar, 2008). Li and Olorunniwo present more specific information in this regard and identified that partnering enables electronic manufacturers to avoid huge capital expenditure for transportation and technology for information systems to manage returns by relying on their partners' (3PRLP) expertise (Li and Olorunniwo, 2008). Access to new technology/market is another relationship driver which involves close collaboration between product making expertise and product remanufacturing expertise to enable each to access and use the other's technology expertise to improve the whole RL process (Badenhorst, 2015). This benefits the understanding of access to better technology and new markets, driving partners into collaboration relationships.

In addition to drivers, there are some barriers identified to collaboration which hinder the improvement of relationships.

2.4.7.7 Relationships barriers in RL practice

The most common barriers identified in table 2.12 contribute to failed close collaboration relationship are lack of common interest and lack of understanding. Generally, organisations involved in RL practice are from different sectors, for example some of them are from product making and selling sectors and some recycling sectors. Therefore, there is a lack of common interest, where each partners wants to focus on their own expertise, which hinders their interest in close collaboration (strategic level collaboration) to focus on RL activities (Daugherty et al., 2002). However, collaboration starts with contracts. A very clear contract which delivers the same understanding to all involved parties is mandatory. Companies are partnering with each other without understating the job responsibility from each side which is identified in RL collaboration relationship where partners sign contracts without a clear knowledge of their responsibilities (Merkisz-Guranowska, 2014). This allows partner to ignore their main responsibility and create uncertainty dealing with returns.

Table 2. 12 Relationship Barriers in RL practice

Barriers	Detail	Studies
Lack of common interest	• Different sectors partners what to focus on their core which hindering to have a close collaboration relationship to operate RL activities.	Daugherty et al., 2002
Lack of understanding	• Lack of understanding of each other responsibilities creates misunderstanding between partners in terms of operationalising RL activities according to their contract	Merkisz-Guranowska 2014

Source: Daugherty et al., 2002; Merkisz-Guranowska 2014

2.4.7.8 Relationship impact in RL process

The relationships between players identified in literature has a positive impact on speedy processing, decision making, return tracing, flexibility to deal with customer demand, inventory data, warehouse information, and transportation/scheduling data (Li & Olorunniwo 2008). Researchers have also demonstrated that the greater the collaboration relationship, the higher the level of RL activities in terms of reducing uncertainty between demand and supply (Carter & Ellram, 1998). The nature of strategic alliance with close collaboration activities involved, includes joint forecast arrangements, joint planning arrangements, jointly established performance measures, sharing processes and process information (Li and Olorunniwo, 2008). Relationships with IT expertise increase information support between partners, which empowers the partners to be more responsive to each other to achieve greater RL competency (Morgan et al., 2016).

However, there is limited knowledge of the relationship impact and much of the research focuses on the relationship between firms for information technology (IT) activities (Li & Olorunniwo, 2008). There is therefore a need for explanatory research for identifying structural relationships in the RL process with details of levels of collaboration. Moreover, the focal point of most research is the firm itself, overlooking interrelationships with its supply chain partners (e.g. Rogers & Tibben-Lembke, 1999, 2001). How relationships between partners in RL practice impact on RL process/players is still not clear (Li & Olorunniwo, 2010). Therefore, this research aims to investigate relationship details between players in the RL process with collaboration types and their impact on the RL process.

After establishing all the players and their roles, the next question is why these players are involved in the RL process and whether there are any other players who are supposed to be involved with this process but for some reason are not involved or if there are any barriers hindering the improvement of the RL process. So, the next section discusses RL drivers and barriers identified in the existing literature.

2.4.8 Drivers for players involved in accepting and processing returns

The drivers for the players of the product-ins and the initiator of the RL activities. The aspect of “drivers” concerns the driving forces behind companies becoming active in RL. As mentioned above, firms engage in RL because the operation is profitable, because the law requires them to do so, and/or because they “feel” socially motivated to do it. These driving factors have been categorised by de Brito and Dekker (2003) under three main headings: Economics, Legislative, and Corporate Citizenship. They also point out that these factors are not mutually exclusive drivers, and it is sometimes difficult in practice to set boundaries between them. Also, Sarkis et al. (2010) suggest that cultural, legal, social, political and a host of other macro-environmental variables differ by location. Therefore, drivers influencing a certain region may not influence in other regions (Sarkis et al., 2010). This therefore suggests that RL drivers for different sectors and countries might differ from those suggested by de Brito and Dekker (2003).

All the reasons identified in the literature are organised into six categories: legislation pressure, economic gain (direct and indirect), stakeholder pressure, competitive pressure, corporate social responsibility and asset protection are captured in table 2.13.

Table 2. 12 Drivers influencing players to become involved with RL practice

Drivers	Detail	Motivated players	Action taken	Impact of the action	Studies
Legislative pressure	Environmental laws are increasingly forcing players return product proper disposal to protect environment from waste as failure to do so will have strict noncompliance penalties.	Manufacturers	Battery Manufacturers working together with battery recycler and local authority together to educate public to recycle household batteries	Increased the awareness where 42 percent having recycled a battery	Fleischmann et al., 1997; Carter & Ellram, 1998; Rogers & Tibben-Lembke, 1998; Gungor & Gupta, 1999; de Brito & Dekker, 2003; Yang & Wang (2007); Kumar & Putnam, 2008; Xie & Breen, 2014
Direct Economic gain	Use of recovered raw materials, less waste generation also reducing disposal cost.	Recycler			Fleischmann et al., 1997; de Brito & Dekker, 2003
Indirect economic gain	Value by managing/taking back returns working as marketing trigger for green profile	Manufacturers			Fleischmann et al., 1997; de Brito & Dekker, 2003
Stakeholder pressure	Suppliers and buyers are demanding take back policies from manufacturers	Manufacturers	Implementing take back policies and getting more involved with returns.	Increasing collection of return products for proper management which saving disposal cost.	Carter & Ellram, 1998; Gungor & Gupta, 1999
Competitive pressure	Market competition desire green practice (RL practice to reduce waste) and globalising growth for recycled and remanufacturing product	Manufacturers and retailers	Looking for close collaboration relation with recycling expertise to deal with return		Carter & Ellram, 1998; Rogers & Tibben-Lembke, 1998; Kumar & Putnam, 2008
Corporate Social Responsibility	Corporate citizenship concern to save environment and society	Manufacturers and recyclers			Fleischmann et al., 1997; de Brito & Dekker, 2003
Assets protection	Assets protection of unique components and materials	Manufacturers	Manging own products return internally		Fleischmann et al., 1997; de Brito & Dekker, 2003

Source: Fleischmann et al., 1997; Carter & Ellram, 1998; Rogers & Tibben-Lembke, 1998; Gungor & Gupta, 1999; de Brito & Dekker, 2003; Yang & Wang (2007); Kumar & Putnam, 2008; Xie & Breen, 2014

The section below discusses in detail all these drivers in terms of the driver, players affected by that driver, actions taken and their impact.

1. Legislative pressure

Legislative pressure is government regulations for return products. These indicate that a company should recover their products or accept them back. Organisations face direct government regulation pressure, such as in many countries organisations are strictly regulated for recycling products and packaging. In Europe especially, there has been an increase in environmental legislation where government regulation requires manufacturers to take back their products for recycling and recovery (Nunes & Bennett, 2010). The literature emphasises direct government regulation pressure, such as in Fleischmann et al. (1997), who argue that environmental regulation is a reason for RL that is of growing importance where extended producer responsibility has become a key element of public environmental policy in several countries. In this approach, manufacturers are obliged to take back and recover their products after use in order to reduce waste disposal volumes. Further, Carter and Ellram (1998) developed a framework of motivating forces for RL and identified government regulations as the main force pressurising organisations to implement return policy and recycle return products. On the other hand, Gungor and Gupta (1999) explored an environmental design where they mentioned governmental regulations on environmental issues driving organisations for environmentally conscious manufacturing, which is concerned with developing methods for manufacturing new products from conceptual design to delivery and ultimately to end-of-life (EoL) disposal, such that the environmental standards and requirements are satisfied; and product recovery, which aims to minimise the amount of waste sent to landfills by recovering materials and parts from old or outdated products by means of recycling and remanufacturing (including reuse of parts and products). This is mainly driven by the ever-increasing deterioration of the environment, e.g. diminishing raw material resources, overflowing waste sites and increasing levels of pollution. So, environmental laws are increasingly being enforced and recycling activities are becoming additional burdens for manufacturers (Yang & Wang, 2007). A recent study also identified that the UK Government could face fines of millions of pounds if the target recycling rate (more than 45 per cent) is not met; these fines will be passed to battery manufacturers which, in time, will raise the price of batteries to customers. Therefore, the directive and regulations enforce certain responsibilities on all the actors in the household battery RL system except individual customers, requiring producers to incorporate waste management practice at three levels: reduce, reuse and recycle (Xie Breen 2014).

Legislation is identified as mainly driving manufacturers (Yang & Wang, 2007) and other supply chain players (Xie & Breen 2014), such as retailer and recycling companies.
It is understandable that organisations get involved with RL practice due to legislative pressure but knowledge of what exactly they are doing to meet regulations is very limited. Carter and Ellram (1998) found that players are seeking close collaboration in relation to facing these regulatory pressures and further Xie and Breen (2014) suggest that firms require strategic level collaboration to manage RL activities to meet legislation.

In term of the result of actions taken by players due to legislative pressure, knowledge is also very limited. Only Xie and Breen (2014) have considered the impact of the above actions and identified that the success of the publicity campaigns has proved significant in changing behaviour in the recycling of household batteries, with two in five people (42 per cent) having recycled a battery and this green practice also enhances the corporate green image of firms.

2. Economic gain:

Economic gains are divided into two categories:

Direct economic value: Direct economic gain can be earned by reusing return product, parts and materials recovered. Researchers explain that recovery is often cheaper than building or buying new products or `virgin' materials (Fleischmann et al., 1997). Goggin and Browen (2000) state that in the electronic industry many products return at the end of their useful life in a short period but with their components still having economic value. Other studies also agreed with the above statement and suggested that used parts and recycling materials, especially metals, could bring direct economic value in the electronic industry (Kumar & Putnam, 2008). Thus, direct economic value could be gained by selling recovered products, materials, parts etc., depending on the type of product. Also, direct economic gain could be achieved by reducing disposal waste, which reduces the cost of disposal.

Indirect economic value: on the other hand, with no direct profit, organisations can also be involved with RL as a strategic step to comply with legislation and promote their green image, as RL practice reduces disposal, which in turn protects the environment. Considerable attention in the previous literature explores the indirect economic value of RL, such as a group of researchers who suggest that used product take back and recovery is an important element for building up a `green' profile, which companies are increasingly paying attention to (Fleischmann et al., 199). Customer satisfaction is another indirect economic value identified, where researchers mention satisfying customers by providing after sale services (Nunes & Bennett, 2010) and taking back used products. This may be seen as a service element by taking care of the customer's waste disposal needs (Fleischmann et al., 199). Direct economic gain was found to mainly influence recyclers but discussions are mostly general and do not indicate details of actions taken and their impact.

3. Stakeholder pressures

Manufacturers identified face pressures from their suppliers and buyers to have take back policies in place (Carter & Ellram, 1998). Also increasing awareness of environmental issues make customers more sensitive to act to save the environment, which indirectly forces manufacturers to have reverse logistics practice in place to deal with returns (Gungor & Gupta, 1999). These force manufacturers to implement take back policies and get more involved with returns which was also found to increase collection of return products for proper management, which saves on disposal cost.

4. Competitive pressure

Due to global warming, every organisation is trying to show best environmental performance. In addition, dealing with return helps firms to increase their environmental performance (Carter & Ellram, 1998). On the other hand, customer satisfaction is also identified as becoming a competitive performance indicator and dealing with customer returns and product quality conformity can create more satisfied customers (Rogers & Tibben-Lembke, 1998; Chan et al., 2011). Literature cited manufacturers and retailers as mainly facing this pressure to get involved with RL activities to deal with their return product. This leads manufacturers and retailers to look for close collaboration relation with recycling companies to deal with returns (Carter & Ellram, 1998).

5. Corporate social responsibility (CSR)

CSR basically comes down to how a company can make a positive impact on society. This concerns some morals that in this case drive organisations to become responsibly engaged with RL. CSR covers a very broad area that affects the following: Society (public accountability, health and safety, human rights and community), Environment (pollution, reduction of resources, impact of output and optimisation of waste/reuse) and Economy (fiduciary duty and contribution to economic prosperity). Researchers state that organisations are getting involved with RL in association with the concept of environmental management in CSR practices. They also suggest that many firms have extensive programmes for their own product return and recycling where both social and environmental issues become priorities (de Brito & Dekker, 2003).

6. Asset protection concern

Asset protection is another motive for companies to take back their products after use. In this competitive age, organisations are afraid of leakage of technology; therefore they are becoming involved in RL to recover their own product to avoid the leakage of technology or entering the market (de Britto & Dekker, 2003). For example, one of the reasons for IBM's involvement with parts recovery is not to allow brokers to do it to avoid the leakage of technology or entering the market (Dijkhuizen, 1997). So, in this way, companies seek to prevent sensitive components from leaking to secondary markets or competitors. Moreover, potential competition between original `virgin' products and recovered products is avoided in this way (Fleischmann et al., 1997 and de Brito & Dekker, 2003). Manufacturers were found to be mainly motivated by this driver (de Brito & Dekker, 2003). This influeces manufacturers to implement in-house RL activities to protect their sensitive assets.

2.4.9 Barriers in the RL process

The barriers for those who do not partake in RL activities and also for those who are facing challenges during RL practice/barriers for better practice.

Barriers influencing players to ignore RL

Lack of government initiatives: no strict regulation for RL process; as a result, organisations also not focusing on return activities (Xie & Breen 2014).

No economic value: some products do not have recovery value, such as medicine (Xie & Breen 2014), which discourages players from involving themselves with RL activities, as they believe they are only an extra cost (Rogers & Tibben-Lembke, 1998)

Barriers hindering better RL performance

Slow return process: RL process to recycle products was identified as slower compared to return flow, which created a jam for storage, and pressure for processing (Rogers & Tibben-Lembke, 1998).

Negative perception of recycled product: Customer perception of poor-quality of recycled product hindering recovered product sale (Rogers & Tibben-Lembke, 1998).

Lack of management attention: Top management not focusing on return activities, as they do not see the advantage of focusing on return (Rogers & Tibben-Lembke, 1998).

Table 2. 13 Barriers in reverse logistics

Barriers	Detail	Affected players	Action taken	Impact of the action	Studies
Barriers influencing to ignore RL activities					
Lack of government initiatives	No Government initiatives for medicine recycling in the UK allowing organisations to ignore to deal with return medicine.	-	-	-	Xie & Breen, 2014
No economic value	No economic value initiatives for medicine recycling	-	-	-	Xie & Breen 2014
Barriers hindering better RL performance					
Slow return process	Return arriving faster than processing/Lengthy processing cycle time	-	-	-	Rogers & Tibben-Lembke, 1998
Negative perception on recycling product	Customer perception of poor-quality on recycled product	-	-	-	Rogers & Tibben-Lembke, 1998
Lack of management attention	Top management not focusing on return activities	-	-	-	Rogers & Tibben-Lembke, 1998

Source: Rogers & Tibben-Lembke, 1998; Xie & Breen 2014

2.5 Summary of phase one

This phase has discussed the themes that underpin this study, to establish a background understanding of logistics, supply chain, and fundamentals of RL. This phase then discussed the key aspects conducted for this study to understand and characterise existing research that addresses RL practices conceptualized using four key themes, namely 1) return reasons and nature of return product; 2) RL process for return product in terms of how, where and when 3) Players involved in RL and their relationships; and 4) Drivers and barriers in the RL process. As a result, this phase has established a background understanding of the themes that underpin this study's research area, identified the contribution and the shortcomings of the extant empirical studies. Now the applicability of these key aspects is investigated in the automotive industry perspective in phase two to identify the gap in the literature and shape the research context.

Phase two

2.6 Reverse Logistics in the automotive industry

This section focusses on automotive industry reverse logistics, starting with a brief discussion of the automotive industry in general with i) different constituents of the automotive industry, including different stakeholders and products of the automotive industry; ii) the automotive industry supply chain with all the players involved with material flows between them, including changing circumstance and the life cycle assessment of vehicles; iii) the automotive industry and sustainability; iv) the automotive industry and the circular economy; and v) the automotive industry and corporate social sustainability. Furthermore, this section discusses details of RL key aspects in the auto industry and systematically identifies the gap which generates the research questions in this study.

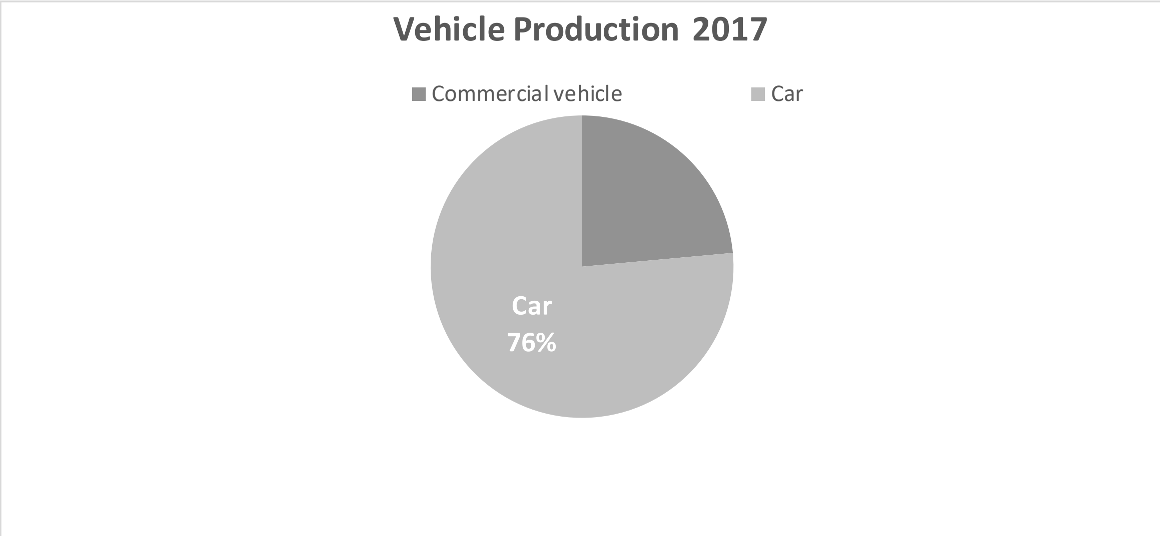
2.6.1 Automotive industry in general and its fundamentals related to reverse logistics

The automotive industry is a wide range of companies involved in the design, development, manufacturing, marketing, and selling of motor vehicles. It is one of the world's largest economic sectors by revenue. It contributes significantly to the gross world product, as it is the sixth largest economy in the world. It produces millions of cars across the world annually, providing employment, directly or indirectly, to over 100 million people in approximately 100 countries and exports cars and automotive components, while also investing over US$100bn per year in R&D (Kierzkowski, 2011).

The industry's products are passenger cars and light trucks, including pickups, vans, and sport utility vehicles, commercial vehicles (i.e., delivery trucks and large transport trucks, often called semis) and a number of components/parts. The automobile industry is a pillar of the global economy, a main driver of macroeconomic growth and stability, and technological advancement in both developed and developing countries, across many adjacent industries (Klink et al., 2014).

The car is identified as the primary product in the automotive industry, as the car is a primary mode of transport for many developed countries. By "car" this research refers to passenger cars, which are defined as motor vehicles with at least four wheels, used for the transport of passengers, and comprising no more than eight seats in addition to the driver's seat. Cars (or automobiles) make up approximately 76% of the total motor vehicle annual production in the world. It is estimated that over 1 billion passenger cars travel the streets and roads of the world today (The International Organization of Motor Vehicle Manufacturers, 2018).

Figure 2. 6 Automotive production in terms of cars and commercial vehicles



Source: The International Organization of Motor Vehicle Manufacturers, 2018

With the increasing global demand for cars, it is estimated that there will be 2 billion of them by 2020. In fact, with 10 billion people living on Planet Earth by 2050, there could be around 6 billion cars registered if developing countries follow the same patterns of mobility and car ownership as the USA and Europe (Nunes et al., 2013).

Nowadays cars are a reason for poor urban air quality, fatal accidents and increasing concerns about end-of-life waste and landfill availability. Therefore, the automotive industry has a twofold scope of influence on the emission balance: reducing emissions when making vehicles, including production, transportation and reverse supply chain activities, and reducing emissions when using vehicles with cleaner powertrains.

Recently, enforced by governmental regulations, the European automotive industry is making a fresh attempt towards zero emission mobility. The main attempt to reach this goal in the next decades is setting reduced CO2 emission limits and supporting the introduction of electrified vehicles, such as pure electric vehicles or plug-in hybrids powered by energy generated from renewable resources.

Various governments have introduced incentive programs for the purchase and use of electric cars (no taxes, free lanes and parking in cities, etc.). Moreover, countries like Germany and China have released plans to establish local electric vehicle prime markets. The German chancellor announced plans to reach one million electrified cars on the road by 2020 (Federal Ministry of Economics and Technology of Germany, 2010), while China intended to obtain this amount by 2015 (KPMG, 2011) and to reach 5 million electrified cars in the fleet and 1 million annual production by 2020 (Reuters, 2010). Today, due to considerable production and specifically high battery costs and minor driving ranges, the electric vehicle is still a niche product. However, further technological progress, more advanced batteries, related battery control and switching systems will enhance the range of these vehicles and bring down the costs in the future.

2.6.1.1 Automotive supply chain

Automotive supply chains are among the most complex in the world, with each vehicle containing more than 20,000 parts originating from thousands of different suppliers. Furthermore, with production of electric vehicles increasing, all parts of the supply chain must evolve — suppliers are making new parts, automakers are working closely with those suppliers, and carriers are figuring out the best ways to transport electric car parts.

The auto industry is undergoing an unprecedented period of enormous disruption. Influenced by new computer systems, new manufacturing processes and innovative designs, neither vehicles nor auto manufacturing facilities look like they did a decade ago.

The change is putting tremendous pressure on original equipment manufacturers (OEMs) and auto suppliers to evolve and innovate. Many are changing their business strategies to focus on innovation, rather than production, while refining their product offerings to the best that they do. Others are also working more closely with their buyers to be a part of the design-to-market cycle and to make themselves an invaluable supplier.

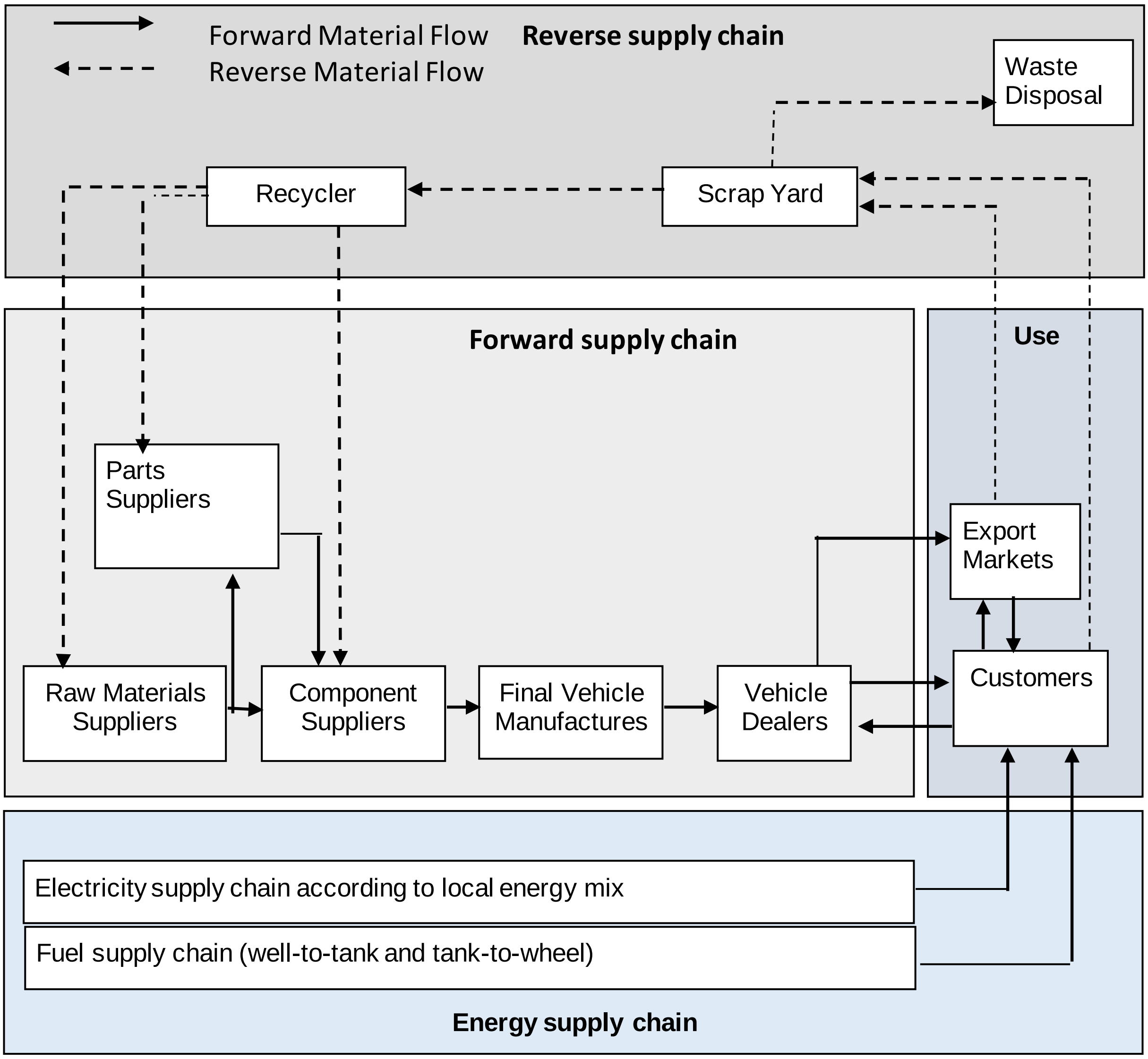
With new technologies transforming the automotive industry, auto manufacturers and OEMs need to adapt to the logistical changes they are facing. Globally, the electric car is emerging as the dominant alternative powertrain, regardless of current problems with mass production of batteries. Traditional powertrains have 1,500-2,000 components versus 50-60 for electric, and they use different suppliers. Transporting the dense, heavy batteries with hazmat issues will also change logistics. It is difficult to ship lithium ion batteries. Concerns over battery fires and weight will increase as batteries increase in density to hold more charge.

2.6.1.2 Players in the automotive supply chain and their role

Primarily, automotive industry players can be separated into four categories (Günther et al 2015);

- Forward supply chain players: Raw materials, parts, components and final vehicle manufacturers, dealers/distributors of vehicles
- Reverse supply chain players: Scrap yards, recyclers, waste disposal companies.
- Energy supply chain players: Electricity suppliers, fuel suppliers
- Players who are using: Customers, export market
- Others: Transportation companies, insurance companies, government agencies

Figure 2. 7 Automotive industry supply chain



Source: Gunther et al., 2015

The actual vehicle manufacturing steps are performed within the forward supply chain using either raw materials from different suppliers or secondary raw materials, which are produced in the recycling facilities of the reverse channel. It is expected that both the primary and recycled raw materials meet quality standards and therefore are considered equivalent. The final vehicle assembling job is done by the vehicle manufacturers and distributed by the dealers in the primary market to customers and to export markets, respectively.

Electricity for making and using electrified vehicles is supplied according to the local energy mix. The fuel supply chain consists of the well-to-tank stage, which covers the supply from crude oil exploration to the distribution of fuel, and the tank-to-wheel stage, which refers to the internal use of fuel by the powertrain.

The fleet of vehicles consists of new as well as used vehicles. During their lifetime used vehicles can be sold back to distributors and retailed on the secondary market. Finally, vehicles that have reached their "end-of-life" are delivered to the scrap yards where they are dismantled. Lastly, the dismantled parts are either recycled or wasted. The "end of life" vehicles are defined here as cars that are seriously damaged due to age and/or accident (Schultmann et al., 2006).

2.6.1.3 The changing situation in the automotive industry

Looking at history, the automobile industry has had a few radical changes over the last 30 years. The changes there have been were often remarkable and had a significant impact on practice and academia. Mass production and the modular consortium are important innovations from the production system perspective. Also, the transfer of assembly plants to globally are obvious changes to the industry's business and operations strategy. In addition, the automobile industry was the pioneer in using robots and it is still the main user of robotic devices, still being responsible for 60% of their applications across the world (The Economist, 2008).

On the other hand, product innovation changes have been less prominent and people continue to drive four-wheeled vehicles with an internal combustion engine running on fossil fuels similar to the early days. In fact, car manufacturers are now locked to three technological paradigms (all-steel body, internal combustion engine, and multi-purpose design), which make radical innovations difficult due to the industry's complexity and extension (Orsato and Wells, 2007).

The innovation strategy adopted by car manufacturers has not been sufficient to make the sector more environmentally sustainable. After two consecutive years of contraction (due to the recession), global production grew around 25.9% in 2010, 3.1% in 2011 and 5.2% in 2012 (TFL, 2013). This unquenchable global demand is creating a radical change in paradigm of green innovation. Automakers need to evaluate green ideas and select more environmentally friendly ways to produce, sell, use and dispose of vehicles globally. This will need to be done in a cost-effective and strategic manner.

In the past, innovation was predominantly driven by the intention of exceeding customers' expectations or to create simpler and less costly processes, but now organisations are responding to environmental and social demands (Nunes et al., 2013). With regard to the environment, the major concerns this century are: atmospheric pollution (and its consequences for human health, global warming and ozone layer depletion), energy and food security, scarcity of freshwater and raw materials, and land availability. These environmental concerns have a profound impact on how companies manage their business, and so drive innovation. For instance, in Europe alone, between 8 and 9 million tonnes is generated each year from end-of-life automotive waste (RC, European Community, 2013). As a consequence, the availability of land puts pressure on the prices for landfill disposal, which forces car manufacturers to innovate in order to reduce waste from their production sites and end-of-life products (Nunes et al., 2013).

To deal with the relationship between the automotive industry and environmental protection, and to reduce the impact of automotive manufacturing and consumption on the environment, sustainable development in the automotive industry is a central issue that cannot be ignored (Hilton & Levinson, 1998). Sustainability is presented as the intersection among the environment, society and the economy (Giddings et al., 2002). In order to create sustainable development in the automotive industry, manufacturers facing challenges to ensure the scale and benefits of the whole industry (Bellmann & Khare, 2000).

Therefore, the automotive industry manufacturing more hybrid-vehicles and electric vehicles which capable of using alternative fuels, and the main global automotive manufacturers have focused on sourcing renewable and recyclable materials on the processes of manufacturing, using alternative and less toxic materials to improve recyclability (Williams, 2006).

Also, the European Parliament and the European Council passed the End-of-Life Vehicle (ELV) Directive in 2000. The goal was to reduce waste and improve environmental performance by enhancing end-of-life vehicle recovery. This forced automotive industry to focus on RL practice for their EoL product. In the automotive industry, reused components, repaired parts, recycled materials and chemical recycling are considered particularly environmental and make use of economic resources (Bellmann & Khare, 1999).With the rapid development of economies, overdrawn resources and environmental destruction, various countries have realised the necessity of EoL RL practice as an inevitable strategy of sustainable development (Lou & Zeng, 2007).

The open-air discarding of waste automotives not only produces waste materials and pollutes the environment, but also causes land to be occupied. Therefore, scrapped automotive recycling, utilisation and disposal has attracted special attention in various countries (Cui & Roven, 2010). From an environmental protection perspective, recycled plastics can be manufactured into plastic products.

Therefore, the automotive industry appreciates the implementation of RL for automotive EoL products is a way to solve the economic, environmental and social problems caused by automotive. The next section, therefore, discusses the RL practice in the automotive industry.

2.6.2 Reverse logistics practice in automotive industry

The management practices, organisational forms, and particularly the response to environmental pressures adopted by the automotive industry are important and the products of this industry are a part of people’s daily lives - not only by providing personal mobility for millions, but also by presenting a wide range of challenges. The deterioration of local air quality in urban areas, along with global issues such as global warming, and the treatment of scrapped vehicles are just a few examples of such challenges (Frigant, 2011). The automotive industry in particular has, over the years, proven to be beneficial to the environment and economically profitable for the companies involved as well as to their customers (Sundin et al., 2013). The benefits of the automotive industry are globally accepted, but the traits possessed by this industry are serious. Strict measures and cooperative practices, which are already set in some countries, can change the climate and broad support from all around the world is inevitable to make the automotive supply chain greener (Shaan & Subramaniam, 2012). On the other hand, the innovative global automotive consumer market is becoming more and more mature, with intense market competition, rising consumer status, sound environmental regulations and resource utilisation (Vaz et al., 2017). For instance, recalling defective automotives could improve customer satisfaction, thereby enhancing the recyclability of products and the product throughout its life cycle, reducing the pollution of the environment. Thus, the application of RL in the automotive industry has become increasingly important (Reynaldo & Erterl, 2009).

So, this section considers detailing the RL practice in the automotive industry and its importance. This section also details the key aspects of RL (discussed in phase one) in the automotive industry and their interconnection.

As mentioned before, the automobile industry is one of the largest and most important industries in the world. The automotive industry involves a series of supply chain activities in order to produce and deliver a vehicle, including sourcing and procurement, production and all logistics management activities. As its supply chains involve a large number of parties due to globalisation, the supply chain structure is found to be relatively complex (Chan et al., 2011). This is because:

- The involvement of such a high number of players in this industry makes the control of RL activities challenging, as the complexity of the supply chains makes coordination and integration between players difficult (Chan et al., 2011) .
- In addition, many owners may take their vehicles to garages outside the manufacturers' supply chain system for service or maintenance. Therefore, valuable, though used, parts or components may 'leak' from the system. Thus, these items cannot be transported back to the manufacturers' sites (Chan et al., 2011).
- On the other hand, vehicles are normally highly customised, which means that even if different vehicles of the same model are disassembled at the same time, the parts or components may not be as homogeneous as the other products. This introduces difficulties in forecasting the recovery of parts and components in the automotive RL system.
- Also the increasing number of automobiles raises significant concerns about environmental issues due to increasing awareness of environmental impacts and the legal requirements of disposing of vehicles (Chan et al., 2012).

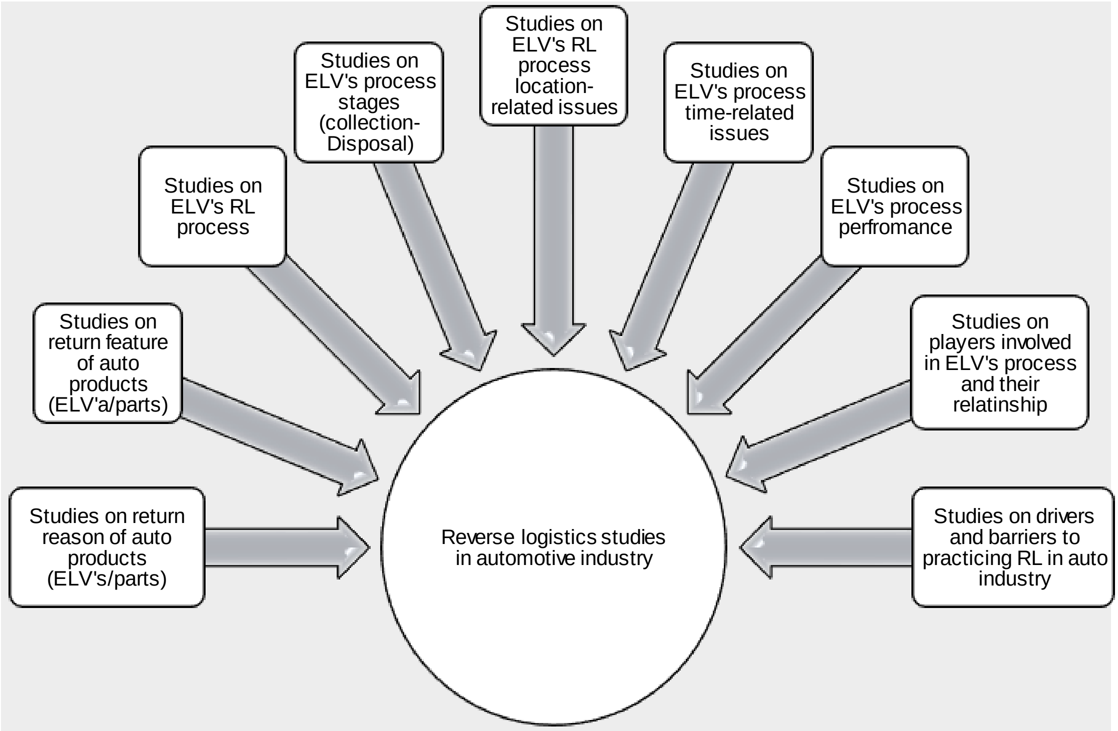
All the above matters, where on one side RL of the automotive industry needs to save resources and gain value from return vehicles and on other side, the complexity and uncertainty of dealing with return vehicles, make RL very challenging in automotive industry. However, the automotive industry was one of the earliest adapters of RL (Shaan et al. 2012).

2.6.3 Reverse logistics key aspects in auto industry

All the key aspects discussed from the generic RL perspective in phase one, including product returns reasons, nature of return products, the RL process, location for processing, time related issues in the process, performance of the RL process, players, relationship between players, drivers and barriers in RL practice are now considered from an automotive industry perspective.

This research attempts to accumulate knowledge from the literature and by assembling studies from across the auto industry. Studies were considered based on the above key aspects where, for each study, at least one key aspect was considered. Figure 2.9 presents a clear picture of the studies collected to investigate RL key aspects in the automotive industry (all key aspects are presented in one table in the appendix 2). Furthermore, for a richer assessment, each aspect has been presented in separate tables in this chapter, where table 2.15 presents automotive products return reasons, 2.16 return nature of automotive products, 2.17 RL process of automotive product, 2.18 Players involved in automotive product RL process, 2.19 RL drivers in automotive industry and 2.20 RL barriers in automotive industry.

Figure 2. 8 Automotive Reverse Logistics studies in automotive industry considered for this study



2.6.3.1 Return reasons of auto products

Consumers are identified as the main source of automotive returns (Chan et al., 2011). Other return reasons discussed in phase 1 of this chapter, including service/repair returns and end of use returns from customers, are not discussed in the auto products literature. Furthermore, returns from distributors and manufacturers are not discussed either. Return reasons identified for automotive products are captured in the table 2.15.

However, for automotive products, “cars” are found to be the main attention of scholars and the return reason of cars discussed in the literature is end of life (EoL) and the main reason specified for cars becoming EoL is accident and age (Schultmann et al., 2006). An “EoL car” is defined as a car that has reached the end of its useful life, owing to ending its determined lifecycle or being damaged in accidents (Mansour & Zarei, 2008).

Table 2. 14 Automotive products return reason

Source of return	Condition of products	Reason of return	Studies
Consumers	• Defective parts (production defect, shipping damaged and quality complaints)	Refund/exchange	Rogers & Tibben-Lembke, 1998; Olorunniwo & Li, 2011
	• Unwanted /wrong parts being ordered	Refund/to obtain the right parts	Rogers & Tibben-Lembke, 1998; Olorunniwo & Li, 2011
	• Warranty return (customers change their minds)	Refund	Rogers & Tibben-Lembke, 1998; Olorunniwo & Li, 2011
	• Shipping to wrong destination	-	Olorunniwo & Li, 2011
	• End of Use	-	
	• **End of Life cars**	-	Schultmann et al., 2006; Cruz-Rivera & Ertel, 2009; Zhang et al, 2010; Zarei, et al. 2010; Merkisz-Guranowska, Chan et al., 2011; Harraz & Galal, 2011, Olorunniwo & Li, 2011

Source: Rogers & Tibben-Lembke, 1998; Schultmann et al., 2006; Cruz-Rivera & Ertel, 2009; Zhang et al, 2010; Zarei, et al. 2010; Merkisz-Guranowska, Chan et al., 2011; Harraz & Galal, 2011, Olorunniwo & Li, 2011

Though in the generic automotive industry discussion in this chapter, it has been noticed that vehicles can be cars, vans, motor cycles, HGVs and busses, most ELV studies in the literature focus on cars only. The reason can be legislation which have been developed in the European Union on waste minimisation and ELVs, namely: Directive 2000/53/EC on ELVs (European Council 2000). This regulation only applies to vehicles up to a maximum unladen weight of 3.75 tonnes, which are mainly cars and not applied to motorbikes, lorries and buses. This is one of the reasons RL for cars has received more attention than other vehicles. Also, a car is a complex product and so its EoL management is a complicated task. One of the main problems associated with car recycling is separating the different material streams in order to recover pure and non-contaminated materials. It is estimated that 8–9 million EoL cars are discarded annually, of which approximately 75% of the weight of the car was recycled and 9 million tonnes of waste is generated per annum. Hence, The ELV directive is aimed at preventing and managing this waste (Soo et al., 2017).

Therefore, consumers are identified as the main source of returns in the auto industry and EoL cars are the main return product. Though scholars have stated that the main EoL cars return reason is age and accidents (Schultmann et al., 2006), there is a lack of detailed knowledge of accident damaged conditions and age and how cars become EoL. In addition, what influences consumers (senders) to return EoL cars is not discussed, such as if there is any economic or other reason driving them to bring the car back or dispose the car as EoL.

2.6.3.2 Nature of return auto products

For composition of cars, only one "nature of return cars" is cited in the in the auto industry. There has been significant discussion on hazardous components of EoL cars which require special treatment (Schultmann et al., 2006; Mansour & Zarei 2008; Soo et al., 2017; Xiao et al., 2019). Also Chan et al. (2012) state that cars are normally highly customised and the parts or components are mostly heterogenous, which can create difficulties in the RL process.

Table 2. 15 Return natures of automotive products

Return features	Details	Impact on the RL process	Studies
Compositions / configuration of products	• Numbers of components and materials used in car	• Difficult recovery process	Chan et al., 2012
	• Some of car components contains hazardous materials	• Impact on recovery process as special treatment required	Schultmann et al., 2006; Mansour & Zarei 2008; Soo et al., 2017; Xiao et al., 2019
	• Material heterogeneity	• Difficult recovery process	Chan et al., 2012

Source: Schultmann et al., 2006; Mansour & Zarei 2008; Chan et al., 2012; Soo et al., 2017; Xiao et al., 2019

On the other hand, as discussed in phase 1, deteriorations, usage patterns and packaging of products are important features which have significant impact on RL process in terms of value recovery are not found in the auto industry literature. Therefore, linking with other products and in general return reasons and return features discussed in phase 1 of this chapter, there is a rich knowledge gap identified which is presented in the next section 2.6.3.3.

2.6.3.3 Gaps affecting facilitation of return reasons and return nature

As seen in the phase 1, many researchers have focussed on identifying return reasons in the reverse chain (Fleischmann et al., 1997; Rogers & Tibben-Lembke, 1998; de Brito & Dekker, 2003, Khan & Subzwari, 2009; Olorunniwo & Li, 2011; Xie & Breen, 2014). Here, consumers are found to be the main reason for return and especially for End of Use (EoU) and End of Life (EoL) return. Similarly, EoL return was found to be the key return reason in the automotive industry ((Cruz-Rivera & Ertel, 2009; Zhang et al, 2010; Zarei, et al. 2010; Merkisz-Guranowska, Chan et al., 2011; Harraz & Galal, 2011, Schultmann et al., 2006).

However, there is very limited knowledge on return reasons for end of life products and how they become end of life both from a generic perspective and from the automotive industry perspective. However, some researchers cited age (Schultmann et al., 2006) and accident (Mansour & Zarei, 2008) as the reasons for EoL cars, but details of age and how age makes a car EoL have not been discussed.

Also, the reasons for other products being returns are cited by the literature in both generic and automotive contexts, for example, customers bringing warranty return products back to get a refund or to exchange the product. However, end of life products being returned is not discussed in detail in terms of why senders decide to return the product/ what the individual facts are that influence them to return EoL products in general and in the automotive industry.

In terms of identifying the nature of return products and its significant impact on RL process to recover value also captured in the literature in both general and in the automotive industry, it is apparent in table 2.16 that only a few studies (Chan et al., 2012; Schultmann et al., 2006; Mansour & Zarei 2008; Soo et al., 2017; Xiao et al., 2019) have looked at return product nature in the automotive industry which involved only EoL car composition nature in terms of use of materials and hazardous materials presence. Moreover, these few studies did not consider the way the components were put together, components category for different cars, size/weight of the components and how all this composition nature of EoL cars impacts on the recycling process to recover value. As a result, the detail of composition nature is unclear. There is limited understanding of other return natures in the generic literature (see table 2.4 in phase 1 of this chapter) including deterioration, use pattern and packaging of product and their impact on RL process, but none of the studies in the automotive industry consider these natures (deterioration, use pattern and packaging of product). Therefore, a clear understanding of return nature, and its impact in the RL process to recover value, is important for practitioners and policymakers involved in RL practice in general and in the automotive industry .

To summarise, a comprehensive understanding of both return reason and return natures, and their impact on managing return and reprocess, can guide practitioners and policy-makers with a solid understanding of how to control/reduce return and manage RL process of these returns, which could ultimately lead to greater RL practices adoption across the sector.

This leads to the first research question:

RQ 1: Why are end of life (EoL) cars returned and what is the nature of the return of EoL cars which has significant impact on the RL process?

To understand the reverse logistics of EoL cars, it is important to identify why cars return as EoL and how cars become EoL. This is because identifying the return reason and its category can help to know where the system can improve to eliminate or avoid or manage the EoL car return better.

Therefore, this RQ investigates:

a) the reason of EoL cars coming back with details of what age cars are coming back as EoL and why, who the source of these EoL cars are and what motivates them to bring it back.

b) The nature of all these returned EoL cars in terms of features such as size, design, material composition, components structuring, components category, intensity of usage that affect different economics at RL different process stages and therefore overall value recovery from the EoL car.

After outlining the reasons for automotive product returns and the nature of the returns the following question arises - how are these return processed? So, the next key aspect discussed below is the “reverse logistics process for automotive products”.

2.6.2.3 Reverse Logistics Process in Automotive industry

Significant attention in the literature has been paid to the RL process in the auto industry (see the table 2.17). Studies have mostly considered the return process for End of life auto products including generic vehicles, cars and parts (Olorunniwo & Li, 2011; Chan et al., 2012;

Subramanian et al., 2014). The RL process stages for automotive products identified in line with other products' return processes are discussed in phase one of this chapter section 2.4.3.2. However, the "gatekeeping" stage of the RL process was identified as a part of the collection stage for auto products and, as discussed earlier, Gatekeeping can be carried out in the collection stage as well (Yang & Wang, 2007). However, there is one more stage identified by research focusing on auto products' RL process - "ASR recycling" - highlighted in table 2.17.

Table 2. 16 RL process of automotive products

RL process stages for auto products	Details	Product type / return reason	Studies
Collection	• Car manufacturers are responsible for setting up collection centre network with minimum distance to car owners where cars are collected by car take back centres • a network for EoL car collection with close distance with car owners suggested by researchers can minimise cost and environmental impact. • Not only developing but also developed countries like Australia, the lack of a proper collection system gives opportunities for unauthorised recycling facilities to compete with legitimate recycling sectors in acquiring EoL cars. • On the other hand, in Belgium one non-profit organisation managed the collection, treatment and recycling of EoL cars found minimising the risk of unauthorised recycling.	• End of life (EoL) car	Mansour & Zarei 2008; Cruz-Rivera & Ertel, 2009; Zarei, et al. 2010; Harraz & Galal, 2011; Subramanian et al., 2014; Soo et al., 2017
Assessment and sorting	• EoL cars are sorted for recovery options (direct use/repair/refurbish/remanufacture/recycling) according to cars condition and market value.	• End of life (EoL) car	Chan et al., 2012; Subramanian et al., 2014
Hazardous separation	• Removal of fuel, oil, coolants etc to avoid danger of spilling harmful substances during further removal of marketable parts activities; draining protects the further treatment activities from being contaminated.	• End of life (EoL) car	Schultmann et al., 2006; Mansour & Zarei 2008; Soo et al., 2017
Hazardous recycling	• Recycle to recover parts and materials for reuse	• End of Life (EoL) car	Schultmann et al., 2006; Mansour & Zarei 2008; Soo et al., 2017
Marketable parts removal and reuse	• Valuable components removal and recovery and redistribution	• End of Life (EoL) car	Schultmann et al., 2006; Mansour & Zarei 2008; Cruz-Rivera & Ertel, 2009; Harraz & Galal, 2011; Chan et al., 2012; Subramanian et al., 2014; Soo et al., 2017
Compact car shell	• Compaction attempts to decrees car shell density to reduce transport costs and for ease of transportation to send to shredder	• End of Life (EoL) car	Schultmann et al., 2006
Shredding Car hulk	• the car hulks are then processed in material recycling facilities to recover valuable materials such as ferrous (Fe) and non-ferrous (NF) metals and automotive shredder residue (ASR) dust.	• End of Life (EoL) car	Schultmann et al., 2006; Mansour & Zarei 2008; Cruz-Rivera & Ertel, 2009; Chan et al., 2012; Subramanian et al., 2014; Soo et al., 2017
ASR shredder	• the remaining ASR is further treated through post-shredder technologies to achieve the set recycling targets in Belgium but in Australia 25% ASR dust goes to landfill rather than further ASR recycling due to lack of strict legislation	• End of Life (EoL) car	Mansour & Zarei 2008; Cruz-Rivera & Ertel, 2009; Soo et al., 2017

Disposal of waste	• Where recycling is not possible are disposed by incineration/landfill • the strict recycling targets and scarcity of available landfill space in Belgium have further encouraged minimal ELV waste disposal (only 5%) due to high landfill costs. On the other hand in Australia 25% of ASR dust goes to landfill for disposal	• Consumer – End of Life (EoL) return	Schultmann et al., 2006; Mansour & Zarei 2008; Cruz-Rivera & Ertel, 2009; Olorunniwo & Li, 2011; Subramanian et al., 2014; Soo et al., 2017

Source: Mansour & Zarei 2008; Cruz-Rivera & Ertel,2009; Zarei, et al. 2010;Harraz & Galal, 2011; Subramanian et al., 2014; Soo et al., 2017

1.Collection/acceptance of auto products

Collection is the first and very important stage for the RL process in the auto industry. The main focus identified here is collection centre location (Harraz & Galal, 2011) and players (Subramanian et al., 2014) involved at collection centres. The growing concern for collection centre location and players in developed countries is mainly driven by European Union Regulations to minimise environmental pollution, where the manufacturer is responsible for free take back and recovery of its ELVs and must bear all or a significant part of the collection and treatment costs (Mansour & Zarei, 2008). Manufacturers are facing challenges for how to collect the EoL cars and what to do with them in order to obtain the maximum economic benefits from their recovery and, at the same time, fulfilling the relevant legislations. Therefore, to minimise cost and environmental impact, involvement of new car distribution centres as EoL car collection centres was identified as a good solution (Zarei, et al., 2010). Furthermore, collection point locations closer to car owners were identified as another solution to minimise transportation cost (Harraz & Galal, 2011). Research also suggested in order to achieve efficient management of the recovery process and minimising the costs, manufacturers should cooperate with treatment facilities, hence creating a network (Mansour & Zarei, 2008). For ELV collection and management some countries in developed nations, like Belgium, have organisations (non-profit) who manage the collection process (Soo et al., 2017). On the other hand, some developed countries like Australia still lack proper ELV collection systems, which increases waste from ELVs for landfill.

2. Assessment and sorting of returned auto products

When auto products arrive at collection centres, the testing and inspection on the returned auto products (ELVs and parts) has already been carried out (Olorunniwo at al., 2011). In the previous phase, phase one, the generic RL literature presents inspection as depending on product condition, which is also the case in the auto industry. If the car is in good condition, it is resold in the secondary market; but if the returned car does not carry a profitable resale value, it will then be transported to an automobile salvage yard or an automobile recycler for recycling (Chan et al., 2012).

3. Hazardous product separation and component removal for return auto products

As mentioned above, auto products (ELV, parts) contain toxic material which is harmful for health and the environment. This is the main reason why hazardous components are removed from ELVs for a separate recycling process (Schultmann et al., 2006). This also helps to reduce damage to good condition marketable parts and materials by spilling harmful substances in the next stages of the process.

4. Recycling of hazardous components and parts for auto products and reuse

As mentioned above, that hazardous component including batteries, fluids and other materials that contain hazardous chemical get separated from the car to protect marketable components and materials which are then collected by hazardous recycling centres for further treatment (reuse, repair/refurbish/remanufacturer, recycling). Further treatment of hazardous components was found in the literature to be very important for recovering valuable materials from the components (Schultmann et al., 2006) and reducing waste for landfill (Soo et al., 2017).

5. Removal of marketable auto components/parts and redistribution

Most auto products, including ELVs and components, contain valuable parts which have good market value in the secondary market (Olorunniwo & Li, 2011; Subramanian et al., 2014). The process of dismantling marketable parts is done manually, which saves on the use of energy and reduces CO2 emission (Halabi et al., 2015).

6. Compacting auto products

ELVs' shell is compacted after removing all the valuable components. The reason for this stage is pressing the ELV to make it as small as possible to transport to the shredder (Schultmann et al., 2006).

7. Shredding auto products

The car shell, called the "hulk", is shredded to recover materials (Chan et al., 2011; Subramanian et al., 2014). Auto parts which cannot be repaired and do not hold good condition components for recovery are also shredded to recover materials (Olorunniwo & Li, 2011). The shredding process is mainly done by machines (Halabi et al., 2015) which recovers valuable materials like ferrous and non ferrous metals (Mansour & Zarei 2008; Chan et al., 2011; Olorunniwo & Li, 2011; Subramanian et al., 2014; Soo et al., 2017).

8. Automotive Shredder Residue (ASR) recycling

Automotive Shredder Residue (ASR) has been targeted for further recycling of valuable metals and non-metallic materials to meet strict legislation. ASR that would be landfilled in some countries' recycling facilities undergoes further treatment processes in other countries recycling facilities where strict EU regulation is present (Soo et al 2017). The post-shredder treatment utilises density separation to further segregate the variety of non-metallic materials and heavy metals. Plastic recycling is the focus in this process, and the recovered plastics are further sorted to different plastic types to improve purity and thus increase the value of secondary plastics. However, the recycling efficiencies vary vastly from one plastic type to another (Soo et al., 2017). After shredding the ASR hulk, the ferrous metals are separated for redistribution. The remaining material is divided into non-ferrous metal fraction, which is further recycled by the metal separators (Mansour & Zarei 2008).

9. Disposal of waste from auto products

Where recycling is not possible, the material from automotive products becomes automotive waste. This waste can be disposed of by tte incineration process or by dumping in landfill (Mansour & Zarei, 2008). Reduction of this automotive waste is very important to save environment and to reduce landfill space scarcity (Olorunniwo & Li, 2011). The literature cited that strict regulation for recycling targets can help reduce automotive waste (Soo et al., 2017). Also, increasing cost to landfill waste can help reducing waste but the landfill costs are still low in some countries like in Australia, where landfill costs are low compared with Europe, which can be the reason why in Australia approximately 25% of the EoL cars in ASR end up in landfills (Vermeulen et al., 2011). On the other hand, in European countries like Belgium, 5% waste goes to landfill from ELV and the reason is identified as strict regulation (EU directive for ELV) (Soo et al., 2017).

In summary, the automotive industry reverse logistics process is identified as mainly focusing on cars and the key return reason identified here is EoL which are mostly collected direct from public, used car dealers, local councils, and car towing service operators (Halabi et al., 2015). Upon arriving at a holding yard, the ELVs are inspected, inventoried, and then moved into a processing hangar for depollution (Chan et al., 2012) including drainage of fluids (i.e. coolant, hydraulic fluids, engine oil, gearbox and differential oils, and fuel) while air conditioning (A/C) gas and liquid petroleum gas (LPG) and batteries are extracted. After that quality parts - wheels/tyres, tow bars, and catalytic convertors are removed manually (Subramanian et al., 2014). Parts deemed to be in high demand, good condition, and high value are dismantled (e.g. engines, transmissions, door mirrors, audio equipment, etc.). These parts, including useable batteries and wheels/tyres, are tagged and warehoused for sale as quality used parts (Halabi et al., 2015). Once all marketable parts are removed, a hydraulic compactor compacts the car shell to transport it to the shredder (Schultmann et al., 2006), where materials including ferrous and nonferrous are recovered and the shredder puff is landfilled (Olorunniwo and Li, 2011). After shredding the car shell, the ferrous metals are separated and sent to the material recyclers. The remaining material is divided into non-ferrous metal fraction, which will be sent to the metal separators and the relevant recyclers, and the non-metal fraction and ASR dust goes for further shredding process for more recovery to reduce waste for disposal (Mansour and Zarei 2008). Finally, the shredder puff which is mainly not possible to recycle anymore are disposed by incineration process or dumping to landfill.

2.6.2.3.1 RL process performance in auto industry

In terms of RL process performance in the automotive industry, growing attention is noticeable including TBL performance of the RL process with three dimensions of sustainability: economic (increasing recovery of parts and materials), environmental (reducing waste for disposal) and social (creating jobs) (Harraz & Galal (2011).

All the performance indicators with actual performance cited in the automotive RL literature are presented in the table 2.18.

Economic performance measurement (value related) has received the most attention in the automotive industry, where strict legislations (Soo et al., 2017), use of IT (Olorunniwo and Li, 2011) and suitable location (Harraz & Galal, 2011) for EoL car collection present positive impact on business in terms of ROI, recapturing value, process efficiency and customer satisfaction. In terms of cost measurement, outsourcing RL activities was identified as reducing RL process cost in the automotive industry (Richey et al., 2005). The strict implementation of the ELV directive has led to better environmental performance as in developed nations too, like Belgium, as it forces the adoption of advanced recycling technologies which improve recovery rate and reduce waste production (Soo et al., 2017). However, most performance measurement in the automotive RL process is IT based (see the table 2.18), where research measures performance to see how use of IT impacts on the RL process. Use of IT to deal with return is acknowledged as having a positive impact on RL process efficiency (Olorunniwo & Li, 2011) in terms of improved customer satisfaction, as IT enables a quick authorisation process by tracking records in the system (Daugherty et al., 2005).

Table 2. 17 RL process performance

Indicators to measure RL performance	Actual performance impact	Studies
Economic - Value related		
Return on investment (ROI)	• EU legislation impact on RL process identified increasing revenue by recovering more products/materials and reducing disposal cost	Soo et al., 2017
Recapturing value	• Suitable location of collection centre in RL process encourage sender and receiver both to collect and recycle ELV which increase the recovery of parts and materials • IT capability on RL process can improve as in extracting and recovering raw materials for use in the production of new products by improving the quality of recovered materials	Harraz & Galal, 2011; Daugherty et al., 2005
RL process efficiency	• IT impact in RL process for time to obtain return product authorisation was quick as companies are using pre-paid return label, called SmartLabel in some firms that goes out with the original shipment as it leaves the warehouse. The SmartLabel's intent is to make it as convenient for the customer as possible to make a return, to remove any inhibitors for that customer to purchase directly from the company • IT impact on RL process in terms of time for credit processing was little improved • IT impact on RL process for time for repair and refurbishing was little improved • Policy restrictiveness impacts on RL process identified increasing the adoption of updated recycling technology which increases recycling efficiency • Outsourcing RL activities has positive impact on process effectiveness in contrast to developing in-house	Richey et al., 2005; Li and Olorunniwo, 2008 & Olorunniwo and Li, 2011; Soo et al., 2017
Customer satisfaction	• IT impact on RL process providing return facilities with quick return authorisation process creating satisfied customers • IT capability on RL process can improve customer satisfaction by tracking, handling and authorising return with less time and accurate decision making (Daugherty et al., 2005)	Daugherty et al., 2005; Li & Olorunniwo, 2008 & Olorunniwo and Li, 2011; Soo et al., 2017
Economic - Cost related		
Operation/logistics cost	• Outsourcing in RL process activities acknowledged reduce operation cost in RL process	Richey et al., 2005
Compliance cost	• IT capability on RL process can improve the system of return tracking, handling and authorising can help to achieve compliance and reduce the cost of noncompliance activities	Daugherty et al., 2005
Environmental		
Waste reduction	• Suitable location for collection and treatment increasing recovery which reducing the waste for landfill	Harraz & Galal, 2011
Social		
Local job creation	• Improving the network for collection and treatment increasing collection and treatment centres locally which creating local jobs	Harraz & Galal, 2011

Source: Richey et al., 2005; Li and Olorunniwo, 2008; Harraz & Galal, 2011 & Olorunniwo and Li, 2011; Soo et al., 2017

2.6.2.4 Location of auto product return process

There is growing attention on the importance of setting up EoL car collection networks in terms of location and number, where researchers have suggested collection points set up near end users encourage and facilitate the process and can reduce transportation cost and save the environment and help society (Harraz & Galal, 2011). Though there is very limited knowledge in terms of a clear understanding of current practice on location for each stage in the auto industry discussed above, there are a number of proposed models. These models suggest that manufacturers and new vehicle distributors should get involved in collecting ELVs to reduce the cost and environmental impact (Zarei, et al. 2010). Researchers propose best possible models for location and numbers, but these are based on developing countries, which may not be applicable for developed countries, especially EU countries, as EU countries' RL practice is identified as much more mature than developing countries and, indeed, any other developed countries (Soo et al. 2017).

2.6.2.5 Time related issues in auto products reverse logistics process

Timing of collection of ELVs/cars is identified as one of the issues facing recyclers (Beullens et al., 2003) but there is a lack of knowledge of this aspect in terms of how they are managing this challenge and also when each stage of EoL car RL processing starts and how long it takes.

2.6.2.6 Gaps affecting facilitating RL process in each stage including location and time related issues

In summary, considerable attention has been paid to the RL process for auto products, with a focus on EoL cars; though most of the studies use the term "End of Life Vehicle/ELV", they mainly focus on EoL cars.

In terms of each stage of the EoL cars RL process, the collection of automotive products stage was considered by some studies (Mansour & Zarei 2008; Cruz-Rivera & Ertel, 2009, Despeisse et al., 2015). These studies mainly focused on EoL car collection. But details of the collection process is not discussed in terms of how EoL cars are collected, such as management of transportation, collection centres facilities, services, technology etc. Car manufacturers are responsible for EoL car collection and take back centres collecting EoL cars in developed nations (Mansour & Zarei 2008; Cruz-Rivera & Ertel, 2009). How car manufacturers manage this collection process is not considered by these studies. Also, this stage is regulated by government agencies, which mainly implement it in developed countries, especially in EU countries, where EoL cars should be collected to an authorised treatment facility (ATF) who will issue a certificate of destruction (SOD) to the last car owner (Despeisse et al., 2015). But what those regulations are, and their impact, and what companies are doing to meet the regulations, how cars are collected to ATF in terms of logistics (transportation facilities, cost and distance related issues) and details of these activities, are not discussed in either generic or automotive industry studies.

In the assessment and sorting stage, the EoL car assessment and sorting stage for recovery options is recognised by the literature, which mentions that it is dependent on return nature and market value (Chan et al., 2011). But details of the conditions of EoL cars and how market value impacts on EoL car assessment are not discussed. Furthermore, some cars arriving as End of life can still be repaired and refurbished and resold to the secondary market mentioned by researchers (Chan et al., 2012), but the conditions of those cars and their seller and buyers (players) are not known. The generic literature cited this stage as complex in nature, requiring skilled workers; therefore, manufacturer quality control teams were identified as being involved here (Bai & Sarkis, 2013). None of the automotive industry studies found considered this point of who are assessing EoL cars for recovery options, how (the processing) and where?

Hazardous products separation in the automotive industry is mainly the removal of hazardous components from EoL cars (Schultmann et al., 2006). This stage was found in the literature, mainly for EoL products in generic and automotive contexts. In both generic and automotive industry perspectives, knowledge of this stage is very limited in terms of how the separation is done - manually or electrically? who does it? where? What are the components which contains hazardous chemicals? What are those chemicals? In the auto industry, this stage was found to be regulated by government (Soo et al., 2017); but what are the regulations and their requirements? To whom these regulations apply, and what they are doing to meet the regulations, are not known. So, there is a gap in the detailed knowledge of the process in terms of storage and redistribution and also if there are any hazardous components in EoL cars that have restrictions on reuse, in addition to what all the components are that should be removed and where they are kept and stored and where they are going for further treatment.

In the recycling of hazardous stage, the generic literature mentions the complexity of this stage, and that it is important for saving the environment and also that economic value can be recovered from hazardous products recycling rather than sending them to landfill (Hu et al. 2002). This is acknowledged by the automotive literature as well (Schultmann et al., 2006). But what is the process of collection of hazardous materials? Is there any waste coming from these hazardous parts? Are these wastes non-hazardous? Can they go to landfill as non-hazardous waste? Related important knowledge could not be found in either the generic or automotive contexts. Similarly, the marketable components removal stage was also discussed but with very limited knowledge. For instance, the literature mentions that marketable parts are removed according to market value of components and customer demand (Olorunniwo & Li, 2011; Subramanian et al., 2014) but what those parts are that have customer demand and how the removal process carried out in terms of where and by whom are not known. Similarly, in the shredding and ASR recycling stage, type of equipment/machines being used, percentage of recoverable materials, factors Affecting waste percentage, materials in ASR dust, and shredder plant location related issues are not discussed in the literature.

Disposal of waste coming from products is considered as one of the most important stages in both the generic (Xie & Breen, 2014) and automotive (Mansour & Zarei 2008; Soo et al., 2017) literature. But detail of the disposal process in terms of how the incineration and landfill works and differences between two process, as well as what goes to landfill and what for incineration, and which one is better and why, are not discussed by these studies.

In terms of RL performance, there is a lack of information of actual performance of the RL process in terms of who are measuring these performances and why. In addition, connecting to the RL performance for other products discussed in phase one (table 2.7), not all the environmental and social perspective performance indicators are acknowledged in the automotive industry literature.

To summarize, a comprehensive understanding of each stage of the RL process, and their regulatory restriction, detailed activities, location and time related issues can guide practitioners and policy-makers with a solid understanding of RL process in terms of how, where, when and who to implement RL process, which could ultimately lead to greater RL practices adoption across the sector.

This leans to the second research question:

RQ 2: How, where and when are end of life (EoL) cars processed to recover value and what is the performance?

This investigates the following:

- How are the return EoL cars processed, including each stage from collection to disposal with detail of nature of infrastructure, technology, capacity and workforce planning and management used at each process stage, the performance measures used and actual performance on those measures at each process stage.
- Where is the processing done in terms of the locations of the processing for all stages and if these location related issues have any influence on the process efficiency and effectiveness
- When does the process start and how long it takes - are there any time-related factors associated with each of the reverse logistics stages.

After gathering the knowledge on the automotive product process, location and time related issues in the process the next question is to know the detail of these players and their relationships to activate RL process.

2.6.2.7 Players involved in the automotive product reverse logistics process

The five different types of players that have been identified in the automotive literature are as follows. All the players discussed in the literature, including their roles and relationships, are presented in table 2.19. In terms of activities, from forward chain players, car manufacturers were identified as only responsible for the network for ELV collection (Schultmann et al., 2006) and the ELV recovery target, which is 95% of total ELV weight (Soo et al., 2017). Material suppliers and auto part manufactures also redistribute recovered materials and parts to the second-hand market ((Schultmann et al., 2006; Subramanian et al., 2014). From the reverse chain, collectors of ELV were identified as only responsible for collection of cars (Schultmann et al., 2006). Authorised treatment facilities and dismantlers were also identified as collecting ELV (Soo et al., 2017). Shredders recover metals by shredding ELV hulk (Subramanian et al., 2014) which is further recycled by material recycling centres to recover materials (Cruz-Rivera & Ertel, 2009). In developing countries' scrap yards, small body shops and service centres were also identified as collecting and dismantling ELV (Cruz-Rivera & Ertel, 2009), which is not applicable for developed counties, especially in EU countries, as each treatment centre has to be government authorised to dismantle ELV (Soo et al., 2017).

Table 2. 18 Players involved in RL process

Players	Activities	Studies
Forward chain players		
Manufacturers	• Responsible for collection network	Mansour & Zarei 2008
Retailers	• Collecting EoL cars	Mansour & Zarei 2008
Reverse chain players		
Dismantlers	• Removing and recovering parts	Mansour & Zarei 2008; Kumar & Putnam, 2008; Cruz-Rivera & Ertel, 2009; Aitken & Harrison, 2013; Subramanian et al., 2014; Xiao et al., 2019
Shredders	• Shredding car shell and recovering materials	Mansour and Zarei 2008; Kumar and Putnam, 2008; Cruz-Rivera & Ertel, 2009; Aitken & Harrison, 2013; Subramanian et al., 2014
Hazardous recycling centre	• Recycling hazardous components	Xiao et al., 2019
Waste management companies	• Disposing automotive waste	Mansour & Zarei 2008
Others		
Government agencies	• Organisations responsible for compliance	Fuller & Allen, 1997
Membership body	• Manage RL process	Soo et al., 2017
ATF	• Collect EoL car	Soo et al., 2017
Collectors	• Collecting EoL cars	Mansour & Zarei 2008; Subramanian et al., 2014, Xiao et al., 2019
Consumers	• Source of EoL car	Subramanian et al., 2014; Soo et al., 2017

Source: Mansour & Zarei 2008; Kumar & Putnam, 2008; Cruz-Rivera & Ertel, 2009; Aitken & Harrison, 2013; Subramanian et al., 2014; Soo et al., 2017; Xiao et al., 2019

Apart from these, there are more players identified in the auto industry including non-profit organisations which play an important role in managing the RL process for EoL cars from collection to disposal by supervising each player in the chain (Soo et al., 2017). Government agencies are also another important player in the auto industry, making policies and being responsible for compliance (Mohamad-Ali, et al. 2018).

2.6.2.6.1 Relationship between auto industry players and its impact on RL

Some players face some problems in the auto industry, especially manufacturers, in terms of how to collect EoL products and what to do with them in order to obtain the maximum economic benefits from their recovery and, at the same time, fulfilling the relevant legislation. The introduction of the European Union Directive on end-of-life vehicles (ELVs) means that the manufacturers are responsible for free take back and recovery of their vehicles. Implementing this directive will impose new additional costs on manufacturers. To deal with this, researchers have suggested that manufacturers should join with treatment facilities, hence creating a network order to achieve efficient management of the recovery process and minimising the costs (Mansour and Zarei 2008). Aitken and Harrison (2013) also agreed that the relationship between the partners in terms of information flow and knowledge management enabled the establishment of the RL system. Knowledge which had been tacit for the salvage agents in terms of the disassembly process became, in part, codified. Lack of know-how has been found to be a significant barrier to implementing RL systems (Gonzalez-Torre et al., 2010) where close level collaboration can help. But for some reason limited focus has been put on the relationship between firms to enable RL systems in the auto industry (Aitken and Harrison, 2013).

2.6.2.6.2 Gap identified for RL process players

In summary, players are identified in the automotive industry as a little diverse from other industry players discussed in phase one of this chapter, which differentiates RL practice in automotive industry from other industries.

The literature mentions manufacturers as responsible for collection networks (Mansour & Zarei 2008) but what the activities are here and how they manage the activities are not discussed. Similarly, membership bodies are managing the RL process (Soo, et al., 2017) process, but how they managing it and why are not discussed. Also Authorise Treatment Facilities (ATF) are mentioned in the collection of EoL cars (Soo et al., 2017); however, other collectors are collecting EoL cars, but who these collectors are and who ATFs are and whether they are doing any other activities in the RL process or only collecting EoL cars and why are not discussed.

Regarding relationships between players, there is growing attention to the automotive reverse logistics process, which is in line with other sectors, but still there is limited knowledge compared with the generic supply chain and logistics management literature. Moreover, there is no empirical research found in the automotive industry RL literature on relationships between players practicing RL. However, to effectively engage with the automotive RL process, studies have suggested that manufacturers should join with treatment facilities to achieve efficient management of the recovery process and minimise the costs (Mansour & Zarei 2008). Aitken and Harrison (2013) also agreed that the relationship between the partners in terms of information and knowledge sharing can enable the establishment of the RL system in the auto industry. Gonzalez-Torre et al., (2010) also suggested lack of expertise in auto RL process can be solved by close level collaboration with third party expertise. All these present the importance of close relationships between players in the automotive sector practicing the RL process but for some reason there is no focus on current practice in the relationships between firms for RL activities in the auto industry (Aitken & Harrison, 2013).

To summarize, a comprehensive understanding of each player and their role/activities in the RL process, relationships between them to manage activities, and related issues, can guide practitioners and policy-makers with a solid understanding of stakeholders contributions in implementing RL process, which could ultimately lead to greater RL practices adoption across the sector.

This leans to the second research question:

RQ 3: Who are the key players involved in reverse logistics practice of EoL car and what are their roles and what are the relationships between them?

This investigates as follows:

- Who are the players involved at the different EoL car RL process stages?
- What is the relationship between players to process EoL car RL including key flows are; material, informational, financial flows between players?
- What is the collaboration nature in these relations?
- What influencing players for these relationships (the drivers) and barriers in these relationships?
- Any impact of the players/firm features such as size, ownership, sector etc.?

After knowing all the players and their roles in the automotive RL process the next question is why these players are involved in the EoL car RL process and are there any other players supposed to be involved with this process but for some reason are not involved, or are there any barriers hindering the improvement of the RL process? So, the next section discusses RL drivers and barriers in the automotive industry identified in the existing literature.

2.6.2.7 RL drivers in the automotive industry

As discussed earlier in phase one, firms engage in RL because the operation is profitable, because the law requires them to do so, and/or because they “feel” socially motivated to do it. These driving factors have been categorised by De Brito and Dekker (2003) under three main headings: Economics, Legislative, and Corporate Citizenship. This is also found in line for automotive industry players as well, as discussed below. Apart from the three drivers there were other drivers also identified in phase one including stakeholder pressure (Gungor & Gupta, 1999), competitive pressure (Chan et al., 2011) and assets protection concern (de Brito & Dekker, 2003), which were not discussed in automotive industry players literature.

1. Legislation pressure

Together with generic and other industry drivers in the auto industry, regulations put pressure on car manufacturers and tend to make them responsible for the End of Life (EoL) of their products for proper disposal (Gehin, et al. 2008; Chan et al., 2012; Subramanian et al., 2014). Furthermore, Soo et al. (2017), also mentioned that Strict ELV directives require 95% recovery from a car’s weight in European countries like Belgium, which is forcing players to get involved with the RL process for EoL cars. This is mainly forcing car manufacturers (Gehin, et al. 2008). The action taken for this regulatory pressure is car manufacturers reconsidering making new cars with more recyclable materials (Gehin, et al. 2008).

2. Economic gain

Direct economic gain from recovered parts and materials was identified as motivating auto industry players to get involved with the EoL car recycling process (Chan et al., 2012; Subramanian et al., 2014). Furthermore, researchers also identified that recovered plastic and metal in Europe has good market value, which encourages players to get involved with recycling activities of EoL cars. Also increased recovery is reducing disposal cost, as the disposal cost is higher than the recycling cost in Belgium (Soo et al, 2017).

3. CSR (Environmental consciousness)

Different norms have encouraged companies to reconsider their ways of producing to protect the environment (Gehin, et al. 2008). Car manufacturers are mainly influenced by CSR drivers (Gehin, et al. 2008)

Table 2. 19 RL drivers influencing players in automotive industry

Drivers	Detail	Motivated players	Action taken	Impact of the action	Studies
Legislative pressure	• Regulations put pressure on manufacturers and tend to make them responsible for the End of Life (EoL) of their products. • Strict ELV directive require 95% recovery from a car weight in some countries like Belgium. .	Manufacturers	Reconsidering making new car with more recyclable materials	-	Gehin, et al. 2008; Chan et al., 2012; Subramanian et al., 2014; Soo et al., 2017
Direct Economic gain	• From return cars, recovered parts and materials. • use of recovered plastic and metal and reducing waste saving disposal cost as disposal cost is higher than recycling cost in some countries like Belgium	-	-	-	Chan et al., 2012; Subramanian et al., 2014: Soo et al., 2017; Mohamad-Ali, et al. 2018
Corporate Social Responsibility	• Different norms have encouraged companies to reconsider their ways of producing to protect the environment	Car Manufacturers	Making new cars with more recyclability	-	Fleischmann et al., 1997; de Brito & Dekker, 2003

Source: Fleischmann et al., 1997; de Brito & Dekker, 2003; Chan et al., 2012; Subramanian et al., 2014: Soo et al., 2017; Mohamad-Ali, et al. 2018

2.6.2.8 RL barriers in the automotive industry

There are two different category barriers noticed which are hindering players to ignore EoL car RL practice completely and other barriers hindering players who are already involved in the improvement of the RL process.

What hinders player to ignore RL

1. Lack of remanufacturing technology

No maturing technology standards to control the quality and reliability of remanufactured products in China (Zhang et al, 2010). Remanufacturers are affected here and this also creates more waste for landfill and remanufacturers are ignoring to recycle cars.

2. Return uncertainty

Not everyone disposes of their cars by formal channels in China. Therefore, car volume from recycling is very small for huge recycling setup and cost (Zhang et al, 2010). This is hindering remanufacturers and recyclers to ignore engaging and investing in the car RL process

3. No value added tax refund policy

Tax is still the same as producing new products. There is no value added tax system for remanufactured products in China (Zhang et al, 2010). This is hindering remanufacturers and recyclers to engage and invest in the car RL process.

What hinders better RL performance

4. Lack of strict regulations

Due to lack of strict legislation in Mexico, operations for ELV management are not standardised. Poor practices in ELV management activities lead to negative effects on the recovery value from ELV, like contamination of shredder material by operative fluids, as they do not follow the RL procedure, such as ignoring recovery of fluid before sending the car to the shredder (Cruz-Rivera & Ertel, 2009).

5. Negative perception of recycled products

In terms of quality perception of remanufactured products, in countries like China, India and Spain, customer perception of remanufactured products is not 'as good as new'. Customers' poor perception of the quality of remanufactured products was identified as a barrier where organisations are sometimes struggling to sell remanufactured products due to their price (Ravi & Shankar, 2004; Gonzalez-Torre et al, 2010; Zhang et al, 2010).

6. Lack of top management attention

Top management are not focusing on return activities in counties like India and Spain. Moreover, they do not have strategic planning and policy to manage return, no arrangement of training and education for employees, updated IT systems, performance measurement policy and expertise, because there is a lack of awareness and knowledge in top management regarding RL practice advantages (Ravi & Shankar, 2004 Gonzalez-Torre et al, 2010).

Table 2. 20 RL barriers hindering RL practice in the automotive industry

Barriers	Detail	Affected players	Action taken	Impact of the action	Studies
Barriers influencing to ignore RL activities					
Lack of technology	• Lack of advance technology to recover quality materials also influencing recycler to ignore as they can not get good value of those poor quality materials recovered from cars	Recycler -	-	-	Zhang et al, 2010; Subramanian et al., 2014
Return uncertainty	• Very few customers bring their car back for disposal which is the reason recycler do not deal with automotive product recycling.	Recycler	-	-	Zhang et al, 2010; Subramanian et al., 2014
No value added tax refund policy	• Countries like China, Malaysia recycler ignoring automotive product recycling as it requires them to pay text	Recycler	-	-	Zhang et al, 2010; Subramanian et al., 2014; Mohamad-Ali, et al. 2018; Xiao et al., 2019
Barriers hindering better RL performance					
Lack of strict regulations	• Due to lack of strict legislation operations for ELV management are not standardized in terms of hazardous components removal process.	Recycler	-	-	Cruz-Rivera & Ertel, 2009; Shaan & Subramoniam, 2012
Negative perception of recycling product	• customers perception on poor quality of recovery parts and materials reducing recovered products market value.	Recycler	-	-	Ravi and Shankar, 2004; Shaan & Subramoniam, 2012; Gonzalez-Torre et al, 2010; Mohamad-Ali, et al. 2018

Lack of top management attention	• Top management not focusing on return activities and they do not have proper planning and policy for RL activities as they do not understand the benefit of it.	-	-	-	Ravi & Shankar, 2004; Gonzalez-Torre et al, 2010

Source: Ravi & Shankar, 2004; Gonzalez-Torre et al, 2010; Zhang et al, 2010; Subramanian et al., 2014; Mohamad - Ali, et al. 2018; Xiao et al., 2019

2.6.2.9 Gaps affecting to RL drivers and barriers

As previously mentioned, it is important for practitioners and policymakers to understand the drivers and barriers of RL practice for EoL cars, as they can explain aspects such as why some firms are active in implementing the RL process for EoL cars while others are not; and why some show extensive implementation of green practices while others show limited or no implementation.

Like other sectors, the automotive sector could also benefit from looking at these drivers and barriers. While the literature provides some information on the nature of these drivers and barriers presented in table 2.20 and 2.21, the understanding is far from comprehensive.

One of the reasons for this lack of comprehensive understanding of RL drivers and barriers is that the studies that have investigated these drivers and barriers in the automotive sector are limited in number. Also, these studies are either descriptive or generic, i.e. without stakeholder focus, or have investigated drivers for specific RL practices with limited stakeholder focus. Moreover, most of the drivers and barriers are from a developing country perspective, which may not be drivers or barriers for developed nations.

Therefore, a comprehensive investigation is warranted to unearth the nature/details of various drivers and barriers. This includes identifying the various drivers and barriers based on their perceived importance/relevance by different stakeholders. For example, pressure from the government in the form of regulations on car manufacturers could be higher or lower compared to the governmental pressure on recycling industry firms. Also, even if all car manufacturers face the same government regulation, some may consider it very important, while others may consider it less important or may choose to ignore it all together. Similarly, lack of RL expertise, a barrier to RL practices in auto industry, could be perceived as a greater or lesser barrier by different stakeholders and individual firms depending on their ability to manage it. In short, the perceived importance of these external and internal drivers and barriers could vary among the supply chain stakeholders and firms depending on their conflicting interests and their ability in managing these drivers and barriers.

To summarise, a comprehensive understanding of RL drivers and barriers for each supply chain stakeholder is important for practitioners and policymakers to predict the auto sector RL practice and to devise strategies for each stakeholder so that they can maximise/leverage the drivers and minimise/eliminate the barriers for improving sector-wide efficient and effective RL practices. This leads to the next research question:

RQ4: What are the drivers and barriers for implementing the reverse logistics process for EoL cars for individual car making and car recycling sector stakeholders and their perceived importance/relevance?

This investigates;

- What influencing (drivers) stakeholders to involve in/develop EoL car RL process?
- What are challenges (barriers) stakeholders facing to ignore/improve EoL car RL process.

2.7 Summary of phase two

Phase two has discussed the key aspects for the automotive industry that are acknowledged in phase one. This section discussed the key aspects to address RL practices in the automotive industry specifically. Therefore, this section has established a background understanding of the themes that underpin this study's research area, identified the contribution and the shortcomings of the extant empirical studies, identified the gap in literature and shaped the research context.

Now, this present study can be done in a different country context; however, this research selected one country - the United Kingdom (UK), where RL practice is becoming more challenging due to the high demand of cars and advanced reverse logistics practice, discussed below in detail.

Phase three

2.8 Reverse logistics in UK automotive industry

2.8.1 The UK automotive sector

The UK automotive industry is the six largest in the world. The industry has developed a highly incorporated industrial system that offers amazing value and convenience to consumers worldwide through proficient logistics, enormous scale, global trade, and sophisticated systems integration skills. Technological improvement has observed dramatic improvements in vehicle safety, environmental impact, fuel economy, performance and comfort and versatility, while offering an ever increasing choice through model variety expansion. A huge contribution of technological, industrial and commercial innovation has been seen as well (NAIGT, 2009). There are approximately 2,350 UK companies that consider themselves as 'automotive' suppliers, employing about 82,000 people. The government has identified a £3bn opportunity for domestic suppliers to provide parts to UK-based vehicle manufacturers. This supply chain constructs on average £4.8bn of added value annually. Currently, about 80% of all component types required for vehicle assembly operations can be procured from UK suppliers (SMMT, 2014). There are some characteristics found in the UK automotive industry which differentiate UK automotive industry with other countries automotive industry. One of them is high demand of the car in the UK. According to a UK automotive report, there are 1.6 million cars produced in the UK each year and it is believed that car manufacturing volumes are going to break all-time records by 2020. Data from the OICA (2016) shows vehicle throughput in the global automotive industry is also growing. Nearly 100 million cars and commercial vehicles were manufactured in 2015, almost double the output in 1997, to meet growing demand for personal mobility. Due to the introduction of new features designed to meet customer demand and government regulation for environment friendly cars, markets demand more new cars to replace old cars. In more mature markets, such as the UK, where the stock of vehicles is stable, there is demand also for replacement vehicles (Cooper et al., 2017). As a result, vehicle production in the UK automotive industry is increasing (ICCT, 2016) to meet this demand. This increasing number of car production means in the end, increasing numbers of EoL cars to deal with. Another interesting factor is cars are larger in size and heavier in the UK. In the UK, the average material intensity of vehicles is growing. In spite of efforts to switch to lighter materials and lightweight design, cars have become larger in size and heavier across all vehicle segments. This is partly due to the introduction of new features designed to improve comfort, safety, security and emissions control (Zervas, 2010). On the other hand, customer needs are independent and differ across countries, reflecting different driving and styling preferences, which means that a model sold in two different countries may have the same body structure but completely different interiors, vehicle performance and features. A very recent paper posits that increasing vehicle material intensity is partly due to an ageing driver population and evolving customer preferences for features which increase car weight and size in UK automotive industry (Cooper et al., 2017).

2.8.2 Reverse logistics in the UK automotive sector

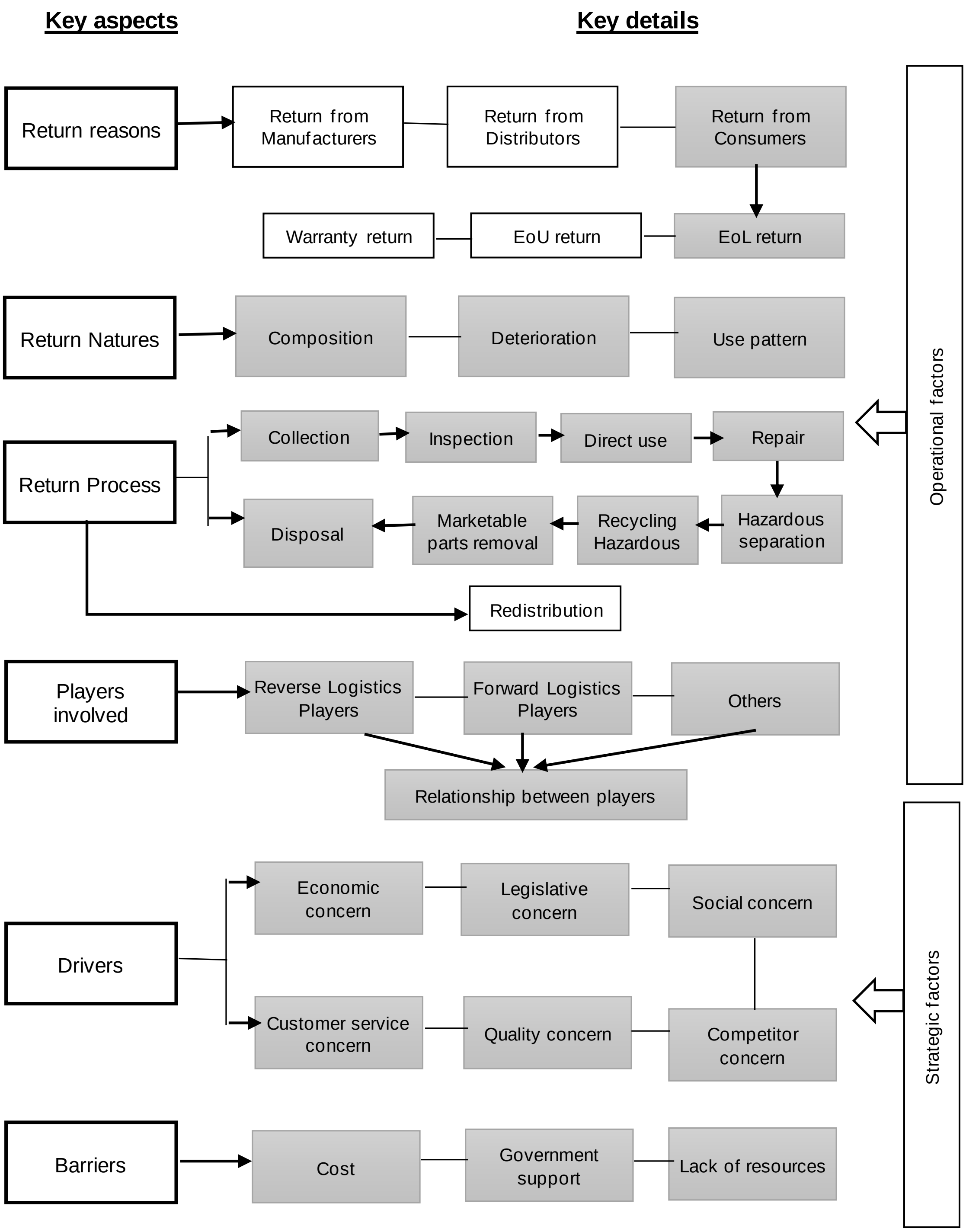
Over one million end-of-life vehicles (ELVs) come Into the reverse chain in the UK each year (Kollamthodi et al., 2003). The recycling of these vehicles and recovery materials at end-of-life has the potential for the sustainability of the automobile through resource protection and waste minimisation. The end-of-life vehicles directive (2000/53/EC), introduced in 2000, has attempted to bringing vehicle manufacturers closer to the recovery of their products via extended producer responsibility (EPR), to facilitate more sustainable closed-loop thinking.

The UK transposition of the ELV directive requires vehicle manufacturers to provide free take-back and treatment for all their own vehicles post 2007 and meet stringent recycling and recovery targets of 95%. Vehicle manufacturers have chosen to conform to the legislation by moving away from actively getting involved and investing in their own recovery facilities, in favour of utilising the existing infrastructure and waste recovery processes within the UK. This has led to the establishment of “collection contracts”, whereby the existing vehicle recovery industry has agreed to fulfil the requirements laid down by the ELV directive on the vehicle manufacturer’s behalf.

All of this mean the UK automotive industry is advanced in terms of RL implementation (Aitken & Harrison, 2013), as this is one of the most environmentally aware manufacturing sectors and they moved from the business practice of traditional manufacturing to eco-friendly solutions. But surprisingly, not many studies have been identified in terms of RL practice in the UK automotive industry. This could be partly because the effort devoted to this area is not very systematically investigated (Chan et al., 2012). To support this statement, this study can also refer to appendix 2 in this thesis, which presents the automotive industry studies based on RL key aspects and identified a very limited number of studies focused on the UK automotive industry, while no study on cars in the UK appears to have been done in terms of all the key aspects discussed. Hence, given the limited investigation and therefore limited understanding of the RL of cars in the UK, this subject has been taken up in this study, as there is a need for RL study in UK automotive industry for EoL cars.

Hence, a content framework served as the theoretical outline that guided the development of conceptual model, RQs, and data exploration of this study. The exploration of auto RL practice in the UK, and the application of the RL framework in the UK automotive industry forms one of the core contributions of this thesis. Hence, it is important to identify relevant constructs from extant literature in order to fully operationalise this framework, and develop an empirically informed, and theoretically grounded insight of RL practices in the UK automotive industry. This extensive framework portrayed in Figure 2.10 is employed in this study to facilitate a holistic exploration of automotive industry RL practices in the UK. The framework takes into consideration both the strategic and operational factors of RL. The grey shading indicates the areas which are addressed as part of this thesis.

Figure 2. 9 Conceptual model to examine RL practices in the UK automotive industry



This is further supported by the fact that studies in RL have started to apply extant and emergent theory, which helps in the advancement of RL as a cross-disciplinary field and helps in making meaningful generalisations and inter-sectorial transfer of knowledge (Touboulic & Walker, 2015). A comprehensive understanding of the various theories that have been applied or proposed in the RL context would be a good starting point towards developing a reliable theoretical basis for the RL in any sector including automotive. In the next section, the existing studies in RL that have used/proposed established/emerging theories are reviewed.

2.9 Theories used in reverse logistics research

Theoretical values are important to decision-making and managerial actions as well as to the advancement of any field (Chen & Paulraj, 2004). Mentzer, (2008) claimed good research is grounded in theory (Mentzer, 2008), because understanding the potential extant and emergent theories is important to relate RL to a larger body of knowledge and in providing a deeper, broader and more simplified conceptualisation of its various aspects (themes/sub-themes). Currently there is a gap in the literature on RL management studies in terms of theory (Dowlatshahi, 2000). There is very limited theoretical support for explaining the existence or the boundaries of RL management. Researchers have analysed the use of theory in reverse logistics, which indicates that the majority of the articles (63%) analysed did not discuss any underpinning theory (Salvador, 2017). Also Carter and Ellram (1998) confirmed the lack of use of theories in RL in research. Based on Salvador, (2017) systematic review theories used in RL research are;

Table 2. 21 Extent of use of relevant theories for RL research

Theories	Extent of use in RL research (%)
Sustainability theory	5%
Resource-based view	4%
Institutional theory	2%
stakeholder theory	2%
transection cost theory	1%
resource dependency	1%
Mathematical models	22%
No theories	63%

Source: Salvador, 2017

A few authors have tried to provide theoretical foundations for different areas related to RL by employing organisational theories, presented in the table 2.23.

Table 2. 22 Relevant theories in RL

Theories	Description	Relevance to RL	Studies that used/suggested these theories in RL
Sustainability theory John Elkington, 1994	Sustainability, as defined by its 'triple-bottom line' factors of economic, environmental, and social dimensions, to develop and apply a strategic justification tool with sustainability implications	Changes in organisations for RL practice in terms of economic, environmental and social impact.	Sarkis et al., 2010
Resource-based view (Barney, 1991)	Competitive advantage may be sustained by connecting resources including knowledge that is valuable, rare, imperfectly imitable, and non-substitutable	Relationship between RL innovation and environmental and economic performance	Huang & Yang 2014; Karia, et al., 2014; David & Shalle, 2014
Institutional theory (DiMaggio and Powell, 1983)	External pressures (coercive, mimetic and normative) can influence organisational actions	Effects of institutional pressures on organizational position towards RL implementation	Huang & Yang, 2014; Ye et al., 2013; David & Shalle, 2014; Shaharudin,et al., 2015; Vlachos 2016
Stakeholder theory (Freeman, 1984)	Firms do have the responsibility to ensure their activities meet the expectations of its various stakeholders, that are both internal and external to the firm	How companies create value and trade with each other in RL	Álvarez-Gil et al., 2006
Transaction cost economics (Williamson, 1981)	Transaction cost economics focuses on how much effort and cost is required for two entities, buyer and seller, to complete an activity (economic exchange or transaction	RL capabilities impact on firm performance	Vlachos, 2016
Resource-dependence theory (Pfeffer and Salancik, 1978).	In the supply chain, firms are dependent on resources provided by others to sustain growth, as well as other organisations that may be dependent on them	How firms and other organisations rely on each other's resources	Hakansson, Snehota, 1978

Source: Huang & Yang, 2014; Ye et al., 2013; David & Shalle, 2014; Shaharudin, et al., 2015; Vlachos 2016

The resource-based view (RBV) has become one of the most important and quoted theories in the record of management theorising. It aims to illustrate the internal sources of a firm's sustained competitive advantage. The main concern of this theory is to achieve sustained competitive advantage - a business has to obtain and control valuable, rare, inimitable, and organised (VRIO) resources and capabilities (Barney, et al. 2001). For reverse logistics practice, Resource Base View (RBV) theory has been applied to examine the relationship between RL innovation and environmental and economic performance to see how RL could bring sustainable competitive advantage for businesses by an organized resource flow (Huang & Yang, 2014).

Recently, there has been some attention on using Institutional Theory in RL (Ye, et al., 2013; David & Shalle, 2014; Shaharudin, et al., 2015; Vlachos, 2016) to show the effects of institutional pressures on organisational position towards RL implementation. Also, Transaction Cost Economy (TCE) theory is found in current RL studies used to examine the impact of RL capabilities on firm performance and mediating role of logistics strategies (Vlachos, 2016).

Stakeholder theory is a theory of organisational management and business ethics that addresses morals and values in managing an organisation. It was originally detailed by R. Edward Freeman, (1984) in the book Strategic Management: A Stakeholder Approach. It identifies and models the groups which are stakeholders of a corporation, and both describes and recommends methods by which management can give due regard to the interests of those groups. In the traditional view of a company, the shareholder view, only the owners or shareholders of the company are important, and the company has a binding fiduciary duty to put their needs first, to increase value for them. Stakeholder theory instead argues that there are other parties involved, including employees, customers, suppliers, financiers, communities, governmental bodies, political groups, trade associations, and trade unions. Even competitors are sometimes counted as stakeholders – their status being derived from their capacity to affect the firm and its stakeholders. Stakeholder theory is used in RL to analyse how companies create value and trade with each other in RL (Álvarez-Gil et al., 2006).

Also Resource Dependency theory (Hakansson & Snehota, 1978) was used in RL to show how firms and other organisations rely on each other's resources (i.e. access to raw materials, goods, services, finance, knowledge) for their survival and success.

This clarifies that to capture the broad concept of RL practice several theories are needed to explain the themes/sub-themes. A total of six key management/organisational theories were identified from the literature including the few popular macroeconomic theories, namely resource-based & knowledge-based view, stakeholder theory, and institutional theory; and others, namely resource-dependence theory, transaction cost economics and agency theory to understand the RL concept. A brief outline of these management theories and their relevance to RL is provided in Table 2.23. At this point, it is presumed that these mentioned theories would be comprehensive enough to explain all the relevant findings of this thesis in the construction sector. If not, the thesis will further explore other potential theories including lesser known/ emerging theories outside the realm of RL. The explanatory and predictive capability of the proposed theories is expected to enhance the practical application of RL in the automotive and in other sectors generally, as well as contribute significantly towards the theoretical advancement of the field.

2.10 Chapter Summary

To summarise, this chapter began with a brief discussion of RL including its definition and importance in terms of how several authors defined it and looked at it from multiple perspectives. Then, the significant progress in RL across sectors was discussed, including RL key aspects: return reason (what and why), return nature (what and how), return process (how), players involved (who), drivers and barriers in RL implementation (why), location related issues (where) and time related issues (when), to characterise RL issues to process return, recover value and reduce environmental issues.

The chapter then discussed the outcomes of the comprehensive (generic) review and content analysis of studies that encapsulated the main scope of RL in terms of managerially relevant RL themes/sub-themes. Before conducting the review of RL studies in the automotive industry, the chapter discussed the automotive industry in terms of its key stakeholders, features, similarities and differences with other sectors. This knowledge of the automotive industry significantly helped frame the review of RL studies in the automotive industry. The review of RL-related studies in the automotive sector was conducted in combination with the RL studies in other sectors which have seen significant progress and application in line with this study's research objectives to understand the pertinent gaps in the literature and for formulating relevant, precise and demanding research questions. Finally, the chapter discussed the rationale for choosing the UK as the exemplary research setting for conducting the investigation.

The next chapter will discuss the methodology adopted to carry out the RL investigation in the UK automotive industry.

CHAPTER 3. RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses in detail the overall research process undertaken to answer the research questions, including the methods used, their relevant explanation and justification. This chapter also describes the qualitative analysis of the data, including the practical steps involved in the analysis, evaluating whether and how the data illuminated and answered the research questions in Chapter 4, 5, 6 and 7.

Hence, this chapter has three phases.

Phase one discusses the research methodology employed for this thesis by firstly discussing the philosophical underpinnings and paradigms, research nature in reverse logistics and philosophical stance of this study. The research design for this study is then discussed alongside the associated research design issues, including the literature review process, research method (case research), population of this study, case selection and sampling, data collection location and process, pilot study, main study and data analysis process. This phase ends with the research ethics.

Phase two describes the researcher's research experience in the UK, i.e. issues that affected the researcher's data collection activities in the UK, factors that shape or affect the quality of the data, as well as the measures employed to mitigate their effect and conceptual framework of this research. This conceptual framework defines the constructs that will be used to structure the presentation of the analysis, and to generate insights from the empirical data obtained from the field study.

Phase three presents each case-category setting and the relevance for each construct analysis to answer the research questions. This clarifies how different analysis (within case, within case-category and cross case category) approaches were used to present the findings.

3.2 Research Philosophies and Paradigms

Selecting an appropriate philosophical stance is important in order to collect data in an effective and appropriate manner that relates to the development of knowledge and the nature of that knowledge with regards to particular research (Saunders et. al., 2016). Especially in business and management, researchers' philosophical commitments are very important to make sure the choice of research strategy has a significant impact on what they do, and how they understand what it is they are investigating (Johnson & Clark, 2006). It comprises critical assumptions of researcher views to determine the research strategy, design and methods for their research (Saunders et al., 2016). Epistemology and Ontology are two distinct philosophical assumptions that are most often used in the social science context (Saunders et al., 2016; Bryman, 2016).

The motivation of Epistemology is directing on the researcher's view regarding acceptable, valid and legitimate knowledge in the discipline, and the way the knowledge is communicated to others to address particular social concerns (Bryman & Bell, 2015; Bryman, 2016; Saunders et al., 2016). On the other hand, ontological assumptions shape the way in which the researcher studies research objects include organisations, management and individuals (Saunders et al., 2016; Bryman, 2016).

These philosophical positions can be represented in three important paradigms that are commonly adopted in business research: positivism, interpretivism and pragmatism (Creswell, 2013; Saunders et al., 2016; Bryman & Bell, 2015). Positivism involves a belief based on the assumption which encourages the use of natural sciences methods in management research, which can be confirmed by the senses, measured and generalised (Denscombe, 2008). This therefore, is preferable for observable social reality research (Welman et al., 2005). Quantitative research methods, therefore, are considered to be positivist in approach, characterised by a numerical orientation and emphasis on the measurement and analysis of causal relationships (Saunders et al., 2016). Interpretivism is the opposite of positivism.

Interpretivism holds the view that the social world cannot be understood by applying research principles adopted from the natural sciences (Gephart, 1999), as natural science is concerned with experimental matter, while social science is concerned with the subject matter (Bryman, 2016). Qualitative research methods, such as interviews, case studies and focus groups are considered as the interpretivist view. Pragmatism emerged from the paradigm war of positivism versus interpretivism (Tashakkori & Teddlie, 1998). This paradigm is used when a problem is not sufficient to understand with either a positivist or interpretivist approach, where indeed both approaches may help for better understanding (Morgan, 2014). Now, before deciding on the appropriate research philosophy and paradigm to effectively answer the research questions, the nature of research in previous RL studies should be critically evaluated to guide in making the right choice for this research. The next section discusses the nature of research in previous RL studies.

3.3 Research nature in reverse logistics

Rubio et al.'s (2008) research findings regarding research natures in RL show that research on 'management of the recovery and distribution of return products' is characterised by both quantitative and qualitative research techniques i.e., mathematical models and case study/interview. All the studies consider for RL key aspect captured in appendix 1 and appendix 2 also enable to understand the nature of RL research. Further, Wang et al.'s (2017) analysis and Salvador's (2017) analysis identified that 22% of RL articles analysed did not discuss research methodology and from the rest, the majority of studies employed case study and interview-based research methodology, which is about 33% and the remainder by survey (14%), literature review (9%), analytical method (8%), questionnaire (7%), content analysis (3%) and mathematical model (4%). These suggest that most of the research methods employed in RL research are qualitative (interpretivist) in nature.

These statements are also supported by Dunn et al. (1993), Näslund (2002), and Sachan and Datta (2005), as their findings confirmed the dominance of qualitative (interpretivist) research methods in logistics. This study also employed the qualitative (interpretivist) research methods, as this research's key research questions are mostly the "how" and "why" perspective (Sachan & Datta 2005).

3.4 Philosophical stance of this thesis

The nature of the research in previous studies and the nature of the research questions posited in this study determined the philosophical stance of this thesis. An epistemological position and an interpretivist approach to research are considered in this thesis.

The reason for choosing an epistemological position is because this study is attempting to extend the knowledge of RL in the automotive industry and in general. The interpretivist approach is chosen because this could well explain the recent trend in the literature as seen in the previous section. Also, the nature of the research questions proposed in this study such as 'what', 'why', 'how', 'why' and 'why not' mandates the use of qualitative methods, as these questions respectively require detailed qualitative information with greater emphasis on human behaviour and its role in the research context to explain the social phenomenon (Yin, 2003; Saunders et al., 2016). Therefore, the interpretivist approach seems to be the right approach for conducting the research proposed in this thesis. The next section discusses in detail the research design this thesis adopted.

3.5 Research design

A research design refers to the basic strategy of research, and the reason behind it, that will make it possible and effective to gain comprehensive conclusions from it (Oppenheim, 2000). A good research design allows the researcher to gain a clear understanding from data in terms of simplification, association, and connection (Oppenheim,2000). Therefore, the research design for this thesis is focused on making the RQs researchable, by setting up the study and method of investigation in a way that produces specific answer to each of the RQs.

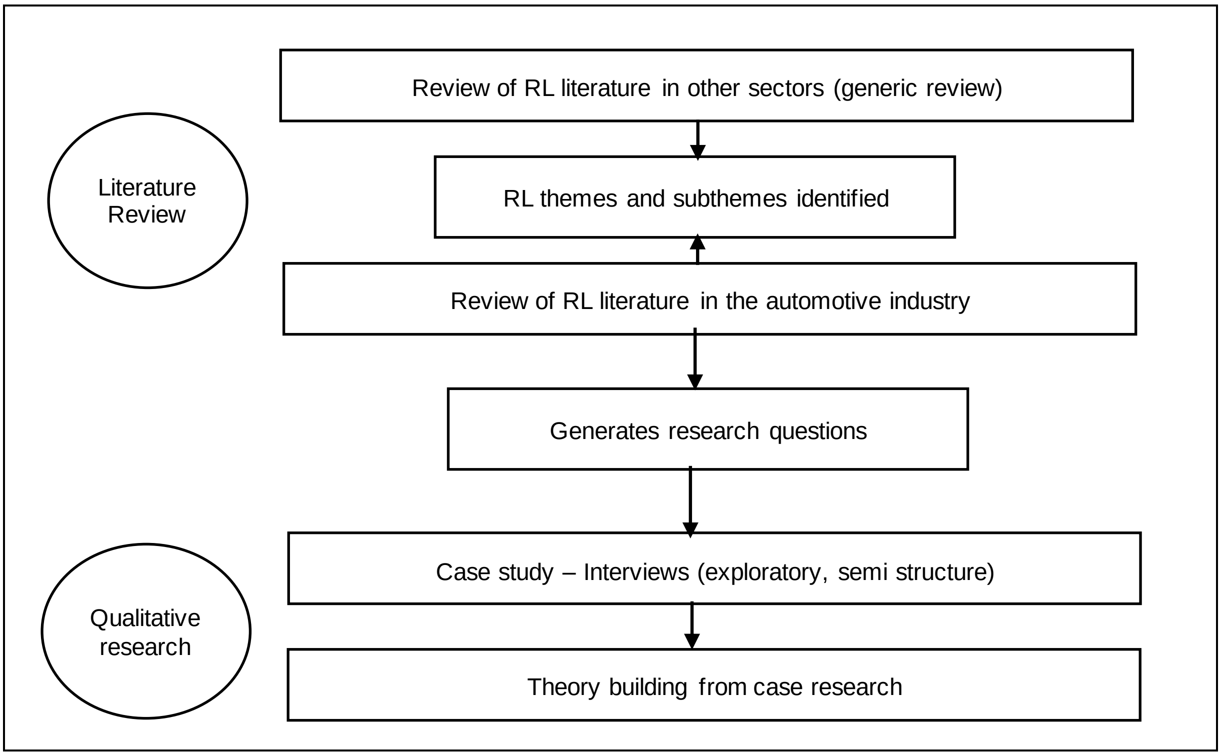
The first methodological choice in a research design is to decide on whether to follow a qualitative, quantitative or mixed methods design and this decision mainly depends on the research questions and research philosophy (Saunders et al., 2016). The research questions nature for this study were proposed in chapter 2 and the interpretivist approach discussed in the above section permits the use of the qualitative research method. Now, to answer the proposed research questions, such as what are…, how do…, why…, permits the use of sequential exploratory research design.

Figure 3.1 illustrates the sequential exploratory research design adopted in this thesis including the different methods used to collect and analyse data.

As seen in figure 3.1, a comprehensive review and critical interpretation of the literature was carried out first to define the RL themes/sub-themes and to formulate the important research questions based on the pertinent gaps in the literature (discussed in chapter 2). With regards

to the qualitative phase, as seen in the figure, the multiple case research method was used in this study where the qualitative data was collected using interviews.
Semi-structured exploratory interviews were carried out to explore and define each RL themes/sub themes identified in the literature. The collected data were analysed and categorised as per the RL themes and sub-themes. Interviews were an important part of this research because they contributed to the overall research in multiple ways. Firstly, interviews largely contributed to the findings by answering the research questions. Secondly, they helped to understand themes/sub-themes at the operational/implementation level with more focused and in-depth interviews. Further, the findings of the case research were used to develop theory (Eisenhardt, 1989). Detail clarification of research design is discussed below.

Figure 3. 1 Research design used in this thesis



3.4.1 Literature review process

The literature review process is an investigation of the current state of theory and research relating to the researcher's field of interest that outlines what is already known/unknown and that frames and validates the research questions (Bryman,2016). Saunders et al. (2002) also explains that the literature review is the foundation of most research.

In this thesis, the literature review was conducted in two phases. In the first phase, a critical assessment of RL studies across all sectors (referred to as generic review), was carried out and in the second phase, a critical assessment of RL related studies in automotive industry that mainly looked at RL key aspects found in the phase one. In the first phase, the study conducted a comprehensive review of existing literature in RL to conceptualise its main themes, sub-themes and their interrelationships.

In the first phase of review, the study was able to conceptualise the key RL themes, sub-themes that influence RL practice. The generic review identified a wide range of studies focusing on reverse logistics key aspects where only three main studies only focused on the RL key aspects generically, in the second phase considerable attention was found in RL practice related studies but none of the studies focused on RL key aspects related studies that explored the relevant, but isolated RL aspects of in the automotive industry. The knowledge gained from first phase helped in the second phase of the literature search process as well as in delineating the relevant gaps in the auto industry which led to validating research questions for this study.

3.5.2 Research Method (Multiple Case-Research)

The objective of this study is to explore EoL car RL practices among a sample of the car manufacturing sector — recycling sector players in the UK automotive industry. This also includes other sectors including government agencies and local authorities, as they are involved with the EoL car RL process in the UK. The goal is to develop an empirically informed and theoretical knowledge of RL from the UK automotive perspective, as well as to suggest improvement opportunities where possible. Thus, this research is exploratory in nature. As a result, the multiple case research design is considered a very important concept in this thesis, as a multiple case research method represents replications that enable the development of a rich, theoretical framework.

A case research methodology is appropriate for the present study as it provides depth and insight into a little-known phenomenon (Ellram, 1996). There are several options available in conducting case research such as the number of cases to be used, case selection, and sampling (Voss et al., 2002). Hence, case studies can involve single or multiple cases (Rowley, 2002). Single or multiple case studies can be used to describe a phenomenon, or predict outcomes based upon past occurrences in similar cases. However, the more cases that can be marshalled to establish or refute a theory, the more robust are the research outcomes (Rowley, 2002). Depending on resource availability, fewer or single case research presents greater opportunity for depth of observation, but the shortcoming is the limited generalisability of the conclusions, models or theory developed from single case research (Voss et al., 2002). Furthermore, single case research includes the risk of misjudging a single event and exaggerating easily available data (Voss et al., 2002). Although risks exist in all case research, they are somewhat mitigated when events and data are compared across multiple cases (Voss et al., 2002).

Multiple case research augments external validity and helps guard against observer bias (Voss et al., 2002). It is, however, argued that the depth of multiple cases may be reduced but this will only occur when research resources are constrained (Voss et al., 2002). Nevertheless, multiple case research is applicable to either predict similar results among replications, or to show contrasting results, but for predictable, explainable reasons (Ellram, 1996). Hence, multiple case design is the preferred method for this thesis. The decision to adopt a multiple case research method for this study was also influenced by the primary purpose of this research, which is to explore the EoL car RL practice in the UK by studying the key perspective RL to generate an empirically informed and theoretically grounded findings.

3.5.2.1 Theory building from case research

Case research can be used to test theory or to develop theory (Eisenhardt, 1989). A more common application of a case study research is to build theory, which can then be tested using further case studies, survey data, or another relevant method (Ellram, 1996). The focus of this thesis is to explore EoL car RL practices from the UK automotive industry perspective; generating insight by way of detailed description and establish knowledge of the phenomenon using evidences from multiple case studies.

Preferably, theory building research should start as close as possible to the idea of no theory under consideration and no hypothesis to test but it is impossible to achieve this idea of a clean theoretical slate (Eisenhardt, 1989). However, attempting to approach this idea is important because preordained theoretical perspectives or propositions may be bias and limit findings. In theory-building research, no matter how inductive the approach may be, a prior view of general constructs or categories of the research area, and their relationship, is required (Voss et al., 2002). Hence, this study identified the research area, established the research problem, and identified important variable/constructs with reference to existing theories and literatures. This approach can help to validate EoL car RL practice constructs. This itself is a significant research contribution given that construct development and validation is at the heart of theory building (Venkatraman 1989) and the study significantly contributes towards the theoretical advancement of RL practice. Also, several established / emerging management / organisational theories that offer a reasonable basis to explain the behaviour of players in implementing EoL car RL practices are discussed. These include, resource and knowledge-based views, resource-dependence theory, stakeholder theory, agency theory and institutional theory.

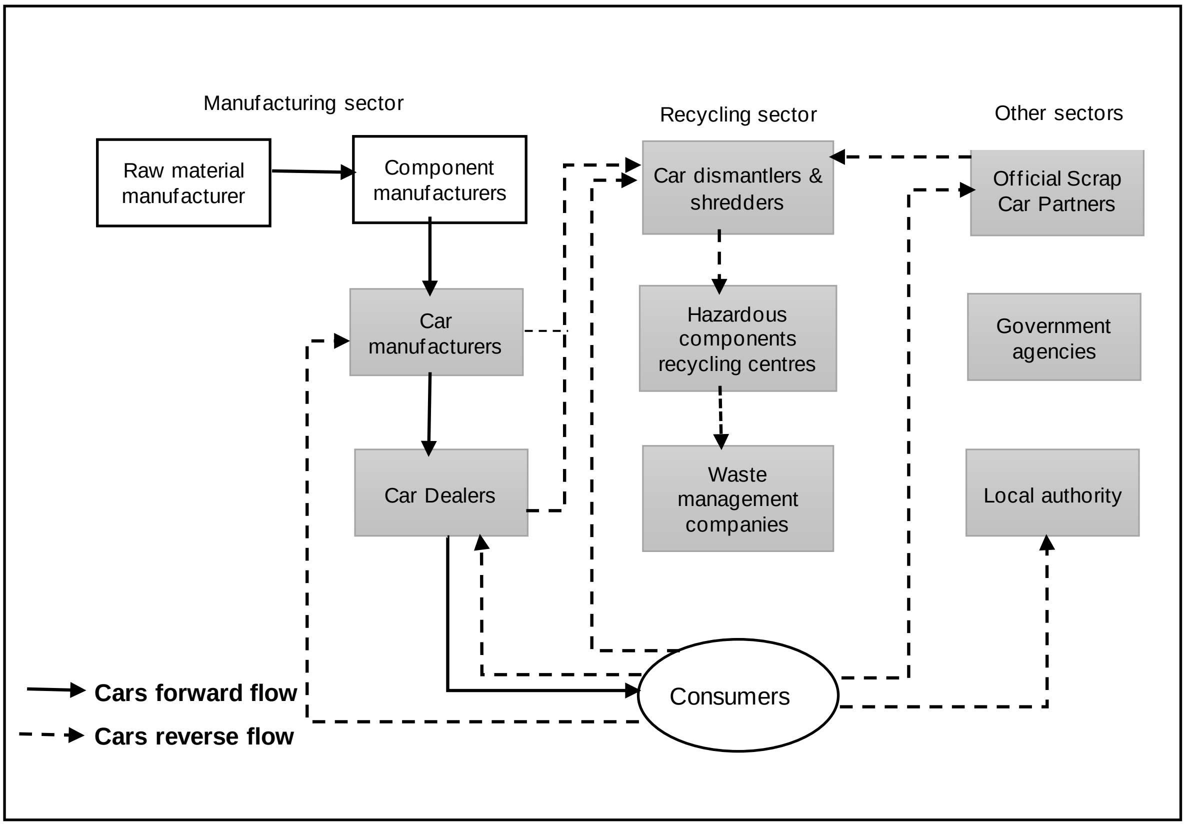
Overall, multiple cases within each players group allow replicability of findings obtained from each type of players. The purposeful and diverse sampling allows the domain of the research to be specified and increases the generalisability of the research findings. This facilitates theory building and insight across the various types of players in the manufacturing, recycling and other sectors of the UK automotive industry involved with the EoL car RL process.

3.5.3 Population for this study

As discussed earlier, the industry of this study is UK automotive industry. The UK automotive industry contains multi sector engagement in their RL practice which is divided in this research, namely the car manufacturing sector, car recycling sectors and others. The car manufacturing sector's key players are mainly raw material manufacturers, component manufacturers and car manufacturing; and car dismantlers and waste management companies are the key players in the recycling sector. In addition to these players, another category name, Official Scrap Car Partner, is also found to be a player type in the automotive industry specially involved in RL management as a membership body for auto industry players who are involved with RL practice. Apart from this, government agencies and local councils also found involved in automotive industry RL process.

This study focuses mainly on the players who are the key responsible companies for EoL car RL. Thus, this thesis excludes raw material and components manufacturers from car manufacturing sector as they are not involved in RL practice for EoL cars. Those who were part of this investigation are highlighted in grey in figure 3.2.

Figure 3. 2 Different sectors involved in the UK automotive industry for RL practice and players (highlighted) consider for this study



3.5.4 Case selection and sampling

There are two approaches to sampling in qualitative research, namely probability and non-probability sampling (Bryman, 2016). The selection of sampling depand on the nature of the answers being required in answering the research questions (Bryman, 2016). In this thesis, it was necessary to be selective in recruiting professionals so that they represented all the key stakeholders in the supply chain (car manufacturers and car recyclers) as well as the others (Consumers, Official Scrap Car Partners, Government agencies and local councils). Therefore, a form of non-probability sampling was chosen for this study. The goal of no-probability sampling is to sample cases / participants strategically so that those sampled are relevant to the research questions that are posed.

In terms of the strategy used to recruit participants, a sequential sampling strategy was used (Teddlie & Yu, 2007). In this strategy, sampling is an evolving process in which the researcher usually begins with an initial sample and gradually adds to the sample till the goals of the research are met. First, based on the qualifying criteria, in total sixty company were personally contacted by email, telephone and by post. These companies are in London, Luton, Oxford, Liverpool, Birmingham and Kent and Leeds, as these were at a convenient distance. Other cities further away were not considered due to distance, accessibility, time limitations, and travel cost issues. In the end, the case qualification operations produced a list of twenty-one companies that expressed willingness to participate in the research are presented in the table 3.1.

Table 3. 1 Twenty-one case settings

Case number	Case companies	Stakeholder Type	Origin of Brand	Partnership	Product/service type
C1	CMA	Car manufacturers	Japan	-	Car making, selling and financing
C2	CMB	Car manufacturers	German	-	Car making, selling and financing
C3	CMC	Car manufacturers	UK	-	Car making, selling and financing
C4	CMD	Car manufacturers	US	-	Car making, selling and financing
C5	CDA	Car Dealers	Japan	CMA dealers	Car selling and financing
C6	CDB	Car Dealers	German	CMB dealers	Car selling and financing
C7	CDC	Car Dealers	UK	CMC dealers	Car selling and financing
C8	CDD	Car Dealers	US	CMD dealers	Car selling and financing
C9	OSCPA	Official scrap car partners	UK	CMA, CMB, CME – partner	Managing EoL car RL
C10	OSCPB	Official scrap car partners	UK	CMC, CMD, CMF - partner	Managing EoL car RL
C11	ATFA	Car Dismantlers	UK	OSCPA	Dismantle and sell all CM's used cars and parts
C12	ATFB	Car Dismantlers	UK	OSCPA	Dismantle and sell all CM's used cars and parts
C13	ATFC	Car Dismantlers and shredders	UK	OSCPB	Dismantle and sell all CM's used cars, parts and recovered materials
C14	ATFD	Car Dismantlers and shredders	UK	OSCPB	Dismantle and sell all CM's used cars, parts and recovered materials
C15	HRCA	Hazardous recycling centers	UK	ATFA, ATFC	Car fluid recycling company
C16	HRCB	Hazardous recycling centers	UK	ATFD, ATFB	Car fluid, battery, airbags and other hazardous components recycling company
C17	WMCA	Waste management company	UK	OSCPA & OSCPB	Deals with all hazardous and non-hazardous waste disposal
C18	WMCB	Waste management company	UK	OSCPA & OSCPB	Deals with all hazardous and non-hazardous waste disposal
C19	GAA	Regulation body	UK	N/A	Acts as an operating authority, a regulatory authority and a license authority
C20	LCA	Source of EoL cars	UK	-	

C21	LCB	Source of EoL cars	UK	-	Local authorities are responsible for waste collection services, disposal, enforcing waste legislation, encouraging good waste management in their areas.

Source: Author

The respondents selected for this study were mainly involved and experienced with the RL process operation for EoL cars. Table 3.2 depicts the eight case-category in terms of stakeholders type investigated in this study, respondents, location etc. The respondents were purposefully selected, as they were involved in the RL operation for the company. Managers (inbound & outbound logistics), Assistant managers (inbound & outbound logistics), Area Managers and Operation Managers, Heads of Aftersales and Aftersales Managers were selected because they are involved in dealing with return EoL cars in terms of collection, redistribution, resale, storage and disposal. Heads of partnerships, and relationship and carrier managers were selected because they are involved with managing the relationships between players to process EoL car RL activities. Managers of Regulatory Affairs, Environmental technicians, Compliance officers and Responsible officers were selected in order to gain insight from a regulatory perspective. The IT and financial managers were selected in order to identify the use of technology and financial accountability for the EoL cars RL process. Site managers and supervisors, recycling operatives, recycling centre attendants, Project coordinators (hazardous waste), Project Engineers (Waste Management) and Operation specialists (landfill) were selected to gain insight knowledge of each stage of the EoL car RL process. Hence the respondents were not only purposefully selected but are also diversely selected.

Table 3. 2 Case-catagories for this research

Number	Case Category	Number of cases	Cases	Interview number	Respondents	Location	Time for each interview	Other source of data
1	Car manufacturers (CM)	4	CMA	3	Head of partnership (supply chain), Logistic Manager (inbound& outbound logistics), Area Manager and Operation Manager.	Derbyshire	40minuts - 1houre	Annual reports and newsletters
			CMB	3	IT manager, Financial Manager, logistics manager,	Oxford	45 minutes – 1 hour	Annual reports
			CMC	2	Head of Aftersales Administrator, Operation Manger.	Birmingham	40minuts - 1houre	Quality assurance reports received from regularly body
			CMD	4	Technical Project Co-ordinator (Automotive), head of aftersales, Operation Manager, IT Manager.	Birmingham	40minuts - 1houre	-
2	Car Dealers (CD)	4	CDA	1	Office Manager	Kent	40 minutes	Annual reports
			CDB	1	Service Technician	London	1 hour	
			CDC	1	Dealership IT specialist	London	1 hour	-
			CDD	1	Business Development Representative	Leeds	1 hour	-
3	Official Scrape Car Company (OSCP)	2	OSCPA	3	Waste and recycling project support manager, waste operative, Maintenance manager	Coventry	1 hour	-
			OSCPA	3	Environmental and community coordinator, Operation manager, Relationship and carrier manager	Liverpool	1 hour	-
4	Authorised treatment facilities (ATF)	4	ATFA	2	Chief Operating Officer, Responsible officer	Kent	1 hour	Compliance reports submitted to regulatory body
			ATFB	2	Coordinator (collection and assessment), Operation Manager	London	1 hour	-
			ATFC	3	Customer service representative, Operation specialist, Finance manager	Leeds	1 hour	Quality assurance reports received from regulatory body
			ATFD	2	Administrative support associate, Head of operation	London	45 minutes -1 hour	-

5	Hazardous Recycling centre (HRC)	2	HRCA	2	Plant operator, Technical support manager	Cambridge	1 hour	-
			HRCB	4	Head of Operation, Transpiration Manager, Hazardous Waste Project Specialist, Waste Operation Manager	London	40 min – 1 hour	-
6	Waste management Companies (WMC)	2	WMCA	2	Operation Manager, Landfill operative manager	Kent	1 hour	-
			WMCB	2	Operation specialist (landfill), Waste Contract Manager	Kent	1 hour	External Audit report
7	Government agency	1	GAA	1	The Agency acts as an operating authority, a regulatory authority and a license authority.	Bristol	45 min	-
8	Local Councils (LC)	2	LAA	1	Area Team leader	London	1 hour	-
			LAB	1	Planning support officer	Kent	1 hour	-

Source: Author

Now the detail of the qualitative research, how the data was collected and analysed, is discussed.

3.5.5 Data Collection and research instruments

3.5.5.1 Data collection locations

The UK has one of the most capable and fast-growing automotive markets in Europe. For the purpose of this study, car manufacturing, recycling and other sectors, including government agencies and local authorities' companies operating in London, Luton, Oxford, Liverpool, Birmingham and Kent and Leeds were visited. According to Vehicle Licensing Statistics 2018 from the government portal in UK about 42 million cars are registered and from them about 38 million cars are registered in England where these cities (London, Luton, Oxford, Liverpool, Birmingham and Kent and Leeds) are the largest cities with busy business areas for the automotive industry. These attributes and the importance of these cities in the UK make them appropriate locations to conduct this study.

3.5.5.1 Data collection process

Case studies typically combine data collection methods such as archives, interviews, questionnaires, and observation (Eisenhardt, 1989). This thesis employed the interview method to collect qualitative data from multiple automotive supply chain stakeholders who are involved with EoL car RL process. Further, wherever accessible, company documents including annual reports, newsletters, internal performance/audit reports (compliance reports submitted to regulatory body and quality assurance reports received from regularly body) were also sought to complement the interview findings to improve the data quality and reliability of the research. The advantage of using interview in this case study research is that it offers the researcher possibilities of modifying the line of inquiry, following up an interesting response and investigating underlying motives in a way that postal and other self-administered questionnaires cannot (Robson, 2002). Bias in interview is a concern which is difficult to rule out in interview methods. To mitigate the effect of these shortcomings, a high degree of professionalism of the researcher is followed (Robson, 2002). Nevertheless, interview has the potential of providing rich and highly illuminating material (Robson, 2002) which is a major reason for its appropriateness for this exploratory study. Interviewing can be time-consuming; anything under half an hour is unlikely to be valuable while anything going over an hour may be making unreasonable demands on busy interviewees (Robson, 2002). To prevent this issue, the interview sessions for this study took about forty minutes to an hour. According to Saunders et al. (2012), the nature of an interview should be consistent with the RQ(s) and objectives, the purpose of the research and the research strategy. One typology of categorising interviews is the level of formality and structure. Hence, interviews can be structured, semi-structured or unstructured (in-depth). The semi-structured interview data collection technique was employed in this study as it suited the interpretivist nature of enquiry; it provides a deeper understanding of issues, structures, processes, and policies that permeate participants' stories, hence, giving a fuller appreciation of the complexities and difficulties of change (Brashear et al., 2012). Semi-structured interview is widely used in flexible designs, either as the sole method or in combination with others (Robson, 2002). Semi-structured interviews are associated with the phenomenological paradigm, and qualitative methodology. This is because the questions are likely to be open-ended and probe to explore the research topic in some depth (Collis & Hussey, 2003).

Therefore, the semi-structured interviews performed at each of the twenty-one-case research organisations were guided by the interview guide presented in table 3.3, which helped facilitate the reliability of the qualitative data collected. The semi-structured interviews were conducted face-to-face at the office of the respondent. Further follow up interviews for clarifications were conducted by telephone and some of them also face to face. Face-to-face and telephone semi-structured interviews were done complementarily, as some information not captured during the face-to-face interview was captured in the follow-up telephone conversation with the respondents.

3.5.6 Pilot study

Prior to the actual interview, the interview questions were first pilot tested for validity and reliability. According to Saunders et al (2012), "a pilot test is a small-scale study to test a questionnaire, interview checklist or observation schedule, to minimise the likelihood or respondents having problems in answering the questions and of data recording problem as well as to allow some assessment of the questions' validity and the reliability of the data that will be collected".

In this thesis, a pilot semi-structured interview was conducted with two respondents from the car manufacturing and recycling sector who are involved with EoL car RL practice in London and Luton, which enabled further improvement of the interview questions. Academic experts in management and the RL area from researchgate, academia and linkedin were also asked to comment on the representativeness and suitability of the interview questions and positive feedback about the questions was received.

The interview questions were then pilot tested for execution issues, time taken to complete the interview, typos, content validation, and elimination or rephrasing of questions which produced undesirable responses. At the end of the pilot-test, the feedback was reviewed; typos were corrected, and questions were restated in order to obtain a more accurate account of these phenomena in practice.

3.5.7 Main study

The set of documents constructed for the semi-structured interview are open questions which impose no restrictions on the content or manner of the reply, other than the subject area. Hence, open-ended questions were designed for this interview. According to Robson (2002), open-ended questions are flexible; facilitating more depth and understanding of the subject area. Open-ended questions enable the testing of the limit of the respondent 's knowledge. Open-ended questions also encourage co-operation, and rapport between the interviewer and the interviewee. This facilitates a more accurate assessment of the respondent's view. The disadvantage, however, lies in the possibilities of the interviewer losing control, which can make interview data more difficult to analyse when compared with data obtained from closed questions.

To avoid this problem, this research adopted a pre-structured case outline in developing the interview guide. The pre-structured case is an excellent way to deal with the recurrent problem of data overload in qualitative studies (Miles & Huberman, 1994); it makes it easy for the respondents to review the report for accuracy and for the researcher to locate the data related to a particular issue across all cases (Ellram, 1996). This semi-structured interview guide was used as a standard format for all the cases in this study. A copy of the semi-structured interview guide is presented in Appendix Five of this thesis.

In order to enhance the depth of the data collected, prompt and probe questions were used. A probe is a trick to get an interviewee to expand on a response when an interviewer perceives that they have more to give (Robson, 2002). It is a term used to describe a follow-up question, after the respondent has given a first answer to the main question (Oppenheim, 1992). This formula was employed in developing the interview questions for this study.

The questions in the semi-structured interview guide were structured under six major headings: The background of the organisation, especially in terms of RL practice, their involvement with the EoL car RL process; EoL car return reasons and nature details, EoL car RL process with detailed activities with sub questions such as use of workforce, equipment, technology, finance and also location and time related issues and impact of these activities on RL, and how the practices can be improved; players involved and their relationships including all the flows such as information, product and monetary flow and drivers and barriers in RL practice. In conducting the semi-structured interview for this study, the following sequence of activities and questions (presented in the table 3.3) was followed.

Table 3. 3 Semi structured interview protocol used in this research (adopted from Robson, 2002)

Stages	Detail
Introduction	• Interviewer Introduction • Purpose of interview • Confidentiality assurance • Permission for record and note
Warm-up	• Start with easy and non-threatening question
Main body of interview	• Asking questions assigned under different theme • Use probes and prompts
Cool-off	• Asking straightforward questions
Closure	• Closing comments • Switch off recorder and close the notebook • Thank you

Source: Author

3.5.8 Data Analysis

Ellram (1996) states that data analysis processes used in case study research may come from quantitative or qualitative disciplines, depending upon the type of data gathered (Ellram, 1996). Once data are collected, they were documented immediately and coded. Four stages followed in this research to analyse the data are;

- Data documentation
- Data reduction
- Data display and
- Conclusion drawing/verification.

3.5.8.1 Data Documentation

A detailed write up was done immediately after each site visit as suggested by Voss et al. (2002). This process helps to maximise recall, to facilitate a follow-up, and to fill gaps in the data. Documentation of the qualitative data in this study involved typing up of notes taken during the semi-structured interview, transcription of recordings, documentation of ideas, and insights that arose during or subsequent to each site visit. Also, each interviewee was presented with a draft copy of the interview report to review for amendment where necessary. After a full transcription (audio recording and field notes), documentation, review of the semi-structured interviews data from the audio recordings and the field notes, the next line of action to analyse the data is data reduction, discussed below.

3.5.8.2. Data Reduction

The collected information was organised into codes to achieve data reduction (Miles & Huberman, 1994). Coding helped here to organise the raw data into conceptual categories. The data coding approach employed in this study was similar to the open-coding method, which is step one of the three-step coding scheme suggested by Strauss and Corbin (1990): step one is open coding, step two is axial coding and step three is selective coding. Open coding is a method used to break down case study data in order to analyse, conceptualise, and develop categories for the data (Ellram, 1996). With open coding in this study, the empirical data from cases were systematically broken down, examined, coded and categorised. Axial coding is a set of techniques that makes connections among categories developed in open coding (Ellram, 1996). The objective of axial coding is to regroup, and link categories into each other in a rational manner (Voss et al., 2002). This approach focuses on interactions and conditions which help provide greater insight into the data (Strauss & Corbin, 1990). Hence, axial coding was used to establish preliminary connections among each case summary per stakeholder type by reviewing each case summary, identifying similarities and differences between cases. This resulted in the conceptualisation of the empirical findings per stakeholder in the EoL car RL practice. Selective coding was the final process whereby all themes from the document of the combined participants' themes, were divided into a selected number that comprised the final presentation. This involved "examining the data, and reducing it to a small, manageable set of themes to write into the final narrative" (de Vos, 2005).

Table 3.4 Data reduction process

Raw data		**Data reduction**			
Questions	Answer	Quote	Code	Category	Themes
Total forty - nine questions were asked during interviews are noted separately	Forty-four Respondent answers are noted from records and transcripts and looked for concepts in the text	Quotes are separated from each respondent	Concepts found in the answers are labeled to a phrase or other short sequence of the text	Several passages of the text that share the same code are categorized in order to reduce the number of different	At this stage higher-level of categorisation are catagorised to identify the major aspect (perhaps one of four of five) of the entire

				pieces of data in the analysis	analysis of the texts

Source: Author

The result of this coding process was the summaries of all the twenty-one cases, which constituted the within-case analysis of this study. Within-case analysis is defined as detailed write-ups of each case in terms of the research subject areas (Eisenhardt, 1989). Further details of the within case analytical process are discussed in phase two of this chapter.

3.5.8.3. Data display

A data display is a visual format that presents information systematically to facilitate a valid conclusion by the user (Voss et al., 2002). To draw conclusions from the mass of data, a good display of data, in the form of tables, charts, networks and other graphical formats is used in this research. The overall idea of data display of this research was to become intimately familiar with each case as a stand-alone entity, which allowed the unique patterns of each case to emerge before seeking generalisation across cases (Eisenhardt, 1989). The data reduction operation described above resulted in detailed display of twenty-one case study write-ups, which established within-case analyses. Further, as this is a multiple case research study, within case-category and cross-case category analysis were key activities in the data analysis process of this study, aimed at enhancing the validity, reliability, and generalisability of the research findings. The overall ideal of this within case-category analysis was to force the researcher to go beyond initial impression of a single case by viewing the phenomenon from multiple perspective of all the cases grouped under the same category stakeholder but it cannot be generalised across the eight categories. Hence, cross-case category analysis was required. Hence, a combination of within-case, within case-category, and cross case-category analysis of the empirical data was conducted in this study as characterised in Table 3.5.

Table 3. 5 Characteristics of within case analysis, within case-category analysis and cross category analysis

Within Case Analysis	Within Case- Category Analysis	Cross Case-Category analysis
Involves detailed case study write-ups for each site and data reduction	Involves the selection each category, searching for similarities and differences among the cases of the same category.	Involves the selection of each category, and the identification of similarities and differences across categories
Allows familiarity with each case as a stand-alone entity	Securities the tendency of making premature and false conclusion associated with information-processing biases	Securities the tendency of making premature and false conclusions about the phenomenon of study.
This process allows unique patterns of each case to emerge before cross-case generalization is reach	Establishes preliminary connections among cases of each categories	Identifies similarities and differences across categories and integrate empirical evidences into a cohesive whole.

Source: Eisenhardt, 1989; Strauss & Corbin 1990

Within case analysis allows unique patterns of each case to emerge before case-category overview scope. The process also gives the researcher a rich familiarity with each case and makes case-category analysis clear. Table 3.1 highlights the specific settings of each segment, the cases, and their respective elements, such as stakeholder type, origin of brand, partnership and product/service type. These elements were selected as each directly or indirectly influences EoL car RL practices and the strategies adopted by the cases. As showed in the Table 3.1, the twenty-one companies investigated are considered case research companies and each is coded alphabetically by using stakeholders' initials. This coding approach was employed in order to maintain the uniqueness of each case research company and to maintain the anonymity of each organisation. Hence, the first case research company was coded as CMA (Car Manufacturers A), the second was coded as CMB (Car Manufacturer B) consecutively until the twenty-one case research companies coded which end with LCB (Local Council B).

Within-case analysis involves detailed write-ups of each site in terms of the research subject areas (Eisenhardt, 1989). Hence, this process comprises detailed write-up, analysis, and presentation of the empirical findings. Write-ups from each of the twenty-eight cases allows to identify the unique patterns of each case with further feed into case-category generalisation. Utilising the findings from each within-case analysis of each case, chapter 4, 5, 6 and 7 presents consistence within a general overview of each aspects findings which is then followed by within case-category analysis and cross case category analysis for each aspect to answer RQs 1, 2 , 3 and 4.

On the other hand, within case-category analysis was conducted to counter the tendency of making premature and false conclusions associated with information-processing biases.

Hence, the within case-category analysis involved selecting each category one by one, searching for similarities and differences among the cases categorised under each category. The cross case-category analysis involved the selection of each category, and the identification of similarities and differences across the categories of the automotive industry stakeholders from different sectors. Details of each case category settings and their implications for each construct (presented in the table 3.6) were employed to answer research questions in this research are discussed in the phase three.

3.6 Research Ethics

In order to gain clearance to conduct the research, several ethical concerns had to be considered that impacted the research methods and design.

Firstly, the study is conducted in accordance with Middlesex University Ethical Code of Practice for Research (for further information, please refer:

http://unihub.mdx.ac.uk/study/research_Ethics/index.aspx).

In addition, participants were assured that interviews would last no longer that one hour, restricting the time available to question and probe participants.

Secondly, informed consent was required, which was supplied via the information sheets and consent forms, examples of which can be found in ***Appendix E*** and *Appendix F*. Participants were also given the option of not answering questions and of withdrawing from the research at any time. No participants declined to answer any questions, although several participants who initially agreed to take part, withdrew. Finally, participants were offered anonymity, both for themselves and the organisations through which they were employed. Blanket anonymity was required, as certain examples came from different industry sectors, where the identification of one organisation would permit the identification, through elimination, of other organisations. Although blanket anonymity meant that examples could not be identified, it did provide a reassurance to certain participants, which may have boosted participation rates. This ethical practice explains how well this research formulates, in terms of research, designs a research and gains access to data, collects data, processes and store data, analyses data and writes up the research findings in a moral and responsible way (Saunders et al., 2012). In this study, the researcher ensured that the research design employed is methodologically sound and morally defensible to all those involved. Therefore, the following guidelines were followed to ensure that the overall research operation followed ethical considerations;

- Obtain and adhere to the University ethics guidelines set for the conduct of research
- Ensure the consent form is submitted to the university research ethics committee
- Recognise the voluntary nature of participants and the right to withdraw partially or completely from the process
- Inform the interviewee about the purpose and nature of the research
- Interviewees were requested to propose the interview date and time according to their convenience and availability
- Ensure that the interview guide was sent before the actual interview
- Obtain interviewee's permission for recording for the purpose of ensuring the interviewee's meanings and comments are properly interpreted
- Advise interviewee of their right to turn off the recorder at any time
- Assure confidentiality of data provided by interviewees and anonymity of any attributed comments
- The interview transcripts were sent to the respondents for two purposes, first, to validate that the interviewer had understood them correctly and second, in case they wanted to change anything from a confidentiality perspective
- Present interviewee with draft copy of the interview report for review and amendment where necessary.

Phase Two

3.7 Research experience in the UK

Phase one above discussed and justified the methodological approach employed in data collection, documentation, reduction, display, and analysis for this study. This phase discusses the research experience, introducing the actual empirical study and constructs to understand EoL car RL practice in the UK.

3.7.1 Actual empirical study

This study set out to conduct semi-structured interviews with automotive industry stakeholders involved with the EoL car RL process. As shown in Table 3.2, a total of fourty-four interviews was initially secured. Twenty-one semi-structured interviews with Car Manufacturers (CM) were planned but only twelve were successfully conducted. A total of four interviews were successfully conducted from Car Dealers (CD), where twelve were targeted. From Official Scrap Car Partners, eight interviews were targeted and in the end six conducted successfully. Eighteen interviews were targeted from Authorize Treatment Facilities (ATF) but nine were conducted successfully. Interviews from Hazardous Recycling Centres (HRC) targeted eight but conducted six. From Waste Management Companies (WMC) a total four interviews were conducted but six were targeted. Four interviews were targeted from Local Councils (LC) but two were successfully conducted.

Therefore, 63% of interviews were conducted successfully from the total number of planned interviews.

Data collected from multinational companies (CM) came from more than one respondent. For other stakeholders, data came from a single respondent. The use of a single respondent might be sensible for small companies but not for large companies like car manufacturers due to the risk of bias of a single respondent. This risk was however mitigated by interviewing 4 different car manufacturers.

The data collection exercise stopped at interview number forty-four, as data capacity was achieved at this point (Data appearing repetitive). A total of thirty face-to-face semi-structured interviews were conducted, while the remaining fourteen semi-structured interviews were conducted via the telephone, skype and zoom until data capacity was achieved. The telephone skype and zoom interview method was adopted as a complementary data collection method due to time restriction and distance problems in the UK.

3.7.1 Factors hindering data collection

There are a number of factors identified as hindering data collection process in the UK:

1. Time constraint and unavailability of interviewees

Interviewees were too busy, since the interviews were scheduled during their working hours. Some of the interviewees were too busy to be interviewed during working hours while some tended to hurry during the interviews. In order to mitigate the impact of this factor, the researcher adopted the use of telephone interviews. The researcher requested the telephone numbers of the interviewees and arranged telephone-based semi-structured interviews with the interviewees at an agreed time convenient for them. This method of interview not only ensured an uninterrupted conversation but also provided a platform for follow-up questions where needed.

2. Company's policies, and protocol

Some companies do not have a policy of granting interviews, especially with interviewers. This factor also limited the number of cases that could be accessed for interviews.

3. The fear of being implicated

Some of the interviewees from the recycling sector were somehow unwilling at first to grant interviews. This attitude could be attributed to the fear of being investigated by an undercover agent from the regulatory authorities. The impact of these factors on the research activities was mitigated through proper identification of the researcher as a genuine Middlesex University research student, adequately informing the interviewees about the primary purpose of this research, reassuring them as to the confidentiality and anonymity of the research.

Having discussed the researcher's research experience in the UK, the next section re-introduces the conceptual framework adopted in this study for understanding EoL car RL practices in the UK.

3.8 Constructs employed for understanding of EoL car RL practice in the UK

The framework (table 3.6) graphically portrays the main constructs that were addressed in this study. Each construct was used to explore the empirical data obtained from the field and to structure the analysis presentations.

Theories are directly linked to constructs, and constructs provide both systemic and observational meaning (Mentzer & Kahn, 1995). This study's construct is systemic by virtue of being defined within the RL framework, and observational by virtue of its explanatory power acquired via the research questions. Hence, the constructs are operationalised i.e. empirical data were analysed and presented within the context of the constructs of the conceptual framework to address the research questions, which are discussed in the following chapters presented in table 3.6.

Table 3. 6 Constructs employed to address research questions

Construct	RQ's	Chapters	Analysis
EoL car category Reason of becoming EoL Nature of EoL car EoL car nature impact Car design impact Car design to support RL process	RQ one	Chapter 4	• Within case analysis • Within case-category (CC) analysis of return reasons and nature • Cross – case category (CC) analysis of return reason and nature
Collection of EoL cars Assessment and sorting of EoL cars Hazardous components removal Hazardous components recycling Marketable components removal Shredding and sorting Disposal of ASR waste Time related issues in EoL car RL activities Location related issues in EoL car RL activities	RQ two	Chapter 5	• Within case analysis of RL process findings • Within case-category (CC) analysis of RL process • Cross – case category (CC) analysis of RL process
Players involved in EoL car RL practice Relationship nature between players Relationship drivers Relationship barriers Relationship impact	RQ three	Chapter 6	• Within case analysis of players and their relationships findings. • Within case-category (CC) analysis of players and relationship between them • Cross – case category (CC) analysis of players and relationship between them
Drivers influencing to involve with EoL car RL practice Drivers influencing to improve EoL car RL process Barriers hindering to involved with EoL car RL practice Barriers hindering to improvement of EoL car RL process	RQ four	Chapter 7	• Within case analysis of RL drivers and barriers findings • Within case-category (CC) analysis of RL drivers and barriers • Cross – case category (CC) analysis of RL drivers and barriers

Source: Author

Now the next phase discussed each case-category setting and their implication for each construct presented in the above table (table 3.6).

Phase three

3.9 Case-category settings and their implication for each construct

3.9.1 Within case-category analysis

The within-case analysis of the twenty-one cases feeds into within case-category analysis, designed to compare similarities and differences between cases within categories. Hence, the case companies depicted in Table 3.1 are differentiated into eight different case-categories (CC) as presented in Table 3.2 which separate within case-category analyses were therefore conducted. It is important to note that this study considers within case-category analysis as the cross-case analysis of all cases categorised under the same stakeholder (category). All eight case-categories settings are presented below.

1. Case Category - one (CC1) – Car Manufacturers (CM)

Table 3.7 is organised in this section to highlight the setting of each case research company categorised as Car Manufacturers (CM); Case Category one (CC1).

The table shows the stakeholder type, origin/ of brand, and product/service type. These elements were specifically highlighted as influences on the ARL operations of each case companies.

Table 3. 7 Case category one settings

Case companies	Stakeholder Type	Origin of Brand	Product/service
CMA	Car manufacturers	Japan	Car making, selling and financing
CMB	Car manufacturers	German	Car making, selling and financing
CMC	Car manufacturers	UK	Car making, selling and financing
CMD	Car manufacturers	US	Car making, selling and financing

Source: Author

Table 3.14 presents within CC1 analysis valid for the constructs: EoL car category , Reason of becoming EoL, Nature of EoL car, Car design to support RL process to answer RQ1 which presented in chapter 4 of this thesis; Collection of EoL cars to answer RQ2, which is presented in chapter 5; Players involved in EoL car RL practice, Relationship nature between players, Relationship drivers, Relationship barriers and Relationship impact to answer RQ3, which is presented in the chapter 6; Drivers influencing to involve with EoL car RL practice, Drivers influencing to improve EoL car RL process, Barriers hindering to involved with EoL car RL practice and Barriers hindering to improvement of EoL car RL process to answer RQ4, which is presented in the chapter 7.

2. Case Category two (CC2) – Car Dealers (CD)

Table 3.8 is organised in this section to highlight the setting of each case research company categorised as Car Dealers (CD); Case Category two (CC2).

The table shows stakeholder type, dealership with CMs and product/service type. These elements were specifically highlighted as they influences the EoL car RL process operations of each case companies.

Table 3. 8 Case category two settings

Case companies	Stakeholder Type	Dealership with CM's	Product/service type
CDA	Car Dealers	CMA	Car selling and financing
CDB	Car Dealers	CMB	Car selling and financing
CDC	Car Dealers	CMC	Car selling and financing
CDD	Car Dealers	CMD	Car selling and financing

Source: Author

Table 3.14 presents within CC2 analysis valid for the constructs: EoL car category , Reason of becoming EoL, Nature of EoL car to answer RQ1, which presented in chapter 4; Collection of EoL cars to answer RQ2 which is presented in chapter 5; players involved in EoL car RL practice, Relationship nature between players, Relationship drivers, Relationship barriers and Relationship impact to

answer RQ3, which is presented in chapter 6; Drivers influencing to involve with EoL car RL practice, Drivers influencing to improve EoL car RL process, Barriers hindering to involved with EoL car RL practice and Barriers hindering to improvement of EoL car RL process to answer RQ4 which is presented in chapter 7.

3. Case category three (CC3)- Official scrap car partners (OSCP)

Table 3.9 is organised in this section to highlight the setting of each case research company categorised as Official Scrap Car Partners (OSCP); Case Category three (CC3).

The table shows the stakeholder type and partnership with CMs and product/service type. These elements were specifically highlighted, as they influence the EoL car RL process operations of each of the case companies.

Table 3. 9 Case category three settings

Case companies	Stakeholder Type	Partnership with CM's	Product/service type
OSCPA	Official scrap car partners	CMA, CMB, CME	Membership body for automotive industry players who are involved with EoL car RL process and responsible to Manage EoL car RL activities.
OSCPB	Official scrap car partners	CMC, CMD, CMF	Membership body for automotive industry players who are involved with EoL car RL process and responsible to Manage EoL car RL activities.

Source: Author

Table 3.14 presents within CC3 analysis valid for the constructs: EoL car category, Reason of becoming EoL, Nature of EoL car to answer RQ1, which presented in chapter 4; Collection of EoL cars to answer RQ2, which is presented in chapter 5; players involved in EoL car RL practice, Relationship nature between players, Relationship drivers, Relationship barriers and Relationship impact to answer RQ3, which is presented in chapter 6; Drivers influencing to involve with EoL car RL practice, Drivers influencing to improve EoL car RL process, Barriers hindering to involved with EoL car RL practice and Barriers hindering to improvement of EoL car RL process to answer RQ4 which is presented in chapter 7.

4. Case Category four (CC4) – Authorise Treatment Facilities (ATF)

Table 3.10 is organised in this section to highlight the setting of each case research company categorised as Authorise Treatment Facilities (ATF); Case Category four (CC4). The table shows the stakeholder type, partner of OSCP and product/service type.

Table 3. 10 Case category four settings

Case companies	Stakeholder Type	Partner of OSCP	Product/service type
ATFA	Dismantlers only	OSCPA & OSCPB	Dismantle and sell all CM's used cars and parts
ATFB	Dismantlers only	OSCPA & OSCPB	Dismantle and sell all CM's used cars and parts
ATFC	Dismantlers and shredders	OSCPA & OSCPB	Dismantle and sell all CM's used cars, parts and recovered materials by shredding process
ATFD	Dismantlers and shredders with ASR plant	OSCPA & OSCPB	Dismantle and sell all CM's used cars, parts and recovered materials by shredding and further ASR shredding process

Source: Author

Table 3.15 presents within CC3 analysis valid for the constructs presented in this table, as these companies are involved with almost all the activities of EoL car RL process.

5. Case category five (CC5)- Hazardous Recycling Centre (HRC)

Table 3.11 is organised in this section to highlight the setting of each case research company categorised as Hazardous Recycling Company (HRC); Case Category five (CC5).

The table shows the stakeholder type, partnership with ATF and prodcust /s ervice category.

Table 3. 11 Case category five settings

Case companies	Stakeholder Type	Partner of ATF	Product/service type
HRCA	Hazardous recycling company	ATFA, ATFC	Car fluid recycling company
HRCB	Hazardous recycling company	ATFD, ATFB	Car fluid, battery, airbags and other hazardous components recycling company

Source: Author

Table 3.15 presents within CC5 analysis valid for the constructs: 'hazardous component recycling' to answer RQ2 which is presented in chapter 5; 'players involved in EoL car RL practice', 'Relationship nature between players', 'Relationship drivers', 'Relationship barriers' and 'Relationship impact' to answer RQ3 which is presented in chapter 6; 'Drivers influencing to involve with EoL car RL practice', 'Drivers influencing to improve EoL car RL process', 'Barriers hindering to involved with EoL car RL practice' and 'Barriers hindering to improvement of EoL car RL process' to answer RQ4, which is presented in chapter 7.

6. Case category six (CC6)- Waste Management Company (WMC)

Table 3.12 is organised in this section to highlight the setting of each case research company categorised as Waste management Company (WMC); Case Category six (CC6).

The table shows the stakeholder type and partnership with the CM and product /service type.

Table 3. 12 Case category six settings

Case companies	Stakeholder Type	Partner of OSCP	Product/service type
WMCA	Waste management company	OSCPA & OSCPB	Deals with all hazardous and non-hazardous waste
WMCB	Waste management company	OSCPA & OSCPB	Deals with all hazardous and non-hazardous waste

Source: Author

Table 3.15 presents within CC6 analysis valid for the constructs: 'Disposal of ASR' to answer RQ2, which is presented in chapter 5; 'players involved in EoL car RL practice', 'Relationship nature between players', 'Relationship drivers', 'Relationship barriers' and 'Relationship impact' to answer RQ3, which is presented in chapter 6; 'Drivers influencing to involve with EoL car RL practice', 'Drivers influencing to improve EoL car RL process', 'Barriers hindering to involved with EoL car RL practice' and 'Barriers hindering to improvement of EoL car RL process' to answer RQ4, which is presented in chapter 7.

7. Case category seven (CC7)- Government Agencies (GA)

Table 3.13 is organised in this section to highlight the setting of each case research company categorised as Government Agencies (GA); Case Category seven (CC7).

The table shows the stakeholder type and product/service type.

Table 3. 13 Case category seven settings

Case companies	Stakeholder Type	Product type
GAA	Regulation body	Responsible for developing and monitoring ELV directives

Source: Author

Table 3.15 presents within CC7 analysis valid for almost all the constructs to answer RQ1, RQ2, RQ3 and RQ4, as these companies are developing and monitoring ELV directive including car design restrictions, EoL car collection to disposal process (see all the regulations in RL process for EoL cars in the UK in appendix 4).

8. **Case category eight (CC8)- Local Council (LA)**

Table 3.14 is organised in this section to highlight the setting of each case research company categorised as Local Council (LA); Case Category eight (CC8).

The table shows the stakeholder and product type.

Table 3. 14 Case category eight settings

Case companies	Stakeholder Type	Partner of OSCP	Product type

LAA	Source of EoL cars	N/A	Local authorities are responsible for waste collection services, disposal, enforcing waste legislation, encouraging good waste management in their areas.
LAB	Source of EoL cars	N/A	

Source: Author

Table 3.14 presents within CC8 analysis valid for the constructs: 'EoL car collection' and 'EoL car nature' to answer RQ2; and all aspects presented to answer RQ3 and RQ4, as these companies are involved with abandoned car collection process as sender /source of EoL car.

As mentioned before, all these within case-category analysis findings are then fed into within cross case-category analysis. Cross case category analysis settings are presented in the next section.

Table 3. 15 Case category analysis implications for each construct

Construct	Within case category analysis								Details	Cross-CC analysis	RQs	Chapters
	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8				
EoL car category	√	√	√	√	-	-	√	√	As CC1, CC2, CC3 and CC4, CC6 and CC7 involved in EoL car collection process	√		
Reason of becoming EoL	√	√	√	√	-	-	-	√	As only CC1, CC2, CC3 and CC4 involved in EoL car collection process	√		
Nature of EoL car	√	√	√	√	-	-	-	-	As only CC1, CC2, CC3 and CC4 involved in EoL car collection and further treatment (CC4) process	√		
EoL car nature impact	-	-	-	√	√	-	-	-	As only CC4 companies involved with EoL car further treatment	√		
Car design to support RL process	√	-	-	√	√	-	-	-	As CC1 only involved in car designing	-	RQ 1	Chapter 4
Collection of EoL car	√	√	√	√	-	-	√	-	As only CC1, CC2, CC3 and CC4 involved in EoL car collection process	√		
Assessment and sorting of EoL cars	-	-	-	√	-	-	-	-	As only CC4 companies involved with EoL car assessment process	-		
Hazardous components removal	√	-	-	√	-	-	√	-	As only CC4 companies involved with EoL car hazardous removal process	-		
Hazardous components recycling	-	-	-	√	√	-	√	-	As only CC4 and CC5 companies are involved with EoL car hazardous component recycling (collection to disposal)	√		
Marketable components removal	-	-	-	√	-	-	-	-	As only CC4 companies involved with EoL car marketable components removal process	-		
Shredding and sorting	-	-	-	√	-	-	-	-	As only CC4 companies involved with EoL car shredding process	-		
Disposal of ASR waste	-	-	-	√	√	√	√	-	As only CC4, CC5 and CC6 companies are involved with EoL car waste disposal process	√		
Time related issues in EoL car RL activities	√	√	√	√	√	√	√	√	As time related issues are discussed for each stage of EoL car Process			
Location related issues in EoL car RL activities	√	√	√	√	√	√	√	√	As location related issues are discussed for each stage of EoL car process		RQ 2	Chapter 5
Players involved in EoL car RL practice	-	-	-	-	-	-	-	-	Within and cross case-category analysis is not applicable here as this constructs mainly presents all the stakeholders (case-categories) involved in RL practice.	√		
Relationship nature between players	√	√	√	√	√	√	√	√	As all case-category companies were involved in EoL car RL process	√		
Relationship drivers	√	√	√	√	√	√	√	√		√		
Relationship barriers	√	√	√	√	√	√	√	√		√		
Relationship impact	√	√	√	√	√	√	√	√		√	RQ3	Chapter 6
Drivers influencing to involve with EoL car RL practice	√	√	√	√	√	√	√	√	As all case-category companies were involved in EoL car RL process	√	RQ4	Chapter 7

Drivers influencing to improve EoL car RL process	√	√	√	√	√	√	√	√		√		
Barriers hindering to involved with EoL car RL practice	√	√	√	√	√	√	√	√		√		
Barriers hindering to improvement of EoL car RL process	√	√	√	√	√	√	√	√		√		

Source: Author

3.9.2 Cross case-category settings

Table 3.16 presents an overview of the settings of all categories of stakeholders investigated including the organisational type of each category, supply-chain stakeholder type of each category, type of products, and sources. These strategic features were selected, as they shape the EoL car RL practices and strategies employed.

Table 3. 16 Cross case-category settings

Case-categories	Stakeholder Type	Origin of company	Product/service type
CC1	Car manufacturers (CM's)	Japan, German, UK and US	Car making, selling and financing
CC2	Car Dealers (CD's)	UK	Car selling and financing
CC3	Official Scrap car partners (OSCP's)	UK	Membership body for auto industry to manage RL process for EoL cars
CC4	Car Dismantlers (ATF's)	UK	Responsible for collection to disposal of EoL car RL process
CC5	Waste management companies (WMC's)	UK	Responsible for Hazardous and non-hazardous wastes recycling
CC6	Government agencies (GA'S)	UK	Regulation related to car design, manufacturing and distribution and EoL directive
CC7	Local authority (LA's)	UK	Responsible for abandoned car collection, handling and disposal

Source: Author

The table shows the varieties of products/services category dealt with, by each category, including new cars, EoL cars, parts recovered from EoL cars, materials recovered from EoL cars, membership and regulation imposing and monitoring services. The focus of this study is, however, on the exploration of EoL car RL practice related operations of EoL cars in the UK auto industry. Essentially, this table depicts some of the strategic similarities and differences among the case-category (CC) companies investigated in this study.

In terms of cross case-category implication for each construct discussed in the table 3.15 presents cross category analysis relevant almost for all the constructs employed for this research to answer RQs. However, 'assessment and sorting of EoL cars', 'hazardous components removal', 'marketable components removal', 'shredding EoL car shell' are not valid for cross case-category analysis as these constructs related activities are performed by only case-category four (CC4) companies.

3.9 Chapter Summary

Phase one of this chapter outlined the methodological approach of the research. The research aim, objectives and questions were identified in order to guide the research, followed by the establishment of a pragmatic realist methodological stance. This stance was felt most appropriate for the answering of the research problem, focusing on the attainment of answers and solutions. The research design was noted, including its various phases as well as the role of theory, both with regard to this project and qualitative research more generally. The identification of a suitable data collection technique, namely the use of semi-structured interviews, for use with a range of research participants was outlined, including the identification and recruitment procedures undertaken during the securing of the participants. Ethical considerations were also noted before the chapter outlined the data analysis techniques. These included initial coding and categorisation efforts in order to allow further meaning and understating to be gained and theory building to be undertaken. Finally, the limitations of these methods were noted, alongside efforts taken to mitigate their effects and impacts. In addition, an overview and characterisation of the data was provided. In phase two, this chapter has discussed the researcher's research experience in the UK including issues that prohibited the data collection activities, as well as measures employed in mitigating their effect. The chapter has defined the constructs and how they were used to explore the empirical data obtained from the field, and to structure the analysis presentations.

CHAPTER 4. END OF LIFE (EOL) CAR RETURN REASONS, NATURES AND ITS IMPACT

4.1 Introduction

In line with the first research question (RQ1), the objective of this chapter is to develop a comprehensive understanding of the various reasons for a car becoming EoL, including the source of EoL cars (senders) and drivers influencing them to bring the car back and the nature of EoL cars that affect different economics at different process stages. Therefore, the study will attempt to develop a comprehensive picture by integrating the findings from interviews.

Utilising the findings from each within-case analysis of each cases presented in the chapter 3, table 3.1, this chapter presents a general overview of EoL cars return reason and nature which than follow the within case-category and cross case category analysis.

Therefore, this chapter presents each relevant fact for EoL car return reasons and nature by integrating the findings from interviews from within-case analysis of each cases presented in the chapter 3 table 3.1, followed by the within case-category analysis and cross case category analysis. The case category analysis which is designed to compare similarities and differences between cases within categories. Hence, the case companies represented in Table 3.2 in chapter 3 are differentiated into eight different case-categories (CC). The eight within case-category analyses of EoL car return reasons and natures then feed into the cross-category analysis to present the similarities and difference cross case-category companies.

Any effects of organisations' brand origin (Japan/German/UK); type of activities (collecting/dismantling/shredding) and sector (manufacturing/recycling) on return reason and features are also discussed in this chapter.

However, the other RL key aspects, such as RL process in terms of the EoL car RL process in terms of how and who, location of the EoL car RL process, time related issues in the EoL car RL process; relationships between players and their impact; and drivers & barriers are discussed in chapter 5, 6 and 7.

4.2 EoL cars category and the reason for becoming EoL.

The qualitative investigation (interviews) found (as per what most respondent said) that an end-of-life (EoL) car is a specified car, which is discarded as waste because the car is at the end of its useful life. The end of useful life can be because of the age of mechanical parts, as they will not function as well as they once did, or heavy damage to the body of car, tire, wheel, electrical system, keys and alarms, engine etc., detail of these categories are discussed below. Based on interviews, cars normally reach the end of their useful lives either due to age and mileage related reason, or because of heavy damage following an accident, flood and fire or because they are abandoned. So, according to the interviews conducted, the types of EoL cars that come to the reverse logistics chain are categorised in this research as:

1. Natural EoL cars – age and mileage related
2. Unnatural EoL cars – due to heavy damage from road accident/flood/fire
3. Abandoned EoL cars – unattended cars (due to accident/breakdown/theft/leftover)

From these three categories of EoL cars, natural EoL cars constitute the highest number followed by unnatural EoL cars, then abandoned EoL cars. Figure 4.1 below presents the percentage of EoL car type. From a total of 630,000 EoL cars collected for four different car manufacturers in 2017, 52% were identified natural EoL cars, 36% unnatural and 12% abandoned.

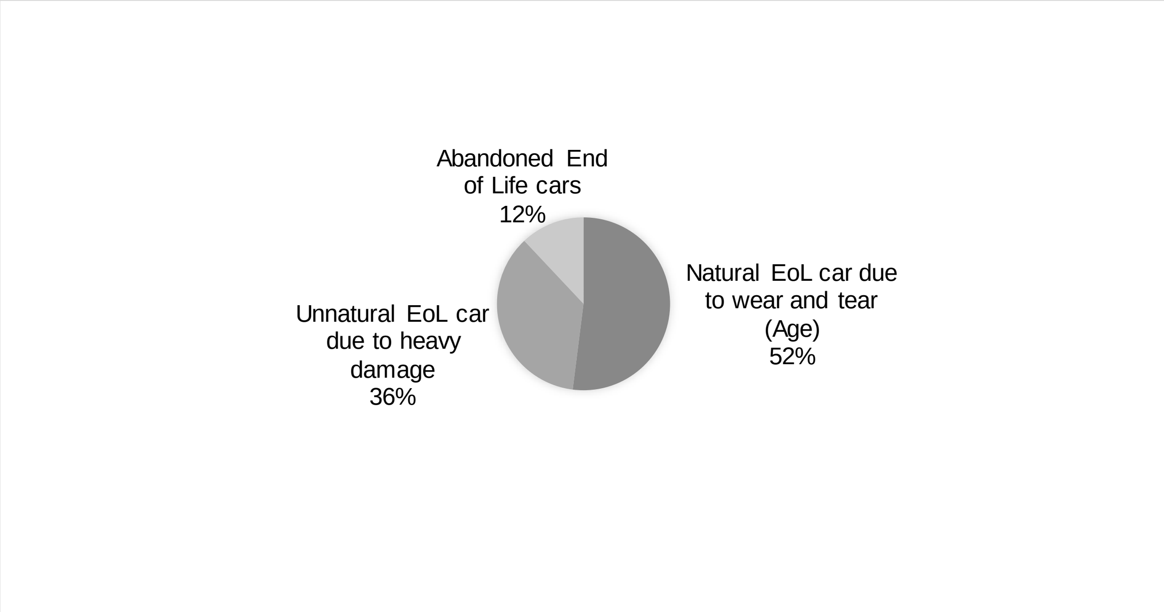


Figure 4. 1 Extent of EoL car categories

1. Natural EoL cars - Age and mileage related

Findings from all the cases mentioned above found that though there is no guidance regarding end of age and mileage of cars from their manufacturers and other stakeholders, a car aged more than 8 years and with a mileage of more than 100,000 can be considered by consumers to be near the end of its age. However, this is not directly driving customers to send the car for scrappage. When customers identify the car as consuming excess fuel or giving polluted exhaust fumes, or other mechanical problems, they normally send it to the repair/servicing centre. If the service centre identifies the car as End of useful life, this means mechanical parts have aged, they will not function as well as they once did or its not the end of useful life and still can be repaired but it may cost a lot to repair. Also, end of life can be when a car owner finds the cars need routine oil changes, tire rotations, suspension alignments or other maintenance and auto insurance policies generally will not cover these standard repairs (even if the car has comprehensive insurance, still mechanical problems like tire rotations, suspension alignment or other maintenance are not covered. But car owners can have mechanical breakdown coverage against this, but it will cost them extra). So, it is likely that it is the owners' responsibility to keep the car in good working order by using their out-of-pocket funds to pay for recommended maintenance. This was identified as becoming more than a financial responsibility. At this stage customers were found to bring the car to scrap. This was mentioned by most of the respondent.

This research also tried to find the average age of all the cars coming as EoL through interviews from each case dealing with EoL cars return. Respondents were asked the age and mileage of EoL cars coming due to age and mileage related reasons. Based on the what most respondent said, the average age of EoL cars is categorised into four groups:

- 8 - 11 years old cars and the average mileage of this group of cars is identified as 100,000– 140,000 miles
- 12 - 15 years old cars and the average mileage of this group of cars is identified as 150,00 – 190,000 miles
- 16 – 20 years old cars and the average mileage of this group of cars is identified as 200,00 – 250,000 miles
- More than 20 years old cars and the average mileage of this group of cars is identified as more than 260,000 miles

It was established that there is no fixed end of age and mileage guide from car manufacturers, and other organisations, at which a car can be considered an end-of-life car (there is only guidance about per year mileage, which is 10,000). But most of the car manufacturers mentioned that the longevity of cars are increasing the average age in the UK, now 8 - 11 is the average age of a car but 20 years ago the average age was about 6 - 7 years (this average age is for on road cars not scrap cars). So, the age of cars on the road has increased, which is not only controlling natural EoL car return but also brings greater environmental benefits.

According to respondents from almost all the companies involved with EoL car collection, including car manufacturers (CM), car dealers (CD), official scrap car partners (OSCP) and authorised treatment facilities (ATF), mostly natural EoL cars are coming to them. To control natural EoL car return, all car manufacturers (CMs) were found to be constantly looking at ways to increase longevity of their cars through car design with lightweight materials (detail of car design discussed in section 4.4) and extending the service time of cars.

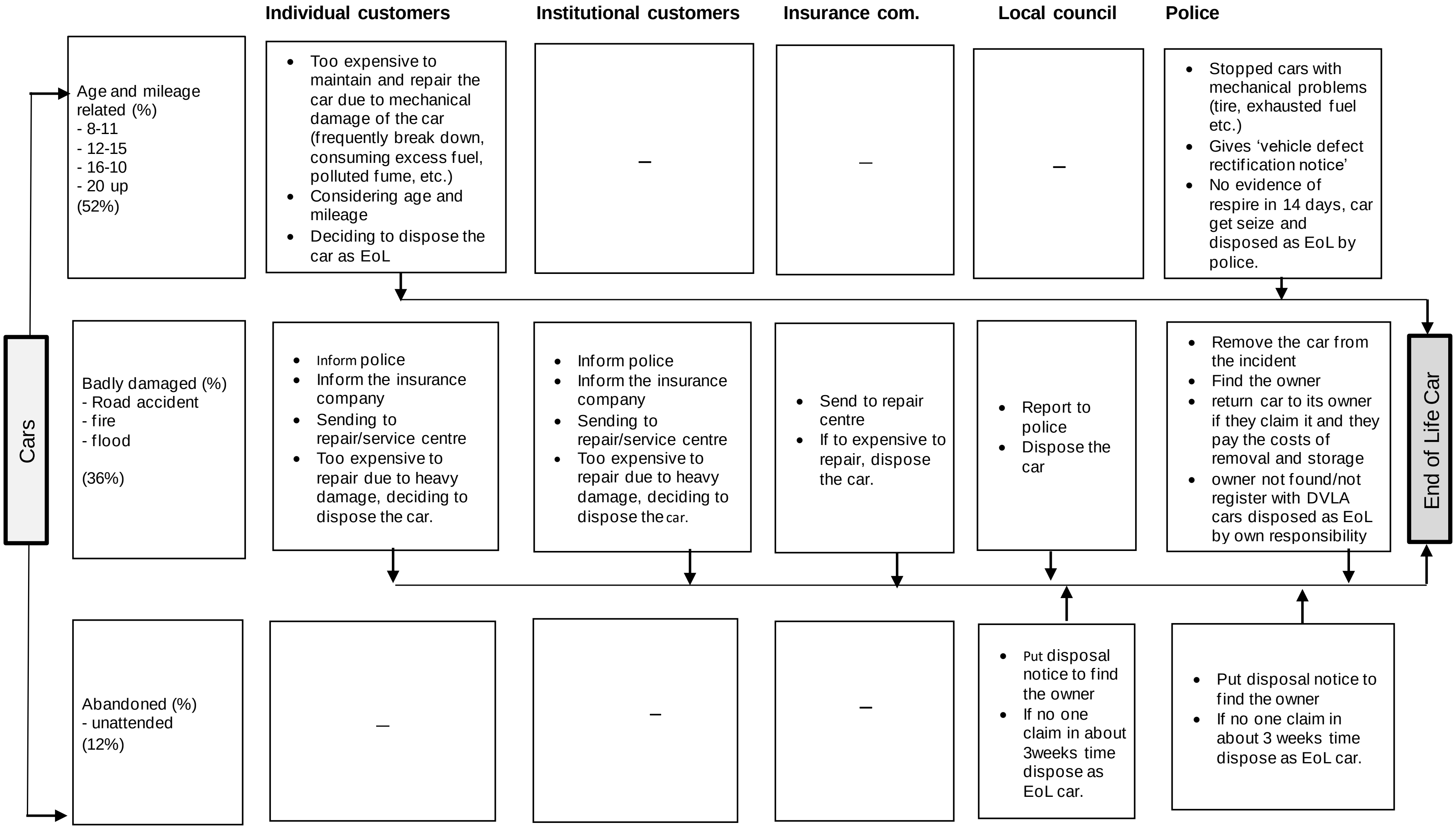


Figure 4. 2 Cars becoming End of Life

2. Unnatural EoL cars - heavy damaged due to road accident, fire or flood

This category was identified as happening after a road accident, or when damage is caused by flood or fire. This category was found from the interviews presented in figure 4.2. These cars come from not only customers but also institutions like insurance companies, local councils and police. In terms of age and mileage, this type of car can be any age. All the companies involved with EoL car collection and acceptance accept unnatural EoL cars. However, according to most of the respondents from car manufacturers (CM) and car dealers (CD), collection request for unnatural EoL cars normally do not come to them. On the other hand, respondents from authorised treatment facilities (ATF) mentioned every year they collect about 35% unnatural EoL cars where mostly (about 28%) are road accident damage.

Therefore, to manage (eliminate/avoid) this category of EoL cars car, car manufacturers (CM) were found to be able to play an important role by making stronger cars but still this will depend on the type of accident. However, this attempt found helped to reduce accident over few years. To support this statement car manufacturer two (CMB) stated that:

“Advanced self-directed safety systems fitted to cars has helped to drive down the number of road accidents in the UK by 10% in just five years”

3. Abandoned EoL cars

This study found that an abandoned EoL car is any car which the owner no longer wants or is stolen and has been left on open land to which the public have access or in someone’s car parking space on private property. For stolen cars, the Police normally arrange to remove them immediately, unless they are burnt out (car fires are caused by an electrical fault or arson, often following the theft of the car). However, because of the toxic material present, the Council may dispose of any car not removed within 24 hours if considered to be a hazard to the public. According to the respondents from authorised treatment facilities (ATF) most of these cars are very old cars and most drivers who have abandoned their car did so because it had broken down and they were unable to afford to have it towed or could no longer afford to run their car at all. Local councils found are responsible for abandoned cars to deal with.

According to Local Council B (LCB), they spend hundreds of thousands of pounds each year clearing roads of abandoned cars in the UK. Therefore, this study found that to manage (eliminate/avoid) abandoned EoL cars, auto industry players (CMs, CDs, OSCPs, ATFs) try to increase awareness through their website, social media and also notifying their existing and new customers about free take back of EoL cars with free collection from any place in order to stop drivers abandoning their cars because they were unable to afford to have them towed. Also, as mentioned above, the government gave the responsibility to local councils to remove cars abandoned on the highway or other land in the open air. According to the respondents from Local Councils (LC), they have started working to reduce abandoned cars, led by the

Association of London Government and in partnership with the DVLA to remove untaxed and abandoned vehicles from the UK’s streets.

Similar practice was found for within Case – Category (CC) companies in terms of type of car coming to the case-category companies and their source. However, some difference found within case-category one (CC1)- Car Manufacturers (CM). as mentioned before, most cars are natural EoL cars followed by unnatural and abandoned EoL cars and this is found similar for CMA (55%), CMB(62%), CMC(60%) brands but for CMD only, cars mostly arriving as EoL are unnatural (accident damage) EoL cars (about 50%) followed by natural (40%) and abandoned (10%) EoL cars. Details of each category of EoL cars coming back for each CM are presented in appendix 6.

Also in terms of natural EoL cars age group, most of the EoL cars for CMA (Japan origin), CMC (UK origin), CMD (US origin) are largely found to be 12 – 15 year old cars, where for CMB (German origin) EoL cars age are found to be mostly 16-20 years old and some of them even more than 20 years old. This indicates German origin brand cars longevity is greatest, followed by Japan, UK and US origin cars. Details of the natural EoL car category for CMs are presented in appendix 7.

Some significant differences were found for cross case-category companies in terms of EoL car type and sources.

Though Case Category one (CC1), Case Category two (CC2) and Case Category four (CC4) accept all three (natural, unnatural, abandoned) types of EoL cars, this qualitative investigation identified CC1 (CMs) and CC2 (CDs) as mainly receiving natural EoL cars that are 8-11 years old, from individual customers.

According to CMC, customers mainly return their car to CMs for scrappage schemes. CMs (most CM) have launched scrappage schemes over the past couple of years. The deals are designed to reduce the pollution caused by diesel cars, as well as increasing the uptake of low-emissions cars in the UK. Therefore, buying new cars and returning the old car to be scrapped can save about £1000 – £7000, depending on car brand and model. On the other hand, EoL cars returning to CC4 (ATF) companies are not only natural EoL cars from individual customers but also unnatural and abandoned EoL cars from other sources including institutional customers, local authorities and police.

Therefore, this empirical investigation found that the sector (manufacturing/recycling) has an impact on EoL car source/senders, where institutions prefer to contact recycling sector (CC4) companies (ATFs) to dispose of cars rather than manufacturing sector (CC1 and CC2) companies (CMs and CDs).

Having gained this understanding of EoL car category detail, the next section discusses the details of all these EoL cars nature and their impact on reverse logistics process.

4.3 Analysing the nature of EoL car and its impact on the RL process

As per what most correspondents said, it was found that EoL cars' natures can be categorised into the following three categories:

i) Composition of EoL cars in terms of components material weight (heavy/light); use of dismantling mark; use of electric devise and batteries
ii) Deterioration of EoL car in terms of car parts functionality
iii) Use pattern of EoL cars in terms of EoL cars sources

All these natures have noticeable impact on the RL process in terms of product in (transportation), out (reuse) and it has impact on process activities efforts as well as in terms of how complicated/easy the process is. Detail of each category findings are discussed below.

1. **Composition of EoL cars in terms of components material weight (heavy/light); use of dismantling mark; use of electric devise and batteries**

Despite cars being designed with the same types of components, in terms of materials and structure, this study has found diverse types of EoL cars in terms of component composition and use of materials.

Materials weight (Heavy metal & Light metal)

According to what most of the respondent said, this finding found, in terms of components weight, EoL cars have two different natures — one with heavy materials components and the other one is light materials. The reason identified from the interviews with Car manufacturers (CMs) is that cars put on the market after 3rd November 2003 require (government regulations on car design) materials and components that do not contain lead, mercury, cadmium or hexavalent chromium. So, most of the cars identified as put on market before 2003 were designed with heavy metal and all cars design after 2003 were identified as designed with light components.

To make lightweight components, common materials identified are Magnesium, Carbon Fiber, Aluminum, Titanium, Glass Fiber, High Strength Steel. The reason of this restriction was clarified by case 19 (GAA) which was to protect the environment and address resource scarcity, the government introduced this regulation so cars use parts and materials that can be used again, whether they are reprocessed for use in manufacturing, recycled, or used in a completely different way, for example as an alternative source of energy.

In terms of its impact, according to the respondents from authorised treatment facilities (ATF), heavy metal components parts have almost no market value, so mostly the only use for these parts is shredding and recovering materials. Respondents also declared the materials recovered from these components are mainly lead, mercury, cadmium and hexavalent chromium, which are not used anymore to make car components so the market value for these materials is also less than before. On the other hand, lightweight materials used to make new cars were also identified as having a negative impact in terms of recovering materials which require advanced technology mentioned by authorised treatment facility C (ATFC) and authorised treatment facility D (ATFD). They were also identified as producing more ASR waste for landfill (see detail in the life cycle assessment impact in the section 4.4).

Use of the Dismantle Mark

According to the respondents from authorised treatment facility (ATF) companies, some cars contain V-shaped grooves at the points in the bodywork where the instrument panel is attached, making it easier to remove. Car manufacturers specified this design is to make recycling easier when it reaches the end of its useful life by helping to reduce its lifecycle carbon emissions and also permits more efficient recycling of some of the useful materials it contains. Some cars also have a mark for certain parts with an Easy to Dismantle symbol to show clearly where they can be most easily taken apart and sorted into different material streams for recycling. According to authorised treatment facility B (ATFB), dismantle mark parts were found to be easier to recover, while parts without dismantle marks are complex and take more time to dismantle.

Use of Electric devices and Batteries

Hybrid and electronic cars are also another category which has an impact EoL RL process. The components used here are generally messy traction batteries, electric motors and generators, as well as other types of electrical devices and on-board equipment, for example in modern vehicles with alternative force systems with hydrogen as the fuel cell.

So, the composition nature of the car in terms of component weight, dismantle mark and use of electric device and batteries was found to be important to analyse the efficiency of the RL process based on value recovery and from an environmental viewpoint. This finding also helped to identify the reverse logistics process for EoL cars starts with the car design stage. According to Car manufacturer A (CMA) in the stage of car components design, full consideration is taken of removability, maintainability, recyclability, reusability, components compatibility and continual applicability, thereby enhancing product value, and reducing the environmental pollution caused by manufacturing products. Therefore, it allows reutilisation, recycling and saving resources. Detail about car design has been discussed further in this this chapter.

2. Deteriorations of EoL car/parts in terms of cars and parts functionality

An available functionality is how much economic value can be recovered from the EoL car and its parts. The findings from the data collected from authorise treatment facility (ATF) companies found functionality of EoL cars can be divided into four categories:

Full functional: the car can be repaired and reused

Mostly Functional: Though cars in this category have sustained damage to their structural frame, parts/components can be reused, repaired and resold and have market value (engine oil, oil filter, glass, engine, transmission, tires, suspensions, water pump, starters, alternators, belt, rubber hoses, mates/carpets, doors, plastics)

Partly functional: Some parts are functional (engine oil, oil filter, engine, tire, suspensions)

Non-functional: These cars are typically crushed after the removal of hazardous components, while parts of the car that might be salvageable must also legally be destroyed. A number of reasons were identified here for parts not being reusable including heavy damage due to age or accident (fire/flood); because of legislation restrictions some parts made with heavy metal are no longer an option for reuse.

This nature was found to be linked with the type of EoL cars (see table 4.1). The nature of deterioration does not have any impact on the product in transportation and ease / complication of process efforts, but it has important impact on product out (how much can be reused).

Table 4. 1 Functionality of EoL cars in terms of EoL car category

EoL car types	Deterioration/Functionality	Product out
Natural EoL cars		
8 - 11 years old cars	**Fully or mostly functional:** The car can still be functional and in need of repair and refurbishment; if not parts are mostly functional (engine oil, oil filter, glass, engine, transmission, tires, suspensions, water pump, starters, alternators, belt, rubber hoses, mates/carpets, doors, plastics)	Repair/refurbish and resell the car
12 - 15 years old cars	**Mostly functional:** Car is no longer functional but most of the parts can still be functional (engine oil, oil filter, glass, engine, transmission, tires, suspensions, water pump, starters, alternators, belt, rubber hoses, mates/carpets, doors, plastics)	Repair/refurbish/remanufacture parts and resell
16 – 20 years old cars	**Partly functional**: Some parts can still be functional (engine oil, oil filter, engine, tire, suspensions)	Repair/refurbish/remanufacture parts and resell
More than 20 years old cars	**Non-functional**: no parts can be reused	Material can be recovered and resold
Unnatural EoL cars		
Road accident	**Fully or mostly functional:** The car can still be functional; if not parts can be mostly functional (engine oil, oil filter, glass, engine, transmission, tires, suspensions, water pump, starters, alternators, belt, rubber hoses, mates/carpets, doors, plastics)	Repair/refurbish/remanufacture and resell
Flood	Non-functional	Materials can be recovered
Fire	Non-functional	Materials can be recovered
Abandoned cars		
Premature (new cars stolen)	**Fully or mostly functional:** The car can still be functional and in need of repair and refurbishment; if not parts are mostly functional (engine oil, oil filter, glass, engine, transmission, tires, suspensions, water pump, starters, alternators, belt, rubber hoses, mates/carpets, doors, plastics)	Repair/refurbish/remanufacture and resell
Mature (EoL cars dumped)	Non-functional	Materials can be recovered

Source: Author

3. Use pattern of EoL cars

The use pattern of EoL cars depends on the source of EoL cars discussed above. Where cars come from as EoL, helps the analysis of the quantity (individual: one car; industrial and institutions: could be bulk) and intensity of uses. It is identified that for EoL cars quantity and intensity do not have any substantial impact on the reverse logistics process but it has an impact in terms of drop off by customers and collection by receivers.

EoL cars coming from individual customers were found to be mainly dropped off by customers. On the other hand, for EoL cars coming from other destinations, receivers were required to arrange transportation. Therefore, transportation cost is affected here in the collection process (details were discussed in the collection stage of RL process aspect)

As per the above discussion, return car nature and its impact within case-category (CC) companies was found to be similar. However, there were differences identified for EoL car nature impact between cross case-category, which are discussed below. However, the nature of EoL car influence on RL process mainly impacted Case-Category Four (CC4) – Authorise Treatment Facilities (ATF) companies, as they are the key players involved in dismantling, shredding and disposal stages of EoL car RL process and also Case-Category Five (CC5)-Hazardous Recycling Company (HRC).

According to CC4 companies, the impact of materials used (light/heavy weight) in cars has negative impact on RL process specially for shredding and disposal stage. On the other hand CC4 companies also agreed that "use of dismantle sign" has a great positive impact on RL process dismantling stage (detail of impacts is presented in the table 4.2).

Source of EoL cars nature found has impact on all the Case-Category (CC1, CC2, CC4) companies who are involved with collection stage. However, CC4 companies are more affected here as industrial and intuitional source are mainly coming to CC4 (ATFs) companies.

Table 4.2 Impact of EoL car nature on reverse logistics process in terms of products in (transportation), process (effort) and out (reuse) between cross Case-Category (CC) analysis.

EoL car natures	**Impact on**			**Impact on Case-Categories (CCs)**							
	Collection (in)	**Effort (process)**	**Reuse (out)**	**CC1**	**CC2**	**CC3**	**CC4**	**CC5**	**CC6**	**CC7**	**CC8**
Impact of EoL car composition nature											
Use of lightweight and heavy metal	-	-	**Reducing parts resale value**: Heavy metal parts contain lead, mercury, cadmium or hexavalent chromium are restricted to use for cars registered after 2003 which reduced parts resell value.				√				
	-	**Complex shredding process**: Lightweight materials including Magnesium, Carbon Fiber, Aluminum, Titanium, Glass Fiber, High Strength Steel are complex to recycle and recover materials.					√				
	-	**Generating more waste:** Lightweight materials producing more waste for disposal process	-				√				
Use of electronic devices and batteries	-	Time consuming hazardous removal process	-				√				
	More transportation cost: heavy and bigger battery collection increasing transportation costs	**Complex hazardous recycling stage:** lithium ion batteries in electric cars use a variety of chemical processes, making it difficult to develop standardized hazardous recycling process	-					√			

	-	**More waste for incineration:** More hazardous chemicals to burn making the disposal proceed costly	-					√			
Dismantle mark on car parts	-	Easy to remove without interrupting/damaging parts saving time and labour cost in the dismantle stage	Better quality parts and materials as there is no interruption and damages during dismantle process				√				
Impact of Deterioration nature of EoL car											
Fully functional	-	-	Resell the car with/without minor repair				√				
Mostly functional	-	-	More parts to reuse				√				
Partly functional	-	-	Less parts to reuse				√				
Non-Functional	-	-	No parts for reuse				√				
Impact of EoL car source nature											
Individual consumers	Mostly dropped by customers which reduces transportation cost	-	-	√	√		√				
Industrial consumers	Collection required so transportation cost is affected here in the collection process	-	-	√	√		√				
Institutions	Collection required so transportation cost is affected here in the collection process	-	-	√	√		√				

Source: Author

EoL car nature, in terms of composition was found to be significantly related to EoL car design. Therefore, the section below provides detailed findings on car design and its impact on RL process.

4.4 Car design to support RL process

For almost all the car manufacturers (CMs), car design was identified as not only thinking of the environmental (global warming potential) and economic value for production, use and EoL but also thinking of recycling cars, including use of renewable materials and ease of recycling signs. According to CMC, car manufacturers face huge pressure from government regulation (details of regulations in RL process for EoL cars in the UK are presented in Appendix 4) to make lightweight material car components, which drives car manufacturers to develop and use lightweight materials to make their cars. Steel has been slowly replaced with high strength-to-weight ratio materials such as aluminium, advanced high strength steel (AHSS), magnesium, and carbon fibre composites. Thus, the total vehicle mass has reduced gradually. Manufacturers (all) have made a significant effort to replace conventional steels with high strength-to-weight ratio materials to reduce mass while maintaining the stiffness, durability, and energy absorption ability for crush zones. On the other hand, to reduce the emissions that contribute to climate change and smog, improving public health and reducing ecological damage, manufacturers are designing electric and hybrid cars. Charging cars on renewable energy such as solar or wind minimises these emissions. Safety is another priority for car manufacturers (all) and the pace of technological change is faster than ever before.

All these were identified as significant impacts on the car use stage, but car designs were found to be developed not only thinking of the use stage on cars but also thinking of EoL and recycling stage as well, which includes use of renewable raw materials including natural fibres in door panels and sound proofing. Also ease of recycling signage was found in components structure to make the dismantling process more effective and efficient. Also use of materials in new cars which are recovered from EoL cars is another important and growing concern identified to reduce use of natural resources. Use of recycled materials has been used in cars for over a decade now, but mostly in out-of-sight places, like components under the bonnet and they have always represented a very low proportion of total vehicle weight. As recycled material quality has improved, there has been a recent growth in the use of recycled materials in more visible areas of the car, especially in car interiors. Recycling materials uses less energy and water compared to creating new (virgin) materials, and it creates fewer emissions. In many cases, it also prevents the physical environmental damage from extracting raw materials from the earth's surface or under the seas. Overall the key factors identified in design of new cars are captured in table 4.3 which also present how all these changes in car design impact on the entire life cycle of a car and in the reverse logistics process.

Table 4.3 Car design impact on its Life cycle in terms of environmental and economic value

(How design impacts in different stages of cars' life cycles highlighted and its positive/negative impacts presented in terms of environmental and economic value perspective)

Innovation in design	Different stages of car life cycle			Environmental impact			Economic impact		
	Produc-tion	Use	End of life	Positive	Negative	Details	Positive	Negative	Details
Developing lightweight materials (Plastic, Magnesium, Carbon Fiber, Aluminum, Titanium, Glass Fiber, High Strength Steel for car body)					√	• More water and energy consumption during material development process		√	• More investment in R&D • More time to prepare materials • Costly process of mixing and development of new materials
				√		• Consumes less fuel which reduce CO_2 emission	√		• Saving fuel cost
				√		• Increasing car longevity	√		• Higher mileage and age due to less compression in engine (less fuel consumption) and no rust in new developed materials
					√	• Use of more plastic and composite materials ended up with more waste production		√	• Consuming more time and expensive process (equipment, expertise) to recycle and incinerate to reduce landfill waste
More number of electric devices for safety features								√	• More investment in R&D
				√		• Safety features reducing accidents and increasing longevity.			
					√	• Car increased longevity controlling EoL car return and reducing waste (scrap car)			
More number of batteries and wire harness using in hybrid and electric cars								√	• More investment in R&D • Investment (time and money) transection period from fuel cars to hybrid/electric

				√		• Consuming less fuel reducing CO_2 emissions			• Saving fuel cost
					√	• More hazardous components to remove especially big size batteries, transport and recycle consuming more fuel for transportation, energy to recycle		√	• Incising transportation cost (fuel, driver, time) and cost for special treatment of hazardous components
Renewable raw materials (using bio-fiber reinforced composite materials, which are mainly based on poly(propylene) with reinforcing bio-fibers jute, flax, hemp, and wood)				√		• Reducing waste	√		• Reducing disposal cost
Ease to dismantle sign in parts structure				√		• Reducing waste as dismantling signs enable easy recovery process without damaging any parts	√		• Recovering quality parts and materials
Use of recycling materials in new cars (mainly interiors including seat fabrics, under hood parts, carpets, sound absorption materials, bumpers, headliner fabrics)				√		• less energy and water compared to creating new (virgin) materials, and it creates fewer emissions.	√		• Less expensive process compared to making new materials
				√		• Reduction of CO_2 emissions	√		• Lower fuel consumption • Reduction of insurance cost

Source: Author

Innovation in car design in terms of lightweight materials development, higher number of electric and safety devices, and hybrid & electric cars were identified as negatively impacting the production phase in terms of consumption of more energy and costly processes but at the same time these innovations are reducing environmental impact in use and EoL stage by consuming less fuel and by increasing longevity of cars which is identified as reducing environmental pollution and increasing economic value 20 times higher than the loss of production stage.

Also, use of renewable raw materials, easy to dismantle signs and use of recycling materials in new cars were identified as having highly positive impact on both environmental and economic value gain in the recycling of car stage.

Although significant improvements in car longevity controlling natural (age related) return reason and CO2 emissions in terms of energy consumption have been acknowledged, in the recycling stage an increasing amount of solid waste generation was identified, which increases CO2 emissions. The attempt to reduce the negative impact in the car use phase has ended up with a negative impact in the recycling stage. This is particularly the case for the usage of more plastic and composite materials in car design that mostly ended up in landfills.

Therefore, table 4.3 presents how car design impacts on the car recycling stage (recycling stage for EoL cars defined here RL process of EoL cars) where car design was found to have a highly positive impact on protecting the environment from CO2 pollution. Details of these process stages are discussed in chapter 5 of this thesis.

As mentioned in the methodology chapter of this thesis, findings for car design related facts are mainly found from the data collected from category one (CC1) – Car Manufacturers (CM) as these companies are only involved with car design. On the other hand, the impact of these design related data was mainly collected from case-category five (CC5) and case-category six (CC6), as these companies are mainly involved with EoL car further treatment process.

According to the respondents from most of the authorised treatment facilities (ATF) companies, most of the EoL cars coming to car manufacturer A (CMA) were 8% heavy weight cars and 92% light weight (10% hybrid).

These companies also mentioned that this 8% of heavy weight cars with no dismantling signs were identified as very time consuming to recycle and giving less economic value (details of recycling discussed in chapter 5 in the dismantling and shredding phase). In terms of the other 92% light weight EoL cars, component recovery was identified as easier and less time consuming due to the nature of materials used and dismantle signs.

Car manufacturers A (CMA) mentioned, to make sure the car and its components could be used repeatedly, the designer has designed the car with a simplified and standardised model structure, which not only uses light materials and saves resources, but also designed for ease of recycling using recycling marks, so it can be recycled and the standard components reused.

This allows components to be recycled and reused, rather than becoming unrecoverable waste. There are two ways in recycling, one is the original recycling that recycled wastes to produce new products of same type, the other is to transform waste resources to raw materials for other products (Nawrocky et al., 2010). Comparing these two ways, original recycling could save natural resources better. In short, it uses less raw materials and energy to achieve the production or consumption purposes, thus saving resources and reducing pollution from the headstream. In terms of use of recyclable materials in new cars, car manufacturer A (CMA) using some newly developed recycled materials which are lighter than their alternatives, helping to bring down total vehicle weight. A newly developed material, Hycolene, is used to make interior parts that are between 10 and 12 percent lighter compared to CMAs virgin plastic equivalents. In terms of use of recyclable/renewable materials, CMA make use of bio-plastics to make 10 different interior parts; from the door panels to the seat trims and the carpets. This organic material amounts to nearly 53% per car.

Cars coming to car manufacturer B (CMB) were found to be 15% heavy weight cars and 85% light weight (6% Hybrid). The percentage of heavy weight cars identified here - 15% - is higher comparing CMA, CMC and CMD origin cars. The reason identified is that CMB cars' EoL age is more than other cars, meaning the longevity of cars are more than other cars; as a result there are still a good number of cars coming to the scrapyard which are registered before 2003. On the other hand, CMB cars were also identified as focusing on the design of lightweight cars with dismantling signs and one of their managers explained that they adopted the design to establish the scrapped automotive recycled system. This is called detachable design which enables automotives to gain high efficiency and low cost to combine components,

components demolition and classification demolition materials in order to be reused and recycled. For example, all the liquid in the automotive can be recycled, including gasoline, engine oil, coolant, brake fluid and air conditioning fluid, and 90% of the materials are adopted to five types of recycled materials, which are steel, glass, oil, plastics and rubber, and the required steel to manufacture an automotive could be obtained from secondary recycled materials.

The manufacturing development manager said;

> *"We design our cars using parts and materials that can be used again, whether they are reprocessed for use in manufacturing, recycled, or used in a completely different way, for example as an alternative source of energy."*

In terms of use of recycled materials, some of CMBs greenest features do not utilize recycled materials, but instead, consider the environmental impact of the manufacturing process. Rather than using formaldehyde or other chemicals to tan their leather seats, they use olive leaves. Panels on the doors and dash are made from renewable natural fibers like open-pore eucalyptus that has been certified by the Forest Stewardship Council (FSC).

EoL cars coming for CMC found 10% heavy weight cars and 90% light weight (10% Hybridg). Due to the environmental impact coming from their production, car manufacturers of UK origin cars were found to be very concerned with making the most significant improvements here. They are investing heavily in research, engineering and manufacturing to deliver innovative solutions that will reduce the environmental impact of their cars throughout their entire life cycle. When designing new cars, CMC aim to make them even more sustainable than their prototypes. To achieve this, they examine every aspect of a car — from its design to the end of its life — to identify ways they can reduce its overall environmental impact, whilst increasing the cars's performance and longevity. They call this the Life Cycle Assessment (LCA). It is an approach that is leading to a new generation of efficient cars which are coupled with lightweight aluminium technology. They select materials such as leather, natural rubber, wood and cotton from sustainable sources. They were also found to be researching new types of natural fibres that could reduce the weight and life cycle impact of car components compared to plastic.

Cars coming to CMD as EoL were 12% heavy weight cars and 88% light weight (8% Hybrid) in 2017. They also focus on use of lightweight materials to design cars and they have trimmed car weight that is up to 200kg (130kg on average) lighter than each car's prototype. They are using completely new vehicle architecture in weight reduction. They check every component for compact design and lightweight materials. The body shell weight alone was also reduced by 20 per cent from 357kg to 280kg. Also they are using high-strength and ultra-high-strength low-weight steels, compact subframes and reducing weight to the front and rear axle. There is also a partnership relationship between CMC and CMD and the aluminium manufacturer; 30,000 tonnes of press shop aluminium scrap were recovered from CMC and CMD plants and recycled by aluminium manufacturers, to be incorporated into new body panels.

They also identified focusing on careful selection of recycled and recyclable materials, optimised construction techniques and the labelling of plastic parts with their material type, so their car can be recycled as efficiently as possible. They are designing cars thinking of the whole life cycle of their car from car design planning and development to the recovery of end-of-life cars. One of the engineers mentioned that;

"we are using internal guidelines and in-depth information to create cars that are as recyclable as possible."

He also mentioned;

"For all our new cars we check the environmentally friendly properties in a recycling analysis. The details are given to recycling companies to ensure environmentally friendly recycling at the end of a car's life.

The above discussion clarifies at a very detailed level differences within case-category one - car manufacturer (CM) companies in terms of designing cars to support RL process. However, overall practice is similar within case-category one companies. And also, similar practice is noticeable in the above discussion within case-category four (CC4) – ATF companies - as mostly EoL received by them are with similar nature.

4.5 Summary of the chapter

This chapter mainly established a report on the EoL car return reasons, nature of those EoL cars and car design related facts which presenting EoL car category, reason of becoming EoL car, nature of EoL car and car design to support RL process by analysing each case (within case analysis), within case-category, and cross case-category analysis. This chapter has specifically analysed and compared similarities and differences for EoL car return reasons and nature of those cars among the eight type (CC) of stakeholders investigated related issues that characterised the UK automotive industry in terms of EoL cars category coming for disposal and nature and design related issues of those cars with its impact on the RL process different stages.

Further key aspects including RL process, relationship between players and drivers and barriers will be presented in a similar method in Chapters Five, Six and Seven.

A discussion of the implications of these results (Chapter Four, Five, Six and Seven), how the triangulated empirical findings corroborate or contrast with the extant literature and extant theories will be presented in Chapter Eight. The overall conclusions and implications for further research will be drawn in Chapter Nine.

CHAPTER 5: END OF LIFE (EOL) CAR REVERSE LOGISTICS PROCESS

5.1 introduction

In line with the second research question (RQ2), the objective of this chapter is to develop a comprehensive understanding of the various stages of EoL car RL process in the automotive sector including regulatory restrictions to find if each stage of EoL car RL process is regulated or not, detail of activities including use of information technology and workforce arrangement to find if activities are done in-house or outsource, location to find where all the EoL cars being processed, time related issues for each stages and what being reused and redistributed from each stage.

Therefore, the study has attempted to develop a comprehensive picture by integrating the findings from interviews from within-case analysis of each cases presented in chapter 3 table 3.1, followed by the within case-category analysis and cross case category analysis.

Players involved at different process stages are also discussed in this chapter, but more detail of players and the relationship between players to practice EoL car RL are discussed in the chapter 6 and the drivers influencing these players to practice RL, and the types of barriers they face to practice RL for each phase are discussed in chapter 7.

5.2 Reverse logistics (RL) process for End of life (EoL) car

There are procedures in place at all the companies for EoL car collection, sorting, storage, dismantling, recycling and disposal at all the companies. It was identified that depending on the collection arrangement, the collection point either needs to pick up the EoL car from the site of customers, or the customer drops the car at the collection point. Thus, picking up the car in question depends on the collection arrangement in place. Immediately after the car is collected/accepted the Certificate of Destruction (CoD)/deregistration certificate is issued. Assessment of recovery options of each car is an important activity, as it provides the instruction for further treatment.

As per most respondents from authorised treatment facility (ATFs) companies, further treatment starts from dismantling of the EoL car. The dismantling activities are carried out in two different stages. First is the separation of all the hazardous components including disposition of battery, airbags, air condition and seat belt tensioners. The second part of dismantling is the removal of marketable parts, which was mostly done manually. After all these removals the EoL car was transferred to the shredder. In this stage the recovery of materials was done by the post-shredder technologies, which is sorted materials into ferrous, nonferrous (reusable) and ASR dust. The ASR dust came from material recycling which was further recycled to recover materials. Disposal is also an important stage like others because waste that is not properly disposed of can leak and contaminate soil and water, which can lead to issues with both the environment and human health.

All these seven stages were investigated in detail to understand EoL car RL process in terms of its detailed aspects, including relevant regulation regulating the process; method of processing in terms of equipment, workforce, technology and finance; location of each stage (including distance, facilities, storage and environmental perspective), time related issues (including when the process starts and how long it takes), reuse and redistribution of recovered cars/parts/materials, players involved and its performance impact on TBL (Economic, environmental and social) characteristics. Detail discussion of findings for each stage are presented below.

These findings define “recovery” as anything recaptured from the EoL car for reuse; “redistribution” is defined as resale of recovered car/parts/materials/energy which includes transportation and market/customers; and “treatment” is defined as any activities to recover car/parts/materials/energy; “recycling” is defined as all the activities relevant to dismantle, shredding and disposal.

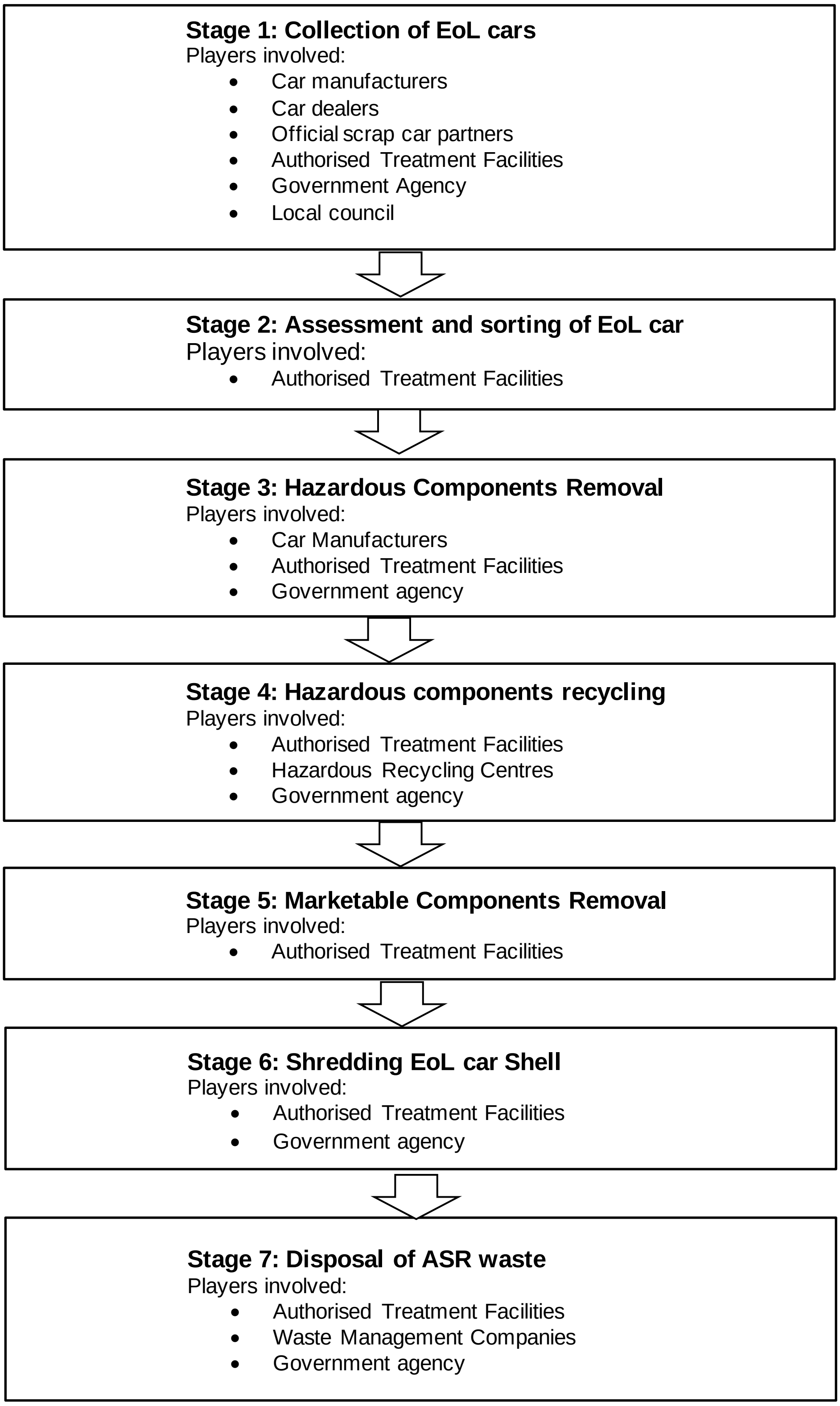


Figure 5. 1 EoL car reverse logistics process stages with players involved in each stage

5.2.1 Collection of EoL cars

This is the first stage of EoL car RL process. Table 5.1 shows many players involved at this stage including Car Manufacturers (CM), Car Dealers (CD), Official Scrap Car Partners (OSCP), Authorise Treatment facility Centre (ATF) and Government Agencies (GA). However, each player is responsible for different activities as presented in table 5.1.

Table 5. 1 Players involved in EoL car collection stage

Reprocess stage / players involved	Car manufacturers (CM)	Car Dealers (CD)	Official Scrap Car Partners (OSCP)	Authorize Treatment Facilities (ATF)	Government Authority (GA)	Local Council (LC)
Collection of EoL cars	Responsible for EoL car collection network with free take back facilities	Responsible for EoL car collection as non-ATF collection center	Responsible for EoL car collection network setup and collection of EoL cars as non-ATF collection point	ATF duties for Free take back and issuing CoD	Develop and manage regulations for free take back and CoD.	Source of abandon ed EoL cars

Source: Author

Details of EoL car collection activities of all these players in terms of key constructs including regulatory restrictions, activities, location and time related issues, reuse and redistribution and its performance measurement are discussed below.

5.2.1.1 Regulatory restrictions for EoL car collection

Most respondent said that the EoL car collection process is heavily regulated (see the detail of RL related regulations to consider in UK in the appendix 4). This particular regulation is ELV directive (2000/53/EC) which requires car manufacturers (CMs) to take the responsibility for the network for EoL car collection with;

- A network which requires that 75% of car owners should be within 10 miles of the collection points and the rest should not be more than 30 miles away.
- The network should allow free take back which means collection of cars must be free for last car owners
- The deregistration certificates should be issued only by ATFs, not other collection points who do not have an ATF license

To meet the regulation, all car manufacturers have developed the system by associating a third party organisations called an Official Scrap Car Partner (OSCP) (detail of each player are discussed in chapter 6). According to car manufacturers, OSCPs mainly allocate the collection centres from their existing network of Authorise Treatment Facilities (ATF). Forward chain players including car manufacturers (CM) and car dealers (CD) also play the role of collection point to minimise collection point setup and monitoring cost. But these collection points (CM and CD) are not authorised for further treatment of EoL cars or issuing deregistration certifications or other treatment of the EoL car. Authorise Treatment Facilities (ATF) were mainly identified as holding an ATF licence, who were eligible to issue certificate of destruction (CoD) to deregister EoL cars.

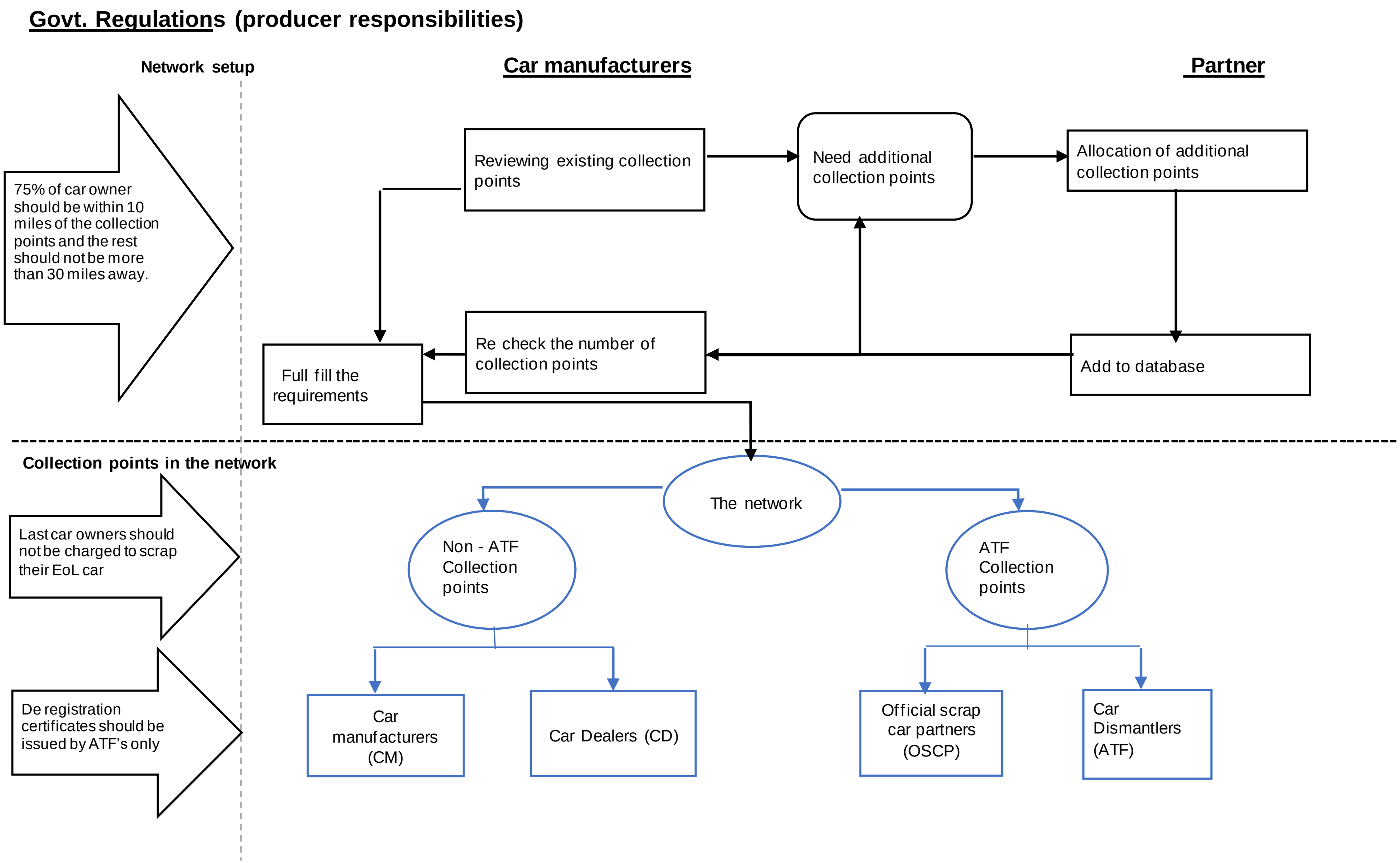


Figure 5. 2 EoL car collection network setup and collection points

According to the respondents from government agency (GA), not meeting the collection point requirements, including collection point setup near car owners (75% of car owners should have access to available collection points within a 10 mile distance and the rest should not be more than 30 miles) and free takeback of EoL cars collection, car manufacturers (CMs) will receive noncompliance penalties and the information shared for public access (news, government agencies website, report). Also, failure to follow the regulations and carry out duties may result in prosecution and a fine (license revocation/financial penalty).

The findings identified that in the UK, case-category one (CC1) - car manufacturers (CM) companies (CMA, CMB, CMC, CMD) have similar practice and have successfully managed to develop this network accordingly where some of them also managed to cover more than 75% of car owners within a 10-mile distance. Though all these CC1 companies follow the regulations, most of the respondents said that they are not only trying to meet the regulations but also trying to establish their best practice to collect all their EoL cars for proper disposal. Therefore, there are some differences identified within CC1 (CMs) companies as discussed below. According to CMA, the 10-miles requirement covered 80% of their cars and the rest fall within 30 miles distance, where they have about 265 collection points around the UK. From all these collection points, 160 are from reverse chain players and 105 from the forward chain. This is identified in their collection system, as they have at least one authorised treatment facility in each local authority area that will provide CoD for deregistered EoL cars. In 2016, they sold around 95,000 cars and in 2017 around 101,000 cars in the UK's 59 cities. CMA found developing and managing this network with OSCPA. According to CMB, identified 90% of the final keepers and/or owners can deliver their discarded vehicle to a collection point within a radius of 10 miles of their place of residence and rest in 30 miles. Where they have about 300 collection points. 150 from reverse chain players are official scrap car partners and ATF (dismantler and shredder). 150 from forward chain are car manufacturers and dealers (show rooms and service centres). In 2016 they sold around 182,000 cars and 2017 around 175,000 cars in the UK's 59 cities. CMB also developing and managing this network with OSCPA.

According to CMC, in 2016 they sold around 250,000 cars and in 2017 around 195,000 cars in the UKs 59 cities. They are developing and managing this network with OSCPB. They have about 410 collection points (around 170 reverse chain and 240 forward chain). Car manufacturers stated that 82% of the final keepers and/or owners can deliver their discarded vehicle to a collection point within a radius of 10 miles of their place of residence and the rest within 30 miles.

According to CMD, 75% of the final keepers and/or owners can deliver their discarded vehicle to a collection point within a radius of 10 miles of their place of residence and the rest within 20 - 30 miles,. where they have about 277 collection points (around 160 from reverse chain and 117 from forward chain), they are developing and managing this network with OSCPB. In 2016 they sold around 82,000 cars and 2017 around 75,000 cars in the UKs 59 cities.

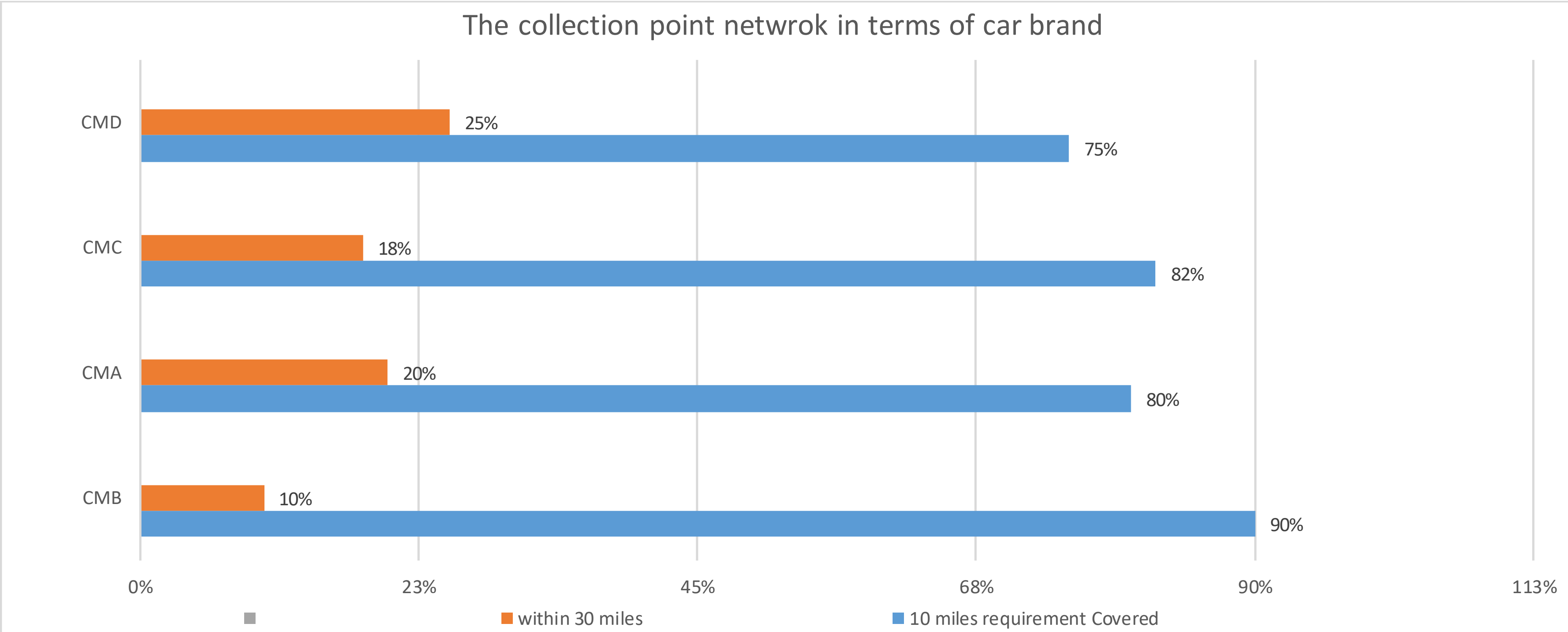


Figure 5. 3 EoL car collection network for CC1 (CM)

So, regulation was found to be relevant to Case-Category one (CC1), and Case-Category four (CC4), as CC1 (CMs) companies are the car producer and CC4 (ATF) companies are responsible for issuing CoD. CC1 is monitored for producer responsibility for collection point network setup and free takeback. On the other hand CC4 companies are also monitored for free takeback operation and issuing CoD. CC2 and CC3 companies were not monitored by Government but they are still responsible and reports to CMs to support the collection network setup as CC2 companies are the dealers of CC1 companies, and CC3 companies are the partner of CC1 companies in managing the EoL car collection process.

5.2.1.2 Activities for EoL car collection

According to both official scrap car partners (OSCPA and OSCPB), this setup of collection points network has provided more widely spread collection points where consumers have the options to bring the car back to the car dealers (CD), car manufacturers (CM) or directly to a authorised treatment facility (ATF). Car manufacturers (CMs) and Authorise Treatment Facilities (ATF) companies were found as being able to accept/collect EoL cars but only ATF companies were authorised to issue CoD. According to Government Agency A (GAA), the ATF must issue the last owner with a CoD which demonstrates that the car was collected at an ATF and enables deregistration of the cars from the Driver and Vehicle Licensing Agency (DVLA) database. Government Agency (GA) also mentioned this system has been enforced in the UK since 2002 to ensure better monitoring of EoL cars. Most of the car manufacturers (CMs) said that customers were happily dropping the car to the collection point within 24 hours of acceptance of the car and the overall collection process, including value calculation of the EoL car, acceptance, credit transfer and collection and deregistration certification, was found to be very quick and convenient for customers and collection centres. Government Agency (GA) agreed that collection of EoL car process was found to be well-planned and managed than before. Though collection centres are decentralised and both forward and reverse chain members accept EoL cars, deregistration of EoL cars is controlled and centralised by ATF. EoL cars were dropped off by senders and were accepted and transported to ATFs from non ATFs but any EoL cars collected by collection centres were directed to the ATF by non ATF centres. When an EoL car owner goes to a car manufacturer’s or dealer’s website to scrap the car, it directs the customer to their nearest ATF via an online link.

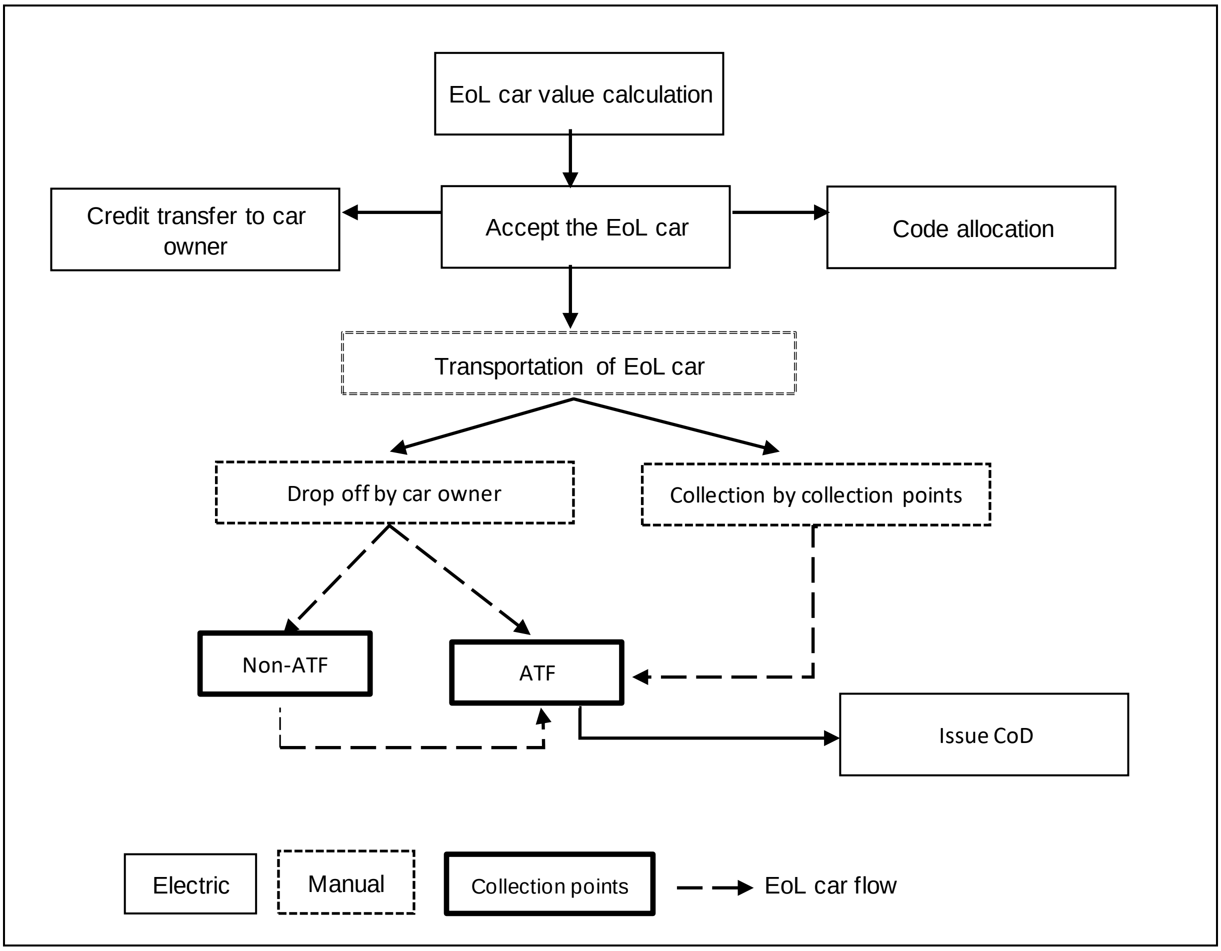


Figure 5. 4 The EoL car collection procedure

In terms of the workforce for collection of EoL cars, it was found that collection points from forward logistics were mainly using their forward logistics managers to manage and maintain the collection of EoL cars and send the car to the nearest treatment centre (ATF) with their car distribution transportation/drivers. On the other hand, reverse chain collection points have a dedicated workforce to execute, manage and monitor the EoL car collection process, which is also a continual process which aligns with needs and priorities. These needs and priorities mainly depended on return forecasts. Return forecasting was carried out in terms of car age and mileage and type of senders (discussed in chapter 4) and forecasting returns of EoL cars was identified as one of the difficult parts where the statistical distribution of the number of cars by year and dismantling of the cars along with the average age of the cars that are recycled helped to forecast the return of EoL cars. When car manufacturers submitted details of a car to International Dismantling Information System (IDIS), they were also sending their estimation return time for that particular car. This helps IDIS to forecast the return number of EoL cars per year in the UK. At the same time, this estimation also helps car manufacturers to forecast the EoL car return for their brand. But this forecasting has limitations, as EoL car returns are uncertain because not all EoL cars are due to age and mileage. From a total of 48 percent, EoL cars also come due to accident (36%) and abandonment (12%), which was discussed in detail in the previous chapter 4. So the return of EoL cars is still uncertain, requiring more effective management of EoL car collection. In this case setting up collection points near car owners (within 10 miles) and increasing the number of collection points have a positive impact on managing this return uncertainty. such as return of medical equipment from hospitals which is a bulk amount and from one location. In the case of EoL cars, if cars come from an individual consumer, normally the EoL car quantity per consumer is one. So, ten consumers means ten cars and ten different locations to collect these cars. Similarly, when the sender is an institution like council or insurance company most of the time the number of cars is one (only if there is an area flooded or burned in this case it is different). In this case to collect ten cars requires going to ten different locations, no matter whether they come from an individual customer or institutions. This was identified as not possible to forecast quantity even in terms of location of the EoL cars. So, here too, increasing the number of collection points and locations (near car owners) helps to manage the uncertainty.

In terms of the car collection process finance, key costs were identified here as the cost of integrated portal, internet and employee salary. In terms of the cost for transportation and payment for car value to the last car owner a free takeback fees have been put in place to be paid by producers for each car sold; these funds are collected in the Recycling Fund which is dedicated to the collection, recovery and treatment of EoL cars.

As discussed earlier, car manufacturers (CMs)- case category 1 (CC1) and car dealers (CD) – case-category 2 (CC2) can only accept/collect the EoL car but cannot issue CoDs. Also these companies do not hold EoL cars for more than 24 hours of acceptance/collection. These practices are found to be similar within case-category companies for CC1, CC2 and CC3.

On the other hand, CC4, ATFs are responsible for issuing CoDs and stores EoL cars for further treatments. Within Case-Category four (CC4), companies (ATFA, ATFB, ATFC, ATFD) who are the key collection points were also found to have almost similar practice for EoL car collection process. However, in terms of facilities to collect cars ATFA, they have about 17 branches around UK, where in each branch they have about 10 to 15 drivers for 10 – 15 small (for one car) and big (up to 5 cars) auto carrying track to collect EoL cars, ATFB has about 40 branches to cover a number of areas in the UK with 12 - 20 auto carrying trucks and drivers, ATFD also have about 10 – 20 branches around the UK with a number of (10 to 15) auto carrying trucks and drivers to collect EoL cars. According to ATFB, sometimes they require more trucks to collect EoL cars; in this case they use their third-party logistics partner's transportation and this practice was also identified as similar for other ATF's.

5.2.1.3 Location related issues for EoL car collection

In terms of how convenient the location distance for collection centres/how close to the EoL car owners, as discussed above, this is heavily regulated and the findings identified that all car manufacturers have at least 75% of car owners within 10 miles of collection centres and the rest within 30 miles. So it was convenient for customers to drop off and for collection centres as well to collect the EoL car from the customer. Thought the distance between ATF and non-ATF collection centres was not regulated but still found important for most of the respondent here as cars must be delivered to an ATF to issue CoD and further treatment, it was important to identify the distance between ATF and non ATF centres to identify how convenient it was in terms of transportation cost and fuel consumption. It was found to be around 5-10 miles.

Similarly, distance between ATF and car owners was found to not be regulated but it still an important issue mentioned by ATFD, because all the cars were mainly collected from the last car owners to the ATF. Each car owner was within 7-15 miles from an ATF, which was convenient to customers and collection centres as well in terms of transportation cost and impact on fuel consumption (CO2 emission).

From a facility perspective, available space was identified as one of the key factors for collection centres. Collection centres from forward chains (non-ATF) had the space to hold about 10-15 drop-off scrap cars. The reason for only having that small space was mainly because EoL cars are transported to an ATF the same day. So they do not hold EoL cars. On the other hand reverse chain collection points (ATF) were identified as having around 10,000 to 20, 000 square feet of space to store EoL cars.

From a storage perspective, most respondents stored de-registered EoL cars mainly in dismantlers' scrap yard cars for further treatment. Here most of the scrap yards identified use 4 to 6 storage stands/racks, which significantly reduced footprint – the capacity of vehicles stored increased and reduced handling operation costs and time. Reduced damage to vehicles improves health and safety, allowing easy access to selective stock. On the other hand, some dismantlers' scrap yards still stored cars in the traditional way without any rack system. Environment perspective found there were no restriction in terms of location for EoL car collection and storage.

All case-category one (CC1)- Car Manufacturers (CM) companies were identified as meeting the regulations (detail discussed above in the network section). For the distance between CMs and the nearest ATF, according to CMB, the nearest ATF to drop off EoL cars is about 5 miles away. CMA, CMC, and CME also mentioned the nearest ATF they have is about 5 to 10 miles away. For the distance between ATF and car owners, according to CMA and CME, these companies' network of ATFs has been set up in a way that each car owner can find an ATF (CDs) within 7-15 miles. CMC also mentioned their car owners can find an ATF within a 12-mile distance.

Within CC2 (CDs) companies the distance between CDA and the nearest ATF to drop off or collect the EoL cars is about 2 miles away. CDA, CDC, and CDE also mentioned the nearest ATF they have is about 2 - 4 miles away. In terms of facilities, all CC2 companies are using their car showroom office where they have facilities to park EoL cars, but they do not hold EoL cars more than 24 hours.

Within CC3 companies both (OSCPA and OSCPB) found not involved directly with the car collection as their partners (ATFs) deal with EoL car collection and storage.

EoL cars are mainly collected to CC4 companies, as they are the key collection centres with treatment authorisation licence. Any cars coming to other non-ATF collection centres, discussed above, are transferred to CC4, companies. For the distance between CC4 (ATF) and car owners found from 2 – 15 mile distance. According to ATFB, ATFD, most EoL cars they collect come from within a 5 to 12 mile distance and cars dropped off by consumers from about 2 – 5 mile distance. In terms of facilities, according to ATFA, available space was identified as one key factor in terms of facilities for these companies. They have around 10,000 – 17,000 square feet of space for each of their branches to store EoL cars. ATFB also mentioned they have about 20,000 square feet of space to store EoL cars for each of their branches. Overall these companies have 10,000 to 20,000 square feet of space to hold EoL cars. In terms of transportation facilities, these companies have 10 to 20 auto carrying trucks and drivers to collect EoL cars. According to ATFD, these companies use 4 to 6 storage stands/racks to storage EoL cars. On the other hand, ATFA and ATFB store cars in a traditional way without any rack system. The reason mentioned by ATFA is that they do not have issues with space. On the other hand according to ATFC, though they do not have a storage problem, they still use a racking system as this gives them easy access to the EoL cars for further treatment.

5.2.1.4 Time related issues for EoL car collection

The time of EoL car return was found to be uncertain, depending on the reason for the return. Return reasons were discussed in chapter 4 as natural return due to age and mileage, unnatural return due to accident and abandoned cars return. In the case of collection, cars were collected within 24 hours of online acceptance by the nearest ATF companies. In terms of authorisation and car value calculation, it does not take customers time more than 5 minutes to complete the form. In terms of CoD, ATF issues the CoD as soon as they receive the car and last car owners found received it within seven days by post. According to the respondents from ATF companies, car value payments take 48 hours to reach last car owners' accounts. This practice was found to be similar within CC4 companies. There were no time related issues were found for collection stage within CC1, CC2 and CC3 companies as cars are mainly collected by ATFs (CC4).

5.2.1.5 Reuse and redistribution in the EoL car collection stage

EoL cars are collected at this stage (coming in); as mentioned before any cars accepted by non-ATF centres are distributed to ATF companies for further treatment. According to CMs, cars are mainly collected by ATF companies from CMs. Similar practice found for EoL car distribution where any cars accepted by case-category one (CC1) and case-category two (CC2) companies (CMs and CDs) are collected by nearest ATF for further treatment.

5.2.1.6 Performance of EoL car collection

The findings bring to light that only car manufacturers are keen to measure performance. Evidently, these performance characteristics are used in the collection phase and they are important sets of measures when car manufacturers want to save the environment and meet regulation by establishing the right network and process for EoL car collection. The majority of the respondents from car manufacturers (CM) reported that they measure performance for the collection stage separately to monitor the EoL car collection process in terms of its economic, environmental and social impact.

According to CMA the collection point network managed to collect 95% of EoL cars. The increasing number of EoL cars ensuring the network efficiency to eliminate the unauthorised/illegal collection and distribution of EoL cars. Though there is no direct regulation on EoL car percentage to collect, if any EoL car identified goes to an unauthorised treatment centre or is exported illegally, the responsibility falls on car manufacturers for a detailed explanation of how this happens and why, which may cause a penalty in terms of not having a system which failed to manage EoL car collection in an environment friendly way. Most of the respondent from CMA, CMB, CMC and CMD declared reduction of distance between collection points and car owners also reducing fuel consumption by optimising transportation to drop off or collect EoL cars. This EoL car collection process also found has positive impact in terms of social impact. CMC and CMD mentioned their engagement with stakeholder (CDs, OSCPs) especially with OSCPs who are doing a great job for car manufacturers by allocating collection points accordingly. Summary of performance indicators and actual performance are presented in the table 5.2.

Table 5. 2 EoL car collection process performance

Performance Indicators	Actual performance	Case Categories (CC) companies
Economic		
Compliance Cost	• Close distance between last car owners and collection points (mostly within 10 miles), free collection and car manufacturers scheme (£1000-£7000) has increased the number of EoL cars (in 2010 about 75% and now about 95% EoL cars are collected) as these encouraging EoL car owners to bring the car back to a authorised collection point rather than going to an unauthorised collection point which preventing cars being illegally exported as used saving car manufacturers from being noncompliant for exporting car which are unsafe to drive.	• CC1: CMA, CMB, CMC, CMD
Environmental		
Emission Impact	• Close distance between car owners and collection points helping transportation optimization which reducing fuel consumption. This helping to reduce CO2 emission as the amount of CO2 a car emits is directly related to the amount of fuel it consumes.	• CC1: CMA, CMB, CMC,CMD
Social		
Local job creation	• To meet regulations for convenient distance to car owner's car manufacturers increasing demands for more ATF which allowing ATF's to increase their branches and setup locally which creating local jobs	• CC1: CMC, CMD
Stakeholders participants	• Joint participation by stakeholders like car manufacturers and dealers participating to gather information for car distribution areas and car owners' addresses. Also, CMs working together with OSCPs setting up the network and managing the collection process for free take back allowing EoL car collection process effective to meet regulation to save environment and society.	• CC1: CMC, CMD

Source: Author

As discussed, earlier, EoL car collection stage performance is only measured within CC1 (CMs) companies. Within CC1 all the companies (CMA, CMB, CMC, CMD) identified measuring performance for this stage (EoL car collection). However, CMA and CMB were only found to measure economic and environmental impact where CMC and CMD also measure social impact as well to find how the collection point network and process impact on society. For instance, most of the car manufacturers interviewed have official measures for reporting environmental performance as environmental performance is one of their key performance indicators and is tracked and reported on a yearly basis. Moreover, in addition to the environmental performance being reported in the annual reports, a few CMA and CMB were also found to publish comprehensive sustainability reports annually with open access to the public.

5.2.2 Assessment and sorting of EoL cars

In this section, returned cars and their conditions are examined to identify EoL cars recovery options. It provides knowledge of where EoL cars go and how they can be reused and on what basis. This is the second stage of the EoL car RL process. Figure 5.1 shows that only Authorise Treatment facility Centre (ATF) – case-category four (CC4) companies are involved at this stage. Details of the assessment and sorting stage in terms of key constructs including regulatory restrictions, activities, location and time related issues, reuse and redistribution and their performance measurement are discussed below.

5.2.2.1 Regulatory restrictions for EoL cars assessment and sorting process

No regulations identified enforced for this assessment and sorting stage.

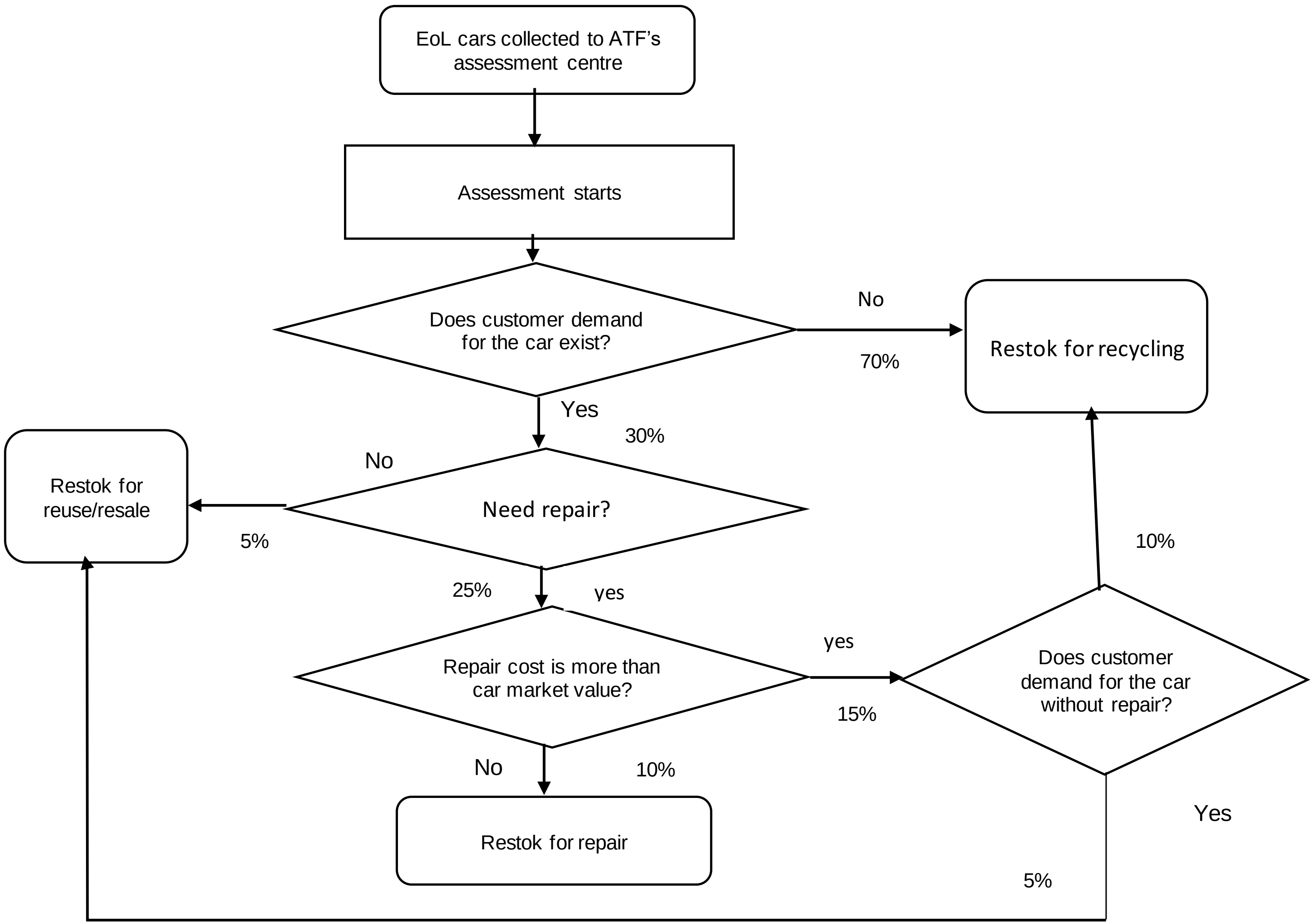
5.2.2.2 Activities for assessment and sorting process

As per most of the respondent from Case-category four (CC4) - Authorise Treatment Facilities (ATF) assessment mainly has two parts, where, first, the initial assessment is based on 2 options, either reuse the car or send for further treatment. All the EoL cars selected for further treatment were assessed to establish their useability in terms of parts functionality.

Initial assessment

As discussed in the chapter 4, when a car is no longer needed, a consumer has choices to dispose of it through car manufacturers, dealers, official scrap car partners, dismantlers and shredders but at the end EoL cars only end up at ATF companies. As per most of the respondents, the ATF would first do testing and inspection on these EoL cars. If the car is in good condition (see details below) and has market value (customer demand), the ATF may not necessarily dismantle the car, separating it for resale. If the car does not carry a profitable resale value, it will then be separated for recycling. Recycling is defined here as all the further treatment of a scrap car including hazardous materials removal, marketable parts removal, shredding and disposal.

Figure 5. 5 EoL car assessment and sorting initial stage


EoL cars collected to ATF's assessment centre
Assessment starts
Does customer demand for the car exist?
No
70%
Restok for recycling
Yes
30%
No
Need repair?
Restok for reuse/resale
5%
10%
25%
yes
yes
Repair cost is more than car market value?
15%
Does customer demand for the car without repair?
No
10%
Yes
Restok for repair
5%

This initial assessment was carried out manually based on the information recorded during car valuation, MOT history, accident history, mileage and experience of Quality Assure (QA) (the person assessing cars). In terms of mileage, the cars were assessed to establish whether the mileage, age and appearance of the car looked consistent. As a general rule, 15,000 miles a year is considered an “average” number of miles. So, a car that is 10 years old would have about 150,000 miles to be considered “average.” Anything significantly more, and a car is considered to be “high mileage.” Anything significantly less, and it is a “low mileage” car. However, it cannot be assumed a car is in good condition because it has “low” or “average” mileage — or that it is in bad condition if it has “high” mileage. Many modern cars with 100K-150K miles are in very good condition and will easily go another 100K. However, if a car has not been maintained properly and has been driven hard or worn-out, it can be junk with only 30K miles on the odometer. So MOT status and history is checked online (with vehicle registration and make) and accident history and physical check like any signs of inconsistent gaps between panels or mismatched colours that could be a sign of extensive repairs or the paint finish even across the car, any traces of paint spray on handles, window seals or plastic mouldings, could show that the car's colour has been changed. Looking under carpets and in other hidden areas in particular can reveal any unusual looking welding under the bonnet or in the boot. They also check cars safety in terms of whether the spare wheel or tyre inflator/sealant kit is in serviceable condition or not, whether the jack and other tools are present, whether all the seatbelts operate correctly, also they check if there are no cuts or fraying that could affect the way they work. If airbags are fitted, they check that warning lights operate as described in the handbook to see if all lights and windscreen wipers/washers work correctly.

They do a test drive to check if all warning lights operate normally. Lights will generally come on to test and then go out – unless there is a fault. The brakes are checked to see if they are effective or if it takes a long time or a lot of effort to stop; and whether braking is even or if the car pull to one side, any unusual noises when they brake, whether the handbrake is effective (for manual), any steering vibration or pulling to one side; if ABS is fitted, whether the warning lights go out after the engine is started; whether there are any abnormal noises when the engine is started, if the oil warning light go out as soon as the engine starts, any signs of excessive visible exhaust emissions, whether the clutch operates normally (for manual), a noise when you press the pedal, or a high biting point could mean that repairs will be required soon. They check the condition of the catalytic convertor the catalytic converter. They also look for a recent emissions test from the MOT. This will confirm that emissions are within the stringent limits applied to modern cars. In terms of locks, windows and general controls they check all the locks, including central locking and remote control, if they work properly; whether all windows, including any sunroof, open/close normally, any signs of forced entry, damaged or different locks, suggesting they have been replaced, have all the right keys; the handbook is also checked to see which keys were provided when the car was new, as modern keys are expensive to replace, particularly the coloured 'master' key provided by some manufacturers to programme new spare keys to the car, wheel nuts are fitted, minor controls operate correctly – heating, ventilation, air-conditioning, radio/CD, navigation etc. If these are in working condition or need little repair, they are separated for resale. If some of them are ok and some are not and need significant repair, which will cost more than the car value, they are separated for further treatment (dismantling) to recycle the car. So, cars are sorted based on their condition and cost analysis (if repair costs more than car market value). Market value is mainly assessed from available online information for similar cars and condition, current price and customer demand.

Further assessment

The assessment identified was done based on the amount of value that can be recovered from an EoL car. The assessment of cars depends on their nature, and is done mainly to identify and recover value from reusable components. As discussed in chapter 4, different nature of EoL cars are heavy/light metal components cars, components with or without dismantle marks, higher number of electric device and battery cars, mostly/less/non-functional cars. At first EoL cars are identified, separated and recorded according to material composition. This part of the assessment is mainly done based on IDIS information provided by car manufacturers. After that each car is assessed again based on IDIS information to separate and record the hazardous components. As mentioned before, all cars are similar in terms of them all having hazardous components, as all cars have air bags, air condition, seat belt pre-tensioners, oils, fluids, liquids and batteries. But the number of hazardous components identified can differ. There are some cars with more than one battery and a higher number of seat belts, and air conditioning. The most important and complicated part of this assessment process is to identify the functionality of components/parts from non-hazardous components. This was found to be done manually by an expert who can assess the functionality of components by examining them. This part is important and challenging because the assessment is manual and it has an impact on the dismantling process in terms of time and workload. If the components are assessed wrongly, the dismantler will remove the wrong parts which are not reusable or repairable and all this work will negatively affect operation cost and value recovery.

Functionality assessment of car components was based on two categories —- one is functionality based on the damage of components and the other is functionality based on the market value of components. If a car's parts are not damaged and they have market value, then those components are functional. Details of which parts are functional and which are not is assess and recorded. Market value depends on demand for particular parts or due to government restriction on use of heavy metal in car parts. So, in this case, even though car parts may not be damaged and are in good condition, due to market value, the car becomes non-functional.

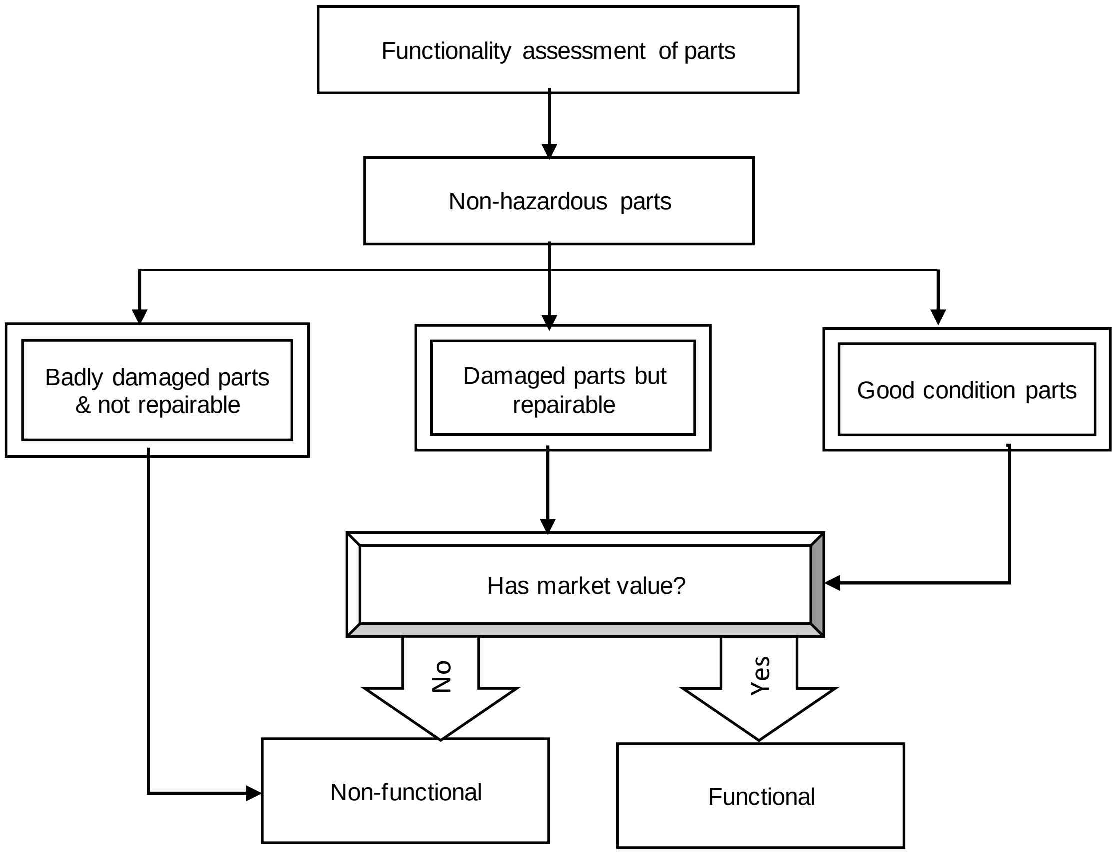


Figure 5. 6 Functionality assessment

5.2.2.3 Location related issues in EoL car assessment and sorting stage

As per what most respondents said, the assessment and sorting stage is done in the ATF's dismantling centres and once the assessment is completed, cars are sorted separately for reuse and repairable in one side of scrap yard and the rest for recycling in another side of scrap yard. In terms of the distance between collection centres and assessment centre, in terms of how convenience, the location distance between collection centres and assessment centres is around 10 to 20 miles.In terms of facilities, available space was identified as one of the key factors for assessment centres, as mostly cars are assessed and stored here. So, assessment centres mainly situated in a location with a scrap yard, which is identified have around 10,000 to 20, 000 square feet have space to store EoL cars. In terms of storage, EoL cars are stored mainly in ATF scrapyards separately according to cars' condition and recovery options. From the environmental issue perspective, there is no restriction in terms of location for EoL car assessment and storage. Location related issues found similar within Case-Category four (CC4) companies.

5.2.2.4 Time related issues in EoL car assessment and sorting stage

These assessment processes identified are carried out either at the time of loading EoL cars from the truck to the dismantling centre or after. In terms of assessment time of EoL cars, this depends on the QA. If the QA is skilled and experienced, they know where all the information can be found easily and what the main areas are to check, which takes not more than 40 -60 minutes. The further assessment was carried out either at the same time of the initial inspection and sorting stage or after. Mostly this was found to be done after, just before they start dismantling the car. Dismantling is defined here as hazardous material removal and marketable part removal. Only some difference was found for time related issues where ATFB and ATFC operate the further assesment activities after the initial assessment. But ATFA, ATFD were identified as carrying out this process together with the initial assessment of EoL car.

5.2.2.5 Reuse and redistribution in EoL car assessment and sorting stage

The empirical findings found about 20% EoL cars were found separated at this stage for resell (see the figure 5.5). EoL cars restored for redistribution with/without repair are mainly placed in auctions. Some of them are also sold directly to used car dealers. These cars are directly placed in the auction and resale to used car dealers does not mean they are fit for road. These cars were found to still need repair to make them roadworthy to pass MOT test. These are further repaired/refurbished by the buyers in the auto repair/body shops (this research does not include this further repair stage done by used car dealer/individual customer after redistribution/sold cars from dismantler).

5.2.2.6 Performance of EoL car assessment and sorting process

None of the ATF companies found to measure performance at this stage.

5.2.3 Hazardous component removal

After assessment of an end of life (EoL) car, it is necessary to remove the hazardous components before the next stage, which involves any reusable parts being salvaged. This practice was followed by all the authorised treatment facility (ATF) – case-category four (CC4) companies as they are mainly involved at this stage. Apart of ATF companies, car manufacturers (CM) – case-category one (CC1) companies were also found to be involved at this stage to provide car making (hazardous components details) information’s in IDIS for ATF access for hazardous component removal process.

Details of hazardous components removal stage in terms of key constructs including regulatory restrictions, activities, location and time related issues, reuse and redistribution and performance measurement findings are discussed below.

5.2.3.1 Regulatory restrictions on hazardous component removal

This stage is heavily regulated for health and safety and environmental issues. Number of regulatory restrictions identified here are (ELV directive);

- EoL car shall be stripped before further treatment where Hazardous materials and components shall be removed and segregated in a selective way so as not to contaminate subsequent shredder waste from the EoL car.
- Stripping operations and storage shall be carried out in such a way as to ensure the suitability of car components for reuse and recovery, and, in particular, for recycling.

- Treatment operations for hazardous removal of end-of-life shall be carried out as soon as is possible.
- All these devices, such as airbags or pyrotechnic seat belt pre-tensioners (regulation for site and operating standard), to be either deployed manually or electrically, depending on car type and year.
- Furthermore, car manufacturers should provide dismantling information and use coding standards. Within six months of putting a new type of vehicle on the market, a producer must provide dismantling information in respect of that type of vehicle. The Department believes that a producer should be able to discharge his responsibilities in this context by providing manuals and/or by means of electronic media, e.g. via a producer's website, or by his contributing to recognised CD-ROM databases, such as IDIS, the International Dismantling Information System.

Apart of this ELV directive other key legislation covering this area includes the Management of Health & Safety at Work Regulations 1999 which impose;

- a duty on employers to make a suitable and sufficient assessment of the risks faced by employees at work, the Control of Substances Hazardous to Health Regulations 2002 (COSHH), which imposes a duty on employers to prevent employees from being exposed to hazardous substances, and the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) – these cover risks of fire and explosion from hazardous substances, the Manufacture and Storage of Explosives Regulations 2005 – these require the licensing of storage of certain explosives; appropriate measures to prevent fire or explosion; limiting the extent of any fire or explosion should one occur; and protecting persons in the event of a fire or explosion.
- Operators removing Airbags and other pyrotechnic devices should be properly trained in order to reduce the risk of injury. From July 4, 2010, operators undertaking the removal of Air Conditioning fluids/gases must be formally qualified under the "F Gas Regulation" (EC No. 307/2008), implemented through the Fluorinated Greenhouse Gases Regulations 2009, which has both safety and environmental implications.

Regulations were applicable similarly for all the companies (ATFs) involved in this hazardous removal process. All these companies (ATFs) have the process in place to meet the regulation. They (ATFA, ATFB, ATFC, ATFD) also presented their compliance report for the last 5 years (2013-2017) as evidence of being compliance. To meet these regulations all companies (ATFs) found have the procedure in place with is discussed next.

5.2.3.2 Activities on hazardous component removal

In order to remove hazardous components from EoL cars all the ATF companies were found to have procedures in place. The main reason identified for this stage is CFC recovery. CFC is a type of hazardous chemical which should be recovered very carefully. This is because Chlorofluorocarbons (CFCs) are fully halogenated paraffin hydrocarbons that contain only carbon, chlorine, and fluorine, produced as volatile derivative of methane, ethane, and propane. These chemicals can destroy the ozone layer, thus reducing the protection the earth offers from the sun's harmful UV rays. CFCs also effect to Global Warming (through "the Greenhouse Effect") and are harmful to human health. The airbags, air conditioning, and seat belt tensioners contains this CFC gas. Therefore, these components are deployed in sites using suitable equipment and all individuals involved with deploying these components are required to attend a suitable training course.

According to most of the respondents, the majority of airbags are electrically deployed, either from a Single Direct Connector or a Deployment Control Unit. Before any work is carried out on electrically deployed airbags, they are disabled by disconnecting the battery. Following battery disconnection, a minimum period of 30 minutes is normally allowed before any work is carried out on airbags to allow any residual charge left in the system to dissipate. In some instances, a supplementary battery back-up system can be found, which will normally be indicated by a flashing LED on the steering wheel, which indicates the airbag circuit is still active. Undeployed air bags are mainly removed and stored. However, as they are classed as explosive devices, the storage facility found heavily regulated which requires separate storage of explosive components. Many modern cars found contain at least two airbags, and some luxury cars may well have more than 10 air bags. Air bags are found stored in airbag storage cabinets which is collected by the hazardous recycling centres (HRC) for recycling and disposal.

Seatbelt pre-tensioners are designed to pull the seat belt tight. Pre-tensioners found contain explosives and have stored mechanical energy (large spring) that is removed mainly identified manually. Manufacturers' guidance on the identification, removal and deployment of seat belt pre-tensioners identified is available in IDIS.

For air conditioning the two types of refrigerant that are used in car air conditioning systems are R12 and R134a. The type of refrigerant is marked on the car. The refrigerant identified is removed using specialist equipment (recovery system which is simple to set up and operate. Some of them switch itself off when the air con system is drained, single valve control for easy changeover from liquid to vapour to purge) and two collection cylinders are used; one for R12 (a CFC gas) and one for R134a (an HFC gas). The equipment is attached to the air conditioning filler valve, and takes about 10-12 minutes (the time depends on the system and the ambient air temperature) to remove all the fluid and transfer it to the collection cylinder. Regulations (EC 307/2008) required qualifications for persons dealing with "gases". These required relevant operatives to be formally trained and in possession of a duly accredited certificate of competence. All fluids of differing types (e.g oils, water-based etc.) were removed and stored in separate containers in a bonded storage area prior to specialist recovery or disposal. As a minimum, separate containers were required for fuels (petrol and diesel separate); oils (lubricating, transmission, power steering and shock absorber oils together); brake fluid (separate); and water based (coolant and screen wash together).The Waste Oils Directive seeks to promote the regeneration of oils, and any mixing of other fluids with oils may restrict this possibility. So, the EoL cars were placed on a support frame or lifting device, to allow easy access below the vehicle, before a number of these operations can be conducted. It is preferable that the device was adjustable to suit the height of the operator. There were health and safety issues with this approach, particularly with regard to possible build-up of fuel vapour in the pit (and hence risk of explosion/fire) during the depollution procedure. Therefore, the car was placed on a support frame which enables easy access to the underside of the vehicle at ground level. The first activity was identified to be conducted is to start draining the engine oil. Other activities were conducted in parallel, but the engine oil draining time typically take 20 minutes to reach the point where no further draining is visible. It was identified that equipment named 'gravity-drain' was used to remove the drain plug at the bottom of the sump and collect the oil. Sometimes the commercially available equipment identified was not used for collecting. A suitable container with a minimum volume of 10 litres was used. This oil was allowed to drain for a minimum of 20 minutes from the engine, or until such time as no visible further draining of oil is occurring.

Table 5. 3 Electric and manual procedures for EoL cars hazardous components removal

Components	Hazard	procedure
Air bags	Contains chemicals (CFC	Electric
Air condition	Contains chemicals (CFC)	Manual and electric
Seat Belt Pre-Tensioners	Contains chemicals (CFC)	Manual
Oils, fluids, liquids	Oils, lubricants, fuel, coolants, refrigerants, anti-freeze fluids, and wash fluids are all considered to be hazardous waste. If disposed of incorrectly, they can contaminate soil and pollute the water supply.	Manual/electric
Radiator and coolant	Contains chemicals (CFC)	Manual
Catalyst converter	contain toxic chemicals	Manual
Batteries	Contains Lead-acid and required recycled at a specialist battery recycling centre	Manual

Source: Author

The oil filter was also removed, and this also done by using a spanner/tool which does not puncture the oil filter during removal. The oil filters were sent to a suitable treatment facility using leakproof transit packaging.

The battery for starting, lighting, and ignition was removed easily with standard tools (Ratchet with extension (¼ inch), Safety glasses, Sockets (8mm, 10mm, and 13mm). The battery pack and batteries were kept dry and were not exposed to high temperatures. Batteries were identified and stored by battery type, according to national legislation (not mixed with lead acid batteries). Waste propulsion batteries in Hybrid Vehicles are classified as "industrial" under the Waste Batteries and Accumulators Regulations 2009, which prohibit their disposal by landfilling or incineration, and require their recycling via Approved Battery Treatment Operators or Approved Battery Exporters. Also, battery producers are responsible for minimising harmful effects of waste batteries on the environment, by paying for waste battery collection, treatment, recycling and disposal.

In terms of workforce, it was identified that removal and storing operations were mostly done by a group of in—house experts with hazardous component removal expertise, and equipment operators to lift the car and remove liquids (oil, fuel, fluids). These workforces were trained every 6 months in term of updates in regulations, any change in car design and dismantling process, and requirements for technology. There were a number of fleet operators identified as companies managing both internally (in-house) and externally (need basis).

In terms of equipment removal of airbag, air-condition and seatbelt tensioners, all fluids, battery, halogen bulbs and gas tank were done both manually and electronically depending on car type and sometimes the choice of the dismantling company. It is recommended by government agencies that depollution activities should be conducted using equipment which has been specifically designed for carrying out the required hazardous components removal operations (see table 5.4). The use of such equipment ensures that a high level of depollution and be achieved in a relatively short time-frame (20-30 minutes). In case the of use of alternative methods to achieve the same levels of depollution, health and safety requirements should never be compromised. An assessment of the risks involved in using alternative methods of depollution must be carried out and measures necessary to comply with relevant health and safety legislation put in place. In addition, if alternative methods are used, these will need to be able to demonstrate that at least the same level of depollution has been achieved.

Table 5. 4 Equipment used to remove hazardous components from EoL cars

Components	Equipment
Air bags	• Air bag deployment unit • Air bag storage cabinet
Air condition	• Air con recovery system • cylinders
Seat Belt Pre-Tensioners	• Standard Flathead Screwdriver • Torx Bit T45 – T50 • Socket Set 10mm – 17mm
Oils, fluids, liquids	• Fluid draining systems • storage tank
Radiator and coolant	• suitable container to drain and storage cooling system • pliers to unfasten
Catalyst converter	• Catalytic Converter Cutter
Batteries	• Ratchet with extension (¼ inch), Safety glasses, Sockets (8mm, 10mm, and 13mm), and Water (almost boiling).

Source: Author

Most of the respondents said that hazardous components removal was done mostly electrically by using up-to-date technology equipment.

Table 5. 5 Manual and electric activities in hazardous components removal

Use of technology	Manual activities
Hazardous component information's (IDIS) & functionality assessment record	Planning for depollution process
Lifting the car	Operating the lifting machine
Removing oils, fluids and liquids	Operating the removal system and storing
Depolluting the airbag	preparation of airbag depollution process and storing
Recovering aircon	preparing of aircon recovery and storing
-	removal of seat belt pretensioner
-	Removal of battery

Source: Author

In terms of cost, most of the ATF companies declared the key cost here is the cost for updated equipment for the removal process and information technology (database system to keep record of each components), as these keep changing with time (almost every year). Storage and transportation was not identified as a cost here, as storage is provided by Special Recycling Centres (SRC) and also collected by them.

The process was found to be similar within CC4 companies, as this stage was heavily regulated in terms of removal process and storage system. Some detail differences were identified within CC4 companies in terms of use of equipment and training for employees. According to ATFA, electric fluid extractor machines are used to remove and store fluids from EoL cars. A similar process was identified for ATFB. According to ATFC, they found removes fluid manually. This manual process was also identified for ATFD. Moreover, in terms of training, according to ATFA, their employees involved with hazardous components removal attended internally arranged training every six months. This is identified as similar for ATFC; however, ATFD mentioned they also arrange training on a needs basis in case of change in internal policy & process and change in the design of cars and regulation. ATFB arranged similar training once in a year.

Overall, hazardous components removal of EoL cars was mainly executed by CC4 companies, as they had an ATF licence and were authorised for EoL recycling activities. CC1 companies found involved here did not process the hazardous components removal but they had a responsibility to provide car make information regarding all the hazardous components, including types of hazardous materials. On the other hand, CC7 companies were also involved for regulation purposes, developing and monitoring CC1 and CC4 for hazardous components information and for whether removal process related regulations were met or not.

5.2.3.3 Location related issues on hazardous component removal

As discussed before, hazardous components removal activities are conducted in the Authorise Treatment Centres (ATFs) facilities where mainly EoL cars were being stored for further treatment. According to most of the respondents, only environmental restrictions were identified as key issues here. As discussed before, most EoL car treatment sites are situated in the countryside in industrial areas. It was also found that they are not located in areas near drinking water, wetlands, buffer zones, schools, hospitals, public buildings, or other places of public gatherings. The reasons identified for this were the requirement of getting ATF license for EoL car treatment. According to the respondents from Local Agencies (LA), the location of the treatment centres should not affect public health, safety, environment, protections from a nuisance condition and aesthetics; and the local governing body may take into account general aesthetic considerations and whether the proposed use will have a negative aesthetic impact on the surroundings.

In terms of the facilities for treatment and storage of components and cars, all companies (ATF) have rainproof surfaces for appropriate areas with appropriate leakage collection facilities. Treatment sites Have waterproof surfaces in appropriate areas with appropriate leakage collection facilities, decanters and cleanser-degreasers. Storage for removed parts, including impermeable storage for oil-contaminated spare parts were also available on sites, as were appropriate containers for storage of batteries (with electrolyte neutralisation), oil filters, storage tanks for the segregated storage of end-of-life cars fluids.

Table 5. 6 Location of hazardous components removal and storage

Components	Storage
Air bags	• Stored in ATF's site
Air condition	• Air condition system dismantled and stored in ATF's site • Gas stored in ATF's site for waste disposal company collection
Seat Belt Pre-Tensioners	• Dismantled and stored in ATF's site
Fluids (Coolant, Engine Oil, Fuel, Brake Fluid, Washer Fluid)	• Stored in a secure fluid store in ATF site
Radiator and coolant	• Dismantled and stored in ATF's site
Catalyst converter	• Dismantled and stored in ATF's site
Batteries	• Stored in a secure battery storage in ATF's site

Source: Author

All these components are then collected by the hazardous recycling centres (HRC) for recycling and disposal.

As mentioned earlier, removal of hazardous components is done in the same site where EoL cars are stored for recycling which was similar for all the Case Category Four (CC4) companies (ATFA, ATFB, ATFC and ATFD). There were some details that differed within these companies. According to ATFA, ATFB and ATFC these sites are situated in industrial areas which are 500 meters away from residential and farm areas. This distance was 800 meters for ATFD. According to ATFB and ATFC, un-depolluted cars at the site were placed in the designated EoL car storage area at the top yard located on the concrete impermeable surface with sealed a drainage system; however, other companies for CC4 took un-depolluted cars directly into the car depollution workshop for processing.

5.2.3.4 Time related issues on hazardous component removal

As most of the respondents said, it normally takes 10 days to 3 months after the EoL car arrives at the treatment centre to remove hazardous components. This was mainly done at the very beginning of the dismantler process because all these parts contained the dissemination of toxic propellant like sodium azide, explosive that can damage recycling equipment. Dismantlement of such devices from cars requires special care and particular cautions for handling and storing operations before further treatment. If the removal is not done properly the sodium azide could damage other useful parts and even recycling equipment. In terms of each component's removal time, it takes 10 to 30 min (depends on the components).

As mentioned earlier, this removal of hazardous components normally starts 10 days to 3 months after the EoL cars arrive at the ATF site. For ATFC and ATFD, cars normally wait 10 to 20 days after arriving at the scrapyard to start the removal process, as they work on a first in first out method. On the other hand, ATFA, ATFB were identified as taking up to a month after storing the car in the scrap yard. In the case of cars leaking fluid, they become a priority proceeding to first in the queue and this was identified as similar for all CC4 companies. In terms of each component's removal time which takes 10 to 30 mins (depending on the components) were found similar for all the CC4 comapneis.

5.2.3.6 Reuse and redistributions on hazardous component removal stage

As mentioned earlier, all these components are distributed to special recycling centres for further treatment (discussed in the hazardous recycling stage). And this practice was found to be similar for all CC4 companies.

5.2.3.6 Performance of hazardous component removal stage

Companies measured performance for this stage and the indicators identified for hazardous components removal of EoL cars included the economic perspective, value related, which is process efficiency; the environmental perspective, which is emission impact; and the social perspective, which is policy to manage the impact on employees and the community. All these were found to have a positive TBL impact where companies (ATFs) have proper policy to remove hazardous materials within a time frame (within a month), which helps to make the entire RL process more effective (on—time hazardous material removal means the car is ready to dismantle marketable components and, at the same time, providing space in the scrapyard to load more cars, which manages storage). Moreover, proper storage facilities prevent the environment from leakage and spillage of hazardous toxins. To minimise emissions, operators try their best, with appropriate measures, to control odour to prevent air pollution, but this was identified as still very challenging along with noise and vibration control. To protect employees from being exposed to hazardous substances, companies have strict policies for training and comply with rules, using safety gloves, glasses and masks during the removal of hazardous components. These were implemented and the accident and incident log did not identify any accident/injury for the last five years during the removal of hazardous material.

Table 5. 7 Hazardous components removal stage performance

Performance Indicators	Detail	Actual performance
Economic- Value related		
Process efficiency	Hazardous removal process start time.	• Companies having policy of starting hazardous components removal process within 10 days to 1 month from the collection of the EoL car at the facilities and it was found that they managed to implement this successfully with a positive impact on its overall process.
	Storage of removal components	• Hazardous waste are stored separately and liquids in containers, are stored in a secondary containment to prevent to minimise, leakage and spillage from the primary container.
Environmental		
Emission Impact	Odour, noice an vibration protection	• To minimise emissions operator used appropriate measures, including, but not limited to, those specified in any approved odour management

		plan, to prevent or where that is not practicable, to minimise, the odour, noice and vibration going out of sites
Social		
Policy to manage impact on employee and community	Policy to manage heath and safety issues for emplyees	• To prevent employees from being exposed to hazardous substances companies have strict policy for training for employees and stick rules to use safety gloves, glasses and mask during the removal of hazardous components. These were implemented and the accident and incident log did not identify any accident/injury for last five years during the removal of hazardous materials.

Source: Author

Within CC4 companies, ATFB and ATFC were found to measure performance to make sure their hazardous removal process policies are operative and competent. There were some differences identified here within ATFB and ATFC in terms of performance indicators. According to ATFB, they were mainly keen to see the impact of their process efficiency in terms of their policy for the removal process starting time which was found manageable (within 20 days of EoL car collection) and it has a positive impact on the entire hazardous removal process specially on storage of EoL cars.

ATFB was also keen to see the impact of their storage system. Their policy to use secondary containment was preventing the leakage and spillage from the primary container. On the other hand ATFC were keen to measure environmental and social performance. Their odour, noice an vibration protection policy found minimise emissions and policy to manage heath and safety issues for employees prevented employees from being exposed to hazardous substances. According to their accident and incident log, there was no accident/injury for last five years during the removal of hazardous components.

Now, the next stage presents the findings for all the above discussed hazardous components recycling processes.

5.2.4 Hazardous component recycling

All the components were removed at the hazardous components removal phase, including airbags, air-condition and seat belt tensioners, fluids(fuel, motor oil, transmission oil, gearbox oil, hydraulic oil, cooling liquids, antifreeze, brake fluids, and air-conditioning system fluids); battery, halogen bulbs and gas tanks are categorised as hazardous components due to the chemicals they contains (discussed in the removal section). These components required special treatment to recover value and proper disposal. This section discusses the findings for the recycling process of all these hazardous components to recover value and protect the environment.

As presented in figure 5.1, this stage involves Authorize Treatment Facilities (ATF), Hazardous Recycling Centres (HRC) and Government Agencies (GA). However, hazardous components recycling was mainly executed by hazardous recycling centre (HRC) companies only, as they have a licence for hazardous waste treatment activities (collection, storage, recycling). Government Agency (GA) were also involved in regulation with the purpose of developing and monitoring CC1 for information availability and CC5 for hazardous components recycling process related regulations.

RL process stage/ players involved	ATF	HRC	GA
Recycling hazardous components	Cooperating with hazardous components collection process in terms of storage and transportation facilities.	Mainly executing the process including collection, storage, recycling and redistribution	Regulating CC1 to provide car make information available, CC5 for hazardous removal process, storage and distribution.

Source: Author

Table 5. 8 Players involved in hazardous components recycling stage

Details of the hazardous components recycling stage, in terms of key constructs including regulatory restriction on hazardous recycling, hazardous recycling activities, location related issues in hazardous recycling, time related issues in hazardous recycling, reuse and redistribution in hazardous recycling stage and performance of hazardous recycling are discussed below.

5.2.4.2 Regulatory restrictions on hazardous recycling

This stage is heavily regulated to make sure that hazardous waste handled by business in the UK causes no harm or damage to the environment. According to most of the respondents, the Hazardous Recycling Centres (HRCs) must meet the “duty of care” responsibilities to recycle hazardous components and also must follow each step below in order to collect and transport hazardous waste.

- Register as a waste carrier.
- Ensure the waste is classified correctly.
- Separate waste correctly during the loading time for transportation.
- Storing them in an authorised waste site.
- Keep records of all documentation for one year.
- For recycling and disposal of hazardous components they must;
- Obtain an environmental permit or register an exemption for the premises.
- Check the consignment/delivery note and waste before accepting it – ensure it is classified correctly.
- Reject the waste if the consignment/delivery note is missing, incorrect or incomplete.
- Keep detailed records.

HRCA was only specialised in fluid recycling; however, all the regulations related to hazardous waste collection, transportation and storage and recycling were imposed on them. On the other hand, according to HRCB, this company has almost all the hazardous components recycling facilities, including batteries. Therefore, apart from these regulations of collection and treatment of hazardous materials, they also had to be an Approved Battery Treatment Operator (ABTO) to recycle industrial waste and automotive batteries.

5.2.4.3 Activities on hazardous component recycling

Every component has a unique recycling process. So, each component’s recycling process is discussed separately in this section, including all the value recovered from each component.

Battery recycling: As mentioned earlier, batteries contain materials that can be hazardous to the environment and human health. By recycling them at authorised centres, this mainly help prevent their harmful materials from polluting the soil and water supplies (and the air, during the recycling process). According to respondents from Hazardous Recycling Centre (HRC) companies most car batteries identified are lead-acid batteries, which contain around 11kg of lead and 5-6kg of diluted sulphuric acid, and 2-3kg of various alloying components. As lead and sulphuric acid are both hazardous materials, this means all car batteries are potentially harmful. Most common practice found that the batteries are added to a group of other lead-acid batteries and then they are all fed into a breaking machine. Rotating hammers in the machine smash the batteries into pieces. This breaks the battery down into five components: plastic (from the casing), lead grids, lead oxide (a lead paste), acid and a sulphur paste. The plastic is separated by machine and transported to a plastic recycling facility.

There, the plastic is cleaned and turned into pellets. The pellets are sold as a recycled material which can be used to create new car battery cases and other plastic goods.

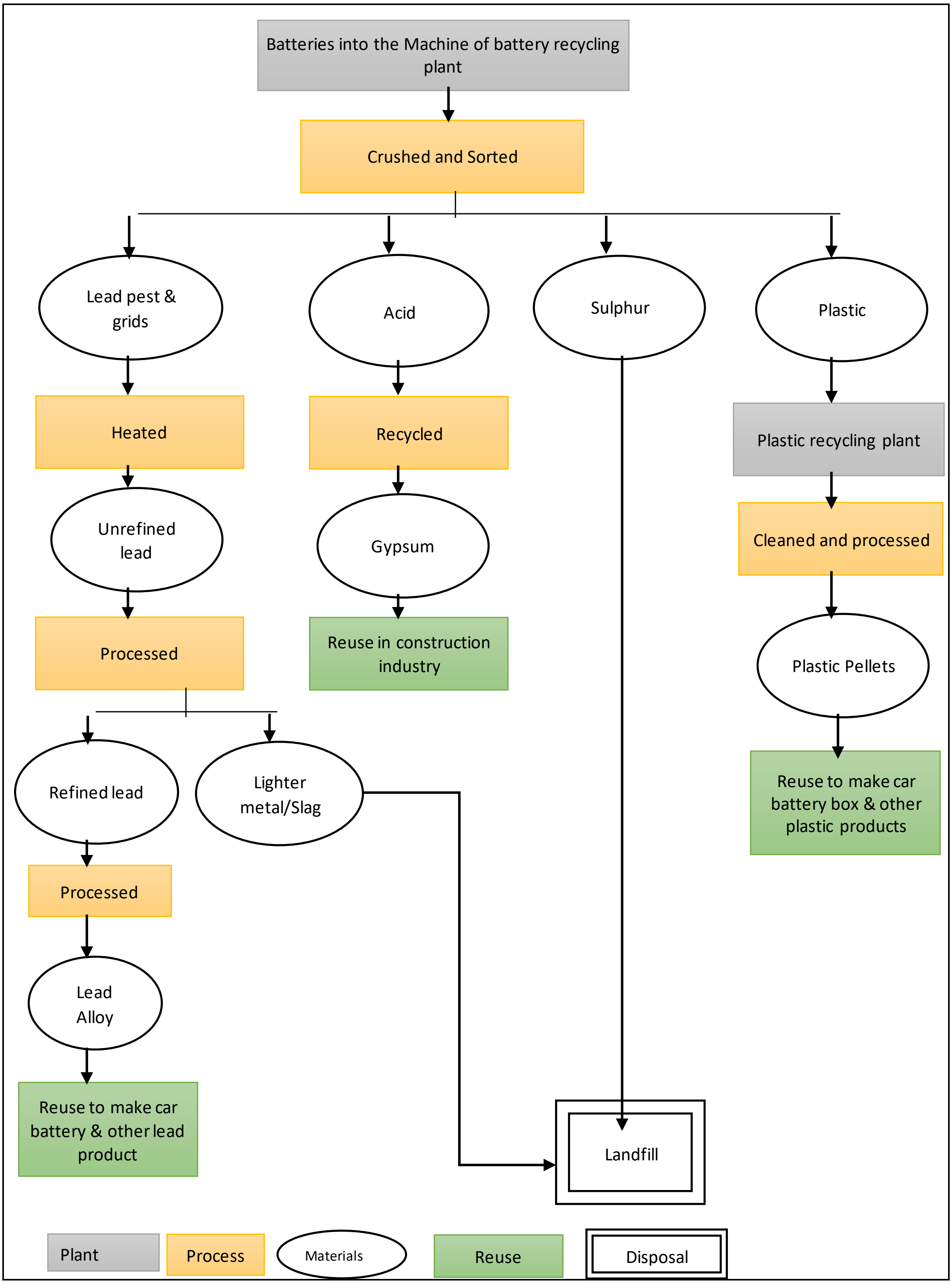


Figure 5. 7 Battery recycling process

The lead paste, acid and lead grids are screened and treated. They are then separated from each other. After the treatment, only a small amount of the acid remains and this can be collected and treated so that it can be reused. Recycling centres found are able to turn the acid waste into gypsum, which can be used in the construction industry. Some is also converted to sodium sulfate, a product used in fertilizer, dyes and other products, or reused in new batteries. The lead paste and lead grids are both placed in an industrial furnace. There, they are heated until they are molten (liquid form). They are now unrefined lead. The unrefined lead is fed into a refinery where it is stored in ‘kettles’ or ‘pots’. The unrefined lead is treated to remove any impurities. As part of this process, a small amount of lighter metals (such as calcium tin and calcium copper alloys) come outs of the unrefined lead. These lighter metals are a waste product known as ‘slag’ and they go to landfill. The purified lead is poured into moulds. The purified lead is allowed to cool as a pure. When the lead has cooled and hardened, it is packaged and transported, ready for sale as reusable materials. The sulphur paste is also a waste product that may be stored and sent to landfill. Using this process, around 97% of the materials in dead batteries are recycled and then used to make new products (including new car batteries).

Recycling seat belt pre-tensioners: Once removed from the car, pre-tensioners must be properly recycled as it contains hazardous materials pyrotechnic substances, which must be disposed of in accordance with the law. The HRC companies dismantled the seat belt pre-tensioner into component including seat belt webbing, retractors, buckles, tongues and pillar loops with proper care. These were found repaired, repackaged and resold by all HRC. In the case of the seat belt parts being not repairable, they were shredded by HRC companies by hazardous waste shredder machine and recover fabric.

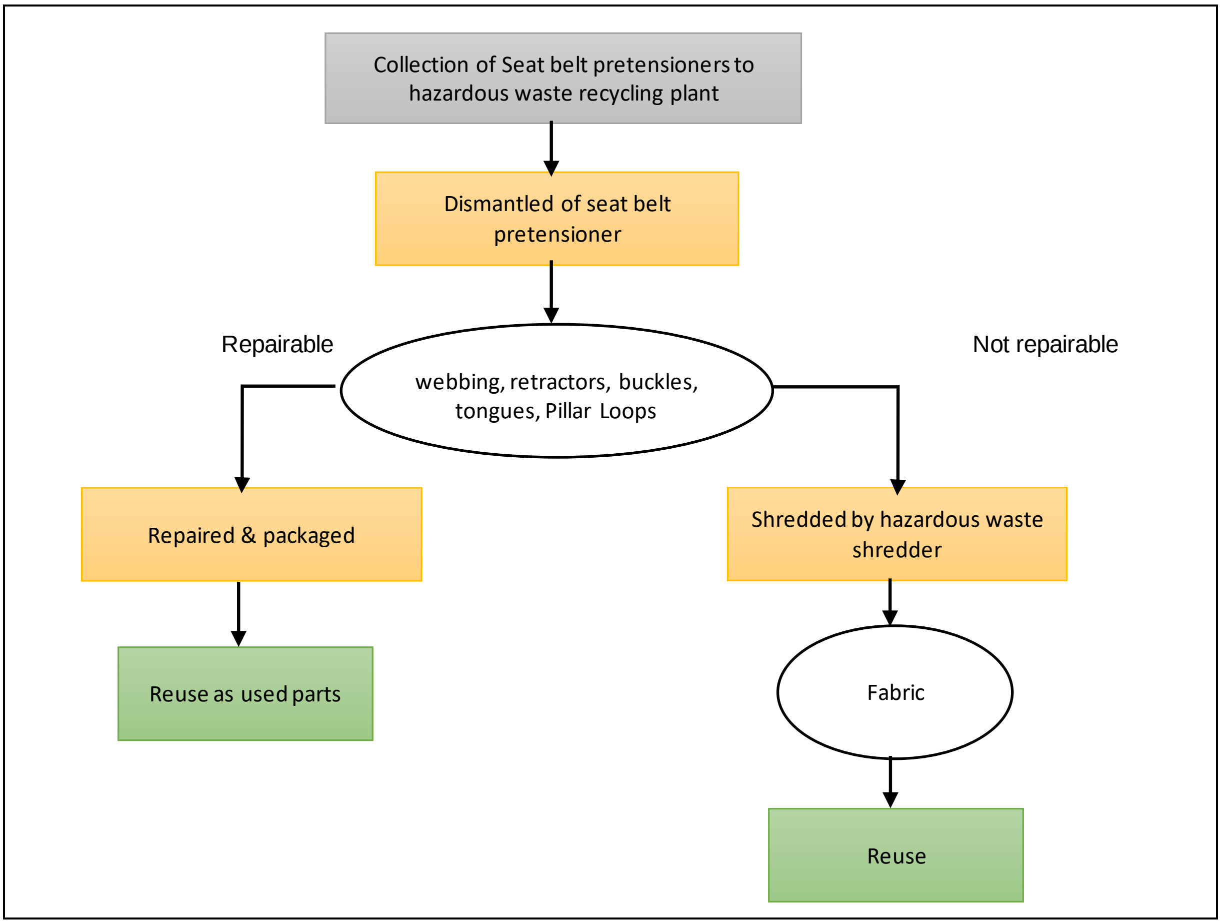


Figure 5. 8 Seat belt pre-tensioners recycling process

Catalytic Converters: As per all the respondent of HRCs, Catalytic converters are expensive and have a good scrap value due to the recovery of Platinum, Rhodium, and Palladium materials. These three precious metals are used in the catalytic converter and are what makes it so expensive to buy. The three metals can be found in the central chamber of the catalytic converter but it cannot be broken into it without special treatment as the inside of a catalytic converter is considered hazardous waste. Therefore, HRC collects them from ATF companies as they are specialists and have the appropriate recycling and safety equipment. These HRC companies found uses a process to extract the precious metals. The recycled platinum, rhodium, and palladium were further used as raw material for catalyst converters and in many different products, including medicine, dentistry, electrical components, jewellery. By recycling the metal container, metals including copper, nickel, cerium, iron, and manganese are also recovered.

Recycling Fluids: As seen in the hazardous parts removal section, scrap cars contain a number of fluids that were removed in the hazardous components removal process stage, including Coolant, Engine Oil, Fuel, Brake Fluid and Washer Fluid. These fluids, as already discussed, are stored separately and securely, as they can contaminate the soil and water supply very easily. Just a small amount of engine oil can pollute large amounts of water. This oil contains toxic materials and are harmful to humans and wildlife, and long-term exposure has been linked to skin cancer. There are many different ways in which the fluids from scrap cars can be recycled, including Distillation, Filtration, Ion Exchange, Reverse Osmosis and

Catalytic hydrogenation. Different recycling centres identified used different techniques. Some recyclers used a Distillation and Filtration process due to the cost of some of the catalytic hydrogenation process, which requires expensive equipment, whereas others used Catalyst Hydrazination to speed up the process. All these techniques have a similar effect in terms of quality and quantity of oil – they separate the oil from any contaminants and other materials (water and gas oil). The oil after that is treated and used as a material in new oil products. Also, gas oil can be reused for boilers and incinerators and water reused for agriculture.

Airbag recycling: Airbag recycling decreases the environmental footprint by diverting waste from landfills. The complete destruction and recycling of recalled airbags is not mutually exclusive. Plastic and metal recovered from destroyed airbags was recycled and sustainably used in the creation of new products. The hazardous waste disposal technique removed hazardous materials from the destroyed airbags and properly disposed of them. The remaining airbag components were recycled to form plastic pellets and metal sheets.

Radiator: Though radiators were identified as having a low market value, good condition radiators could still be repaired and resold in the secondary market. There is not a great profit for remanufacturing a radiator as the value captured is low. Therefore, remanufacturing radiators is not a option here. Radiators were mostly shredded by HRC to recover aluminium and copper, which were found to be valuable.

There are procedures in place at all the companies for the collection and recycling of hazardous components at all the HRC companies. Hazardous components are usually collected at HRC via the company logistics network. Components were dismantled and recycle in-house in the hazardous recycling site. According to HRCA they deal with all the auto fluid including Coolant, Engine Oil, Fuel, Brake Fluid and Washer Fluid. These fluids were stored separately and securely as they can contaminate the soil and water supply very easily. There are many different ways in which the fluids from scrap cars can be recycled, including Distillation, Filtration, Ion Exchange, Reverse Osmosis and Catalytic hydrogenation. HRCA found was using a Distillation and Filtration process due to the cost of some of the catalytic hydrogenation process which requires expensive equipment, whereas HRCB were using Catalyst Hydrazination to speed up the process. Both techniques were identified as having a similar effect in terms of quality and quantity of oil – they separated the oil from any contaminants and other materials (water and gas oil). HRCB also dealt with other automotive components recycling, as discussed above.

5.2.4.3 Location related issues in hazardous componet recycling

As mentioned before, most EoL car treatment sites are situated in country side in the industrial areas. It was also observed that HRC are also located far from drinking water, wetlands, buffer zones, schools, hospitals, public buildings, or other places of public gatherings. The reasons identified were government regulation to obtain the licence for hazardous component treatment. In terms of the facilities for treatment and storage of components, HRC found have rainproof surfaces for appropriate areas with appropriate leakage collection facilities. Sites identified for treatment had waterproof surfaces for appropriate areas with appropriate leakage collection facilities, decanters and cleanser-degreasers. Storage for dismantled spare parts, including impermeable storage for oil-contaminated spare parts, were also available on sites.

Appropriate containers were identified for storage of batteries (with electrolyte neutralisation), oil filters, storage tanks for the segregated storage of end-of-life cars fluids.

HRCA and HRCB were both located about 4 miles away from drinking water, wetlands, buffer zones, schools, hospitals, public buildings, or other places of public gatherings to avoid negative aesthetic impact on the surroundings, as this is the standard requirement of government regulations to get license to treat hazardous waste. In terms of location facilities and storage systems, according both companies found have rainproof surfaces for appropriate areas with appropriate leakage collection facilities, waterproof surfaces for appropriate areas with appropriate leakage collection facilities, decanters and cleanser-degreasers.

5.2.4.4 Time related issues in hazardous component recycling

Like the process and location, the time for holding hazardous components is also regulated. Regulation requires that these components are processed as soon as possible but no specific time was given. Therefore, each HRC companies found has their own policy to recycle hazardous components which was not more than a month after the collection of hazardous removal.

According to HRCB, regulation requires the recycling of hazardous waste as soon as possible, but there is no clear time frame; therefore, these companies have their own policy to recycle hazardous components within a month. According to HRCA, they start the recycling process within 20 days after the collection (first in first out (FIFO) method has been used). They also confirmed hazardous wastes are stored not more than 1 month.

5.2.4.5 Reuse and redistribution of hazardous components

As most respondent said, the importance of handling hazardous waste and reusing recovered parts and materials has been increasing in recent years. The findings show that most of the parts and components and materials are valuable in both primary and secondary markets presented in the table 5.9.

Table 5. 9 Reuse and redistribution of components recovered from hazardous components

Components	**Recovered parts and reuse**	**Recovered Materials**	**Reuse of materials**		**Disposal**
			For New cars	**Others**	
Air bags	-	Plastic palates, metal sheets	-	Other plastic and metal products	-
Seat Belt & pretensioner	Webbing, retractors, buckles, tongues, Pillar	Fabrics	-	Fabric products	-
Fluids	-	Oil	Motor oil	-	-
		Water	-	Agriculture	-
		Gas oil	-	boilers and incinerators	-

Radiator	Repaired radiators	Copper	Radiator	Copper product	
		Aluminium	Radiator	Aluminium product	
Catalyst converted	-	Platinum, Rhodium, palladium,	Catalyst converter	Medicine, dentistry, electrical components, jewellery	-
		Nickel	Break Tubing	Electric product	-
		Cerium	Catalyst converter	Electric product	-
		Copper	Wiring, radiator, connector, breaks	Electric product	-
		Iron	Iron parts	Iron product	-
		Manganese	Iron and steel parts	Iron and steel product	-
Batteries	-	Plastic	Car battery case	Plastic product	-
		Lead	Car battery	-	-
		Acid (converted to sodium sulfate)	Sodium sulfate	used in Fertiliser	-
		Gypsum	-	In the construction industry	
		Sulphur	-	-	Landfill
		Lighter metals	-	-	Landfill

Source: Author

Lighter materials and sulphur coming from batteries were sent to waste recycling companies to landfill the waste. This waste for landfill was identified as about 3% from the battery, as about 97% was recovered as materials (detail of disposal process is discussed in the disposal stage 5.1.9)

All the CC5 companies (HRCA and HRCB) are involved with redistribution of recovered parts and materials from hazardous components. According to HRCA, their recovered oils are reused in cars as motor oil and water and gas oils are reused in agriculture, boilers and incinerators. In addition, HRCA recovered materials are used in new car components including Copper, Aluminium, Platinum, Rhodium, palladium, Nickel, Cerium, Iron, Manganese, Plastic, and Sodium Sulphate to make Radiators, Catalytic Converters, Break Tubing, Wiring, Connectors, Breaks, Iron and Steel parts, Car battery cases and Car batteries. According to HRCB, they also recover some parts from hazardous components including webbing, retractors, buckles, tongues, pillar from seat belt pre—tensioners and also some reflation can be repaired, reused and resold in the secondary market. Also a small percentage of waste was generated in HRCB's recycling plant from batteries, which was transported to waste management companies (WMC) for landfill.

According to HRCB, the hazardous components recycling process generated some waste for landfill (Lighter materials and Sulphur). HRCA mentioned there was no waste generated in their site from the fluid recycling process. This was similar with HRCB too

5.2.4.6 Performance of hazardous component recycling process

Performance measurement was identified as an important aspect here for hazardous recycling companies (HRC) – case category five (CC5) companies (HRCA and HRCB). Economic, environmental and social performance were measured identified at this stage presented in the table 5.10. However, HRCA were found to only measure environmental impact in terms of emission and use of natural resources where their fluid recycling process found had no negative impact. On the other hand, HRCB identified measuring performance to establish the TBL impact of their hazardous recycling process (see detail in the table 5.10).

Table 5. 10 Hazardous components recycling stage performance

Performance Indicators	Actual performance	CC5	
		HRCA	HRCB
Economic - Value related			
Return on Investment (ROI)	Investment on updated equipment and expertise is high but increasing recovery rate and quality of parts and materials increasing annual sales and revenue which identified increasing return on investment		√
Impact on revenue	About 30% recovery of parts, materials and materials reuseable quality for new auto products increasing revenue		√
Recapturing value	Total recovery about 97 % from all hazardous components		√
Economic - Cost Related			
Operation/logistics cost	the recycling process of hazardous components specially the recycling of acid, light metals, plastic is costly in terms of process time, equipments, employees/expertise but financial support from battery manufacturers and car manufacturers (producer responsibility) saving the cost.		√
Compliance Cost	Recyclers were audited by regulators about 3-5 times last 5 years and received 1-2 action plans with no financial penalties. This is because of restricted regulation for transportation, storage and processing. Recyclers are convinced that they have environmentally friendly policy and practice in place. This is identified as reducing compliance cost.		√
Disposal Cost	Disposal cost per tone for non hazardous waste to landfill is about £70 in UK. Recovering more materials reducing waste (3-5%) which is saving disposal cost. Few year before (7-10) about 35% waste was going to landfill and that time also the landfill per tone was about £60.		√
Environmental			
Waste Reduction	About 3% waste going to landfill which is about 30 % less than what was going to landfill just 7 to 10 years before		√
Emission Impact	Emission impact was reduced by elimination/reducing waste for landfill	√	√
Use of natural resources	Reuse of recovered materials and oils in cars reduce the negative impacts that the extraction and processing of virgin materials has on the environment.	√	√
Energy consumption	Recycling process consuming energy with all the equipments uses but still this is about 90% less than processing new raw materials energy consumption.		√
Social			
Policy to manage impact on community	Reducing emission impact by using the lower concentrations of caustic chemicals (NaOH). A lower concentration of caustic decreases solids formation as a result of CO_2 absorption.		√

Source: Author

5.2.4 Marketable components removal

As mentioned in the earlier stage, after removal of hazardous components, cars are moved (same yard next to hazardous removal system) for marketable components removal, including the removal of seats, dashboards and other plastic, engines, gear boxes, tyres, window, hood, wiring harness, radiator, coolant, bumper, transmission, body, door, catalytic converter, suspension and wheels. This section discusses the findings of each of these components' removal process in the marketable components removal activities section below. In addition, this section discusses all the key constructs for marketable components removal including regulatory restrictions on marketable parts, marketable components removal, location and time related issues at marketable components removal stage and performance measurement of marketable components removal stage. Only authorised treatment facility (ATF) -case-category four (CC4) companies are found to be involved at this stage.

5.2.5.1 Regulatory restrictions on marketable components removal

This stage has direct impact on Environmental Protection (Duty of Care) Regulations 1991. According to Government agencies, stores of parts can create a great health and safety risk. For example, tire fires can occur easily, burning for months and creating substantial pollution in the air and ground. Due to their heavy metal and other pollutant content, parts pose a risk for the discharge of toxins into the groundwater when placed in wet soils. So, GA monitoring the storage process for parts removed from EoL cars.

Apart from this, ATF companies also pointed out an indirect impact of regulation for target recovery ensures that cars require the recovery of 95% of their weight when retired, with the responsibility for reaching this target falling on both the car manufacturers and the recovery industry. Here this stage can contribute to meeting the recovery target by recovering as many marketable components as possible.

ATFD mentioned that these companies are monitored by government agencies for storage of components removed from cars and stored for resale in terms of protection of ground water. Apart from this, ATFA mentioned the ELV directive requirement of 95% recovery from a car weight creating an indirect pressure to increase components recovery percentage as much as possible to meet regulation for EoL car recovery (95% of total car weight). Other CC4 companies also agreed with this. This regulatory restriction were found to be similar for all CC4 companies.

5.2.5.1.2 Activities on marketable components removal process

According to respondents from ATF companies, marketable components discussed above were removed manually at this stage. Before the dismantling process of marketable parts, it was identified that it is checked whether the battery is removed or not. Mostly batteries are removed and very rarely are they not removed. In this case, they remove the battery before starting the removal of marketable parts. Components such as car seats, textiles, large plastic components, including bumpers, dashboards, fluid containers and glass, are segregated by type and stored within sealed containers on impermeable surfacing in the yard.

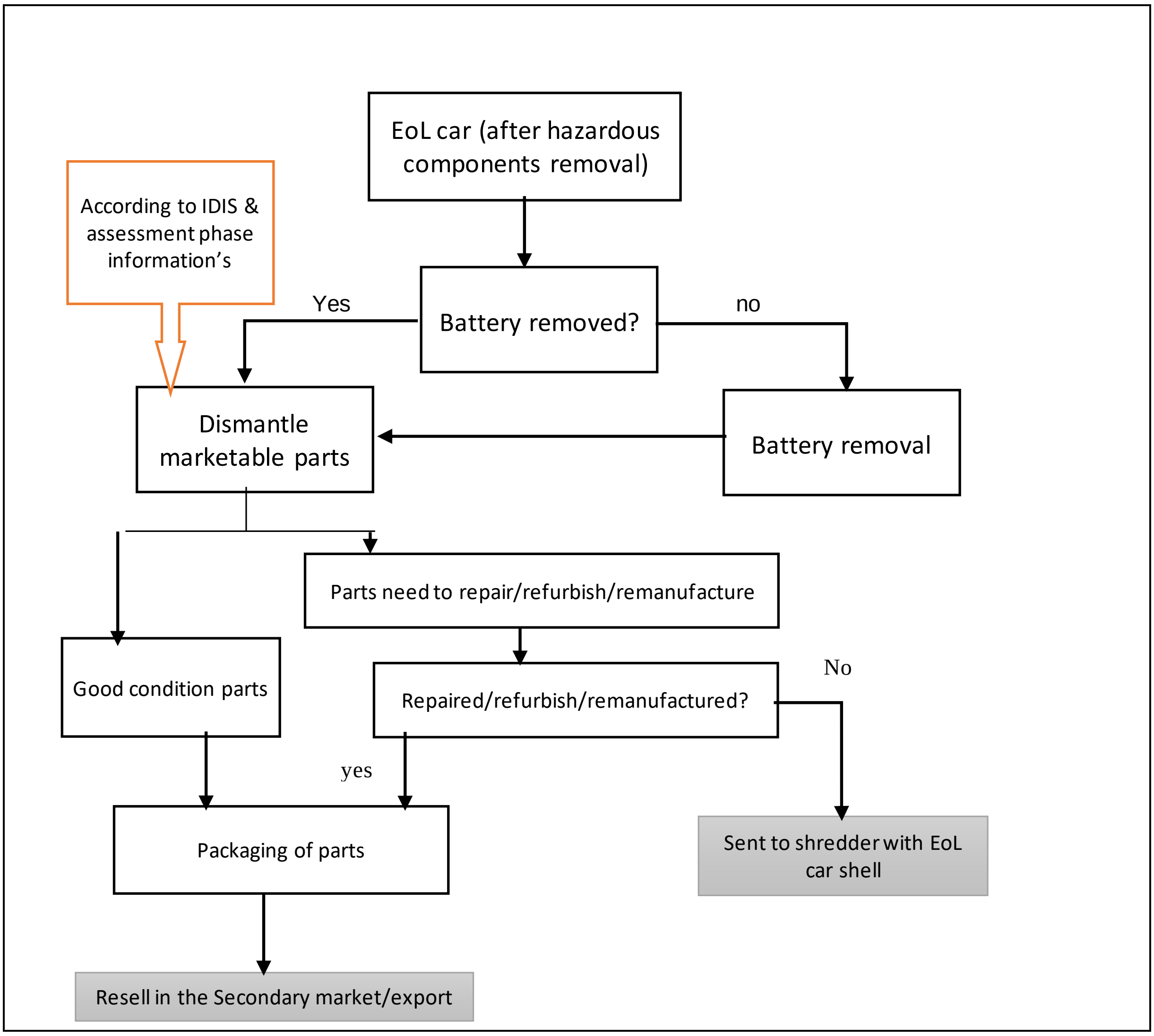


Figure 5. 9 The process of dismantling marketable parts

Engines and gearboxes are removed and placed directly inside designated sealed and covered containers that shall be located on the impermeable surface in the yard. Once the EoL car has been dismantled, as far as possible the metal shell is transferred to the bottom yard for flattening and / or shredding.

Table: 5.11 Components removal and sorting for redistribution

Components	Sorting
Suspension, wheels & Tyres	good condition tyres are stored for resale and rest sent to tire specialist centre
Seat	good condition seats are stored to resale and rest recycled
Window and doors and hood	Good condition windows and doors are stored to resale and rest goes to glass recycling centre
Engine and transmission	Good condition engines and transmissions are separated to resale
Wire harness	Good condition harness are separated to resale and rest sent to shredder
Bumper	Good conditions are separated to resale rest sent to shredder
Trunks and car bodies	get compacted and sent to shredder

Source: Author

At this stage all these parts were also sorted according to part conditions. Parts in good condition were repaired and repackage for resale and bad condition/not repairable parts sent to the shredder. Once all the marketable parts, including the engine, were removed, the car was left in the junkyard until it was time to be pressed.

It was identified that cars can be there for a few hours or even a few months, depending on how big the backlog of cars that need to be pressed. The operator drives the presser to the junkyard and sets it up (if it's a portable crusher). Cars are loaded onto the pressing bed with a forklift, an excavator with a huge claw on the end or a magnet. Some machines have a crane with a lifting claw or magnet built into the presser itself. The operator activates the hydraulics, pressing the cars as flat as possible.

The pressed cars take less than half of the space they originally required, and in some cases as little as ten percent. How flat they get depends on the presser and what kinds of cars are being crushed. Baler presser can reduce a car to a brick of crushed metal that's about three and a half feet high, two feet wide and three to five feet long.

There is also an additional storage period identified before the cars are shipped to a shredder. The cars are loaded onto trucks or a train and shipped to a recycler where they will be shredded down to chunks of scrap metal.

In terms of workforce, it was identified that removal and storage operations were mostly done by a group of in-house expertise. These workforces received training every 6 months in term of updates with regulations, any change in car design and the dismantling process, and requirements of technology.

The amount of equipment was identified for use during marketable parts dismantling process. Each component had removal tools where some are electric and some are manual. Using manual or electric tools was mostly the choice of the mechanics.

Table 5.12 Equipment used to remove marketable parts

Component	Equipment
Suspension, wheels & Tyres	Manual/electric tire removal tool Tire recycling machine
Seat	Seat removal tools (manual)
Window and doors and hood	Window and door removal tool (manual)
Engine and transmission	engine removal stands and tools (manual)
Wire harness	Harness removal tools (manual)
Bumper	Bumper removal tools (manual)

Source: Author

Technology was used in recording and creating reports in terms of number of components recovered and their conditions with details which helps to count the recovery rate at the end for each car in terms of car weight. In addition to this, some components were removed using electric tools (electric tire removal tool).

Marketable components removal activities were similar for all CC4 companies. However, some very detailed level differences were found as presented in the table 5.13 below.

Table 5.13 The difference within CC4 companies in terms of removal of marketable components

Activities	ATFA	ATFB	ATFC	ATFD
Checks the battery before they start removing marketable parts	√	√	√	-
Electric removal of Tire	√	√	-	-
Repairing marketable part if required	√	-	-	√
Packaging marketable parts	√	√	-	√
Compacting the car shell to transport to shredder	√	√		√

Source: Author

ATFC and ATFB do not repair parts because all dismantled parts are collected by their partners (parts dealers and repair centres). They just check the condition of the parts and separate them accordingly (need to repair/good condition/no need to repair). According to ATFA and ATFB, they compact cars to transport them to the shredder, as they are not involved in shredding; but ATFC do not compact cars, the reason being that these companies were also involved with shredding stage and the shredding plant was located next to the dismantling plant. On the other hand, ATFD were compacting cars even though they had a shredding plant next to the dismantling plant. The reason identified is so they can put up to 6 cars at a time in the shredder, making the process faster.

5.2.5.3 Location related issues on marketable components removal process

As per most correspondents, this process is operated in the same ATF yard where hazardous components were removed from the EoL car, but in a separate unit next to it. In terms of the facilities for treatment and storage of components and cars, dismantlers have rainproof surfaces for appropriate areas with appropriate leakage collection facilities, as well as storage for used tyres, including the prevention of fire hazards and excessive stockpiling. All these are stored in the ATF's site for further treatment.

Table 5. 14 Location in terms of dismantling process, storage and further process

Components	Dismantle and Storage	Repairable parts	Non-repairable parts
Suspension, wheels & Tyres	ATF's EoL cars marketable parts dismantling Site	Repaired and stored separately for resell in the same site where they get dismantled and repaired	Tyre recycling centre
Seat	ATF's EoL cars marketable parts dismantling Site	Repaired and stored separately for resell in the same site where they get dismantled and repaired	Shredders
Window, doors and hoods	ATF's EoL cars marketable parts dismantling Site	Repaired and stored separately for resell in the same site where it get dismantled and repaired	Windows are recycled at glass recycling centre and doors/hoods sent to shredder
Engine and transmission	ATF's EoL cars marketable parts dismantling Site	Repaired and stored separately for resell in the same site where it get dismantled and repaired	Shredder
Wire harness	ATF's EoL cars marketable parts dismantling Site		Shredder
Bumper	ATF's EoL cars marketable parts dismantling Site	Repaired and stored separately for resell in the same site where it get dismantled and repaired	Shredder
Trunks and car bodies	ATF's EoL cars marketable parts dismantling Site	-	Shredder

Source: Author

these location related issues were found to be similar within case-category four (CC4)- authorize treatment facility (ATF) companies. However, as ATFA and ATFB did not have shredding facilities, their compact cars were sent to shredders, while ATFC and ATFD stored car shells in the same yard for shredding.

5.2.5.4 Time related issues on marketable parts removal

Marketable components removal is identified as mainly done immediately after the completion of hazardous removal process. In terms of each component's removal time, it takes 10 to 30 min (depending on the component). According to ATFA, the components removal process takes about 2 hours for each car where each component takes 10 to 30 mins, depending on the components category presented in the table above. In terms of the storage time, ATFA and ATFD normally do not store car shells; they compact cars and send to their shredding partners. On the other hand, ATFC and ATFD stored car shells, which takes a few weeks to start shredding process. Difference between CC4 companies time related issues at this stage are presented in table 5.15.

Table 5. 15 Deference between CC4 companies in terms of time related issues in this marketable parts removal issues

Individual EoL dismantle practice in terms of when	ATFA	ATFB	ATFC	ATFD
As soon as the depollution process completes dismantle of marketable parts start			√	√
Dismantle of marketable parts start within 2 to 4 days of depollution process completes	√	√		
Dismantle of marketable parts start based on parts demand	√	√		
Car get compacted within few hours of cars coming in for compact	√	√		
Cars stored for shredding for few weeks			√	√
Sometimes car shells waits for a month for shredding process	√	√		

Source: Author

5.2.5.5 Reuse & redistribution on marketable parts removal stage

A number of components arrive at this stage for reuse purposes. So, this stage has an effect on the EoL car RL process in terms of recovering value and meeting regulation targets. Reusable parts quality and quantity were found to depend not only on the process (how carefully components are removed), but also on the make of car, which was discussed detail in chapter one (design part). In this stage, the average recovery rate from an EoL car was about 15% of the total weight of EoL cars and the rest were compacted and sent for shredding and sorting as materials. Components recovered here were also used and distributed in different ways with different percentages, presented in table 5.16.

Table 5. 11 Parts recovery percentage

Parts	Reuse as used parts	Going to remanufacturers	Going to Shredder	Market type	
	Repair & refurbish and use as used auto parts	Remanufacturer	Shredding	Primary market	Secondary market
Tyres	60%	-	40%		
Suspensions & wheels	50%	40%	10%	-	All
Hood	20%	-	80%	-	All
Seat	5%	-	95%	-	All
Doors	10%	-	90%	-	All
Windows	5%	-	95%	-	All

Engine	60%	40%	-	-	All
Transmission	60%	30%	10%	-	All
Wire harness	5%	-	95%	-	All
Bumper	65%	-	35%	-	All
Trunks and car bodies	-	-	100%	-	-

Source: Author

EoL car Hoods: Hoods were identified mostly as heavily damaged and sent to shredders to recover steel, as hoods are usually are made up of steel. Steel is one of the most popular recycled materials in the world, as steel is a mixture of iron. Steels are a limited resource (Chan et al. 2011). Thus, recycling steel or reusing steel as car parts could be economical, as production cost for purchasing steel would be lowered. Also, it is identified that there are a small portion of hoods recovered as car parts from EoL cars by dismantlers and hoods in good condition are not required to be refurbished or remanufactured, as dismantlers said that it is not economic to refurbish or remanufacturer hoods because of low market demand for used hoods. The reason identified is that each vehicle has its own size and features, which are not compatible with any other cars.

Engines: Good condition engines were stored by ATFs, as they have a profitable resale value and those in good condition but needing to refurbishment are sent back to the engine maker for refurbishment and remanufacturing. All these refurbished and remanufactured engines are used in reconditioned cars as an engine replacement. Refurbished and remanufactured engines are not used to make new cars in the UK due to issues with durability and quality. Findings also found that remanufactured engines could be produced with 83% less energy and 90% fewer raw materials than manufacturing a new engine. Engines which are not repairable are shredded to use/recover their aluminium alloy.

Transmissions: Transmissions were found to mostly be sent by dismantlers for repair, refurbishment and resale as used transmission. Some were also sent back to transmission manufacturers for remanufacture and resale as remanufactured transmission as this has good resale value. A small amount were also sent to shredders to recover steel and aluminium.

Wire harnesses: Small portions of wire harness were identified as in good conditioned and not requiring any repair or refurbishment. However, most of them were found to be damaged and sent for recycling to recover copper. Moreover, wire harness manufacturers are not interested in remanufacturing wire harnesses, as making new harnesses is more convenient and economical than remanufacturing.

Bumpers: Bumpers were repaired and resold by dismantlers, as used bumpers have good market value, as they can be easily broken and there is always demand for used bumpers as replacement parts. Those that are not repairable sent to the shredder to recover steel, aluminium, rubber and plastic. Bumpers were identified as not being refurbished or remanufactured by bumper manufacturers, as it is not economic due to transportation cost to send back to manufacturers.

Tyres: Mostly tires were found to be damaged but could be repairable. So, dismantlers sold these tires to tire repair centres. Tires are also collected by tire recycling centres where they recycle tyres and reuse the rubbers (detail is discussed in the recycling section). As a result of increasing environmental concern, tyre manufacturers collected tires and refurbished them for resale and export.

Suspension & wheels: Suspensions and wheels were found to be repaired and refurbished by dismantlers and were mostly in good condition for resale as used suspension to the secondary market due to high market value. Those that were badly damaged and not economical to repair or refurbish were sent to shredder to recover steel and aluminium. Suspensions and wheels were not remanufactured by their manufacturers due to collection transportation and remanufacturing cost which was not economical.

Doors: It is identified that only good condition doors were repaired and resold by dismantlers and heavily damaged doors Were sent to recover steel. Doors are not remanufactured or refurbished as they have very low value in the market due to its different/customised size for different model cars.

Seats: Used seat are identified having very low market value. As a result mostly seats were sent to the shredder to recover foam, plastic and fabrics**.**

Windows and windscreens: Mostly windows and windscreens were broken, which is found not to be economic to refurbish. So, these were shredded separately by glass shredder.

Trunks and car bodies: These were mainly sent to shredders to recover steel, which has very good market value. No waste went to landfill from this stage.

All CC4 companies are involved with reuse and redistribution of recovered components and parts. According to ATFD, about 15% of cars' weight is recovered at this stage by these companies. According to ATFC, these companies recover and resell repaired hoods, engines, transmission, hood, seat, doors, bumper, wire harness, and windows. Some dismantlers identified repair/refurbish parts before sale but some do not repair or refurbish but just sell to body shops, repair centres and none of them are involved with remanufacturing components and parts. Differences between CC4 companies here are presented in table 5.17.

Table 5. 17 Reuse and redistribution activities between CC4 companies

Individual EoL dismantle practice in terms of redistribution	ATFA	ATFB	ATFC	ATFD	ATFE	ATFF
Resale with and without repair and refurbishment	√	√		√		√
Resale without repair			√		√	
Not involved with remanufacturing components	√	√	√	√	√	√

Source: Author

5.2.5.6 Performance of marketable parts removal process

The findings indicate that ATF companies were keen to measure performance for marketable parts removal stage. Evidently, these performance characteristics are used in the marketable parts dismantling phase and they are important sets of measures when dismantlers want to make profit and protect the environment and meet regulation by establishing the right process. All CC4 companies identified measuring economic and environmental performance of this marketable parts removal stage are presented in table 5.18.

Table 5. 12 Marketable parts removal stage performance

Performance Indicators	Actual performance	CC4 companies			
		ATFA	ATFB	ATFC	ATFD
Economic- Value related					
Return on Investment (ROI)	Use of dismantling sign preventing parts from damages which improved components quality which giving better sales value which increasing revenue and also increasing return on investment as the investment cost for removal of marketable parts are not high because mostly removal process is done manually.	√	√	√	√
Impact on revenue	About 7 to 10 years ago only 5% of car weights was recoverable as components and parts from marketable parts removal stage but now its become about 15%	√	√	√	√
Recapturing value	15% of car weight was recovered at this stage (excluding hazardous components) which was only 5% about 7 to 10 yers ago	√	√	√	√
Process efficiency	The dismantling process identified as a few times easer than before due to the cooperation of car manufacturers (CM) in terms of design of car with ease of recycling sign in the parts and providing car making information.	√	√	√	√
Economic- Cost Related					
Operation/logistics cost	Available ease of dismantle sign and car make information for each component helping dismantlers to save time in the process.	√	√	√	√
Environmental					
Emission Impact	No negative emission impact as the process is mostly manual	√	√	√	√
Reduce packaging	Using materials like corn-based plastic is recommended as it can be broken down in a commercial composting facility. Biodegradable packaging ensures that none of the packaging material goes into the landfills.	√	√	-	√
Energy consumption	Much less energy consumption as mostly dismantling activities are manual and using minimal electric equipment	√	√	√	√

Source: Author

5.2.6 Shredding and sorting stage

As mentioned previously, car shells and non-repairable parts are moved to shredding plants where they are shredded and sorted by a modern technology “post shredder machine” into ferrous and nonferrous materials. In addition, the shredded machine also separates the ASR dust. Then, this ASR dust is moved to the ASR shredder plant developed by the automotive industry to reduce waste and environmental load on landfill sites. Here are the details of the shredding process findings including how this helps to recover value from EoL cars. As presented in figure 5.1 of this chapter that at this stage authorised treatment facility (ATF)-case-category four (CC4) and government agency (GA) companies are involved. However, ATF mainly dealing with shredding activities where GA developing and monitoring regulations disused below.

5.2.6.1 Regulatory restrictions on shredding and sorting stage

Like the marketable parts removal stage, this stage is also responsible for ensuring that cars meet recovery of 95% of their weight when retired by recovering as much material as possible. On the other hand, there is also direct regulation executed for shredder machines, which states that the shredding of a fully depolluted ELV should "give rise to levels of mineral oil in shredder residues of approximately 0.03%w/w - significantly below the hazardous waste threshold of 0.1 %w/w " (a shredder machine should be updated to cover these requirements). The automotive industry in the UK managed to comply with both the targets for recovering 95% of a car weight and the post shredder machine requirements.

Within CC4 (ATF) companies only ATFB and ATFC companies were involved with shredding process. According to ATFB these companies are regulated for the shredder machine requirements (discussed above). Both ATFB and ATFC identified have the updated shredder machine which controls and converts the hazardous ASR dust to non-hazardous.

5.6.2.2 Activities in shredding stage

As mentioned, this shredding process is mainly done my machine/technology. Once the compacted/uncompacted car shell and non-repairable parts were transported to the shredder for further processing the shredder ground the scrap into materials. These materials were then sorted by machine as ferrous, non ferrous and ASR dust by using magnetic and pneumatic techniques.

Table 5. 19 Materials recovered from car shell and non-repairable parts

Components	Sorting
Car shells & non-repairable parts	Ferrous, nonferrous and ASR dust

Source: Author

Furthermore, ASR shredder technology, such as flotation separation, eddy currents, multi level classifications and screening, were used to retrieve more materials from ASR dust. This confirms the accurate sorting of materials and quality to obtain permission to use as secondary raw materials which show that players in auto reverse logistics are ready for current challenges in terms of sustainable business in the auto industry in the UK.

Table 5. 20 Materials recovered from ASR Dust

Components	**Sorting**
ASR Dust	Glass, aluminium, foam, fabrics, copper, raisin/rubber

Source: Author

The ferrous and nonferrous materials identified were redistributed to metal recycling companies who recycle and recover valuable materials including Steel, Aluminium, Copper, Lead, Nickel, Brass and Bronze. All these materials recovered from ASR dust and ferrous/nonferrous materials are further reused as secondary raw metals.

Table 5. 21 Materials recovered from ferrous and nonferrous

Components	Sorting
Ferrous & Nonferrous	Steel, Aluminium, Copper, Lead, Nickel, Brass, Bronze, plastic

Source: Author

To recycle non-ferrous materials a process known as heavy media is used to split the materials – by changing the density of water, operatives can dictate what floats and what sinks. This works well for aluminium, copper and any other metals (around five per cent of a car's weight), but flotation will not work for plastics because they are made up of so many different chemicals. Previously, they went to landfill, but to meet the latest targets, there is now an extra process, called plastic polymers. Recycling car plastics is a vital step as 10 per cent of modern cars use up to 20 different plastics. To avoid sending them to landfill, recyclers joined forces with MBA Polymers, a leader in plastics, to set up a site in Worksop, Notts. Here, the plastics in cars can be separated, taken back down to their original properties and reconstituted as pure plastic pellets. These pellets can then be used to make new moulds.

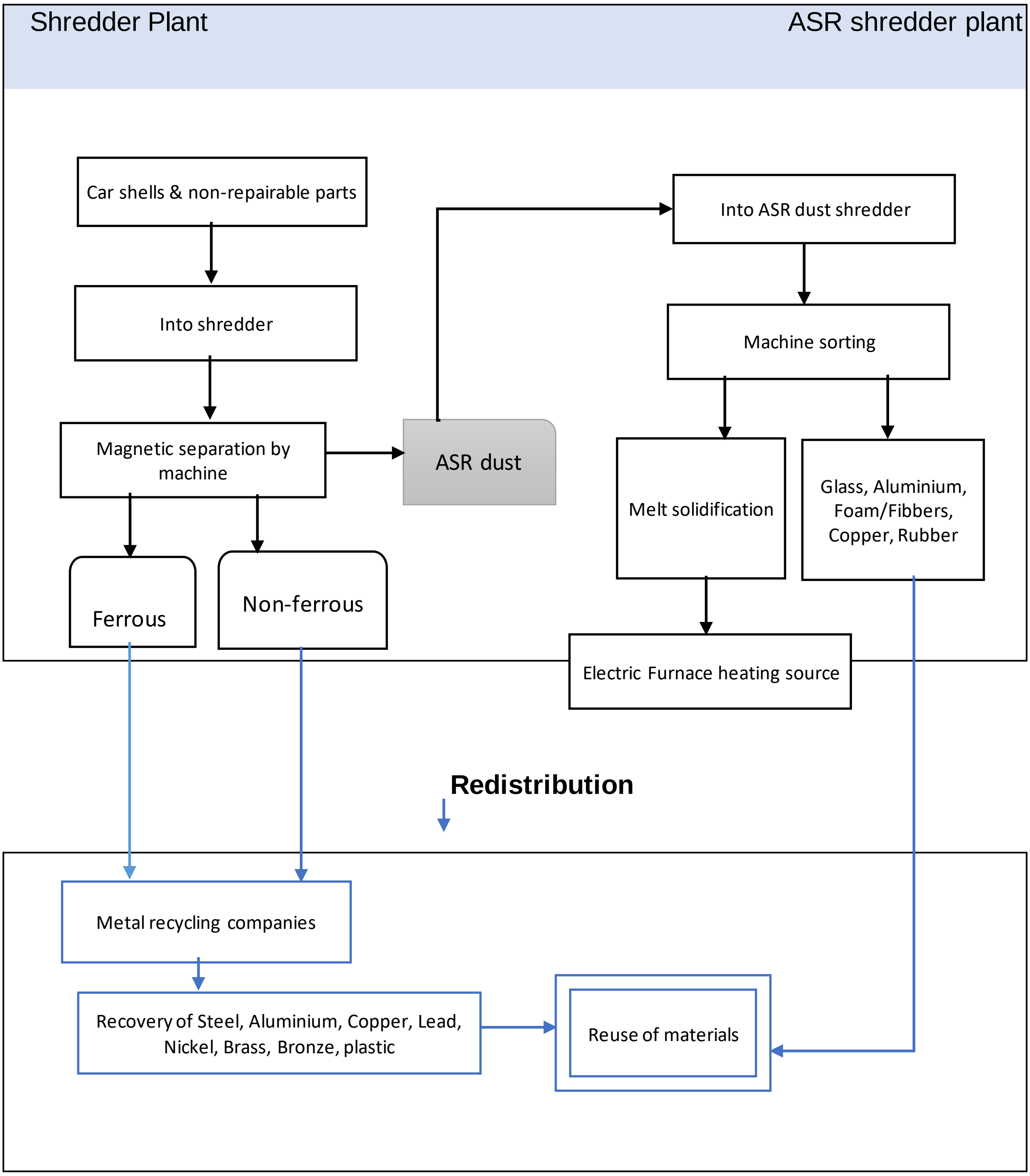


Figure 5. 10 Shredder plant to recover materials

According to most of the respondents, shredding and storing operations are mostly done by a post shredder machine where only machine operators work. These operators are trained before starting work and they also require basic training if there is any change in shredding process or technology.

In terms of equipment Post shredders and ASR shredders identified updated technology equipment developed with a combined effort by auto industry players including car manufacturers, auto recyclers and other stakeholders.

In terms of technology, as mentioned previously, the post shredder machine itself separates all the materials in ferrous, nonferrous and ASR dust by using the pneumatic & magnetic techniques; And the ASR shredder also crushes the ASR dust and separates all the materials by using pneumatic technique. Also, the integrated MIS database system identified was used to record and create reports in terms of quality and quantity of materials, which helps to count recovery rate at the endow the process for each car.

As mentioned earlier, only ATFC and ATFD were involved in this shredding process within CC4. The shredding process activities was found to be similar within ATFC and ATFD companies. However, only ATFD had the facilities to be involved with ASR shredding.

5.2.6.3 Location related issues in shredding process

As discussed in the previous stage (marketable parts removal), some dismantlers have the shredder machine setup in the same yard next to the dismantling system and some do not, where the car shells need to be transported to a separate shredder yard. Similarly, some of the shredder sites identified have ASR shredding facilities and others do not, where the ASR dust is transport to an ASR dust shredder plant for further recovery of materials.

Table 5. 22 Storage for compact cars and recovered materials

Components/materials	Dismantle and Storage	Further Recycling of materials
Compact car shells	Shredder plant	-
Materials from shredder are ferrous, nonferrous and ASR dust	Ferrous & nonferrous stored in shredder plant	ASR dust moves to ASR shredder plant
Materials from ASR shredder are Glass, aluminium, foam, fabrics, copper, raisin/rubber and ASR waste	ASR shredder plant	ASR waste moves for disposal

Source: Author

As ATFA and ATFB had no shredding facilities, after compacting the car they had to send the compacted cars to the shredder plant but for other CC4 companies the shredder machine was set up in the same yard next to the dismantling plant. Similarly, ATFC were not involved with ASR shredding; therefore, ASR dust had to travel to the other ASR shredder plants but ATFD identified as having ASR shredding facilities next to the car shell shredder plant.

5.2.6.3 Time related issues in shredding process

This is identified as mainly done immediately after the completion of the dismantling process. In some cases car shells were stored for months in a queue. It is a continues process. On one side the car shell is put into the machine while the other side of the machine provides three different types of materials (ferrous, nonferrous, ASR dust). Ferrous nonferrous materials are stored for months awaiting collection by metal making companies. ASR dust is identified and moved immediately to an ASR shredder plant where it stored. ASR dust does not wait more than 2 to 3 weeks to be put into the shredder machine, but the materials recovered from ASR dust are waiting months for collection by material making companies. On the other hand, the wastes coming from ASR which are not able to recover any materials, which is a very small amount (not more than 5 %), are dispose by incineration process.

According to ATFC and ATFD, as they have shredding facilities in the same plant the shredding process mainly starts immediately after the completion of dismantling process. But according to ATFA and ATFB, car shells are stored for months for shredding process. According to ATFD, ASR dusts are moved immediately to ASR shredder plant where it is stored. They also said recovered ferrous nonferrous materials from the shredder machine and materials recovered from shredder dust are stored for months awaiting collection by metal making companies. According to ATFC, there are some dusts that ASR plants are not able to recover; these materials are disposed of by incineration process immediately after ASR dust shredding process.

5.2.6.3 Reuse and redistribution in shredding process

This shredding phase can explain more clearly why recycling EoL cars has great value, as at this stage steel, light iron, cast iron and wrought iron from ferrous and from non-ferrous materials, aluminum, lead, copper, tin, zinc and brass are recovered. Due to limited resources such as steel, aluminium, copper, etc., recycling these materials were found to have good resale value, which also drives automotive industry substantially. This is the result of car manufacturers' and recyclers' joint efforts to recover greater value from EoL cars; automobile manufacturers have been increasing their efforts on RL and working with the dismantlers and other related parties. In the shredding phase, the average recovery rate is 45 to 56% of total weight of materials are ferrous and nonferrous and the remaining ASR dust is sent for further recycling and sorting as materials.

Table 5. 23 Reuse and redistribution of materials coming from shredder stage

Materials	Redistribution	Reuse	
		Cars	**Other products**
Steel	Car parts manufacturers and general steel product manufacturers	New cars steel parts	general steel product
Iron	Car parts manufacturers and general iron product manufacturers	New cars iron parts	General iron product
Aluminium	Car parts manufacturers and general aluminium product manufacturers	New cars aluminium parts	General Aluminium products
Lead	General lead product manufacturers		General lead products
Copper	Car parts manufacturers and general copper product manufacturers	New car parts	General copper product
Tin	Car parts manufacturers and general tin product manufacturers	New car parts	General tin product
Zink	Car parts manufacturers and general zinc product manufacturers	New car parts	General zinc product
Rubber	Car parts manufacturers and general rubber product manufacturers	New car parts	General rubber
Raisin	-	-	Use as alternative of Fuel
Glass	Car parts manufacturers and general copper product manufacturers	New car parts	General copper product

plastic	Car parts manufacturers and general glass product manufacturers	New car parts	General glass product
Paper	-	-	General paper product
Fabric	-	-	General fabric product

Source: Author

All these raw materials were injected back into the UK economy as secondary raw materials. These materials were exported just like primary raw materials. For the UK to remain competitive and to preserve the environment, natural resources should be used in the most efficient ways and without reducing the planet's resources. The industry is working to make this easier, and to realise the full potential of these materials. It also promotes the fair and sustainable sourcing of primary raw materials globally.

About 5% waste coming from ASR dust were disposed by incineration process in the same ASR plant. This incineration is the method of completely burning two organic streams of high-calorific waste as an alternative to regular fuel in order to provide low energy costs to industrial boilers and power plants, and to provide district heating. Burning is the complete oxidation of a substance to produce heat at high temperatures. This process is experienced without generating useful products like fuel gases, liquids, or solids. With regards to ASR, burning is generally referred to as incineration because extremely high temperatures are utilized. Incineration is a thermal treatment method that involves the burning of organic material. However, incineration has many operational disadvantages and results in the emission of harmful process remains including acidic gases, volatile organic compounds, and heavy metals (Malkow, 2004). Flame temperatures generally range between 800 ºC and 1650 ºC depending on the fuel, oxidant, stoichiometry, furnace design, and system heat loss (Integrated, 2004). Burning produces heat, oxidized species such as carbon dioxide and water, ash, and pollutants such as chlorides, dioxins, and furans.

The findings identified that the incineration process here has shown that these methods are capable of reducing CO2 emission by controlling the temperature and acidic gases to process ASR waste.

According to ATFC, about 95% of a car's shell weight is recovered at this stage as materials by the companies involved with shredding process and another 5% is also recovered as energy. From both ATFC and ATFD, ferrous and non-ferrous materials are distributed to metal making companies. Also from ATFD , glass, aluminium, foam, fabrics, copper, raisin/rubber recovered from ASR dust are distributed to raw material making companies. The practice of shredding materials distribution was identified as similar for both companies.

5.2.6.3 Performance in the shredding process

The findings indicate that shredders are keen to measure performance in terms process efficiency with materials quality and recovery percentage. Evidently, these performance characteristics are used in the shredding phase and they are important sets of measures when shredders want to make profit and save the environment and meet regulation by establishing the right process. At this stage ATFC and ATFD identified mainly measuring economic and environmental performance. Detail presented in the table 5.24.

Table 5. 24 Shredding stage performance

Performance Indicators	Actual performance	CC4 companies	
		ATFC	ATFD
Economic- Value related			
Return on Investment (ROI)	The investment cost for expensive post shredder machine is high but use of renewable materials in the car parts and the process by post shredder machine (shredding and sorting) identified saving operation cost as it requires less workforce and time. Also the use of renewable materials providing quality materials which can be reuse in new cars again increasing material value.	√	√
Recapturing value	Few years back (about 7 to 10) only 75% of car shell was able to recover which now become up to 95%	√	√
Process efficiency	ASR dust shredder managed to shred ASR dust and produce the ASR waste which further can be dispose by incineration process reducing waste for landfill	-	√
Economic- Cost Related			
Operation/logistics cost	Shredding and sorting at a time done by post shredder machine identified per car take 60 to 80 seconds only where before after shredding the sorting process was manual which was taking hours.	√	√
Environmental			
Emission Impact	Negative impact on CO2 emission for incineration of ASR waste identified reduced by controlling the temperature and acidic gases to burn ASR waste.	-	√
Energy consumption	Use of machines identified consuming energy during shredding process but simultaneously this process also generating energy from ASR waste. Therefore, no negative impact identified here in terms of every consumption.	-	√

Source: Author

5.2.7 Disposal of EoL car waste

This stage also identified as very important because hazardous wastes that are not properly disposed of can leak and contaminate soil and water, which can lead to issues with both the environment and human health. Burning the wrong types of waste can release gases into the atmosphere. When waste is properly discarded, special liners are used to prevent toxic chemicals from leaking out and precautions are taken so that any methane related to burning trash is safely contained. On the other hand, when waste is disposed of properly, it helps to prevent additional pollution, which can improve public health. Polluted air increases the risk of respiratory illness. Waste that is properly disposed of has a lesser chance of getting into the water supply and causing illness. Due to the danger to the environment and public health, the UK regulation for waste disposal is very restrictive and it could cost and affect very negatively the car manufacturer and other stakeholders for not being compliant and failing to meet regulation.

A few years ago, a big percentage (35-40%) of EoL cars materials were dumped into landfill, piling it high at a salvage yard or selling it for scrap. But now regulations won't allow that – and the rules are getting even tighter in the UK. The previous target of recycling 85 per cent of a car's weight was replaced at the start of 2015 by a stringent target of 95 per cent. As we saw in the other section of the RL process in this chapter, the latest developments have managed to recover up to 97% of an EoL car's weight, which has saved half a million tonnes a year from landfill, and as a whole the industry has reduced its landfill waste by 90 percent since 2000.

Now foams, rubbers, fabrics and light plastics are all pulled off the recycling stream. These would previously have been taken to landfill. With plastics, steel and metals such as aluminium and copper now recovered and put back into the system, all that remains are the lighter materials taken out during the vacuum stage at the initial recycling site. These materials – such as foam, rubber and light plastics – used to go to landfill, but are now turned into gas.

As discussed, in the process of unrefined lead, a small amount of lighter metals called calcium tin and calcium copper alloys come out of the unrefined lead. These lighter metals are a waste product known as 'slag' and they go into landfill or are burned to gas depending on the recycler. Sulphur paste is also a waste product that was identified; it was stored and sent to landfill or burned to gas.

5.2.7.1 Regulatory restrictions on disposal process

The Directive on the Incineration of Waste (The European Commission 2000b), unlike the landfill directive, has no prescriptive targets and therefore no part in shaping waste strategy. It does however set limits on emissions, operating conditions and water discharge, and strict controls on permits and monitoring. This directive was transposed into UK law in 2002 with the Waste Incineration regulations. Regulatory restrictions were found similar for all the companies within CC4 (ATFs) and CC6 (WMCs).

5.2.7.2 Activities on disposal process

EoL car waste was disposed either by incineration process or landfill. According to the respondents from ATF companies, waste generating from ASR dust are mainly disposed by incineration process to reduce the amount of waste going to landfill.

In terms of incineration process, it is found there are about 55 active incineration facilities identified in the UK with a total of more than 14m tones of waste treatment capacity. The cost of incineration per tone was about £72, which is almost similar to landfill (about £70) cost per tone. According to the respondent from ATF companies who are involved with incineration process said, incineration involves the burning of organic ingredients contained in waste materials. Incineration of waste materials converts the waste into ash, flue gas and heat. They also mentioned, the ash is mostly formed by the inorganic ingredients of the waste and may take the form of solid lumps or particulates carried by the flue gas. Therefore, the they use the updated machine which cleans the flue gas and particulate pollutants before they are dispersed into the atmosphere. Respondents also confirmed that the heat generated by incineration are used to generate electric power, Using hi-tech plants, where the materials are placed in a four-storey-tall rotating box which is heated up and converts them to gas. This gas is used to generate steam for electricity, with two tonnes of waste creating enough power to run the average house for a year.

As mentioned earlier EoL car waste for disposal (incineration) coming from ASR dust was burned with energy recovery, which is one of several waste-to-energy technologies. Incinerators reduce the solid mass of the original waste by 80–85% and the volume by 95–96%, depending on composition and degree of recovery of materials such as metals from the ash for recycling. This means that while incineration does not completely replace landfilling, it significantly reduces the necessary volume for disposal to landfill.

Regarding landfill the landfill of waste directive (2002) requirement is to assess whether the waste is hazardous or non-hazardous and will go accordingly to landfills for hazardous waste and landfills for non-hazardous waste site. Specific substances are also banned from landfill, including whole tires and shredded tires. The Environment Agency decided (2005) to accept car waste as non-hazardous without testing as long as all of shredded car had been recycled in line with the ELV Regulations for each stage that this could be confirmed through waste transfer notes.

There are about 500 landfill sites in the UK identified as active. As per all the respondent said from Waste Management Companies (WMC), to prepare the land before waste is deposited, several layers of linings are installed to seal up the base. Before starting to deposit waste, this process has to be verified independently for quality assurance. Therefore, the landfill sites are build carefully with number of layers where first a layer is laid down to smooth out the surface. A layer of clay is then put down to provide an excellent impermeable material that helps to prevent liquid from escaping. The third layer is a plastic liner. Geotextile is then placed over the plastic. A fifth layer of gravel is then installed. A layer of geotextile is the final stage of preparing the base. Waste from cars, is brought to the site and tipped into the specially created cells with other non-hazardous wastes. A compactor rolls over the waste to squash it into the hole to fill the space efficiently and to create a level surface. Each cell is built up with waste stage by stage. At the end of each stage, it is covered with inert soils or a special matting that helps to prevent odours and keeps the waste in place until more waste can be placed on top to complete the cell. Gas extraction wells are inserted into the cell to allow the gases that are created as the waste breaks down to be captured to generate electricity. The gases are pumped to a turbine house where they generate electricity for the National Grid. Each cell is filled with waste until it reaches a certain agreed level. Then the area is capped with a permanent plastic cover before begin working to restore the land. Restoration involves creating several layers above the waste to seal in what is below and protect what will grow above using a combination of high tech linings, subsoils and topsoils. The restored land will encourage wildflowers and a variety of other wildlife to the area. Monitoring bore holes are located on and off site to allow to ensure the quality of ground water in the area of the site. Surface water ponds can be found on the site. As surface water runs off the landfill site it is collected in the ponds to allow any soil particles that may have been collected in the process to settle before the water is allowed to discharge off site. Around the perimeter of the site a de-odourising system installed along the fence. This helps to capture airborne odors and neutralize them before they leave the site.

Waste coming for landfill from EoL cars in the UK are a small amount of lighter metals (such as calcium tin and calcium copper alloys) come outs of the unrefined lead from batteries. These lighter metals are a waste product known as 'slag' and they come to landfill. The sulphur paste is also a waste product that coming to landfill.

As mentioned previously, only ATFD is involved in this process of incineration of waste. According to ATFD companies teamed up with energy specialists to open the hi-tech plant, where the materials are placed in a four-storey-tall rotating box which is heated up and converts them to gas. This gas is used to generate steam for electricity, with two tonnes of waste creating enough power to run the average house for a year. Other CC4 companies are not involved as because they are not involved with ASR dust shredding process.

5.2.7.3 Location related issues in the disposal stage

Landfill sites were located far from residential areas. Up to 3 miles distance there are no residential areas identified nearby. This identified similar within CC6 companies.

5.2.7.4 Time related issues on disposal stage

All the waste coming to landfill site is instantly dumped in the site.

5.2.7.5 Reuse and redistribution on disposal stage

Generating energy which is used for housing electricity for heat and light.

5.2.7.1.6 Performance on disposal stage

Authorised treatment facility (ATF) companies measure performance here mainly in terms of environmental impact of the disposal process, because landfills produce landfill gas, which is about 40% to 60% methane, which is a greenhouse gas. Methane is an odourless, colourless, flammable gas. It is used primarily as fuel to make heat and light. It is also used to manufacture organic chemicals.

On the other hand, incinerators do not produce or release any methane but generate energy which prevents the harmful environmental effects of mining coal and drilling for oil and gas. It uses a fuel source that is available essentially everywhere that humans live, does not need to be mined or refined, and avoids fuel and materials supply depletion problems associated with fossil fuels and nuclear power.

Table 5. 25 Performance measurement at disposal stage

Performance Indicators	Detail	Actual performance
Economic- value related		
Process efficiency	Improved disposal process generating energy	The hi-tech plant, where the materials are placed in a four-storey-tall rotating box which is heated up and converts them to gas. This gas is used to generate steam for electricity, with two tonnes of waste creating enough power to run the average house for a year
Environmental		
Emission Impact	Reduction of emision	Odour monitoring, landfill gas controlling process reducing CO_2 emission impact
Social		
Policy to manage impact on community	Monitoring odor in air	They are based on the chemical analysis methodologies, which allow to carry out a determination of the molecules present in a gas stream. The advantage of these techniques is that they allow to determine the exact nature of the chemical species involved and their concentration. Adding the use of appropriate technology, products, and monitoring minimising but not completely eliminate odours.
	Controlling landfill gas	The goal of a landfill gas control plan is to prevent people from being exposed to landfill gas emissions. This goal can be achieved by either collecting and treating landfill gas at the landfill or by preventing landfill gas from entering buildings and homes in the community.

Source: Author

5.3 Summary of the chapter

This chapter mainly established a report on the within case-category, and cross case-category analysis conducted for this study. This chapter has specifically analysed and compared similarities and differences for EoL car RL process aspects among the eight type (CC) of stakeholders investigated with related issues including detail of each stage of EoL car RL process, locations for the activities in each stage and time related issues in each stage of EoL car RL process in the UK automotive sector. This also provides detail of RL process performance measured by all these stakeholders.

Further key aspects including relationship between players and drivers and barriers will be presented in a similar method (within CC analysis and cross CC analysis) in the Chapters Six and Seven.

A discussion of the implications of these results, how the triangulated empirical findings corroborate or contrast with the extant literature and extant theories will be presented in Chapter 8. The overall conclusions and implications for further research will also be drawn in Chapter 9.

CHAPTER 6. RELATIONSHIP NATURE BETWEEN PLAYERS IN EOL CAR REVERSE LOGISTICS PRACTICE

6.1 Introduction

Research question three was conducted in order to provide a holistic overview of the relationships between players involved in EoL car reverse logistics practice and their impact.

The previous chapter discussed some of the key players who are closely related to the EoL car RL process. For a clearer understanding of each of the player, the relationship nature between them, what is influencing them and any challenges facing in this relationship are discussed in this chapter. Therefore, In order to fulfil the requirements, set by the purpose, the objective of this chapter is to provide a holistic understanding of:

- Details of all the players involved in RL practice for EoL cars including their responsibilities.
- Relationship nature between players
- Relationship drivers driven players in that relationship
- Relationship barriers
- Overall impact of this relationship

Therefore, the study has attempted to develop a comprehensive picture by integrating the findings from interviews from within-case analysis of each cases presented in chapter 3 table 3.1, which feeds into within case-category analysis and cross case-category analysis to identify the similarities and differences within and cross case-category companies.

However, the drivers influencing these players to practice RL in terms of each phase, the types of barriers facing the practice of RL and the performance impact for each phase are discussed in chapter 7.

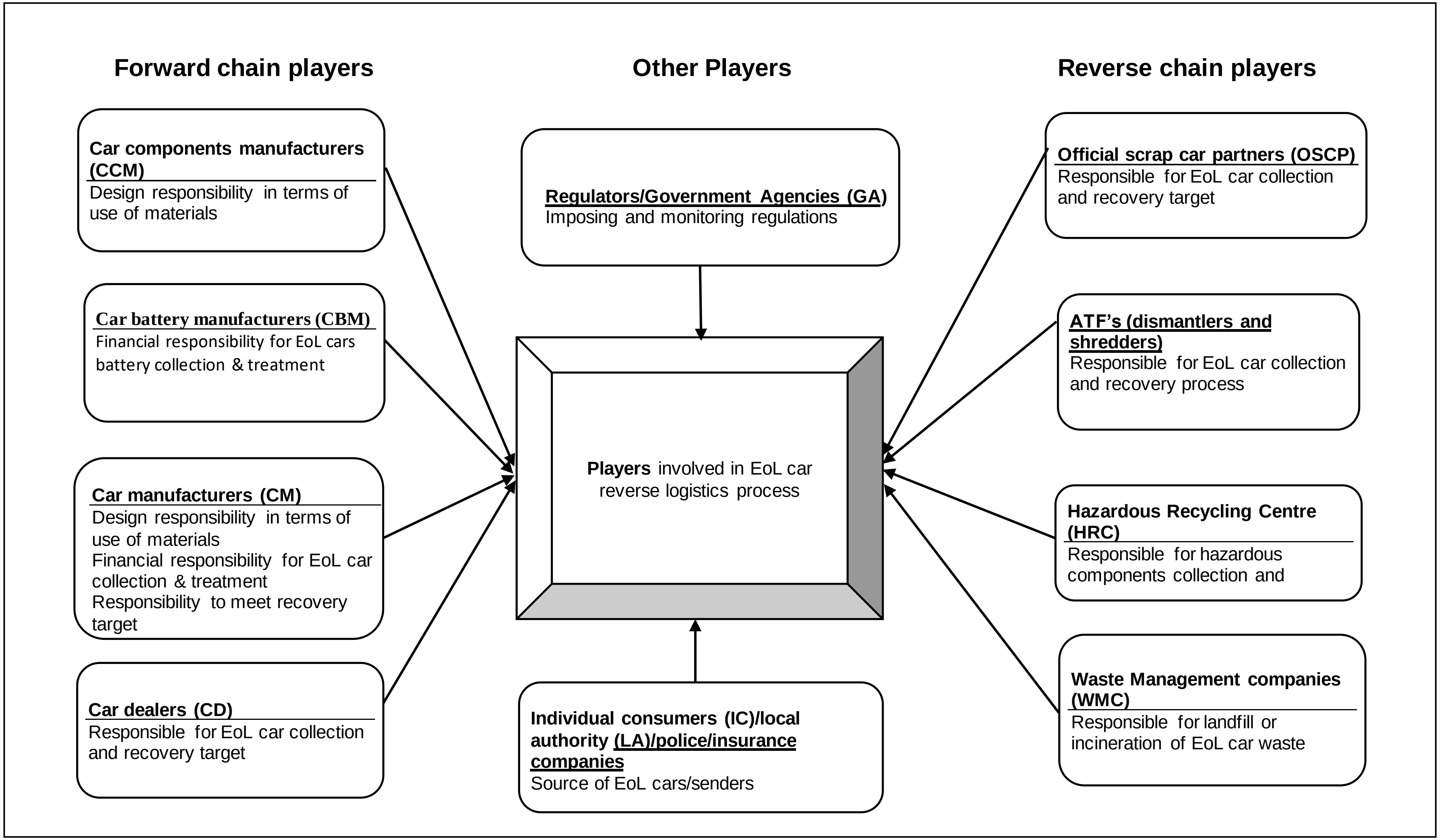
6.2 Players involved in EoL car RL practice

There are five different types of key players identified involved in the RL practice for EoL cars are:

- Forward chain players: Car Manufacturers (CMs), Car Dealers (CDs) and Car Component Manufacturers (CCMs).
- Reverse chain players: Authorised treatment Facilities (ATFs), Hazardous Recycling Centres (HRC), Waste Management Companies (WMCs)
- Regulatory bodies: Government Agencies (GAs)
- Membership body: Official Scrap Car Partners (OSCPs)
- Senders: Individual customers, institutions, local authorities and police

All these players were found to be responsible for different activities in the EoL car RL practice. A summary of players and their activities are presented in figure 6.1

Figure 6. 1 Players involved in EoL car RL process


Forward chain players
Other Players
Reverse chain players
Car components manufacturers (CCM)
Design responsibility in terms of use of materials
Regulators/Government Agencies (GA)
Imposing and monitoring regulations
Official scrap car partners (OSCP)
Responsible for EoL car collection and recovery target
Car battery manufacturers (CBM)
Financial responsibility for EoL cars battery collection & treatment
ATF's (dismantlers and shredders)
Responsible for EoL car collection and recovery process
Players involved in EoL car reverse logistics process
Car manufacturers (CM)
Design responsibility in terms of use of materials
Financial responsibility for EoL car collection & treatment
Responsibility to meet recovery target
Hazardous Recycling Centre (HRC)
Responsible for hazardous components collection and
Car dealers (CD)
Responsible for EoL car collection and recovery target
Individual consumers (IC)/local authority (LA)/police/insurance companies
Source of EoL cars/senders
Waste Management companies (WMC)
Responsible for landfill or incineration of EoL car waste

As discussed in chapter 5, Car Manufacturers are working as one of the collection points and are responsible for their own EoL car reverse logistics process to fulfil and meet the regulation for producer responsibilities. Dealers are mainly car manufacturers' appointed dealers (car showrooms and service centres) who also work as one of the collection points for EoL cars. Official scrap car partners are mainly organisations from membership bodies for the automotive industry, working with car manufacturers for the RL process for EoL cars. They are mainly the network of all auto recycling and manufacturing companies who also work as collection points for EoL cars and coordinate and manage the fund for recycling EoL cars. ATFs are the dismantlers and shredders of EoL cars. Chapter 5 also discussed the three different types of ATFs identified in terms of recycling facilities: one who are only collecting and dismantling and compacting the EoL cars, two who are collecting, dismantling and shredding the EoL car and three who are collecting, dismantling, shredding and also shredding and shorting the ASR dust and disposing of the waste. Other specialist recycling centres are Airbag recycling centres, CFC recycling centres, liquid recycling centres and battery recycling centres, who collect, recover and dispose of all the hazardous components of EoL cars. Landfill/waste disposal companies accept waste from EoL cars ASR dust. Apart from these, there is another key players found from forward logistics, battery manufacturers, who also contribute to recycling batteries (paying recycling fees for each battery sold).

All these players were found to be involved in different activities where forward chain players are mainly involved in planning, managing EoL car return and designing new cars with more recyclability, and reverse chain players mainly execute the RL process for EoL cars including collection, dismantling, shredding and disposal (see in the table 6.1).

Table 6. 1 EoL car RL process activities done by different players

Activities	**Players**									
	CM	**CD**	**CCM**	**OSCP**	**ATF**	**HRC**	**WMC**	**GA**	**CBM**	**IC**
Car design for EoL car										
Car design for more fuel efficiency and recyclability	√									
Use of recycled or renewable materials	√									
Recycling technology for EoL car										
Innovation of post shredder machine	√				√					
Innovation of oil refiner machine	√									
Collection of EoL car										
Information gathering of new car distribution for collection point setup	√	√								
Collection point setup for EoL cars	√			√						
Collection of EoL cars with free take back	√	√		√	√					
Issuing CoD					√					

Inspection and sorting										
Inspecting EoL cars for recovery options					√					
Reuse of EoL cars										
Selling EoL cars with or without repair by auction					√					
Further assessment of car parts										
Assessing car parts for removal options					√					
Removal of hazardous components										
Remove, storage and redistribution of hazardous components					√					
Recycling of hazardous components										
Recycle, resale of parts and materials recovered from hazardous components						√				
Disposal of waste generated from hazardous components						√	√			
Removal of marketable parts										
Resell marketable components and parts with or without repair					√					
Compact the car shell					√					
Shredding car shell and recovering ferrous, nonferrous and asr dust										
Redistributing ferrous and nonferrous					√					
Shredding ASR dust and recovering materials					√					
Incineration of ASR waste					√					
Disposal of car waste					√		√			
Developing and monitoring regulations										
Imposing ELV directive and other environmental regulations								√		
Sending EoL cars										
Helping to collect and dispose abandoned EoL cars									√	
Sending EoL cars for proper disposal										√

Source: Author

Details of all these key activities are discussed in chapter 4, section 4.4, and chapter 5. Therefore, this chapter only discuss the relationship nature adopted by players for each activity below.

6.2.1 Relationship nature between players

Different types of relationship were found between players for EoL cars RL practice. Some players have expertise and resources available for some activities which they operate internally; here players use their internal reverse chain resources and sometimes forward chain resources where they involved in a relationship within organization namely, internal relatinship but for some activities, firms do not have sufficient resources in terms of expertise, logistics, space and technology; here players are involved in a relationship namely, strategic alliances or acquisition nature relationship with other companies who has the necessary expertise. For some activities there is a relationship nature, namely an arm's length relationship, where companies have buyer—seller relationships with price-based negotiations. Collaboration levels in each relationship were found to be different. Table 6.2 presents these four types of relationship nature with collaboration type.

Table 6. 2 Relationship natures in EoL car RL practice and their collaboration level

Internal relationship	Strategies alliance	Acquisition	Arm's length
• In-house logistics facilities • In-house workforce (drivers, administrators, managers) • In-house IT facilities • In-house expertise • In-house equipment's	• Strategic/coordination level collaboration • Sharing investment and car making technology • Planning together • Taking decision together	• Strategic level collaboration • Sharing component making information and technology, investment and ownership of invented technology	• Transactional level collaboration • Sharing car distribution and recycling network information • Sharing EoL car collection related information's • Sharing storage system • Sharing car registration information's • Sharing waste quantity related information's • Receiving good discounted on transections

Source: Author

- Internal relationship within the organizations reverse chain: in-house resources including recycling equipment, expertise, transportation to collect cars, storage system for cars, components and materials, information technology to support integrated portal, communicate and record each car, components details.
- Internal relationship between organisations reverse and forward chain: using forward chain workforce, space for storage to hold cars, transportations to deliver EoL cars to partners if required, and information technology to support integrated portal, communicate and record.
- Arm's length relationship: supporting each other by providing transection level information's and sometimes sharing some resources including storage system and transportation between companies.

- Strategic alliance relationship: here players share information, transportation, technology and cost between case-category companies.
- Acquisition: Sharing information, transportation, technology, investment and ownership within and between case-catgory companies.

Collaboration levels in these relations were found to span every type of relationship. Arm's length relationships were identified at the collaboration level in the form of operation collaboration, where they only share information and sometimes logistics to complete the transaction. On the other hand, most strategic alliance relationships were identified at the collaboration level in the form of coordination collaboration, where they plan, share information and implement the task together. In addition, some strategic alliance activities were identified at the collaboration level in the form of strategic level collaboration, where players share investment as well. In both strategic and acquisition relationship nature the level of collaboration found close strategic level collaboration.

The relationship nature discussed above were found to vary within case-category (CC) companies. As discussed earlier, Case Category one (CC1) – Car Manufacturers (CMs) are responsible for their own cars' recycling in terms of setting up the network for EoL car collection, offering free take back for their cars and each car should be recycled and 95% of total car weight recycled. Therefore, these companies were identified as not directly executing the recycling process but still very much involved with planning, designing, developing and reporting to government agencies, as they are responsible for their own EoL car disposal. According to CMA, these companies are involved with a number of activities in the EoL car RL process, presented in table 6.5. The relationship nature were found to be similar for all CC1 companies. To execute each activity identified, CC1 companies use similar strategies where some activities are done with in—house resources, while other activities were outsourced where they have relationships within CC companies and cross CC companies (Relationships cross CC companies are discussed in section 2.3.3).

Table 6. 3 Relationship nature within CC1 companies for their EoL car RL related activities

Activities	Relationship nature	CC1 companies			
		CMA	CMB	CMC	CMD
New car design thinking recycling of EoL car	• Strategic level collaboration between CMC and CMD where they share investment and ownership of innovated technology			√	√
	• In house activities	√	√		
Development of new technology for recycling	• Acquisition with strategic level collaboration with CC4 companies	√	√	√	√
Planning and implementing EoL car collection point setup	• Strategic alliance with strategic level collaboration with CC3	√	√	√	√
Collecting of EoL car as Non-ATF collection point	• In-house activities by using forward chain workforce	√	√	√	√
Making information available for dismantlers in IDIS	• Internal activities by using forward chain workforce	√	√	√	√
Reporting regulators	• Internal activities using forward chain workforce (all CC1 companies)	√	√	√	√

Source: Author

Case Category two (CC2) – Car Dealers (CDs), these companies were also found to be involved in and responsible for some activities for EoL car RL practice. According to CDB, they are involved here as one of the Non-ATF collection points and also for recording and providing relevant information. These companies were found to have similar practice in terms of relationship nature to perform RL activities. There is no relationship found within CC2 companies.

Table 6. 4 Relationship nature within CC2 companies

Activities	**Relationship nature**	**CDA**	**CDB**	**CDC**	**CDD**
Accepting EoL cars and sending them to one of the ATF collection points	Internal activities • Using forward chain workforce to accept and contact ATF • Use car distribution logistics if needed for EoL car collection	√	√	√	√
Recording detail of EoL cars accepted by them	Internal activities • Using forward chain workforce to record car details	√	√	√	√
Providing sold car details in terms of car owners area and address	Internal activities • They normally keep this record for each car sold	√	√	√	√

Source: Author

Case Category three (CC3) – Scrap Car Official Partners (OSCPs) companies are membership bodies for both car manufacturers and recyclers. Mainly they work for car manufacturers to manage their RL of EoL cars. However, they are also the membership bodies for auto recycling companies; so, they have a huge network of ATF companies. Therefore, these companies are involved with some key activities presented in the table 6.5. Relationship natures were found to be similar for both OSCPA and OSCPB.

Table 6. 5 Relationship nature within CC3 companies

Activities	**Relationship nature within CC3 companies**	**OSCPA**	**OSCPB**
Planning and implementing EoL car collection point setup	Relationship across CC • Strategic nature with coordination level collaboration with CC1 companies	√	√
Collecting of EoL car as Non-ATF collection point	Relationship across CC • Arm's length nature with CC4	√	√

Source: Author

Case Category four (CC4) – Car Dismantler (ATFs), companies are the auto recyclers who are involved with EoL car collection through to the disposal process directly and they are the ATF collection points who are responsible for CoD. Therefore, most of the activities of the EoL car RL process are done by CC4, mostly done in-house. These are presented in table 6.6.

Table 6. 6 Relationship nature within CC4 companies for those activities

Activities	Relationship nature within CC4 companies	ATFA	ATFB	ATFC	ATFD
Collecting EoL cars	• In-house workforce and logistics	√	√	√	√
Issuing CoD to deregister the car	• In-house workforce and IT	√	√	√	√
Inspecting and sorting for recovery options	• In-house expertise	√	√	√	√
Resell and redistributes EoL cars with or without repair through auction	• In-house workforce and IT	√	√	√	√
Involved in further assessment of EoL car parts to dismantle	• In-house expertise	√	√	√	√
Removes hazardous components and stores for redistribution to hazardous recycling companies	• In-house expertise for removal process • Arm's length relation with CC5 for storage and collection of hazardous components	√	√	√	√
Removes marketable parts and resell without or with repair	• In-house expertise and storage	√	√	√	√
Compact car shell	• In-house workforce and equipment	√	√	√	√
Shredding car shells and recovering ferrous, nonferrous and ASR waste	• In-house workforce and equipment	N/A	N/A	√	√
Shredding ASR dust and recovering materials	• In-house workforce and equipment	N/A	N/A	N/A	√
Incinerating ASR waste	• In-house workforce and equipment	N/A	N/A	N/A	√

Source: Author

Case Category five (CC5) – Hazardous Recycling Centre (HRC) companies are the experts in hazardous recycling. Some of these companies focus on only one hazardous component and others have all the necessary facilities to recycle all hazardous auto components. The activities identified, which were discussed in detail in chapter 5, for the hazardous recycling stage are gathered in table 6.7. The relational nature was found to be in-house. Similar practices were identified between CC5 companies.

Table 6. 7 Relationship nature within CC5 companies

Activities	Relationship nature within CC5 companies	HRCA	HRCA
Collecting all type of car fluids	• In-house logistics and storage	√	√
Collecting other hazardous components including airbags, batteries, air condition and seat belt tensioners.	• In-house logistics and storage	N/A	√
Recycle fluid and reuse them	• In-house workforce and equipment	√	√
Dismantle other hazardous components and reuse good condition parts with or without repair	• In-house expertise	N/A	√
Shredding of hazardous components and reuse of materials	• In-house equipment	N/A	√
Disposal of waste	• Send to landfill site	N/A	√

Source: Author

Case Category six (CC6) – Waste Management Companies (WMC) are only involved with the collection of waste from cars and disposing of them either by using the incineration process or landfill. Details of this process was discussed in chapter 5. Similar practice and relationship nature was found in the operation of these activities between CC6 companies.

Table 6. 8 Relationship nature within CC6 companies

Activities	Relationship nature within CC6 companies	WMCA	WMCA
Collection of waste	• In-house workforce, equipment and facilities	√	√
Incineration of waste and generate energy			
Landfill waste and generate methane			

Source: Author

Case Category seven (CC7) – Government Agencies (GA) are involved in developing and monitoring regulation compulsory for all players involved in producing and recycling cars. Here GAA was found to be responsible for ELV directive related regulations development and monitoring.

Table 6. 9 Relationship nature for CC7 companies for RL activities

Activities	Relationship nature within CC7 companies	GAA
Developing and monitoring ELV directive and other environmental regulations for car making and recycling.	• Internal activities	√
Developing regulations and monitoring ATF and special recycling center license validation process	• Internal activities	√

Source: Author

Case Category eight (CC8) – Local authority (LA) companies are responsible for abandoned cars where they help to collect all types of abandoned cars for proper disposal.

Table 6. 10 Approaches for activities

Activities	Relationship nature within CC8 companies	WMCA	WMCB
Send notice to collect the cars and pay the penalty if car owners found (register cars)	• In-house workforce, transport and IT	√	
If the car is not registered inform one of the ATF to collect and dispose the car			
Keep records of each cars			

Source: Author

So, the case-category (CC) companies were found to be involved in different stages of the EoL car RL process, as they have expertise in different areas. For instance, CC1 companies have expertise in car making and selling, while CC2 have expertise in car selling only. On the other hand, CC3 have expertise in the networking of auto recycling companies, CC4 have expertise in auto recycling, CC5 in hazardous recycling, CC6 in disposal, CC7 are regulation makers and CC8 are a source of EoL car collection. Therefore, each CC is involved in the RL process for EoL car according to their expertise. In some cases, though, RL is not CC1's expertise, but they are still required to be involved as responsible producers where they are trying to build and maintain relationships within or cross CC companies. It can be seen from the discussion above that not all case-category companies are involved in all activities and key activities working strategies found either conducting them internally or partnering within case-category or cross case-category. A summary of the activities and relationship nature for those activities between case-category companies are presented in table 6.11.

Table 6. 11 Relationship nature for cross case-category (CC) companies

Key activities in EoL car reverse logistics	**Cross case-category (CC) companies**							
	CM-CC1	**CD-CC2**	**OSCP-CC3**	**ATF-CC4**	**HRC-CC5**	**WMC-CC6**	**GA-CC7**	**LA-CC8**
Car design for EoL car	acquisition -within CC	Not involved	Not involved	Not involved	Not involved	Not involved	Not involved	Not involved
Recycling technology for EoL car	Acquisition -with CC4	Not involved	Not involved	Acquisition - with CC1	Not involved	Not involved	Not involved	Not involved
Collection of EoL car	Strategic alliance-with CC3	Arms length - with CC1 and CC4	Strategic alliance-with CC1	Arms length -with CC2 and CC3	Not involved	Not involved	Not involved	Internal relationship
Inspection and sorting	Not involved	Not involved	Not involved	Internal relationship	Not involved	Not involved	Not involved	Not involved
Reuse and redistribute of EoL cars	Not involved	Not involved	Not involved	Internal relationship	Not involved	Not involved	Not involved	Not involved
Further assessment of car parts	Not involved	Not involved	Not involved	Internal relationship	Not involved	Not involved	Not involved	Not involved
Removal of hazardous components	Not involved	Not involved	Not involved	Internal relationship	Not involved	Not involved	Not involved	Not involved
Collecting and recycling of hazardous components	Not involved	Not involved	Not involved	Not involved	Arms length - with CC4	Not involved	Not involved	Not involved
Removal of marketable parts	Not involved	Not involved	Not involved	Internal relationship	Not involved	Not involved	Not involved	Not involved

Compact the car shell	Not involved	Not involved	Not involved	Internal relationship	Not involved	Not involved	Not involved	Not involved
Shredding car shell and recovering ferrous, nonferrous and ASR dust	Not involved	Not involved	Not involved	Internal relationship	Not involved	Not involved	Not involved	Not involved
Disposal of car waste	Not involved	Not involved	Not involved	Arms length -with CC6	Arms length - with CC6	Arms length - with CC4 and CC5	Not involved	Not involved
Developing and monitoring regulations	Not involved	Not involved	Not involved	Not involved	Not involved	Not involved	Internal relationship	Not involved

Source: Author

The nature of the relationships cross case-category companies were identified as different. Case-category (CC1) companies were found involved in a close collaboration relationship with case -category (CC3) who were responsible managing EoL RL process on behalf of CC1 companies. On the other hand, CC4 companies found conduct most of their activities internally as they are specilised for car recycling and have almost all the resources. However, CC4 were also found to have a close relationship, namely acquisition nature, with CC1 companies where they both share technology, expertise, information to invent greater shredding technology. Close collaboration in relationships was identified as having a very positive impact on the entire RL process in terms of value recovery from the EoL cars (details discussed in the relationship impact section below).

Details of these acquisition, strategic alliance and arm's length relationships (highlighted in the table 6.11) between case-category companies are presented in table 6.12.

Table 6. 12 Relationship between cross case category (CC) companies

Activities	Relationship and collaboration type	Detail	Case-Categories (CCs) companies							
			CC1 (CM)	CC2 (CD)	CC3 (OSCP)	CC4 (ATF)	CC5 (HRC)	CC6 (WMC)	CC7 (GA)	CC8 (LA)
Innovation of post shredder machine	Acquisition with strategic level collaboration	• Sharing technology and expertise and investment to develop post shredder machine (PSM) • Sharing the ownership of the PSM	√	-	-	√	-	-	-	-
Information gathering of new car distribution for collection point setup	Arm’s length with transactional level collaboration	• Sharing car distribution information	√	√	-	-	-	-	-	-
Collection point setup for EoL cars	Strategic with strategic level collaboration.	• Sharing car distribution information • Sharing recycling network • Planning together	√	-	√	-	-	-	-	-
Collection of EoL cars with free take back	Arm’s Length with transactional level collaboration	• Sharing EoL car collection related information’s	√	-	√	√	-	-	-	-
Remove, storage and redistribution of hazardous components	Arm’s Length with transactional level collaboration	• HRC providing storage and collecting them	-	-	-	√	√	-	-	-
Disposal of waste generated from hazardous components	Arm’s Length with transactional level collaboration	• Sharing waste quantity related information’s • HRCs paying discounted disposal fee	-	-	-	-	√	√	-	-

Source: Author

What influences all these players for the relationships discussed above are discussed in the next section 6.2.3

6.2.3 Relationship Drivers

In terms of what have driven the players to the above discussed relationships, minimisation of investment cost and access to new technology were found to be key drivers for both car manufacturers and recycling companies who conduct strategic level collaborations with each other. Some value-related factors were identified as motivating some players, including official scrap car partners and dismantlers in the chain, but from different perspectives. However, some factors, like focus on core, were identified as influencing only car manufacturers. The relationship drivers identified cover eight wider driver categories, which can be separated further to cost, value and cost & value perspectives, presented in table 6.13.

Within CC1, CMC and CMD were collaborating to build the best environmentally friendly cars possible at the lowest possible cost. The reasons for conducting these collaborations is cost. As the automotive industry expands worldwide, the costs associated with making a car increase accordingly, so automakers have to find ways to cut costs without cutting quality or stifling innovation. On the other hand, when designing a new car, automakers have a number of targets to achieve that require a significant amount of costly research. Meeting safety and fuel-economy standards are among the most expensive parts of developing a car. According to CMD, new cars are required to be more fuel efficient than ever before and not only is that type of technology expensive to develop compared to the tried and true internal combustion engine, but it can also be new territory for an automaker. In this situation CC1 companies have to invest huge amounts of money for research or collaborate with someone who shares similar goals. The manager from CMD said,

“The budgets are tough for a single OEM to deal with themselves, so collaborating with each other was our smart decision”.

Other case-category (CC) companies were driven by similar drivers within case-category companies. Therefore, table 6.13 presents drivers in terms of cross case-category which clarifies the similarities and difference of drivers between case-category companies.

Close collaboration was identified between CC1 and CC4 for post shredder machine and oil refining technology development, where they not only share both party expertise technology and investment, but also ownership of the newly developed technology; the main driver here is this relationship helping both CC1 and CC4 to minimize investment responsibility by sharing the investment. Another driver for this is access to new technology, because CC1 have expertise in car making, not recycling, so this relationship enables them to access CC4’s recycling technology, including the limitations of that technology, which enables their expertise to create better technology.

Also, CC1 have a close relationship (strategic alliance) with close collaboration with CC3 to develop a collection point network and manage the RL process; the main driver here is lack of intellectual resources for the recycling network which CC3 have, as they are the membership body for these recycling companies. Also different specialisation was another driver here, as CC1 was a car maker and seller, not a recycler, but due to regulation they have the producer responsibility to make sure their cars are disposed through a proper chain. On the other hand, CC3 are the expert companies in managing the RL process for EoL cars.

Therefore, CC1 passed CC3 the complete responsibility to setup the collection network and collect EoL cars.

CC2 are the dealers for CC1 and are only involved in EoL car collection, as a non-ATF centre, where they have the privilege of utilising the CC1 partnership relationship with CC3.

CC3 have a strategic alliance relationship with CC4 for the EoL car collection process and the key driver here is different specialisation. CC3 are not recyclers for EoL cars; they are the membership body for recyclers, but they are involved with EoL car collection as non ATF collection centres, so any cars coming to them need a ATF collection centre to collect the car for proper disposal, so the relationship with CC4 allows them to direct the collection responsibility to CC4.

CC4 are also involved with CC5 companies in a arm's length relationship to dispose of all the hazardous components. Moreover, CC5 are in a arm's length relationship with CC6 with transaction level collaboration to dispose of the waste coming from hazardous components. According to CC4, they needed a secure source where they can recycle their hazardous components without any risk of being noncompliant and this transactional level relationship is provides them that assurance.

Table 6. 13 Relationship Drivers across CC companies

Drivers	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	Detail
Cost related									
To minimising investment responsibilities	√			√					• Innovation for recycling technology to design post shredder machine and oil refining machine identified requires huge investment where CC1 and CC4 trying to minimise the investment burden by having strategic level collaboration where they are sharing investment and developing technology together.
Saving time and investment	√								• To design new cars with more recyclability and fuel efficiency CC1 having strategic level collaboration within CC1 companies who already have the technology which saving their time and investment to work on formulate the technology.
Value related									
Access to new technology	√			√					• CC1 Collaborating with CC4 because CC4 companies are expertise for recycling where strategic level collaboration allow CC1 to access recycling technology, detail information's of limitation of those technologies to create great technology.
Secure reliable source					√	√			• CC5 companies wanted secure source who can assure proper storage and not damaged delivery of hazardous components therefore they are collaborating with CC4 companies who assuring them proper storage and undamaged hazardous components to deliver. • CC6 companies wanted secure sources who can make sure of non-hazardous waste therefore they decided to have coordination collaboration with CC4 companies who assuring them for non-hazardous waste to deliver.
Attracting customers			√	√					• Collaboration with CC1 helping to extend CC3 recycling network • Becoming a member of CC3 enabling CC4 to use CC3 and their partner CC1 name which attracting more customer (last car owners) to bring their car to CC4.
Others									
Lack of resources	√		√	√	√				• CC1 do not have recycling network to setup collection points where the CC3 have the huge recycling network where the collaboration relation enabling CC1 to use CC3 network. • CC4 do not have hazardous recycling facilities therefore they are having arm's length relationship with CC5 as CC5 are the expertise for hazardous recycling.

Different specialisation	√		√	√					• CC1 are not authorised for EoL car treatment as they are specialisation is car making not recycling therefore they are having collaboration with CC3 who are managing CC1 EoL car collection process. • CC3 are not authorised for EoL car treatment as they are membership body to manage car recycling not to execute recycling operations therefore, they are having collaboration with CC4 who are specialised for car collection to disposal process.

Source: Author

6.2.4 Relationship Barriers

Data indicated that barriers organisations face in these relationships discussed above are mainly lack of common interest and lack of knowledge, but they vary company to company. All organisations in the RL chain are agreed that there are factors hindering collaboration relationships. Lack of common interest was faced by shredders and lack of knowledge by hazardous recycling companies. See details presented in table 6.14.

CC1 companies were found to have a lack of understanding between car manufacturers. According to CMC, their partner CMD sometimes do not try to understand CMC standard and influence for quick development and they release cars on the market that do not fit with the rest of their brand's identity. According to CMC, there was one car model available in market which was cheap and not in line with the rest of their brand's line-up. They had to face considerable criticism as a result and in the end, CMC had to stop producing that model.

CC companies in close collaboration (strategic level) relationships with one another. CC were found to not be facing any significant barriers. However, companies who were in an arm's length relationship across CC companies were facing some barriers. According to CC5, they wanted a close collaboration so they could plan and implement accordingly for hazardous component collection, but CC4 companies were not interested in close collaboration relations.

Another barrier identified here is lack of common interest and this is affecting within CC4 companies who are involved in the shredding process. This is also affecting some CC4 companies that do not have shredding facilities (ATFA and ATFB), where their main interest is dismantling marketable parts. These companies were found to sometimes ignore car shells to compact and send to shredders, which creates a later storage problem for them and also for shredders, as this can create supply unpredictability.

Table 6. 14 Relationship barriers between CC companies

Barriers	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	Detail
Lack of collaboration / cooperation	√				√				• Within CC1 companies relationship influencing to make lower quality cars damaging car brand image. • CC5 companies receiving unexpected return of hazardous sometimes due to lack of cooperation from CC4. • CC4 companies sometimes do not contact CC5 companies on time for hazardous components collection which creates a jam and pressure for CC5 companies to collect, store and recycle hazardous components.
Lack of common interest				√					• Some CC4 companies are focusing on marketable parts dismantling more and ignoring car shell redistribution process which creates a storage problem for themselves and their partner shredder companies

Source: Author

6.2.4 Relationship impact on players

The close collaboration in the relationship within and cross case-category companies was identified as having a positive impact. Relationship between car manufacturers (CM)- case-category one (CC1) companies enabled the design of cars with greater fuel efficiency, which increases car longevity and controls returns due to age and meets regulations for lightweight car designs. Similarly, close collaboration between car manufacturers (CM) - case-category one (CC1) and authorise treatment facilities (ATF) – case-category (CC4) enabled to the invention of new technology post shredder machines, which increased the recovery percentage of cars up to 97% of total car weight. Also, strategic level collaboration between CC1 and CC3 where CC1 used partners' existing networks as collection points, saved CC1 companies time and resources from finding and setting up new collection points. On the other hand, there were barriers between CC companies where CC5 face a lack of cooperation from CC4 and the main reason identified for this was the lack of close collaboration. This was identified as hindering the improvement of RL process in terms of the hazardous components recycling process.

6.3 Summary of the chapter

This chapter mainly established a report on the within case-category, and cross case-category analysis conducted for this study. This chapter has specifically analysed and compared similarities and differences for players involved in the EoL car RL process and their relatinships among the eight types (CC) of stakeholders investigated with related issues including collaboration level for relationships, drivers and barriers for those relations and its impact on players in the UK automotive sector.

A discussion of the implications of these results, how the triangulated empirical findings corroborate or contrast with the extant literature and extant theories will be presented in Chapter Eight. The overall conclusions and implications for further research will also be drawn in Chapter Nine.

CHAPTER 7. DRIVERS AND BARRIERS IMPACTING REVERSE LOGISTICS PRACTICE

7.1 Introduction

Research question seven was conducted in order to provide a holistic overview of drivers and barriers faced by players in the EoL car reverse logistics process. In order to fulfil the requirements, set by the purpose, the objective of this chapter is to provide a holistic understanding of:

- Drivers that motivated players to getting involved in the RL process or following the systematic RL process for EoL car and their impact on RL process.
- Barriers that hinder players to ignore RL practice for EoL cars and to improve the RL process for EoL cars. Actions taken to manage the challenges and the impact of that action.

Therefore, this chapter develops a comprehensive picture by analysing the findings from the interviews to provide a clear understanding which first presents findings from the within case analysis, within case category analysis and cross case category analysis, which is designed to compare similarities and differences within cases categories and between case categories.

All the drivers and barriers and their impact discussed in this chapter can also be understood using theoretical viewpoints which is discussed in chapter 8.

7.2 Drivers influencing EoL car RL practice

There are five key drivers identified which were found for most of the cases. These were driven by the need to get involved in the reverse logistics process for EoL cars in UK. These five key drivers were: legislative pressure, economic gain, stakeholder pressures, competitive pressure, environmental and social awareness.

These drivers are based on the reasons for getting involved with the reverse logistics process for EoL cars in terms of its different activities. Therefore, this not only clarifies why companies are dealing with EoL car,s but also clarifies why companies are recycling cars by following a systematic process with different activities. A systematic process is observed as a means of management to adopt and change procedure for some activities, equipment, etc due to rapid changes in market conditions. The presentation of the findings related to each of these drivers is in such a way that details related to each driver including its relevance/non-relevance for each stakeholder (identified from the interviews) and perceived importance/relevance are discussed in sequence.

7.2.1. Legislative pressure

Regulation for the EoL car collection system

As stated before, drivers or pressures/motives affecting the implementation of RL practices can be classified as drivers forcing involvement with the RL process and drivers forcing the adoption of the systematic RL process for EoL cars. This regulation for the EoL car collection system is driving players to become involved in the RL process**.** This regulation forces producers (car manufacturers) to get involved with the RL process for EoL cars in terms of creating an EoL car collection point system which will offer free take back of EoL cars (Producer responsibilities), collection and treatment, and also it has to meet the geographical requirements (see the regulation table), which was identified as one of the most important drivers of RL practices for EoL car collection phase in the UK automotive sector, forcing car manufacturers to be involved with the collection point setup network.

Table 7.1 presents all CC1 (CM) companies who were identified as strongly forced by this regulation, as they are responsible for the whole system because CC1 companies are the car producer. CC4 also face strong force in terms of free take back and issuing CoD which is regulated by government agencies.

Table 7. 1 Regulation pressure for collection systems across case-category (CC) companies

✓✓ Strong impact, ✓ Moderate impact, - low /negligible impact, N/A not applicable

Legislation pressure	CC1-CM	CC2 – CD	CC3-OSCP	CC4 - ATF	CC5 - HRC	CC6 - WMC	CC7-GA	CC8 - LA
Geographical requirement of collection point network	✓✓	✓	✓	-	N/A	N/A	N/A	N/A
Free take back of EoL cars	✓✓	-	✓	✓✓	N/A	N/A	N/A	N/A
Issuing CoD for deregistration of cars	✓✓	-	✓	✓✓	N/A	N/A	N/A	N/A

Source: Author

The Government Agency inspect their sites regularly. They will get a written report after each visit that records and scores any breaches of their permit. The more scores they receive, the higher their annual fee will be. High scoring sites will get more Environment Agency inspections than low scoring ones. Also it is an offence not to comply with the conditions of their permit or the regulations. Any penalty given to CC1 and CC4 will also be passed to CC2 companies, as they are the dealers of CC1 companies and also CC3 companies, as they are the partners of CC1 who are responsible for this network system. As discussed in the chapter 5, CC5, CC6, CC7 and CC8 are not involved in the collection network system and collection process; therefore, this driver is not applicable for them.

So, to meet the regulation, car manufacturers (CM) partner with a 3rd party, namely official scrap car partners (OSCP)- case category 3 (CC3), who are experts in setting up and monitoring the network (details of this network were discussed in chapter 5 and details of the relationshipin chapter 6). CC1 companies also launched publicity to encourage and raise awareness in the public that scrapping cars will not cost in order to collect more scrap cars through their website. On the other hand, CC4 were found to have advanced their policy and planning for the EoL car collection process with free take back and a secure CoD issue system. According to the last 5 years' records, these companies were compliant with the network system, free take back facilities and issuing CoD.

This action improved the RL process in terms of collection of EoL car network system (discussed in the chapter 5) which is more convenient to car owners to drop off their cars and even convenient for Authorise Treatment Facilities (ATF) -case category 4 (CC4) to collect the car.

Regulation to meet EoL car recovery target (95%)

This is also forcing car manufacturers (CM) – case- category 1 (CC1) to get involved with the EoL car recycling process in terms of making sure that their cars are 95% recoverable. The responsibility for reaching this target falls on both the car manufacturers and the car recycler, namely authorised treatment facilities (ATF) - case category 4 (CC4) companies in the UK. Therefore, as seen in chapter 4 of this thesis, car manufacturers engage themselves in designing cars for increased recovery and, simultaneously, they are also investing in innovation for recycling technology.

As presented in table 7.2, this regulation mainly forces car manufacturers to get involved in both car design and innovation of recycling technology where the recycling industry is also involved in recycling technology, as the regulation forces them not to produce waste for landfill more than 5% of per car weight.

Table 7. 2 Regulation pressure to meet recovery target

✓✓ Strong impact, ✓ Moderate impact, - low /negligible impact, N/A not applicable

Legislative pressure	CC1-CM	CC2 – CD	CC3-OSCP	CC4 - ATF	CC5 - HRC	CC6 - WMC	CC7-GA	CC8 - LA
Regulation to meet recovery target	✓✓	-	-	✓	N/A	N/A	N/A	N/A

Source: Author

To meet these recovery targets, both car manufacturers (CM) and authorised treatment facility (ATF) companies are investing in technology and for that they have chosen close relationships, namely acquisition nature relationship with each other with close strategic level collaboration, where they share information, resources, technology and in some cases cost, investment and ownership as well. Details of this relationship were discussed in the chapter 6 of this thesis. All these actions taken for the recycling technology innovation fund have managed to meet regulations which save noncompliance costs for both car manufacturers and authorised treatment facilities.

Regulation for hazardous components separation

This regulation is driving players who are already involved in EoL car RL practice to follow the systematic RL process. The End of Life Vehicle directive -2000/53/EC requiring the treatment of hazardous components separately was identified as one of the most important drivers of RL practices for the EoL car hazardous removal phase in the UK automotive sector. Regulation forces dismantlers to make sure they remove all the hazardous components before they dismantle marketable parts. They also require a system for recording the quantity of hazardous components including fluids which have been removed. The information which is recorded should be provided to waste regulators and inform annual ELV target performance returns. All hazardous materials (apart from oil) need to be stored in suitable storage facilities which meet all regulations, until they are either treated or sent for recycling or disposal through a suitably licensed waste management contractor. Every drop of engine oil must be removed in order to classify an EoL car as non-hazardous. As presented in table 7.3, this regulation is mainly a strong driver for the authorised treatment facility (ATF) – case category 4 (CC4) companies in the UK to develop strict policies for hazardous removal processes in terms of employee training, safety tools and removal facilities.

Table 7. 3 Legislation pressure for hazardous component separation

✓✓ Strong impact, ✓ Moderate impact, - low /negligible impact, N/A not applicable

Legislative pressure	CC1-CM	CC2 – CD	CC3-OSCP	CC4 - ATF	CC5 - HRC	CC6 - WMC	CC7-GA	CC8 - LA
To treat hazardous components separately	-	-	-	✓✓	N/A	N/A	N/A	N/A

Source: Author

According to ATFC, these CC4 companies have proper planning and policy in place with regular training facilities for the employees who are involved with the removal process. And for storage and transportation to hazardous recycling plants, they also have formed partnership relationships with CC5, who provide storage containers and transportation facilities to collect hazardous components. This was found to have a very positive impact where all these CC4 companies were compliant in terms of proper management of hazardous components removal (according to the last five years compliance report submitted to government agencies).

7.2.2 Economic gain

Direct economic value from the increasing number of EoL cars and marketable components

This is mainly driving those players who were not/little involved before to become involved with the RL process. This is identified as a strong driver in the UK for why auto recycling companies come to this business and apply for an ATF licence to collect and recycle EoL cars. Strict government regulations for free takeback encourages car owners to dispose of their old car by an authorised treatment facility (ATF). Therefore, there is an increasing number of cars coming back to the reverse chain for disposal, which has motivated auto recyclers to get involved with the EoL car RL process, as the increasing number allows them to collect more cars meaning more cars to sell at auction and more parts to sell in the secondary market. Direct economic gain by selling marketable parts is a key driver found for case-category four (CC4)- Authorise Treatment Facilities (ATFs) to get involved in EoL car RL process as CC4 companies are involved with parts recovery and resale.

Table 7. 4 Economic gain from higher number cars and parts for resale

✓✓ Strong impact, ✓ Moderate impact, - low /negligible impact, N/A not applicable

Economic gain	CC1-CM	CC2 – CD	CC3-OSCP	CC4 - ATF	CC5 - HRC	CC6 - WMC	CC7-GA	CC8 - LA
Direct value from marketable parts	-	-	-	✓✓	N/A	N/A	N/A	N/A

Source: Author

According to most of the respondents from CC4 companies, EoL cars and parts recovered from EoL cars in the UK have a good market value. The main reason found is generally EoL cars are in the UK mostly functional (detail of mostly functional car conditions is discussed in chapter 4) which provides more components and parts with better quality for reuse and these also requires minor repair. All these have driven CC4 companies to get involved and expand EoL car collection and dismantling business with more investment and facilities.

Direct Economic value from good quality materials

This influences players to get involved with the systematic RL process. Direct economic value to produce good quality materials has high impact on ATF – CC4 companies who are mainly involved with shredding process. Involvement with the RL process more effectively allows shredders to produce quality materials which can be used to make new cars. More involvement in terms of using updated shredding machines, taking care of proper removal of hazardous components to prevent damage from toxic materials and also contributing to the shredding technology innovation process together with car manufacturers. This systematic RL process also increase in hazardous recycling component collection which influencing HRC-CC5 companies as it also increase in recovery amount from hazardous components that also generating less waste for landfill and saving landfill cost for HRC.

Table 7. 5 Economic gain from good quality materials

✓✓ Strong impact, ✓ Moderate impact, - low /negligible impact, N/A not applicable

Driver	CC1-CM	CC2 – CD	CC3-OSCP	CC4 – ATF	CC5 – HRC	CC6 - WMC	CC7-GA	CC8 - LA
Direct Economic value from good quality materials	-	-	-	✓✓	✓✓	N/A	N/A	N/A

Source: Author

So, direct economic value applies strong inspiration on CC4 and CC5 companies, as they find getting involved formally as regulated recycling centre with RL process for EoL cars can bring direct economic value which can increase revenue and even return on investment, as the materials' value is higher due to the use of these materials in new cars.

Indirect economic value for environmental practice

This drives mainly car manufacturers to get involved with RL process. Recent global worming issues were found to be one of the key concerns of car manufacturers, as cars are one of the main reason of CO2 emission. A typical passenger vehicle emits about 4.6 metric tons of carbon dioxide per year (SMMT, 2017). Therefore, car manufacturers (CM) engaged and started to manage their EoL car scrapping, the demonstration of best practice and a growing body of evidence demonstrate that it is a worthwhile and positive area of environmental management. The ability to gain a competitive advantage and differentiate a business against its competitors through engagement with RL was identified as a driving factor for indirect economic value. This category describes how car manufacturers are able to make the claim to their customers that they are doing more regarding environmental management than their competitors.

Table 7. 6 Indirect economic gain from environmental practice

✓✓ Strong impact, ✓ Moderate impact, **-** low /negligible impact, N/A not applicable

Indirect economic gain	**CC1-CM**	**CC2 – CD**	**CC3-OSCP**	**CC4 - ATF**	**CC5 – HRC**	**CC6 – WMC**	**CC7-GA**	**CC8 - LA**
From environmental practice	✓	-	-	-	N/A	N/A	N/A	N/A

Source: Author

This was found to have a moderate impact on only CC1 companies. CC1 companies were involving themselves more in RL practice for their EoL cars in terms of network setting for EoL car collection, monitoring the whole process, introducing scrappage scheme to attract old car owners, inventing great technology together with other CC1 companies for car longevity and recyclability, inventing recycling technology to increase recovery rate and reducing waste going to landfill together with CC4 companies. The involvement with all these activities for EoL cars identified was not only because regulation requires it but also it become a strategic choice for CC1 companies to add a green image to their brand.

7.2.3 Stakeholder pressure

Stakeholder pressure to have proper plans and policy in place to monitor EoL car collection and treatment network.

This was driving involvement with the systematic RL process, because Car Manufacturers (CM) are forced by regulation related to collection points and free take back directly from the government. However, actual players here are Authorised Treatment Facilities (ATF) companies who mainly collect and do further treatment of EoL cars. So, car manufacturers were found to pass on the responsibilities to OSCP companies to manage their network for EoL car collection and treatment. This forces OSCP companies to take action to develop strict guidelines and policies for the ATF companies which includes free take back collection, proper storage of components, trained workforce and use of updated equipment's. This was found to help to improve the EoL car RL process from collection to disposal stage as seen in chapter five of this thesis, that all the ATF companies were found to have their own policy for improved EoL RL process.

The majority of the official CC3 companies interviewed acknowledged that they faced strong pressure from CC1 companies to have proper planning and policy for EoL car collection network monitoring. Failure to do so may lead to them losing partnerships with CC1. Moreover, CC4 companies mentioned that they are also forced to follow CC3 guidance to create their own policy for the RL process in which they are involved.

Table 7. 7 Stakeholder pressure for proper plan and policy

✓✓ Strong impact, ✓ Moderate impact, - low /negligible impact, N/A not applicable

Driver	CC1-CM	CC2 – CD	CC3-OSCP	CC4 - ATF	CC5 - HRC	CC6 - WMC	CC7-GA	CC8 - LA
Stakeholder pressure for effective policy to monitor EoL car collection, treatment procedure and recovery percentage.	-	-	✓✓	✓✓	N/A	N/A	N/A	N/A

Source: Author

This facilitates a more effective RL process in terms of on-time collection, more care in hazardous removal and storage, use of updated technology for shredding and separation of materials. Also according to the respondents from CC4 companies who are involved with shredding process acknowledged that they faced strong pressure from CC3 companies to increase material recovery by recycling ASR dust. Failure to do so may lead to them losing membership with CC3 companies. Also CC3 companies mentioned they are also forced by CC1 companies to increase their cars recovery percentage by recovering as much as possible from ASR dust. **CC3** encourage CC4 companies to use updated machines for car shell shredding for more recovery of materials. CC4 invest in ASR dust recycling facilities including incineration facilities to have 100% recovery of EoL car shells by producing energy. This was found to be helping to generate zero waste for landfill from EoL car shells.

So, stakeholder pressure was identified as another strong driver for CC3 and CC4 companies who are mainly from the recycling sector and were facing this pressure from the manufacturing sector (CC1).

7.2.4 Competitive pressure

Competitive pressure for free take back, updated technology and innovation

Competitive pressure for free take back, updated technology and innovation was identified as driving involvement with the systematic RL process. Competitor pressure was also identified as a driver for RL practice for free take back facilities, updated technologies and innovations. It was identified that the growing practice of RL in the automotive industry is putting pressure on almost all the players to develop similar practice in terms of collection of EoL cars with free takeback where all the dismantlers and shredders recognized that they have to have ATF licences for the fact that they need to implement free take back practices to stay competitive in the market, otherwise they risk losing market share to competitors. On the other hand, car manufacturers also recognized most of their competitors are getting involved with innovating recycling technology simultaneously with the car design innovation which is pressuring them to do the same.

For CC3, competitor pressure was not found to be a driver, and the reason was identified as the competition in itself is low due to the fact that few Official Scrap Car partners are available in the UK. But CC1 and CC4 identified this is a strong driver for them to get involved with RL with more engagement.

Table 7. 8 Competitive pressure for more material recovery

✓✓ Strong impact, ✓ Moderate impact, - low /negligible impact, N/A not applicable

Competitive pressure	CC1-CM	CC2 – CD	CC3-OSCP	CC4 – ATF	CC5 - HRC	CC6 - WMC	CC7-GA	CC8 - LA
For free take back, updated technology and innovation	✓	-	-	✓✓	N/A	N/A	N/A	N/A

Source: Author

CC4 companies became regulated EoL car recyclers by obtaining ATF licences which allowed them to obtain funding to offer free take back of EoL cars. CC1 get involved more effectively with new car design with more recyclability and some of them are also involved with recycling technology innovation by partnering with CC4 companies.

This found Increasing the ATF network for EoL car collection and treatment, which reduces the chance of creating illegal EoL car reuse and recycling processes. Also, more engagement of CC1 companies in innovation for new car design and recycling technology increases recovery rate up to 97%, which reduces waste for landfill.

So, competitor pressure also influences CC1 and CC4 to get involved with the RL process for EoL cars and this is a strong influence for them, as if they do not follow what their competitors are doing they can lose the market share.

The impact of actions include improved the RL process for EoL cars in terms of more collection of EoL cars with free take back, more recovery from total car weight and less waste for landfill.

7.2.5 Corporate social responsibility (CSR)

Environmental commitment to reduce carbon footprint by reducing CO2 emission

Commitment to protect the environment was identified as a significant driver for collecting EoL cars responsibly across all players. In the case of car manufacturers, it was evident from the interviews that environmental commitment was one of the reasons for firms to be involved with the EoL RL process, including the EoL car collection network system to collect more cars and investment in innovation to reduce waste for landfill. This was identified from other players including official scrap car partners, dismantlers, shredders and waste management companies. One primary focus of the organizations noted from the data is the environment. Businesses, regardless of whether they are car manufacturers or recyclers, have a large of carbon footprint due to the increasing number of cars in production, use of transportation, fuel consumption, use of raw materials, increasing air emissions and resources scarcity. Any steps they can take to reduce those footprints are considered both good for the company and for society as a whole. This responsibility was identified as driving organizations here to be actively engaged in the RL process for EoL cars. This is identified as a common and strong driver for all the players in the RL process for EoL cars. This leads players to work together in close collaboration relationships to invest transformational technology for cars to make 100% recovery and 0% waste for landfill. As a results cars are found more recoverable (up to 97%) than ever before.

Table 7. 9 Environmental commitment to reduce carbon footprint

✓✓ Strong impact, ✓ Moderate impact, - low /negligible impact, N/A not applicable

Driver	CC1-CM	CC2 – CD	CC3-OSCP	CC4 - ATF	CC5 - HRC	CC6 - WMC	CC7-GA	CC8 - LA
Environmental commitment to reduce carbon footprint by reducing CO2 emission	✓✓		✓✓	✓✓	✓✓	✓✓	✓✓	✓✓

Source: Author

This is driving CC1 to invest in innovation for recycling technology and new car design to reduce waste for landfill and reduce the use of virgin materials by creating technology for material recycling which can be reused in the new car and CC3 to manage and monitor the EoL car collection and treatment network to collect more cars for proper recycling. CC4 also driven by CSR and manage hazardous removal and storage with proper care to prevent the damage of water and land from toxic material. CC5 engage proper equipment, drainage and storage systems to implement hazardous recycling. CC6 measure and control temperature from landfill and incineration sites to reduce CO2 emission. CC7 develop and monitor strict regulations for the RL process, car design and recovery percentage.

In terms of its impact, new technology of post shredder machines and ASR dust shredders have managed to generate zero waste for landfill. Collection of more EoL cars means fewer old cars on the road which saves on fuel consumption. Proper removal of hazardous components saves car shells and marketable parts from toxic damage which helps to produce good quality materials to use in the new cars which reduce the use of virgin materials, saving natural resources. Proper measurement of temperature help to control the temperature. Strict regulations force all the players to have proper EoL car recycling process from collection to disposal. All these reduce CO2 emission, which reduces the carbon footprint from car manufacturing and recycling sector in the UK.

Thus far, all the relevant drivers affecting RL practices in the automotive indutry have been identified, assessed and discussed. Next, the various barriers to RL practices and the perceived importance/relevance of these barriers for each stakeholder will be discussed.

7.3 Barriers to implant RL for EoL car

Like the previous section on drivers for EoL car RL implementation, the presentation of findings related to each of these barriers is in such a way that details what is related to each barrier, including its relevance/non-relevance for each players (identified from the interviews) and perceived importance/relevance (captured through the interviews). Two type of barriers found here one, barriers hindering to involved with EoL car reverse logistics process and two, barriers hindering to improve reverse logistics process. All the barriers are discussed below in terms of theirimpact on case companies and case-categories.

Costly process

This was hindering authorize treatment facilities (ATF) – case-category 4 (CC4) companies (ATFA and ATFB) to get involved with shredding process due to the high cost of setup and implementation of shredding and sorting process. Interviewees from ATFA were of the view that high costs associated with the setup of huge upgraded machinery and implementing the shredding process were a barrier. In particular, very quick technological changes/improvements and regulatory requirements to use upgraded technology to increase recovery rate were identified as a barrier here. This was one of the main reasons ATFA and ATFB do not have a shredding plant.

Table 7. 10 Impact of costly process between case- category companies

✓✓ Strong impact, ✓ Moderate impact, Blank cell: low /negligible impact

Barrier hindering to involved with EoL car RL process	Across CC companies							
	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8
Costly process: High cost of setup and implementation of shredding and sorting process	-	-	-	✓✓	-	-	-	-

Source: Author

Therefore, this cost was found to be a strong barrier for all the CC4 companies which caused ignorance of RL key activities (shredding process) by its expert (ATF) companies.

Lack of expertise

This was hindering the improvement of the EoL car RL process. The shortage of RL expertise was acknowledged as a barrier by almost all players, though the relevance varied across players. The general consensus across interviewed car manufacturers (CMs) was that there is a lack of quality academic/training programs in the UK offered in areas such as reverse supply chain management at local universities, colleges and training centers.

Table 7. 11 Impact of lack of expertise between case-category companies

✓✓ Strong impact, ✓ Moderate impact, Blank cell: low /negligible impact

Barrier hindering to improve EoL RL process	Across CC companies							
	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8
Lack of expertise	✓	-	-	✓	-	-	-	-

Source: Author

According to ATFA comapnies, the expertise required for dismantling and recycling activities is difficult to find. This mainly impacts on all the ATF companies who were reliant on workers who lacked information, knowledge and modern technology knowledge to dismantle cars, which made the dismantling process slow and less effective in terms of quality of parts due to the damages occurs during dismantling process.

Lack of last car owner support

This was hindering EoL car RL process improvement. Mainly the coordination from senders during EoL car collection emerged as a barrier to RL practices but in terms of the collecting EoL car phase, it was evidenced from the interviews that stakeholders cooperation was ok here and the only problem identified here in the collection process was with the last car owner, as these owners' expectations have become too high and they are not only expecting free take back but also good value for their scrap car, while at the same time not cooperating with appropriate information about the car at the collection point. This information was identified from almost all the players of car dismantlers who were affected in terms of wrong information about car condition, as they are the players who are mainly collecting EoL cars for further processing.

Table 7. 12 Lack of last car owner support between case-category companies

✓✓ Strong impact, ✓ Moderate impact, Blank cell: low /negligible impact

Barrier hindering to improve EoL RL process	Across CC companies							
	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8
Lack of last car owner support	-	-	-	✓	-	-	-	-

Source: Author

In terms of its impact, it mainly delayed the collection process in terms of payment to car owners and creating misunderstanding between car owners and dismantlers. Therefore, dismantlers improve terms and a condition section, by adding car value that can be changed after physical assessment.

Lack of technology

This was hindering EoL car RL process improvement in terms of making quality of recovered materials as new materials**.** Currently the amount of raw materials identified were still a small proportion distributed as primary raw materials quality. To increase the quality of these secondary raw materials and to make them as primary raw materials, more updated technology is needed in terms of separate collection and sorting and recycling facilities towards a more circular economy.

Table 7. 13 Lack of technology between case- category companies

✓✓ Strong impact, ✓ Moderate impact, Blank cell: low /negligible impact

Barrier hindering to improve EoL RL process	**Across CC companies**							
	CC1	**CC2**	**CC3**	**CC4**	**CC5**	**CC6**	**CC7**	**CC8**
Lack of technology: to make quality of materials as new materials	✓	-	-	✓	-	-	-	-

Source: Author

In terms of its impact, it is identified that a consequence of the use of secondary raw materials is that certain harmful chemicals remain present in recycling streams. They get restricted or banned from use for cars or other new products but older products containing such chemicals can still end up in recycling streams. So, the auto industry needs to work to improve the tracking of chemicals in products and to boost non-toxic material cycles.

Lack of effective disposal systems

This was also found to be hindering EoL car RL process improvement in terms of disposal of the waste coming from EoL cars. Many landfills, especially older landfills, are susceptible to producing leachate. Leachate is an often-toxic liquid that results from rain passing through a landfill and seeping into the ground water. As rainwater passes through the landfill, it picks up organic and inorganic materials that contain elements harmful to humans. These sites are closed and active landfill sites are also becoming full day by day. As a result, Government Agencies are under severe pressure from the European Union to reduce the amount of waste going to landfill and increase recycling. On the other hand, burning waste emits toxic gases and particulates (which can settle in human lungs) into the air. It is not confined to the area where it is incinerated, as air currents can distribute the toxins this burning produce around the world. Both air emissions and incinerator ash include heavy metals and chemicals, such as cadmium, mercury, sulfuric acid and hydrogen chloride, as well as the deadly poison dioxin.

Table 7. 14 Lack of effective disposal system between case- category companies

✓✓ Strong impact, ✓ Moderate impact, Blank cell: low /negligible impact

Barrier hindering to improve EoL RL process	**Across CC companies**							
	CC1	**CC2**	**CC3**	**CC4**	**CC5**	**CC6**	**CC7**	**CC8**
Lack of effective disposal system	✓	-	-	✓	-	-	✓✓	-

Source: Author

To control this, Government Agencies found implementing and monitoring, European Waste Incineration Directive which forces incineration plants to be designed to ensure that the flue gases reach a temperature of at least 850 °C (1,560 °F) for 2 seconds in order to ensure proper breakdown of toxic organic substances. This temperature control process found proved there are no more health issues with the incineration process than any other disposal method. If incineration is combined with energy recovery it is a much better option than landfill. Also car manufacturers, material manufacturers and the recycling industry are investing in R&D for more recyclable cars, recycling technology which aim to recycle 100% and leave no waste for disposal.

7.3 Summary of the chapter

This section summarises the overall findings by concept, namely drivers and barriers. This high-level summary is significant, as it reveals some important observations at the strategic level.

As seen in the above discussion, all stakeholder are motivated to engage in RL practices. In the case of car manufacturers, pressures, especially from government authorities, emerged as the dominant drivers to involvement in RL practices. Moreover, the drivers for the recycling industry players, especially for dismantlers, was regulation, which forced the implementation of systematic RL processes including each activity from car collection to disposal process. Economic gain was not a motivation for manufacturers, as they were not involved with reselling EoL cars, parts and materials. But for the recycling sector this was the main reason to get involved with RL processes of EoL cars and to get involved with a systematic process. Firm size and ownership were not a factor here as regulations are similar for all the firms. In terms of barriers, as this study identified high cost of shredding process and lack of expertise barriers impact very firm size. So, like there is the possibility that firm size may have an impact for other barriers as well; therefore, a more in-depth investigation is still required to understand if firms size has any influence on other barriers as well.

CHAPTER 8: DISCUSSION OF FINDINGS

The purpose of this chapter is to revisit the findings to clarify its contribution to theory and practice.

8.1 Introduction

The cross case-category (CC) analysis findings discussed in chapters 4,5,6 and 7 feed into this chapter. Novel insight obtained from chapters 4, 5, 6 and 7's cross category (CC) analysis findings are discussed in this chapter by linking the empirical findings to the extant literature where possible. The findings are thematically compared to the extant literature to examine the relationships between the empirical research and theory, hence furthering the exploration of the automotive RL practices, associated issues, and innovative ideas from the UK auto industry perspective.

This study's empirical evidence was generated from twenty-four companies in the UK automotive industry. The fundamentals of RL, and the practices in the automotive industry described in the literature review, will be compared with the empirical evidence to ascertain whether the auto industry practices employed by the sample companies support the extant literature or the case companies operate under a fundamentally different RL.

Furthermore, this chapter also examines and compares relationships between analytical generalisations derived from the empirical data, and the existing literature, to find out whether the major findings support the extant literature, extend extant theory or contradict it and why. As a result, a typology of auto RL practices is mapped out to obtain an empirically informed and theoretically grounded insight.

8.2 EoL car reverse logistics practice in the UK auto industry

The empirical findings of this study discovered that in the auto industry, car manufacturers started focusing on RL operations with the government's introduction of the 'End of Life Vehicle Regulations 2003' - a European Directive to ensure the safe treatment and disposal of vehicles when they reach the end of their lives (detail of these regulations are available in table). Also auto recycling industry players started focusing on the RL process for EoL life cars in a more organised way with all the different stages discussed in chapter 5. The UK automotive industry was found to be very systematic and managed in terms of RL implementation for EoL cars. This supports the existing literature findings discussed in section 2.9.1 (advance RL practice in UK), where researchers stated that the UK automotive industry is very advanced (Aitken & Harrison, 2013) and RL practice has become more serious for various reasons, including legislative policies. This portrays a relatively upright practice of RL in the UK. Proper management of EoL cars return is identified as unavoidable for business involved with car making and recycling operations in a regulated country like UK, where EoL cars must be collected and disposed of in a regulated channel, making sure 95% of a car's weight is recovered and waste going to landfill is not more than 5% of the car's weight.

8.3 Key aspects of RL in the UK

There are eight key aspects discussed in the literature review chapter (chapter 2), which are: 1. return reasons, 2. nature of return product; 3. return process; 4. players involved, 5. drivers influencing players, as discussed by de Brito and Dekker (2003). Xie and Breen (2014) expanded De Brito and Decker's work by adding two more key aspects, which are 6. location of the return is processed and 7. barriers for players are ignoring RL practice. Further, Salvador (2017) extended this by adding 8. time related issues in RL.

To develop a more detailed understanding of RL fundamental content, this study further brings more details of each of these key aspect for EoL car RL in the UK by adding car design related issues in RL, which provides more details with a clear understanding of product return reason and nature (key aspect 1 & 2), performance of RL process which helps to clarify the impact of current RL process (key aspect 3), relationship between players by adding to players (key aspects 4) aspects which can explain how players are involved with the RL process and why activities are done in-house or by outsourcing, impact of drivers and barriers (key aspects 5 & 6) in the UK automotive industry. Basically, the key aspects discussed in this study from the eight perspectives of EoL car RL are portrayed in Figure 8.1.

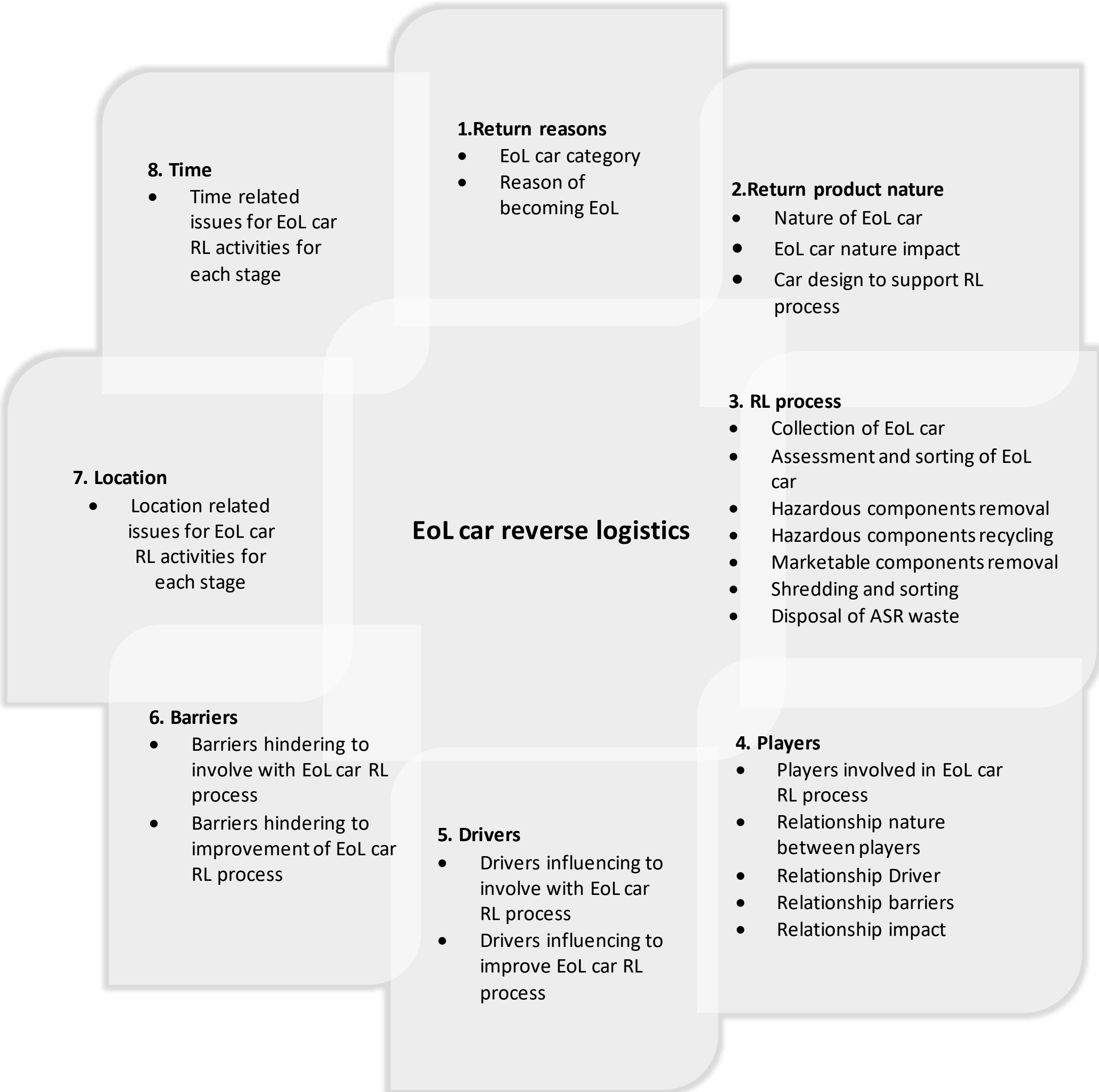


Figure 8. 1 Key aspects for EoL car reverse logistics

Now each of these key aspect's findings were discussed in chapters 4, 5, 6 and 7 and are revisited to discuss their contribution to theory and practice. Also whereever relevent, the literature review, chapter 2, is also revisited to clarify the link between findings and the previous literature.

8.3.1 Return reasons of EoL cars

As discussed in section 2.5.1, in the generic literature review there are three types of return: manufacturing, distribution and consumer returns (De Brito & Dekker, 2003) and in the automotive industry literature, consumer returns were identified as the key sources of return (Chan et al., 2011), where the main concern was EoL cars as this is the category of cars coming to the reverse chain for disposal (Zarei, et al. 2010; Merkisz-Guranowska, Chan et al., 2011). In line with this return reason this study analysed EoL car return reason by adding:

- How do cars become EoL?
- Who is sending them?
- Why are they sending them?

8.3.1.1 Reason of becoming EoL

The findings presented in the chapter 4 found that cars become EoL due to their age and damage, which is in line with the literature (Mansour & Zarei, 2008). Apart from these, the empirical findings show that some EoL cars come for disposal because the car was stolen and its key components were removed and this category of EoL cars are named as abandoned cars in this research. So, the three types of cars becoming EoL identified from the findings are: abandoned EoL cars (12%), unnatural end of life car due to accident, flood and fire damage (36%) and natural EoL cars due to age damage (52%).

8.3.1.2 EoL car senders

The empirical findings discussed in chapter 4, show that EoL cars are coming for disposal not only from individual consumers but also industrial consumers from service companies including taxi providers and retail companies. Also, some institutions, including local authorities, police and insurance companies, were identified as the source of EoL cars for abandoned EoL cars, as government guidelines compel these institutions to take responsibility for abandoned cars for proper disposal.

8.3.1.3 Reason of sending EoL cars for disposal

As per most of the respondents from ATF's confirmed that the reason for sending these cars for disposal was not because the car is a certain age but because the cars were heavily damaged due to wear and tear and had become very expensive to maintain or due to heavy accident (road, flood, fire) which was too expensive to repair. On the other hand, abandoned cars were returned for disposal because the owner was not found, as the car was not registered, or because the car was heavily damaged and was leaking fuel or any other liquid that was harmful for environment and needed immediate disposal.

There is a link identified between these three fundamentals of how cars become EoL, who is sending them and why (see figure 8.2).

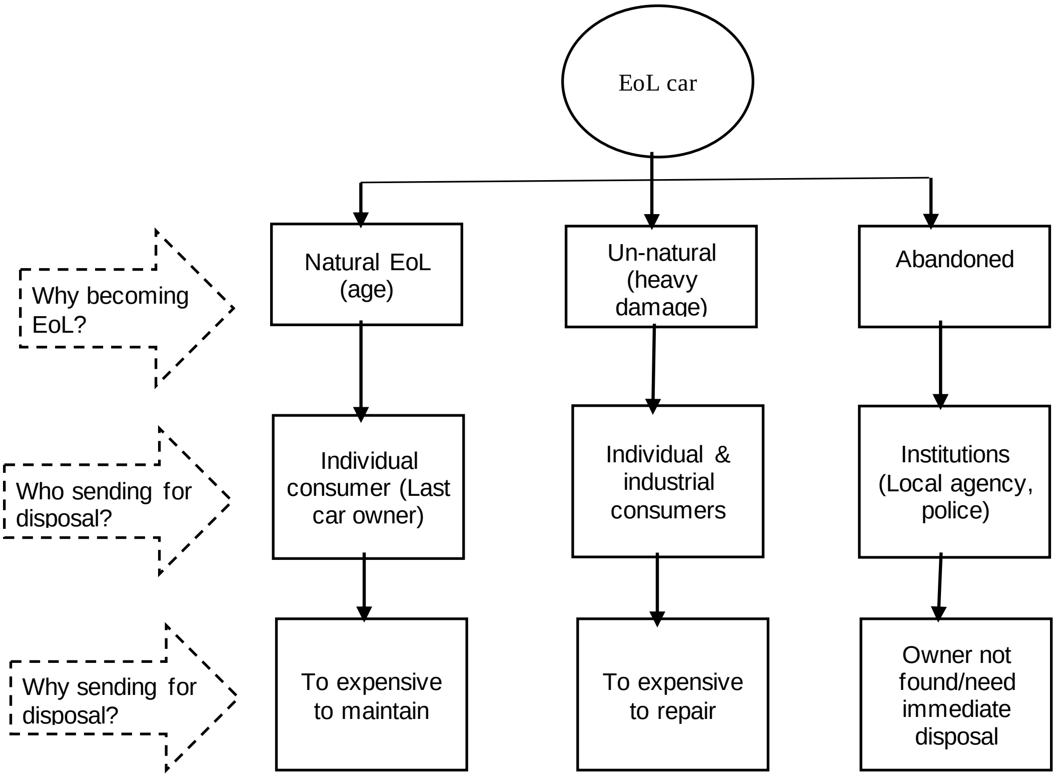


Figure 8. 2 Relation among return reason fundamentals

Also free take-back, scrap car schemes and awareness of environmental issues were the reason for returning EoL cars to one of the authorised collection centres rather than any local repair shop or used car dealers. On the other hand, Local Agencies (LAs) confirmed the main reason for them to send EoL cars to one of the authorised collection centres was mainly government guidance and social responsibilities towards the community.

8.3.2 Nature of EoL cars

In the literature, the nature of RL is what is actually returning in the reverse flow in terms of product structure/design, functionality and usability (De Brito & Dekker, 2003). Further researchers also added the packaging solution (Silvenius et al., 2013) feature. Xie and Breen (2014) discussed product nature in terms of what products are “coming in” and what products are “going out” and its impact. In this study, this section considers product nature in terms of “coming in” and “going out”, mainly focusing on the product leaving the network, which is the reuse and redistribution of the return product, discussed in the RL process aspects (section 8.1.3) of this research.

Product composition refers to the number of components and of materials, how the materials and components are put together, the presence of hazardous materials, and the material heterogeneity of the product. These factors were considered while designing products for recovery, as they will affect the easiness of the recycling process and the economics of RL activities (Gungor & Gupta 1999; Goggin & Browne 2000). Product deterioration concerns the level of product functionality, where the type of recovery options employed by companies is influenced by how the product functions, i.e. whether the product ages during usage (Intrinsic deterioration), whether all parts age equally or not (Homogeneity of deterioration), and whether the value of the product declines quickly (Economic deterioration) (De Brito & Dekker, 2003). Product use pattern or reusability refers to the location, intensity and the duration of use. In this case, the intensity of usage and the location of the collection centres is determined by the source of the returns, which could be from the end-user, institution, retailers etc. (De Brito & Dekker, 2003). The package of a product has an influence on RL to process package-related waste, and this concerns package sizes, shapes and materials used for the packages (Xie & Breen, 2014), which can minimise waste generation and help forward and reverse chain to advantage the lowest environmental impact (Silvenius et al., 2013).

In this study, a viewpoint on RL is also obtained by considering what type of EoL cars were returned for disposal. This is done by specifically considering the composition of components, deterioration of cars and parts and the car usage pattern. The nature of packaging of the product was not applicable for EoL cars in terms of what is “coming in” but if has some impact in what is “going out”, as the distribution of materials and parts required packaging.

1. Composition of components and its impact

Composition of components is similar to the product composition characteristics described in the generic literate by De Brito and Dekker (2003) and Xie and Breen (2014) in terms of component number, the way they are put together, presence of hazardous components and size. Cars contain numbers of different types of components and some of them also contain hazardous materials which made the recovery process difficult and this is in line with auto industry RL literature described by Chan et al. (2012). Of the number of components identified, some contained heavy materials and others light materials and this did not impact on “in” (transportation) but it has impact on “out” (market value of recovered components and materials), as heavy metal parts contain lead, mercury, cadmium or hexavalent chromium, which are restricted from use in new cars. On the other hand, lightweight materials required more updated technology to recover materials and also produced more waste for the incineration process. Use of dismantle marks have a very positive impact on the dismantling stage and use of electric devises and batteries have some negative impact on transportation in the hazardous components recycling stage in terms of transportation and storage and they leave more hazardous chemicals for incineration.

Table 8. 1 EoL cars composition nature and its impact on RL process

Return Nature	**In terms of**	**Impact on the RL process**		
		“In” transportation	**Complexity of process**	**“Out” reuse and redistribution**
Compositions /configuration of products	• Numbers of components with different type of materials (some with heavy and some light materials)	No impact	Difficult dismantling and shredding stage	Less market value for heavy metals
	• Increase in use of battery and electric components also increasing hazardous components	Large number and size increase transportation cost in	Difficult hazardous removal stage	More waste to burn

		hazardous recycling stage		
	• Dismantle sign used in cars	No impact	Easy dismantling stage	Less damage on marketable parts

Source: Author

8.3.2.2 Deteriorations of EoL car and its impact on RL process

Deterioration is similar to the product deterioration characteristics described in the generic literate by De Brito and Dekker (2003) and Xie and Breen (2014) in terms of EoL cars and parts functionality but this had not been discussed in the auto industry RL literature. This empirical finding identified that EoL car deterioration nature has an important role on the inspection and sorting stage of the RL process to separate cars in terms of recovery options. Deterioration nature was mainly categorised in terms of reuse of cars and their parts are full functional; mostly functional; partly functional and non-functional. If a car found can be repair and reuse again are separated and this type of cars are mainly going to auction for sell. Cars found not repairable and recoverable as a car but most of the parts can be repair and reuse are namely, mostly functional which provides more marketable parts to sell. Some cars namely, partly functional found very small number of parts can be repair and resell and rest going to shredder to recover materials. On the other hand, the car namely, non-functional found badly damaged and no parts can be recover to reuse and this type cars are separated to send to shredder.

Table 8. 2 EoL cars functionality and its impact on RL process

Return Nature	In terms of	Impact on the RL process		
		"In" transportation	Complexity of process	"Out" reuse and redistribution
Deteriorations	• Full functional: car can be repaired and reuse	No impact	No impact	Recovering and reselling the car
	• Mostly functional: Most of the parts are recoverable	No impact	No impact	More parts to resale
	• Partly functional: some parts are recoverable	No impact	No impact	Less parts to resell
	• Non-functional: no parts can be recovered	No impact	No impact	No parts to resell

Source: Author

2. Use pattern of EoL car and its impact on RL process

Use pattern was also identified as one of the natures of return EoL cars which is similar to Brito and Dekker's (2003) use patterns characteristics in terms of transportation and handling. This nature category had also not been discussed in the auto RL literature. The empirical finding of this study identified that EoL cars coming from different sources have impact on transportation, where EoL cars from individual consumers are mostly dropped by consumers saving transportation cost but EoL cars coming from industrial consumers and institutions needed collection to be arranged by receivers/players who collect EoL cars.

Table 8. 3 EoL cars use patterns and its impact on RL process

Return Nature	In terms of	Impact on the RL process		
		“In” transportation	**Complexity of process**	**“Out” reuse and redistribution**
Use pattern	EoL, cars coming from individual consumers	Saving transportation cost	No impact	No impact
	EoL, cars coming from industrial consumers	Can not save transportation cost	No impact	No impact
	EoL, cars coming from institutions	Can not save transportation cost	No impact	No impact

Source: Author

The empirical findings of this study exposed that the nature of the EoL cars in the auto RL network strongly affect the recovery process adopted by auto industry players. The effect of composition nature found very much relevant with car design. Therefore, this research considers car design aspects in terms of its effective EoL RL process.

8.3.3 Car design in terms of its impact on EoL RL process

Product composition in terms of components number and type of materials used is an important issue to keep in mind while designing products thinking of its recovery (Gungor & Gupta, 1999). Not only the number and materil type, but also how the materials and components are put together also affect the easiness of recovering them and therefore the economics of reverse logistics activities (Goggin & Browne, 2000; de Drito & Dekker, 2003).

The car design perspective in terms of its impact on the EoL RL process was therefore considered in this study to generate insight on EoL car RL practice from the viewpoint of the car design in terms of the impacts when key activities are initiated in the EoL car RL process. The car design perspective in terms of its impact on the EoL car RL process is unique in how it is recognised in this study, and arguably to the body of knowledge, as the phenomenon has never been adressed in the extent literature. The car design‘s impact on a car‘s lifecyle, including the EoL and recycling stages, are described in chapter 4, section 4.4, of this thesis.

Empirical data revealed all the car manufacturers (CMs) are thinking of recycling cars, including use of renewable materials and ease of recycling signs while designing cars. Overall the key factors identified in design of new cars discussed in the chapter are developing lightweight materials, more number of electric device for safety, more number of battries and wire harness using in hybridge and eklectric cars, use of renewable raw materials, ease to dismental sign in parts, use of recycling materials in new cars.

Using lightweight materials was found to have a positive impact on EoL stage, as it increases the longevity of cars which control EoL car age-related returns, but this was also found to negatively effect the shredding stage, as this requires updated ASR shredders to shred lightweight materials for further recovery to reduce landfill waste. Use of an increased number of electric devices for safety features was found also to control accident damage related returns. On the other hand the use of higher numbers of batteries and wire harnesses was found to have a negetive impact at the EoL stage, as it increases the total number of hazardous components to be removed, especially large batteries, as more fuel and energy are required for transportation and recycling. Use of renewable raw materials, ease of dismantling signs in parts and use of recycleable materials were found to have a very positive impact at the all stages of a car's from production to recycle in terms of reducing waste, CO2 emision and cost.

8.3.3 Reverse logistics process for EoL cars

This section discusses how EoL RL works in practice based on the empirical findings obtained from the field of study, and the extant literature on RL. A viewpoint of RL can therefore be obtained by considering how key processes/activities are carried out in RL systems and how value is recovered in the reverse chain (De Brito & Dekker, 2003). According to the literature (Schwartz, 2000), every RL system should include the following key stages: gatekeeping, collection, sortation and disposition. Further in the automotive indutry these stages were identified as scattered into collection, inspection, hazardous removal, marketable parts removal, shredding and disposal of waste coming from EoL cars (Mansour & Zarei 2008; Subramanian et al., 2014)

The empirical findings of this study discovered that key RL activities for EoL cars are collection, assessment and sorting, hazardous component removal, hazardous component recycling, marketable components removal, shredding and disposal. These empirical findings were supported by the existing literature by Schultmann et al., (2006); Mansour and Zarei (2008) and Soo et al., (2017).

Chapter 5, section 5.2, discussed how the above seven stage of RL process activities are carried out in terms of whether the activities are regulated or not and the process, including workforce planning, technology used and key financial responsibilities. In addition, location and time related aspects are discussed with the process aspects as location and time aspects are very relevant to the RL process and also different stages found have different location and time related issues.

Now, the key activities that make up the EoL car RL processes identified in this study are discussed in relation to extant literature on RL.

8.3.3.1 Collection of EoL car

In this empirical study, the collection stage covers a number of activities, including developing a network of EoL car collection and treatment processes which provides free take-back of EoL cars and Certificate of Destruction (SoD), which should be issued by only by ATF collection points. This also includes returns where customers drop off the car. Returning was discussed in the generic RL literature and mentioned as a part of the collection process (Steven, 2004).

i) Regulatory restrictions

The empirical findings confirm that this stage is heavily regulated (detail of regulations are presented in the Appendix Four in this thesis) in terms of the collection point network and the process of collecting cars with free take-back. The regulation mainly forced car manufacturers to set up a network which collects their cars with free take-back, meaning the collection of the EoL car should not cost its owner; this is supported by the literature (Mansour and Zarei, 2008). Therefore, car manufacturers use their forward chain players, all car dealers, as collection points. This finding is supported by the literature, as Zarei et al., (2010) claimed manufacturers face challenges in how to collect the EoL products and what to do with them in order to fulfil the relevant legislations. Therefore, they use their new car distribution centres as collection centres (Zarei, et al., 2010). But this empirical findings found these are non-ATF collection points, meaning they can only accept cars dropped off by car owners and collected from car owners on requested but in the end these cars have to be sent to an ATF collection point, as only ATFs can issue CoDs and therefore proceed the further treatment process of EoL car. Also the geographical requirement to have collection points within a 10 mile distance was found to be very challenging to meet for car manufacturers, as they are experts in car making and have the network for car making related companies, but not car recycling; therefore, they outsourced a 3rd party with a huge network for ATF for car collection and treatment process. This is also supported by the existing literature, where research suggested that in order to achieve an efficient management of the recovery process, manufacturers should join with recycling industry players, hence creating a network (Mansour and Zarei, 2008). This 3rd party named OSCP mainly managed the network setup for EoL car collection and treatment. This is also consistent with the literature for ELV collection and management, which in some developed nations, like Belgium, have organisations (non-profit) who manage the collection process (Soo et al., 2017).

ii) EoL car collection activities

In regards of the collection process of EoL cars, the empirical findings revealed that non-ATF collection points that receive/collect EoL cars returned by customers at their collection point are collected by ATF collection points within 24 hours of the car arriving At the non ATF centre. But any online requests for collections of EoL cars are directed to the nearest ATF centre by all the non ATF collection points. This suggests that collection activities are mainly performed by car owners, car manufacturers, dealers, OSCP and ATF collection points but in the end all cars arrive at ATF collection points where the CoD has been issued and posted to car owners.

In terms of workforce in this process, car manufacturers and dealers were found to use their forward chain workforce to deal with customers, record and contact ATFs and, if needed for collection, they use their forward logistics. On the other hand, ATF collection points are reverse logistics service providers, so they have in-house workforce and logistics dedicated to EoL car collection and issuing CoDs. These ATFs were also found to be in a partnership relationship with third party logistics providers who work for ATF collection points on a need basis, as they did not require additional transportation system to collect cars all of the time.

In terms of IT, apart from email and websites, an integrated database system (IDS), is used between collection point network players, where all have access for their own company to record each EoL car's details they collect.

In terms of finance, car manufacturers were responsible for providing the cost for collection and treatment of EoL cars and this was also supported by the literature, as it is argued that the growing concern for collection centre location and players in developed countries is mainly driven by European Union Regulations to minimise environmental pollution, where the manufacturer is responsible for free take back and recovery of its ELVs and must bear all or a significant part of the collection and treatment costs (Mansour and Zarei, 2008). The empirical finding in this study identified that this cost is mainly included within the car price when sold as a brand-new car. However, this was only for collection (logistics cost) and car value (paid to last car owners) cost. There was more cost identified here, including IT (Internet for regular communication, continuous website development, IDS), employee wages and office rent, which were the individual companies' responsibilities.

iii) Location related issues in the EoL car collection stage

The where perspective provides insight on the physical network structure where the players are located, and products are collected and processed (Xie & Breen, 2014). As discussed in section 2.5.3.2, this study discussed location from these three perspectives: where products are going (the point) (Rogic et al., 2012, Xie & Breen 2014), the numbers of these points (are they enough) and the distance from customers (how convenient) (Biehl et al., 2007; Xie & Breen 2014).

As discussed above, the collection point locations players are car manufacturers, dealers and ATFs. These ATF companies are mainly dismantlers and shredders of EoL cars and all EoL cars finally are delivered to their scrap yards. In terms of numbers and distance identified, 75% of car owners have their nearest collection point (ATF and Non ATF) within a 10 mile distance and the rest not more than 30 miles away. This finding suggests that the collection network in the UK is convenient for customers and collection points both to drop off or collect the EoL cars.

iv) Time related issues in the EoL car collection stage

Time is discussed in general literature, as the product return process requires companies to be able to reverse the normal logistics flow from supplier to customers so that products deemed unsuitable can be located and returned to the source in a timely and cost-effective manner (Bowersox et al., 1996). The "time perspective" of RL is designed in the literature to generate insight on RL practices from the viewpoint of the time and frequency when key activities are initiated in the RL network.

The "location perspective" of auto RL is unique in how it is recognised in this study, and arguably in the body of knowledge, as the phenomenon has never been addressed in the extant literature of auto industry. The timings and frequencies of when key activities are initiated at each category of stakeholder are described in chapter five for each RL process stage separately. For the EoL car collection stage, this finding identified that EoL cars are collected within 24 hours from the time the car is accepted online and that the CoD reached the last car owners within 7 days by post. Also any car accepted by non ATF centres was collected by ATF within 24 hours.

v) Reuse and redistribution (out) in the EoL car collection stage

This is not applicable for the collection stage, as reuse and redistribution discusses what comes out/what recovered from each stage of the EoL car RL process.

vi) Performance of EoL car collection process

Section 2.1.3.5 discussed Song and Hong's (2008) claim that performance measurement systems can provide companies with relevant, appropriate, complete, and accurate information, so they can monitor and reposition their operations to obtain a highly competitive environment. The many approaches that have been used to develop an RL performance index were also discussed in the section. From them, the TBL and BSC performance indicators were selected from the existing literature to identify RL performance, which facilitated the selection of the TBL model in this research to measure EoL car RL process performance. The key reason for selecting the TBL model for this research was that the TBL model's performance indicators measure the performance in all three dimensions: economic, environmental and social (Nikolaou et al, 2013).

Now, in this collection stage most of the players involved were measuring performance. RL performance in the auto industry existing literature focusses on overall RL practice performance, which was also only from the use of IT perspective; however, in terms of actual performance, especially for the collection stage, there was a gap in literature. Therefore, the performance for collection stage of auto RL is unique in how it is recognised in this study, and arguably to the body of knowledge.

Key indicators identified economic performance in terms of collection process efficiency by calculating how many cars were collected, transportation time and distance, logistic cost by calculating truck drivers and fuel consumption cost, and compliance cost by calculating percentage of EoL cars collected through authorised collection system. Environmental and social performance indicators here were impact of emissions, local job creation and stakeholder participation.

As discussed in detail in chapter 5, section 5.1.1, the actual economic performance of the collection stage improved the number of EoL cars collected by up to 35% more than few years back saving logistics cost due to less distance between car owner and collection points and saving on compliance cost as well as car owners being persuaded by free take back, additional scrap car scheme and convenient distance to drop off the car, which incentivises them to bring the car for proper disposal rather than giving it to an illegal party to scrap. Positive performance was also identified in terms of reduction of emission impact by reducing transportation distance to collect cars, by reducing fuel consumption and by creating local jobs; stakeholders' participants were found to have made a social contribution at this collection stage. The interview findings demonstrate that Car Manufacturers (CMs) are keen on collecting and reporting economic and environmental performance measures. For instance, most of the car manufacturers interviewed have official measures for reporting environmental performance as environmental performance is one of their key performance in dicators and is tracked and reported on a yearly basis. Moreover, in addition to the environmental performance being reported in the annual reports, a few CMs were also found to publish comprehensive sustainability reports annually with open access to the public.

8.3.3.2 Assessment and sorting of EoL cars

The empirical findings of this stage, chapter 5, section 5.2.2, which discussed the two types of assessment processes found: 1) initial assessment of EoL cars, where car condition was mainly assessed to identify its primary recovery options, meaning whether the car was reusable after repair or sent for dismantling and recycling process; this finding is in line with literature (Chan et al., 2012). This stage was mainly conducted by ATF/dismantlers to separate cars for recovery options. And 2) A second assessment was conducted based on the amount of value that could be recovered from an EoL car. This assessment is done mainly to identify and recover value from reusable components. This is supported by the existing (literature

Chan et al., 2011). But details of this stage, in terms of regulations, process, location and time were not discussed in the existing literature; therefore, the findings for assessment details are unique in how it is recognised in this study, and arguably to the body of knowledge.

i) Regulatory restrictions

There was no direct regulation identified here for ATF, who execute the process, but as this stage assesses cars' different component conditions, including presence of hazardous components, this has an impact on car manufacturers' responsibility to make car make information available within 6 months of a new car's registration.

ii) Assessment and sorting activities

Once ATFs receive EoL cars, they would first do testing and inspection on them. If the car is in good condition (see details below) and has market value (customer demand), the ATF may not necessarily dismantle the car. These cars get separated for resale in auction. If the car does not carry a profitable resale value, it will then be separated for recycling. Recycling is defined here as all the further treatment of a scrap car including hazardous materials/parts removal, marketable parts removal, shredding and disposal. This finding was supported by existing literature (Olorunniwo at al., 2011). But this empirical study identified more detail about how the cars are assessed. The assessment process is conducted using information recorded during car valuation, MOT history and also the expertise of QA who assess the car. These cars are then sorted based on their condition and cost analysis (if repair cost more than car market value). Detail of this assessment process and what type of cars are selling at auction and what is sent for disposal are discussed in chapter 5, section 5.1.2.1.

For further assessment as discussed in detail in chapter 5, section 5.1.4.1, the process of this assessment depends on EoL car nature. At first EoL cars were separated and recorded according to material composition/configurations, as discussed in chapter 4. This part of the assessment is mainly done based on IDIS information provided by car manufacturers. After that, each car was assessed again based on IDIS information to separate and record the hazardous components. Finally, the functionality assessment was carried out according to car damage and customer demand for the car. Details of functionality and market value were discussed in chapter 5, section 5.1.4.1.

iii) Location related issues in the assessment and sorting stage

From the generic literature in the literature review, inspection and sorting may be carried out either at the point/time of collection itself or afterwards at treatment facilities (Srivastava & Srivastava, 2006). This study found that the assessment process was carried out in dismantlers' centres where they have facilities to store (yard) cars for resale and for further treatment.

iv) Time related issues in the assessment and sorting stage

As discussed in chapter 5, ATFB and ATFC conduct the assessment process at the time of loading EoL cars from the truck to the dismantling centres while the others do it after storing all cars and assessing them together with the further assessment process. In term of how long QA takes to assess a car, it was found to depend on the team, where ATFA was identified as taking 15-30 min to complete the assessment of each car. On the other hand, ATFD and ATFF said it took about an hour or more to assess a car to decide its recovery options.

These time-related issues were not identified in the auto industry existing literature. Therefore, these time related issues of auto RL are unique in how they are recognised in this study, and arguably contribute to the body of knowledge.

v) Reuse and redistribution

This empirical finding of the study identified that up to 30% of EoL cars can still be in working order with some repair and refurbishment, then redistributed into the secondary market as used cars. This is supported by the existing literature which discussed EoL cars being sold in the secondary market as used with or without any minor repair (Chan et al., 2011). The findings found all the ATF's used online platforms to sell these cars with pictures and details of car condition. Most of the cars were stored with minimum repair and cleaning. These repairs were identified as mainly cleaning and replacing tires/mirrors/bumper/break pad/radiator/window etc., depending on car condition. All these cars went to auction or used car dealers still requiring repair to make them roadworthy or to pass the MOT. These are further repaired/refurbished by buyers from auto repair/body shops (this research does not include this).

vi) Performance

No players were found to measure performance at this stage

8.3.3.5 Hazardous components removal

The main reason for removal of hazardous components from ELV for Use in a separate recycling process is to protect the environment and human health from the toxic they contains. This is supported by the existing literature, which discussed that there are some components in cars that contain toxins, which is harmful for health and the environment. Therefore, these components need to be removed before further processing of the EoL cars (Schultmann et al., 2006). The literature also mentioned removal of hazardous components as helping the following process stages not to damage good condition marketable parts and materials by spilling harmful substances. However, details of this stage in terms of regulations, process, location and time were not discussed in the existing literature; therefore, the findings below are unique in how it is recognised in this study, and arguably to the body of knowledge.

i) Regulatory restrictions in the hazardous removal stage

This stage is heavily regulated, which was discussed in detail in chapter 5. ELV directives require dismantlers to remove and segregate hazardous materials and components in a selective way, so as not to contaminate subsequent shredder waste from the EoL car. In addition, regulation for the site and operating standards also monitor the process; regulation for available information in the IDIS also monitors car manufacturers to update information including details of all hazardous components within 6 months of new car registration.

ii) Hazardous components removal activities

This is the first stage of the dismantling process where all hazardous components, including air bags, air conditioning, seat belt pre-tensioners, oils, fluids, liquids, radiators and coolants, catalyst converters and batteries, are removed and stored separately for further treatment (hazardous component recycling). Some of them were found to be removed manually and others electrically, depending on the components and company procedure. Detail of each component's removal, storage and use of equipment were discussed in chapter 5, section 5.1.5.2.4.

iii) Location related issues in the hazardous component removal process

As mentioned earlier, this activity is carried out in dismantlers' facilities, which are mainly 500-800 metres away from residential and farm areas. Once all components are removed and stored, hazardous recycling companies collect them for further recycling processing of hazardous components.

iv) Time related issues in hazardous component removal process

The hazardous removal process started within 10 days to 3 months after cars arrived at the scrapyard. This timeframe depends on car condition and company policy for maximum holding time. If a car leaks fluid or oil, it is sent to the removal process immediately after its arrival. No dismantlers identified holding a car more than 3 months.

v) Reuse and redistribution in hazardous component removal process

All the components that are removed and stored are redistributed to hazardous recycling centres for further treatment.

vi) Performance of hazardous component removal stage

As discussed in detail in chapter 5, some ATF's are measuring performance for this stage in terms of process efficiency, emission impact and policy to manage hazardous recycling process impact on employees and community. So, the main performance indicators here were from the environmental and social perspectives. No negative emission impact was found here, as the odor, noise and vibration were controlled and measured regularly. Also a positive social impact was identified in terms of having proper policy for employee training and safety.

8.3.3.6 Hazardous component recycling

The existing literature discussed the importance of hazardous components recycling for recovering valuable materials (Schultmann et al., 2006); however, there is a lack of knowledge in terms regulations, process, location and time, which were not discussed in the previous literature; therefore the findings below are unique in how it is recognised in this study, and arguably to the body of knowledge.

i) Regulatory restrictions in hazardous component recycling stage

As discussed in detail in chapter 5, section 5.1.6, this stage is heavily regulated for "duty of care" responsibility where recyclers have to follow a number of conditions for transportation, storage and treatment.

ii) Hazardous component recycling activities

Every component has a unique recycling process which was discussed in detail for each component separately in chapter 5, section 5.1.6, including all the value recovered from each component.

iii) Location related issues in hazardous component recycling process

None of the hazardous recycling centres were located in areas near drinking water, wetlands, buffer zones, schools, hospitals, public buildings, or other places of public gathering, as to obtain a licence, they have to be a minimum of 4 miles away from these areas.

iv) Time related issues in hazardous component recycling process

Government regulation also controls time related issues here and requires the recycling of hazardous components to be carried out as soon as possible. But the regulation does not give any specific time frame; as a result, companies having their own policies which mainly stipulates that none of them hold on to these components more than a month after collection.

v) Reuse and redistribution in hazardous component recycling stage

Most of the components are recovered as materials which have great value in primary and secondary markets, especially the following materials: copper, aluminium, platinum, rhodium, palladium, nickel , cerium, copper, iron, manganese, plastic, lead, acid (converted to sodium sulphate) and oil. These are use again in the production of new cars. There are some other parts also recovered at this stage (see details in the table 5.15 in chapter 5). This stage also generates some waste for landfill which is further collected by waste management companies for disposal.

vi) Performance of hazardous component recycling process

Hazardous recycling companies (HRCs) measured performance to identify the economic, environmental and social impact of their recycling process. It was found that they managed to recover up to 97 percent of hazardous components, where most of the materials were in a 'good as new' quality, meaning they could be used in new car making. Therefore, economic performance in terms of ROI was identified as increasing over the last 5 years. Environmental and social performance were also identified as having a positive impact in terms of emission impact, waste reduction, energy consumption and use of natural resources.

8.1.3.7 Marketable components removal

Most of the EoL cars coming for disposal were found to contain valuable parts with good market value in the secondary market. This finding is supported by the existing literature (Olorunniwo & Li, 2011; Subramanian et al., 2014). This empirical study's findings identified suspension, wheels & tires, seats, windows, doors and hoods, engine and transmission, wire harness, bumper, trunks and car bodies as the main components removed from EoL cars as marketable parts.

i) Regulatory restrictions in the marketable component's removal stage

As discussed in chapter 5, section 5.1.7.1, this stage is not regulated directly but the recovery percentage target (95% of total car weight) has an indirect pressure on dismantlers to recover as many parts as they can. Apart from this "duty of care" responsibility they have a direct influence on storage at this stage for removal of components, as storage can create a serious health and safety risk.

ii) Marketable component's removal activities

The removal of marketable parts process was identified as mainly manual, which was supported by the existing automotive RL literature, whIch mentions the process of dismantling marketable parts as carried out manually, reducinging use of energy and CO2 emission (Halabi et al., 2015). ATF's are the main players here who are dealing with this stage and selling marketable parts. Details of each component's removal, reuse and redistribution were discussed in chapter 5, section 5.1.7.

iii) Location related issues in marketable component's removal stage

This stage is carried out in the same scrapyard next to the hazardous removal facilities of ATF's. There are no location related restrictions identified to dismantle marketable parts. The facilities for treatment and storage of components and car dismantling have rainproof surfaces for appropriate areas with appropriate leakage collection facilities and storage for used tires, including the prevention of fire hazards and excessive stockpiling. All these are stored in the ATF's site for further cleaning, repair and resale.

iv) Time related issues in marketable component's removal stage

This stage is carried out just after completing the hazardous removal process. It was found that cars waited no longer than 4 days for the dismantling of marketable parts stage. Removal time of the components depended on the component type ,which could take from 5 minutes to a maximum of 30 minutes (see table 5.14 for each component's removal time in chapter 5).

v) Reuse and redistribution in marketable component's removal stage

This empirical study found that removal of marketable parts was one of the most important and economically valuable stages in terms of reuse and redistribution. Some components were directly used as used components and parts and some were sent for remanufacturing and others to shredder along with the car shell. Tires, suspensions & wheels, hoods, seats, doors, windows, engines, transmissions, wire harness and bumpers were identified as reusable as used components, but not all of them (see the percentage for each component in terms of redistribution in the table in chapter 5). Suspension, wheels, engines and transmissions were also identified as collected by remanufacturers to remanufacture and resell as remanufactured components.

vi) Performance of marketable component's removal process

ATF's were very keen to measure performance at this stage in terms of economic and environmental performance. A positive economic impact was found in terms of increase in ROI, revenue and recapturing value (see detail of actual performance discussed in the table in chapter 5). In terms of environmental performance, no negative emission impact in the process was found, as the process is mostly manual.

8.2.3.8 Shredding process

The findings identified that after the removal of all marketable components, the car shell is sent to the shredder to recover materials. This was supported by the literature which refers to the car shell as the "hulk" (Chan et al., 2011; Subramanian et al., 2014). Also car parts which cannot be repaired and are not in a good enough condition to be recovered are also shredded to recover materials (Olorunniwo & Li, 2011).

i) Regulatory restriction in shredding stage

This study's findings identified that the shredder machine should "give rise to levels of mineral oil in shredder residues of approximately 0.03%w/w - significantly below the hazardous waste threshold of 0.1 %w/w " (a shredder machine should be updated to cover these requirement).

Apart from this, the 95% recovery target regulation has an indirect impact on this shredding stage. As the hazardous components recycling process generates nearly 3 to 5 percent waste for landfill, this shredding process has to recover 100% including energy. That means there should not be any waste for landfill.

ii) Shredding activities

The shredding process was mainly carried out using machines (Halabi et al., 2015). This empirical study found that all the shredders (ATFC, ATFD, ATFE and ATFF) used updated post shredder machines which carry out shredding and separating and produce ferrous, nonferrous and ASR dust. Then, ASR shredder technology (a separate machine) shredded the ASR dust further, recovering glass, aluminium, foam, fabrics, copper and resin. Not all the shredder facilities have this ASR dust shredder facility. This study found that From four shredder companies, two of them (ATFE and ATFF) have this ASR dust shredder facility.

iii) Location-related issues in shredding stage

As discussed earlier, some dismantlers had the shredder machine set up in the same yard next to the dismantling system and the others that did not needed to transport the car shells to a separate shredder yard. Similarly, some shredder sites had ASR shredding facilities and others did not, meaning they had to transport ASR dust to ASR dust shredder plants for further recovery of materials.

iv) Time-related issues in shredding stage

Time depended on a shredder's internal system where in some cases car shells were immediately transferred to shredder machines after the completion of the dismantling process. For some cases, car shells were stored for months in a queue (mostly in ATFA and ATFB, as they did not have shredding facilities). ASR dust was moved immediately to ASR shredder plants where it was stored. ASR dust was found to be put through the shredder machine within 2 to 3 weeks, but the materials recovered from ASR dust are waiting months for collection by material manufacturing companies. On the other hand, the waste coming from ASR that is not recoverable, a very small amount (not more than 5 %), is dispose of by the incineration process.

v) Reuse and redistribution in shredding stage

As mentioned previously in chapter 5, this shredding can be an example of why RL of EoL car is important for gaining economic value, as at this stage steel, light iron, cast iron and wrought iron from ferrous and from non-ferrous materials are recovered, as are aluminium, lead, copper, tin, zinc and brass. Due to limited resources of steel, aluminium, copper, etc., these materials identified have a good resale values, which also drives the automotive industry substantially.

vi) Performance of shredding process

The findings indicate that shredders are keen to measure performance in terms of process efficiency with materials quality and recovery percentage. Evidently, these performance characteristics are used in the shredding phase and they are important sets of measures when shredders want to make profit and save the environment and meet the regulation by establishing the right process. Details of actual performance in this stage are discussed in chapter 5.

8.3.3.9 Disposal of EoL car waste

The existing literature mentioned the disposal of shredder puff (Schultmann et al., 2006), which is mainly the light materials coming from automobile shredder residues (ASR) (Mansour & Zarei 2008). They also mentioned that the strict recycling targets and scarcity of available landfill space can encourage minimal waste coming from car for disposal due to high landfill costs (Soo et al., 2017). The findings in this study identified that a few years ago, a big percentage (35-40%) of EoL cars' materials used to be dumped in landfill, piling it high at a salvage yard or selling it for scrap. But, as discussed earlier, the latest developments in RL practice for EoL cars have managed to recover up to 97% of an EoL car's weight, which has saved half a million tonnes a year from landfill, and as a whole the industry has reduced its landfill waste by 90 percent since 2000.

i) Regulatory restrictions in the disposal stage

The Directive on the Incineration of Waste (The European Commission 2000b), unlike the landfill directive, has no prescriptive targets and therefore no part in shaping waste strategy. It does however set limits on emissions, operating conditions and water discharge, and strict controls on permits and monitoring. This directive was transposed into UK law in 2002 with the Waste Incineration regulations.

ii) Disposal process activities

As discussed in detail in chapter 5, disposal can be done in two different ways: one, incineration, means burning the waste and the other, landfill, means dumping the waste in a landfill site. Details of how both sites work are discussed in chapter 5. This empirical finding identified incinerators as reducing the solid mass of the original waste by 80–85% and the volume by 95–96%, depending on composition and degree of recovery of materials such as metals from the ash from recycling. This means that while incineration does not completely replace landfill, it significantly reduces the necessary volume for disposal to landfill.

iii) Location related issues in the disposal stage

Disposal sites were located far from residential areas. There was no residential area identified within a 3 mile distance

iv) Time related issues in the disposal stage

All the waste coming to landfill sites was instantly dumped at the site.

v) Reuse and redistribution in the disposal stage

This stage generates energy, which is used for housing electricity for heat and light.

vi) Performance of the disposal process

WMCs were found to measure performance here mainly in terms of environmental impact of the disposal process in terms of emissions impact. This finding identified proper management of odor measurement and gas control systems in the landfill site, reducing emissions.

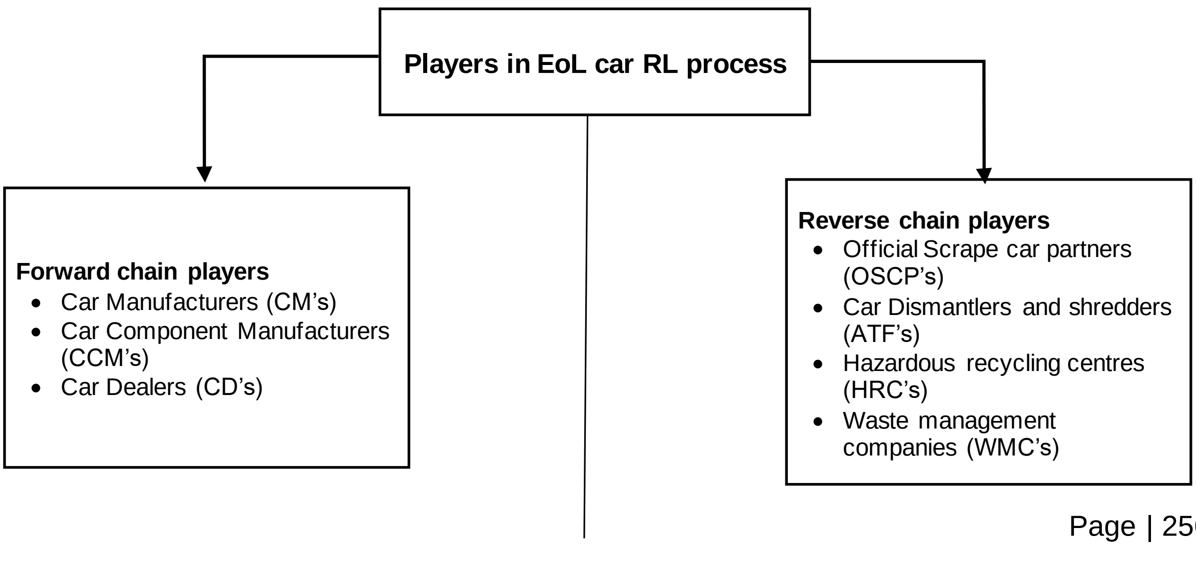
Now from the above discussion of the RL process, the underlying differences in the extent of implementation of reverse logistics process can be understood using resource and knowledge-based view. To a great extent, it was evident from the interviews that the RL process was dependent on the firm's resources, both financial and human resources. This is consistent with the resource based and knowledge based views of the firm. According to the resource-based-view (RBV), an organisation's resources can be defined as all assets, capabilities, organisational processes, firm attributes, information and knowledge possessed by a respective firm (Barney, 1991). Similarly, according to the knowledge-based view (KBV) (an extension of RBV), knowledge is the important resource of a firm. The proponents of KBV argue that the knowledge-based resources of a firm are socially complex and difficult to copy (Grant, 2002).

8.3.4 Players involved in the EoL car RL practice and their activities

A number of players were foundto be involved in processing EoL car RL activities. All these players are categorised into:

- Forward chain players: Car Manufacturers (CMs), Car Dealers (CDs) and Car Component Manufacturers (CCMs).
- Reverse chain players: Authorised treatment Facilities (ATFs), Hazardous Recycling Centres (HRC), Waste Management Companies (WMCs)
- Regulatory bodies: Government Agencies (GAs)
- Membership body: Official Scrap Car Partners (OSCPs)
- Senders: Individual customers, institutions, local authorities and police

These players are responsible for different activities in the reverse chain of EoL cars. Details of each player's responsibilities are discussed in chapter 6. These findings are supported by the literature, as Schultmann et al. (2006) mentioned from forward chain players, car manufacturers were identified as only responsible for the network for ELV collection and reverse chain players were involved with collection and treatment. The literature also explained the role of other players in the auto industry including consumers, who are the source of ELV (Soo et al., 2017); and the non-profit organisations, which are playing an important role in managing the RL process for ELV from collection to disposal by supervising each players in the chain (Soo et al., 2017). Government agencies are also another important player in the auto industry, making policies and being responsible for ensuring compliance, in line with the generic literature discussed in part one of the literature review.



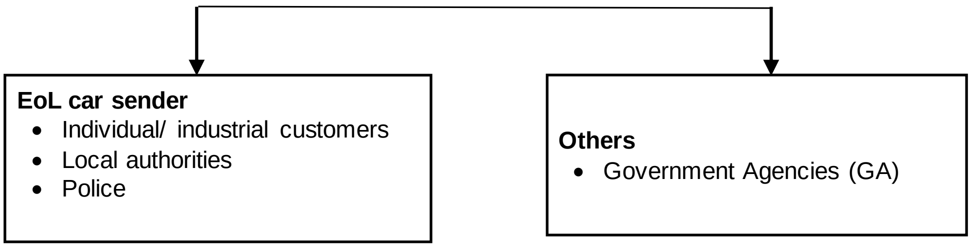


Figure 8. 3 Players involved in EoL car RL process

For a detailed understanding of activities, this empirical study's findings identified a number of key activities for each stage of the RL process for EoL cars, where different players were involved with different activities, presented in table 6.1 in chapter 6 of this thesis.

The empirical findings also identified some companies as having the expertise and resources available for some activities which they operated internally, but for other activities, firms did not have enough resources in terms of expertise, logistics, space and technology. Here, companies were involved with other companies with the requisite expertise in the form of a strategic alliance. For some activities there was an arm's length relationship, where companies have a buyer—seller relationship with price based negotiations. To support these findings, the literature also suggested that to deal with this RL process for EoL cars, manufacturers should join with treatment facilities to create a network in order to achieve efficient management of the recovery process and to minimise the costs (Mansour and Zarei 2008). Aitken and Harrison (2013) also agreed that the relationship between the partners in terms of information flow and knowledge management enabled the establishment of the RL system. Knowledge which had been tacit for the salvage agents in terms of the disassembly process became, in part, codified. Lack of know-how has been found to be a significant barrier to implementing RL systems (Gonzalez-Torre et al., 2010), where collaboration can be helpful. However, there has been limited focus On the relationship between firms to enable RL systems in the auto industry (Aitken & Harrison, 2013). Therefore, the findings presented in chapter 6 and revisited in ection 8.3.5 below on the relationship nature between players with collaboration type for each relationship are unique in how they are recognised in this study, and arguably to the body of knowledge.

8.3.5 Relationship nature between players

The empirical findings found four different types of relationship nature between players: internal activities, acquisition, strategic alliance and arm's length. Details of each relationship nature are discussed in section 6.2.2 of chapter 6 in this thesis. This finding is supported by the logistics management literature where Levi et al., (2003) discussed all these four types of relationship nature from logistics management perspective. The car manufacturers (CMs) and authorised treatment facilities (ATF's) were found to be sharing expertise, technology, investment and ownership of the invented technology for the project of R&D for recycling technology. This relationship nature falls under acquisition type with strategic level collaboration between partners. On the other hand, strategic alliance relationships nature identified between CMs and OSCPs for collection point network setup and monitoring, and between battery manufacturers (BMs) and HWRCs for recycling batteries. Here, the collaboration level was not as close as at a strategic level but still involved sharing information and planning together, which can be described as coordination level collaboration. The rest of the relationships in this study for EoL car reverse chain for recycling EoL cars, including relationships within ATFs to transport car shells, ATFs and HRCs to transport hazardous components, ATFs and WDCs to transport waste, and WDCs and HWRCs to transport waste, were found mainly to be arm's length relationships, where they only share information on collection quantity and time and they on occasion share transportation including trucks and drivers, if needed. Figure 8.4 presents the relationship between case-category (CC) players.

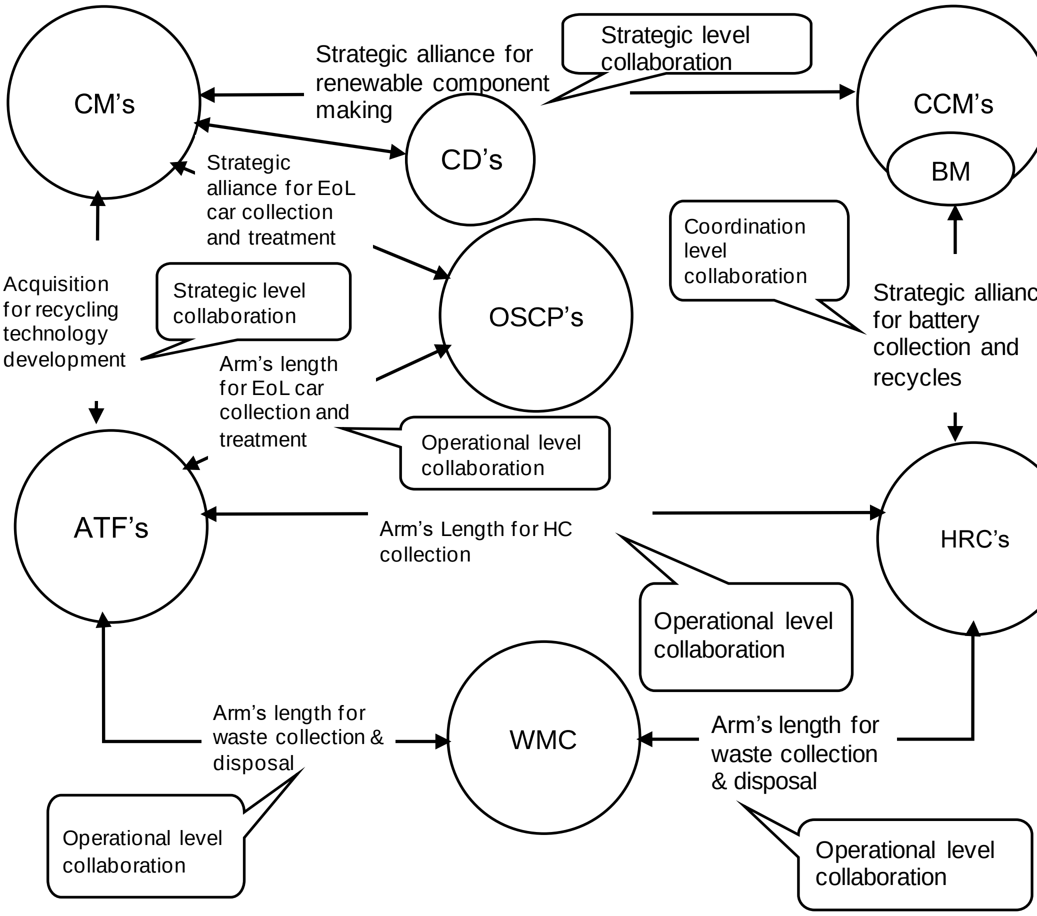


Figure 8. 4 Relationship between case-category (CC) players

In terms of this relationship impact, the overall impact was positive on CMs who were able to meet regulations for setting up a network and recovery target. For ATFs, the impact was also identified as positive in terms of increasing revenue. Apart from these, both car manufacturers and ATFs also managed to save time, resources and cost by managing activities together by speeding up the process, taking decisions together and sharing data. This was supported by the literature, which found collaboration between players as having a positive impact on speedy processes, decision making, return tracing, flexibility to deal with customer demand, inventory data, warehouse information, and transportation/scheduling data (Li & Olorunniwo 2008).

8.3.6 Drivers that motivated players in these relationship

Drivers that influence all these players to establish relationships, especially for strategic level collaboration in acquisition and strategic alliance relationships, are mainly to minimise the responsibility of investment and to gain access to each other's technology for better innovation. This was supported by the literature which suggests that finding a third-party RL provider and partnering with them brings financial benefits by reducing RL operation and investment cost and close collaboration between product making expertise and product remanufacturing expertise can enable the access and use of each other's expertise in technology to improve the whole RL process (Badenhorst, 2015). On the other hand, arm's length relationships are mainly driven by access to a secure reliable source. In addition, lack of resources, information availability and different specialisations also drive players towards close collaboration relationships with other players who have the resources, information and expertise.

From a theoretical standpoint, this can be explained through the lens of resource-dependence theory (Salancik & Pfeffer 1978), where organisations are dependent upon resources provided by outside parties in order to compete (in this case setting up the EoL collection network). For example, car manufacturers developing EoL car collection network by using official scrap car manufacturers network and expertise. This study found that companies were resource-dependent in this EoL car RL practice and it was evident on several occasions in the interviews. For example, respondents from car manufacturers (CM) interviewed had given the entire project for EoL car collection network setup to disposal of EoL car waste to the offcial scrap car partners (OSCP). In this case, the CMs are 100% resource-dependent on the OSCPs. Similarly, OSCPs are also resource-dependent on authorised threatment facilities (ATFs) to collect and treat EoL cars. From a resource-dependence theoretical perspective (Salancik & Pfeffer 1978), organisations are dependent upon resources provided by outside parties in order to compete.

8.3.6 Barriers in these relationships

There were some barriers identified that players faced in these relationships. These include urgency to complete the project which affected both parties. From a theoretical standpoint, this can be explained from the premise of stakeholder theory and agency theory. Both theories individually and in combination give a clear understanding of this barrier. A stakeholder is 'any group or individual who can affect or is affected by the achievement of an organisation's objectives' (Freeman, 1984). In this case, designing a car with more recyclability at the end of its life by two car manufacturers where one partner motivated the other to produce the car within a very short period of time, has affected both partners, as the car was lower quality than their brand status.

This study also identified a lack of common interest as another barrier here which is facing HRCs, created by ATFs who mainly focus on marketable parts and ignore some key activities for hazardous components, including informing their partner to collect hazardous components on time. From a theoretical viewpoints this can be explained by agency theory, as an important concept in agency theory (Eisenhardt, 1989) is the 'self-interested behaviour' or the behaviour of the agent, in this case, ATFs processing their own self-interest rather than in the best interests to have more effective RL practice in terms of hazardous component recycling.

8.3.5 Drivers and barriers in EoL car RL process

1. Drivers in EoL car RL process

In the literature, drivers were discussed to explore why companies are involved with the reverse logistics process. De Brito and Dekker (2003) presented these drivers under three main headings: Economics, Legislative, and Corporate citizenship. De Brito and Dekker (2003) also pointed out that these factors are not mutually exclusive drivers, and it is sometimes difficult in practice to set boundaries between them. Economic drivers influence companies because the operation becomes more profitable, legislative drivers because the law requires them to comply and corporate citizenship drivers because they "feel" socially motivated to do it (De Brito and Dekker 2003).

This empirical study's findings also identified that these three drivers - economic, legislative and corporate citizenship - have strong influence on EoL car RL process in the UK but apart from these, there are also stakeholder and competitive pressure drivers found to influence companies. This is also supported by the literature, where researchers suggest that cultural, legal, social, political and a host of other macro-environmental variables differ by location. Hence, research findings pertinent to a certain region may not be fully applicable in other regions and locales (Sarkis et al., 2010). Also, de Brito and Dekker (2003) pointed out that economic, legislative and corporate citizenship factors are not mutually exclusive drivers, and it is sometimes difficult in practice to set boundaries between them.

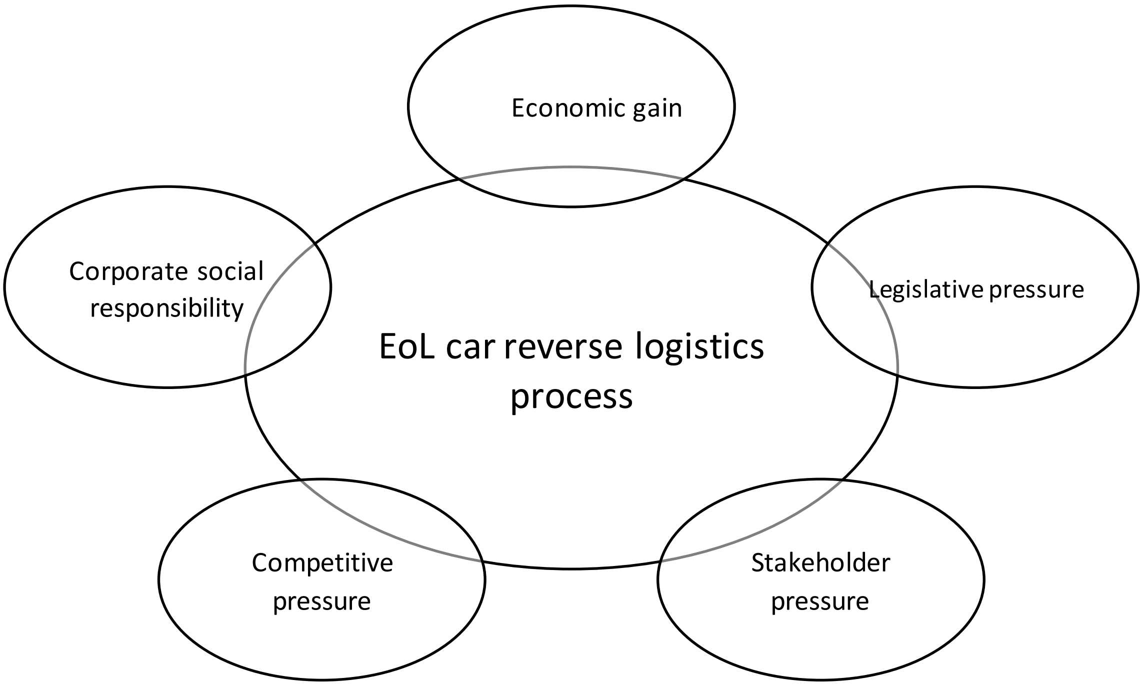


Figure 8. 5 Drivers influencing players to involve and improve EoL car RL process

This empirical study's findings attempted to identify not only the drivers but also found that these drivers are mainly influenced by the particular stakeholder/player and what action they have taken for that driver and its impact. Also two different goals identified here were influenced by these factors; one is drivers influencing players to become involved with the RL process and the other is the driver influencing players who are already involved in implementing more systematic processes.

i) Legislative pressure

Legislation was found to be a very strong driver influencing CMs to become involved with the RL of EOL car process. This is supported by the literature, where researchers mentioned that regulations put pressure on CMs and tend to make them responsible proper disposal of the End of Life (EoL) of their products (Gehin, et al. 2008; Chan et al., 2012; Subramanian et al., 2014). This study's findings identified two key regulations; one is forcing CMs to setup a network for EoL car collection and treatment with free takeback and the other is to meet the recovery target of 95% of a car's weight. CMs identified working together with OSCPs to setup and manage the network and make sure they met the recovery target. According to CMs, they were also working together with each other (within CMs) to make new cars with more recyclable materials. This finding was also supported by literature where researchers stated that CMs were focussing on making new cars with more recyclable materials (Gehin, et al. 2008).

The impact of this practice identified in this finding is that the network of EoL car collection managed to collect about 95% of EoL cars in the UK and they also managed to recover more than 95% from each car in terms of its weight.

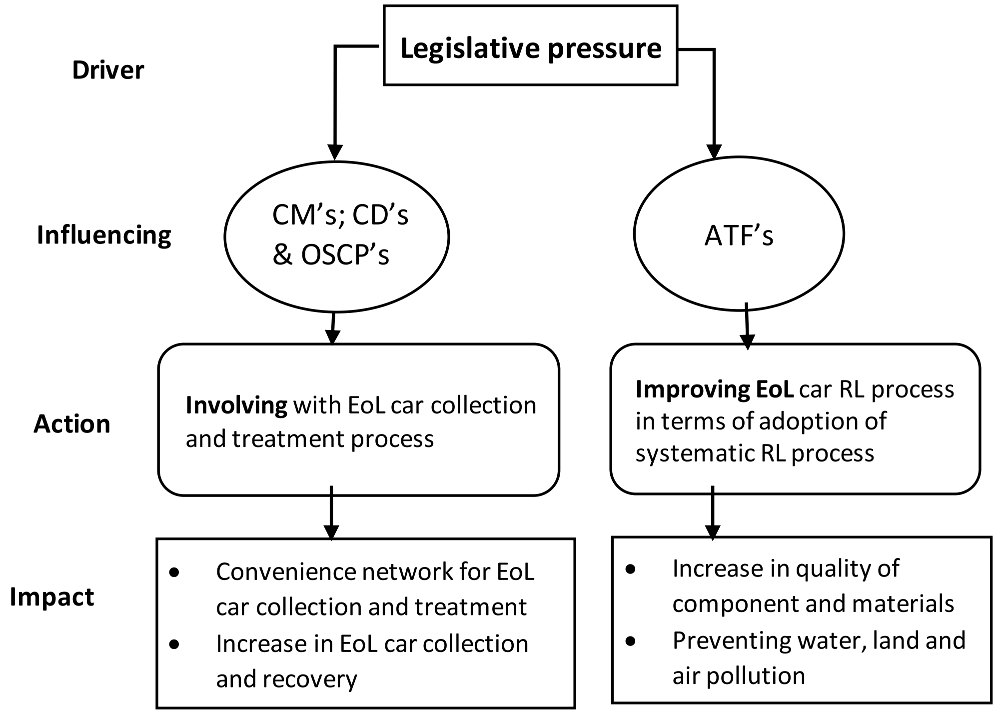


Figure 8. 6 Legislative pressure on players for EoL car RL process

Furthermore, legislation for hazardous separation mainly requires players who are involved in the hazardous removal process (ATFs) to have a system to remove hazardous components first from the car before they remove marketable parts or send it to a shredder. This is a main driver for ATFs and they are identified as implementing the process. A very positive impact identified is that the removal of hazardous components prevents marketable parts and materials from the linkage of toxins and damage, which improves the recovery of good quality parts and materials.

From a theoretical viewpoint, government regulation pressure can be explained through the lens of coercive isomorphism of institutional theory, as coercive isomorphism results from formal and informal pressures; and according to the concept of coercive isomorphism, firms are subjected to pressures from government directives (DiMaggio & Powell 1983). In this regard, organisational practices are direct responses to government directives and policies. Government control and action, or more generally state intervention, has consistently been understood as playing a central function in initiating the structural transformation of organizations (Deng, 2009). The interview findings to some extent conform to this theory, since the study found several instances where case-category (CC) companies are under pressure from government regulations for EoL car collection to disposal process.

ii) Economic gain

Direct economic gain from recovered parts and materials is a common reason why recycling industry players are involved in recycling cars and this is supported by literature (Chan et al., 2012; Subramanian et al., 2014). In addition, free take back EoL car collection was identified as encouraging car owners to dispose of their old cars through an authorised treatment facility (ATF). Therefore, there is an increasing number of cars coming back to the reverse chain for disposal, which motivates auto recyclers to become involved with the EoL car RL process, as the increasing number allows them to collect more cars, meaning they have more cars to sell at auction and more parts to sell in the secondary market. This is identified as a strong driver in the UK as to why auto recycling companies enter this business and apply for ATF licences to collect and recycle EoL cars. This has a very positive impact on EoL car collection in terms of higher numbers of EoL cars being collected and disposed of in an environmentally friendly way.

Also direct economic value in producing good quality materials has a high impact on ATF's who are involved with the shredding process. Involvement with the RL process allows more effective shredders to produce quality materials which can be used to make new cars. More involvement in terms of using updated shredding machines, taking care of proper removal of hazardous components prevents damage from toxins and also contributes to the shredding technology innovation process together with CMs. This efficient and effective RL process in terms of the shredding process recovering materials can be used to produce new cars, which reduces resource (raw material) scarcity in auto industry.

Increased involvement with EoL car scrapping demonstrates that organisations are involved with environmental management practice, which is very important for auto industry players, especially for CMs as they are making the cars. Here, this RL practice demonstrates the ability to gain competitive advantage and differentiate a business against its competitors. This is supported by the generic RL literature which states that due to global warming, every organisation is trying to show best environmental performance and dealing with return helps firms to increase their environmental performance (Carter & Ellram, 1998). This influences CMs to become more involved not only to meet recovery targets, but also to contribute more including more investment in R&D for recycling technology.

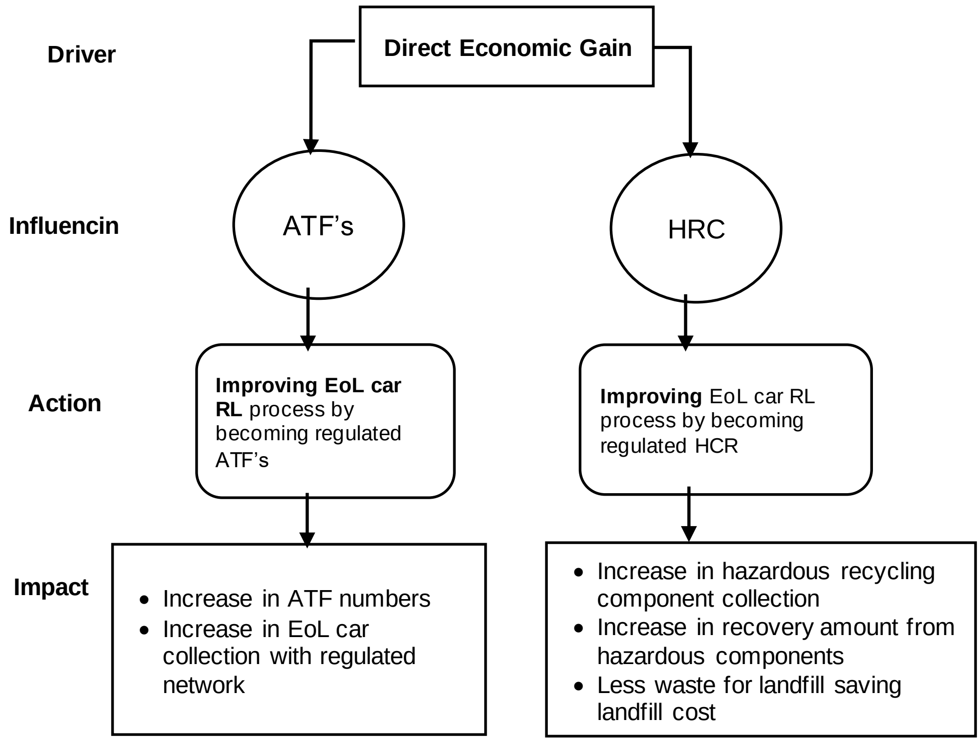


Figure 8. 7 Economic gain influence on players for EoL car RL process

iii) Stakeholder pressure

Stakeholder pressure is identified as CMs mainly forcing OSCPs and, further, the same force is passed on to ATFs by OSCPs to implement a systematic RL process to have proper policy in place for the collection and treatment process and to increase recovery rates of EoL cars. This is supported by the generic RL literature where research mentioned players facing pressures from their suppliers and buyers to have take back policies in place (Carter & Ellram, 1998). This has a positive impact on collection of EoL cars in terms of higher numbers of collection, meaning more recovery, which also means less waste for landfill.

From a theoretical viewpoint, this also can be explained through the lens of coercive isomorphism. Stakeholders who have the power to control other stakeholders were found to exert pressure on them to implement RL practice in terms of the EoL car RL process. According to the concept of coercive isomorphism, institutional pressure is exerted on a dependent firm by other organizations and by cultural expectations in the society in which it operates (DiMaggio & Powell, 1983). Pressure from partners was found to associate with the findings where the recycling industry was facing pressure from car manufacturers for RL activities to increase EoL car collection and recovery percentage of their cars.

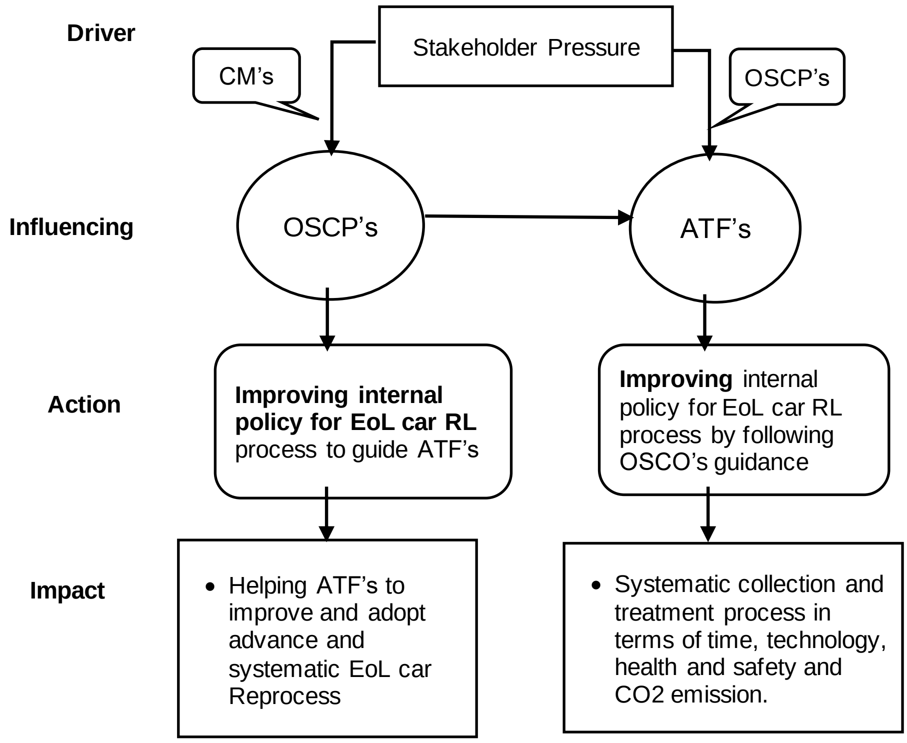


Figure 8. 8 Stakeholder pressure on players for EoL car RL process

iv) Competitive pressure

The RL generic literature states that customer satisfaction has become a competitive pressure, as dealing with customers' return and product quality conformity can create more satisfied customers (Rogers & Tibben-Lembke, 1998; Chan et al., 2011). However, in this study competitive pressure influenced players from a different perspective. The growing practice of RL in the automotive industry in UK is putting pressure on almost all the players to develop similar practice where all the dismantlers and shredders recognize that they have to have ATFs license for the fact that they need to implement free take-back practices to stay competitive in the market, otherwise they risk losing market share to competitors. On the other hand, CMs also recognized that most of their competitors are becoming involved with innovating recycling technology simultaneously with the car design innovation, which pressuring them to do so.

From a theoretical viewpoint, competitor pressure can be explained through the lens of mimetic isomorphism. According to this theory, firms are under constant mimetic pressure to imitate/mimic the actions of their successful competitors in the industry in order to either follow their success or in an attempt to avoid losing their competitive advantage (DiMaggio and Powell, 1983). The interview findings to some extent conform to this theory since the study found several instances of firms trying to copy their successful competitors.

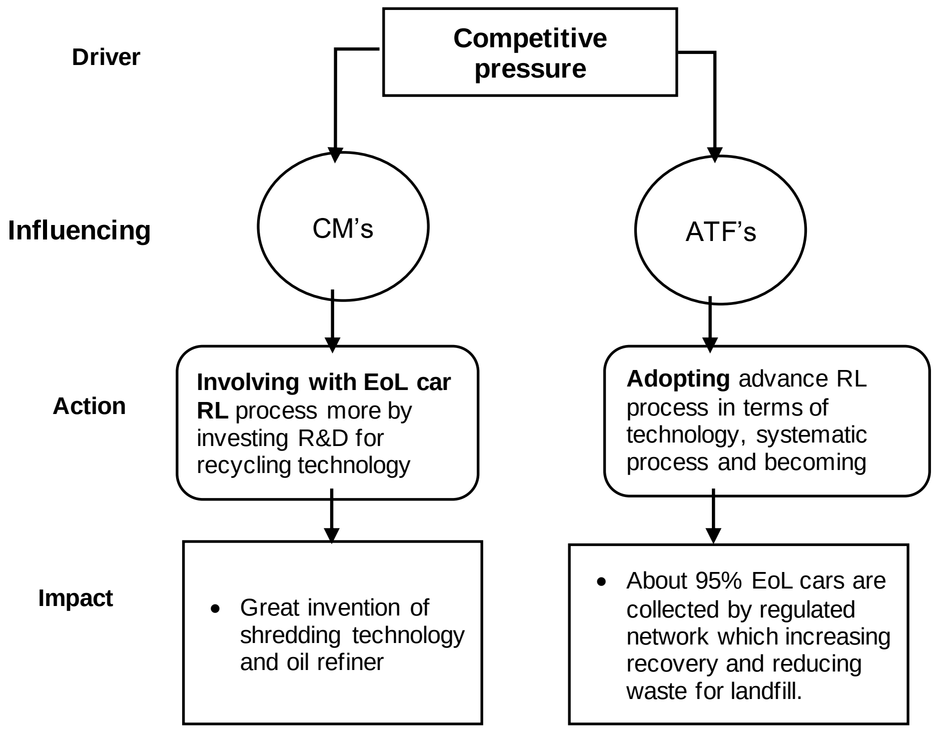


Figure 8. 9 Competitive pressure on players for EoL car RL process

v) Corporate social responsibility (CSR)

CSR basically comes down to how a company can make a positive impact on society. This concerns some morals that in this case drive organizations to become responsibly engaged with RL. This is identified as a common driver for all the players here in UK automotive industry with different reasons related to corporate social responsibilities (CSR), which influenced them to get involved with the EoL car RL process in a more systematic way with increased engagement. This is identified as influencing players to work together within and across the industry to protect the environment and society from the automotive industry's CO2 emissions.

From a theoretical viewpoint, CSR drivers can be explained through the lens of the Value Belief Norms (VBN) model, which is based on the assumption that individuals adopt a pro-environmental attitude if they perceive a moral obligation to protect themselves, other members of society, or the ecosystem in general (Steg & Vlek, 2009). The VBN model was proposed by Stern (Stern et al., 1999) to evaluate the pro-environmental behavior of individuals by linking. The interview findings to some extent conform to this theory since the study found almost all the players here involve themselves in the RL practice for EoL car collection phase because their tendencies favour the responsibility towards society, with high environmental concern.

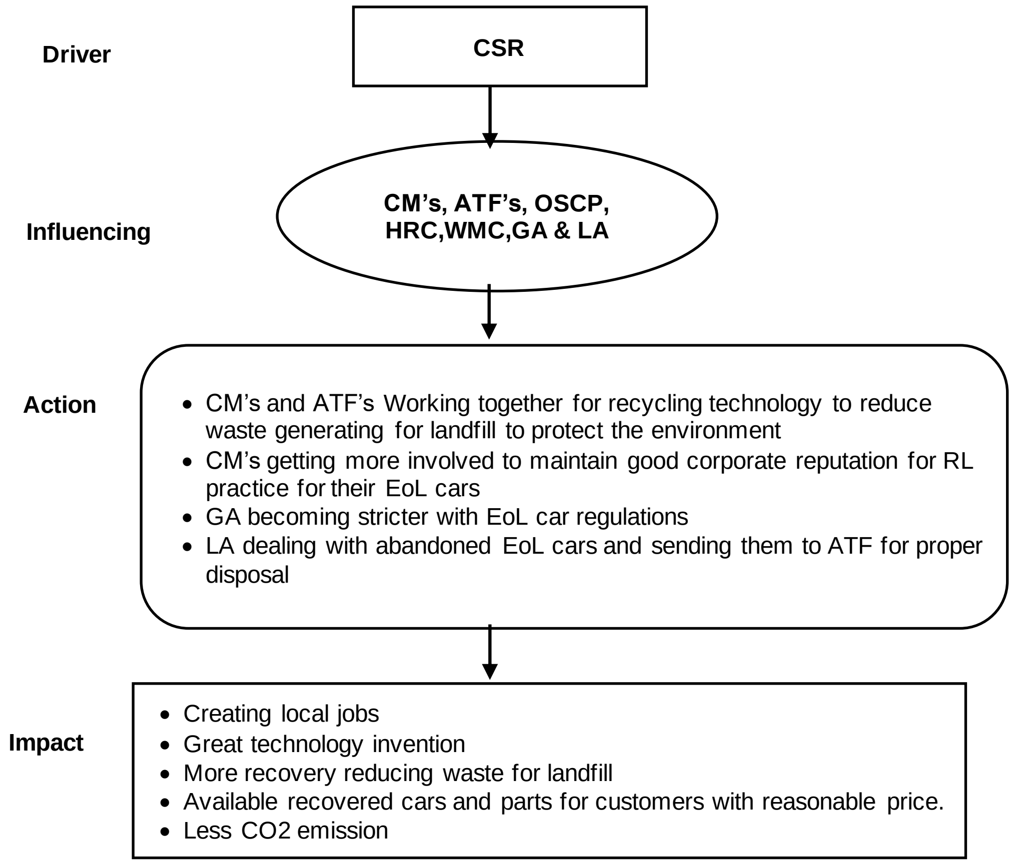


Figure 8. 10 CSR drives players for EoL car RL process

The CSR of firms can also be understood using the new institutional theoretic perspective (Scott, 2001), cultural-cognitive (socio-cultural responsibility) isomorphism. According to this theory, the environmental commitment of firms, generally a voluntary obligation to society, can be viewed as a rational desire to embrace environmental practices that are consistent with the obligations and values of the society in which they function (Hsu et al., 2013).

The empirical findings presenting between case-category (CC) companies, there are similar motivations found which driving CC companies to involve with EoL car reverse logistics practice. From a theoretical standpoint, this can be explained from the lens of institutional theor

From a theoretical viewpoint, why companies act similarly can be explained through the lens of institutional theory. Institutional processes are the means by which the institutional context forces organizations to be isomorphic (DiMaggio & Powell, 1983) or similar to each other, in form and practice. From three isomorphic processes: coercive, mimetic, and normative, the coercive isomorphism results from formal or informal pressures exerted on the organization by the government, other organizations, or the cultural expectations of the environment where these findings are inline, as discussed above that companies within case category (CC) are receiving pressure from government regulations, stakeholders and cultural expectation to save the environment. Also, the challenges of the RL process in terms of meeting regulations, innovating technology also forces organisations within the industry to act similarly, which can be explained through the memetic isomorphism, as this is associated with uncertainty in goals, technology, or market dynamics, which leads organizational decision-makers to adopt structures and practices that model other leading organizations in their fields. On the other hand, normative isomorphism results from the standards and cognitive frameworks that are created and controlled by professions and other moral standards-making bodies which is also identified in these findings - that organisations focus on RL practice, as they sense their responsibility to reduce global warming. The similarities in this willingness/sense/ethics, mainly the awareness and practice of ethics in schools, universities, organisations and societies in the UK has made individuals sense their responsibility to save the environment.

2. Barriers in RL practice

There are some barriers which hinder players to get involved with the RL process (Xie & Breen, 2014) and some hinder the improvement of the RL process (Rogers & Tibben-Lembke, 1998). In terms of RL process for EoL cars in the UK, almost all the responsible players are involved in the RL process of EoL cars but some barriers hinder some RL players from getting fully involved and some from improving the RL process. The barrier for auto RL is unique in how it is recognised in this study, and arguably to the body of knowledge.

i) Costly process

From earlier discussions it is evident that some ATFs are not involved with the shredding process and the reason was identified as the setup of shredding facilities, especially very quick technological changes/improvements and requirements of regulation to use upgraded technology to increase recovery rate. Also high costs are associated with the setup of hazardous removal with the facilities for special treatments, water lines, special storage, updated equipment and expertise to implement hazardous components removal processes were identified as a barrier, as these components were not bringing economic value to ATF's. This is supported by the literature, where researchers stated that some products do not have recovery value (Xie & Breen 2014), which discourages players to become involved with RL activities, as they believe this is the only extra cost (Rogers & Tibben-Lembke, 1998)

ii) Lack of expertise

The shortage of RL expertise was acknowledged as a barrier by almost all stakeholders, though the relevance varied across stakeholders. For CMs there is a lack of quality academic/training programs in the UK offered in areas such as reverse supply chain management at local universities, colleges and training centers. According to ATF's, the expertise required for dismantling and recycling activities are difficult to find.

From a theoretical stance, lack of expertise as a deterrent to the implementation of RL practices can be explained on the basis of the knowledge-based view. According to the theory, knowledge is the most strategically significant resource of a firm. The lack of expertise implies that the firms are expected to lack the heterogeneous knowledge bases and capabilities required for the implementation of RL practices. Firms, therefore, are required to build this knowledge base by training existing employees and/or hiring employees with RL expertise or outsourcing their RL activities.

iii) Lack of stakeholder support

Though this study's findings identified that stakeholders' cooperation was not a significant issue here, one problem identified in the collection process was with the last car owner, in terms of not cooperating with appropriate information about the car and the collection point. This information was identified from almost all the players of ATF's who were affected by delays Iin the collection process in terms of payment to car owners and creating misunderstanding between car owners and dismantlers. Therefore, dismantlers have improved terms, a condition sections by adding car value can be changed after physical assessment.

iv) Lack of technology

Though it was identified that in the UK EoL car RL process most have advanced technology (shredder) to make quality materials, at the moment the amount of raw materials identified is still a small proportion distributed as quality primary raw materials. To increase the quality of these secondary raw materials to make them as good as primary raw materials, more updated technology is needed in terms of separate collection and sorting and recycling facilities towards a more circular economy.

v) Lack of effective disposal system

Most of the old landfill sites are closed and active landfill sites are also becoming full day by day. As a result, GA is under severe pressure from the European Union to reduce the amount of waste going to landfill and increase recycling. On the other hand burning waste emits toxic gases and particulates (which can settle in human lungs) into the air. This is not confined to the area where it is incinerated, as air currents can distribute the toxins that this burning produces around the world. Both air emissions and incinerator ash include heavy metals and chemicals, such as cadmium, mercury, sulphuric acid and hydrogen chloride, as well as the deadly poison dioxin.

Drivers and barriers in RL practice address the fourth research question in this thesis. A comprehensive, theory enabled understanding of RL drivers and barriers in such detail has not been executed previously in the automotive industry RL practice and therefore constitutes the novelty of this thesis. This understanding is expected to guide practitioners and policymakers on ways to leverage these drivers and minimise/eliminate the barriers to achieving wide implementation of RL practices.

8.4 Chapter Summary

This chapter has discussed novel insights obtained from chapters 4, 5, 6 and 7's cross case category (CC) analysis. It has compared and contrasted the empirical findings for each construct to the extant RL literature, thereby confirming whether the auto RL practices employed by the nineteen companies corroborate the RL fundamentals described in the extant literature or whether the case companies operate under a different RL fundamental.

Furthermore, this chapter has compared relationships between analytical generalisations derived from the empirical data, and the extant literature, hence, confirming whether the empirical findings corroborate the extant literature.

Finally, in this chapter, several established/emerging management theories were discussed that offer a plausible basis to explain the behaviour of stakeholders in executing EoL car RL practice. Overall, for practitioners and/or policymakers faced with the reality of addressing complex sustainability challenges, the empirical evidence accompanied by general theoretical principles is expected to inform the wider application of RL practices in the automotive sector.

Chapter Nine will therefore present the summary of this thesis, address the RQs, highlight the theoretical and practical contributions of this study, as well as indicate the implications for further research.

CHAPTER 9: CONTRIBUTION AND CONCLUSION

9.1 Introduction

The purpose of this final chapter is to provide a brief review of this thesis by highlighting its contributions. To do so this chapter first briefly discusses this research background. Second, it revisits and briefly discusses the literature review. Third, it revisits the findings of this study in relation to the research questions and highlights its contributions to theory and practice. Finally, the limitations of this study along with avenues for future research are discussed.

9.2 Research background

This thesis has studied EoL car RL practice, a systematic and integrated approach to process EoL cars coming for disposal. It includes understanding the reasons EoL cars are coming back for disposal, nature of EoL cars and their impact on RL process, the RL process EoL cars from collection to disposal stage and performance of each stage namely environmental, economic and social performance, players involved in this EoL car RL process and their relationship nature, drivers and barriers affecting the implementation of these EoL car RL practices investigated in terms of four separate research questions in this thesis. The systematic literature review (chapter 2) of this study established the increasing interest in RL research in the academic community. A pragmatic approach of qualitative investigation with exploratory and in-depth interviews was used to answer each research question.

9.3 Discussion on research questions

This section revisits the answer to four research questions proposed in this thesis and its contribution to theory and practice.

Research Question 1

RQ 1: Why are end of life (EoL) cars returned and what is the nature of the return of EoL cars which has significant impact on the RL process?

The knowledge of return reason of EoL cars and their nature was found to be important in this study in controling EoL uncertain return and its impact on EoL RL process. Findings confirmed that the reason for sending EoL cars for disposal was not because the car is a certain age but because the cars were heavily damaged due to wear and tear and had become very expensive to maintain or due to heavy accident (road, flood, fire) which was too expensive to repair. On the other hand, abandoned cars were returned for disposal because the owner was not found, as the car was not registered, or because the car was heavily damaged and was leaking fuel or any other liquid that was harmful for environment and needed immediate disposal.

To control age related returns, this empirical finding found car manufacturers investing in car design to increase cars' longevity by using lightweight materials in the car components. This found that the longevity of cars are increasing the average age in the UK, now 8 - 11 is the average age of a car but 20 years ago the average age was about 6 - 7 years (this average age is for on road cars). So, the age of cars on the road has increased, which would bring greater environmental benefits, as this savies significant environmental costs to both manufacturing a new car and adding the old car to the EoL car RL process. To control accidental damage to EoL cars, this study found car manufacturers (CM) designing cars with advanced self-directed safety. Findings show that the advanced self-directed safety systems fitted to cars has helped to drive down the number road accidents in the UK by 10% in just five years. To control abandoned EoL cars, the government gave the responsibility to Local Council (LC) to remove vehicles abandoned on the highway or other land in the open air.

In terms of EoL cars nature and its impact on RL process found; cars contain numbers of different types of components and some of them also contain hazardous materials which made the recovery process difficult and some of the components identified contained heavy materials and others light materials and this did not impact on “in” (transportation) but it has impact on “out” (market value of recovered components and materials), as heavy metal parts contain lead, mercury, cadmium or hexavalent chromium, which are restricted from use in new cars. On the other hand, lightweight materials required more updated technology to recover materials and produced more waste for the incineration process. Use of dismantle marks have a very positive impact on the dismantling stage and use of electric devises and batteries have some negative impact on transportation in the hazardous components recycling stage in terms of transportation and storage and they leave more hazardous chemicals for incineration. Also, deterioration nature has an important role on the inspection and sorting stage of the RL process to separate cars in terms of recovery options. Deterioration nature was mainly categorised in terms of reuse of cars and their parts. In terms of use pattern this identified that EoL cars coming from different sources have impact on transportation, where EoL cars from individual consumers are mostly dropped by consumers saving transportation cost but EoL cars coming from industrial consumers and institutions needed collection to be arranged by receivers/players who collect EoL cars. de Brito and Dekker (2003) pointed out that the type of recovery options employed by companies is influenced by how the product deteriorates: Intrinsic deterioration, Homogeneity deterioration, and Economic deterioration.

Overall, though there is a great improvement found in terms of car longevity and reduction of accident, the return reason of EoL car shows there is still a group of age related cars coming for disposal - 8-11 year old cars and about 36% of cars coming as EoL because of accident damage. This shows there is significant scope for the UK automotive sector to improve its car longevity and safety features in the car to stop cars coming for disposal at the age of 8-11 years and to reduce the accident damage cars coming for disposal. Also, EoL car nature in terms of car design (easy to dismantle sign in parts, use of renewable raw materials, use of recycling materials in new cars) revealed that car manufacturers have a contribution to make the EoL car RL process easy and more recyclable but still use new developed lightweight materials and more electronic devices, including batteries, making shredding and the hazardous recycling process complex, requiring a more advanced shredding process to separate lightweight materials. Therefore, there is significant scope for UK automotive

industry to improve car design in terms of use of materials and invent more advance technology to recover lightweight materials.

A detailed understanding on each of these return reasons and nature of EoL cars and their impact for each EoL car RL process stage has not been undertaken previously in the automotive sector and significantly adds to the novelty of this study. Also, among the findings, importance/relevance of return reasons and its impact on return control and the relationship with return nature and car design with its impact on its recycling stage has not been identified previously in any sector including automotive sector and hence makes a novel contribution to the generic RL literature.

The findings have importance in the automotive sector, because previously practitioners and each stakeholder had limited understanding of the EoL car category and its reason for becoming EoL and the impact of car design on its EoL stage.

In terms of research contribution, this study has validated EoL car return reasons concepts, namely natural EoL car, unnatural EoL car, abandoned EoL car; and EoL car natures concepts, namely composition of EoL cars, deterioration of EoL car and use pattern of EoL car.

Overall, this research question (RQ1) was comprehensively answered in this thesis. A comprehensive investigation of this study to assess the various return reason and nature of EoL car in the automotive sector has not been undertaken previously and therefore it significantly adds to the research contribution of this study.

Research Question 2

RQ 2: How, where and when are end of life (EoL) cars processed to recover value and what is the performance?

The knowledge of EoL car RL process with details of activities of each stage was found to be important in this study, as all these activities found undertaken to minimise the environmental impact in terms of reduction of CO2 for each stage of EoL RL process. Findings confirm seven different key process stages, and each stage provides specific insight on how activities are carried out in terms of whether the activities are regulated or not and the process, including workforce planning, technology used and key financial responsibilities. In addition, location and time related aspects are discussed here as they are very relevant to the RL process.

As described in chapter 5, of this thesis, each stage process flow provides specific insight into the sequence of events in which EoL car RL processes are carried. Each of these stages (ollection of EoL car, assessment and sorting, hazardous components removal, hazardous recycling, marketable parts removal, shredding and disposal) were identified important and interlinked with each other where most of the activities were heavily regulated by government agencis (GA); as a results all the stakeholders found were following a similar process in terms of thesequences of each stage, use of information technology, equipment etc.

The collection of EoL car stage was a huge responsibility given to car manufacturers (CMs) in terms of making collection points distance convenient for last car owners, providing free take back of EoL cars and issueing deregistration certification via an authurised treatment Facilities (ATF). Car manufacturers (CMs) managed to meet the regulation and confirmed their 75% car owners have collection point access within a 10 mile distance and the rest not more than a 30 mile distance. Though there is no regulatory restriction found on EoL car numbers, still one of the performance indicators of car manufacturers was to measure EoL car percentage collected by their network, which confirmed their collection point network managed to collect about 95% of EoL cars, which ensured the efficiency to eliminate the unauthorised/illegal collection and distribution of EoL cars. In the assessment and sorting stage of EoL cars, about 30% of EoL cars were separated, as they could still be in working order with some repair and refurbishmnet. Hazardous components removal has a very positive impact on the shredding stage to recover materials, as it prevents damage of car shell. The hazardous components recycling process was found to recover about 95% to 97% of materials, including energy recovery. On the other hand the shredding process of EoL car shell was found to recover

100% of materials and produced no waste for disposal. Overall the strict regulation has a very positive impact on increasing EoL car recycleability, which minimises CO2 emissions by reducing waste for disposal.

Though there is great improvement found in terms of EoL car RL process, where almost each stage's actual performance was found to be contributing in terms of economic, environmental and social perspective, still there is about 5 % of EoL cars that are not disposed of by an authorised treatment centre and also still about 3 to 5 % of waste going to landfill. Therefore, there is scope for UK automotive industry to improve the EoL car RL process in terms of the collection and recycling processto collect 100% of EoL car and produce 0% waste for landfill.

All the RL stages discussed in this thesis were in line with the literature but a detailed understanding on each of these stages with underlying key aspects (regulation, activities, location, time, performance) has not been undertaken previously in the automotive sector and significantly adds to the novelty of this study.

The findings have importance in the automotive sector because previously practitioners and each stakeholder had limited understanding regarding the detail of each stage (collection – disposal). The findings provide practitioners in the UK and elsewhere with a possible standard of EoL car RL process that can be adopted by each stakeholder for an improved RL process in the automotive industry. The findings are also useful for policymakers to prioritise their actions, strategies and policy interventions to create support/pressure mechanisms to improve the RL process stages.

In terms of research contribution, this study has validated EoL RL process concepts, namely Collection of EoL cars, Assessment and Sorting of EoL cars, Hazardous Components Removal, Marketable Components Removal, Shredding EoL car Shell, Disposal of ASR Waste with underlying concepts, namely regulatory restriction, activities (for each stage), location related issues (for each stage), time related issues (for each stage), reuse and redistribution (in each stage), performance (for each stage).

With regard to theoretical contribution, the study proposes established/emerging theories, namely resource and knowledge-based view theory to understand the RL process implementation.

Overall, this research question (RQ2) was comprehensively answered in this thesis. A comprehensive investigation of this stature to assess each stage of the EoL car RL process in the automotive sector has not been undertaken previously and therefore it significantly adds to the research contribution of this study.

Research Question 3

RQ 3: Who are the key players involved in reverse logistics practice of EoL car and what are their roles and what are relationships between them?

Empirical evidence showed that RL practice in the UK automotive industry has existed since the beginning of nineties. This suggests a relatively long history of RL operation in the UK automotive industry. However, the enormous involvement from different stakeholders' perspectives in the automotive industry was first identified at the beginning of 2004, after the introduction of new regulations for EoL cars RL practice. As a result, RL practice is the main concern of the automotive industry in the UK where all the stakeholders are involved including forward and reverse chain players, and other sector organisations, such as government agencies and local councils.

The knowledge of key players involved in the EoL car RL process with the relationship detail between them was found to be important in this study, as this stakeholder's involvement and the relationship between them presenting how an effective management of relationships with stakeholders is crucial to resolving in the RL process.

Empirical findings revealed that the key players responsible for the management of EoL car RL operations comprises forward and reverse supply chain. Forward supply chain players are the car manufacturers (CMs), car component manufacturers (CCMs), car dealers (CDs) , and reverse chain players are Authorised Treatment Facilities (ATFs), Official Scrap Car Partners (OSCPs), Hazardous Recycling Centres (HRC) and Waste Management Companies (WMC). Also, other players identified are Government Agencies (Gas) who are developing and monitoring regulations for EoL car RL process and Local Councils (LCs) who are taking responsibility for the proper disposal of abandoned cars.

Different players found are responsible for different activities in EoL car RL process according to their expertise and resources, where forward chain players are mainly involved in planning, managing EoL car return and designing new cars with more recyclability and reverse chain players mainly execute the RL process for EoL cars including collection, dismantling, shredding and disposal. Therefore, there is close relationship nature found between players where players were dependent on each other.

Four different types of key relationship nature were identified across players: internal activities, acquisition, strategic alliance and arm's length, where CMs and ATFs are in an acquisition nature relationship for the project of R&D for recycling technology. They also shared ownership of that invented technology, and the collaboration level identified here was strategic level collaboration. The key motivation found here for both CMs and ATFs was to minimising investment responsibility and access to each other expertise and technology. Strategic alliance relationships nature was identified between CMs and OSCPs for collection point network setup and monitoring. Here, the collaboration level was not as close as at a strategic level but still involved sharing information and planning together, which can be described as coordination level collaboration. The key motivation found here was lack of resources and expertise. Lack of resources was also found to be the key motivation for ATF companies to have a coordination level collaboration relationship with HRCs for storage, collection and recycling of hazardous components, where HRCs were found facing some challenges due to lack of cooperation from ATF companies in terms of sharing information for hazardous component collection. On the other hand, the rest of the relationships in the reverse chain for recycling EoL cars, including relationships within ATFs to transport car shells, ATFs and WDCs to transport waste, and WDCs and HWRCs to transport waste, were found mainly to be arm's length relationships, where they only share information on collection quantity and time and they on occasion share transportation, including trucks and drivers, if needed. In this arm's length relationship stakeholders faced some challenges in terms of lack of common interest, as the collaboration level is not closed here companies are busy with their on interest rather than concentrating on both parties interest.

Though stakeholder's involvement and the relationship between them present an effective management of EoL car RL practice with careful consideration of processing each activity, total involvement and cross-sector collaboration are needed from all the players in the EoL car RL process to fulfil RL duties. Therefore, there is scope for UK automotive industry to improve EoL car RL practice with their closes cooperation.

All the players found involved in the EoL car RL process in this thesis were in line with the literature except local council; in addition, each of these player's responsibility details has not been undertaken previously in the literature on the automotive sector; therefore, this adds significantly to the novelty of this study. Also, relationship nature, relationship drivers and barriers were in line with the logistics management literature but had not been discussed before in the RL literature, therefore, significantly adding to the novelty of this study.

The findings have importance in the automotive sector because previously practitioners and each stakeholder had limited understanding regarding the detail of each player involved in EoL car RL practice. The findings provide practitioners in the UK and elsewhere with a possible standard of relationship nature that can be adopted by each stakeholder for improved RL practice in the automotive industry. The findings are also useful for policymakers to prioritise their actions, strategies and policy interventions to create support/pressure mechanisms to improve the RL practice.

In terms of research contribution, this study has validated the relationship between players concepts, namely relationship natures, relationship drivers and relationship barriers.

With regard to theoretical contribution, the study proposes established/emerging theorie,s namely Resource Dependency Theory, Stakeholder Theory and Agency Theory to understand the relationship nature, relationship drivers and barriers to practice in the EoL car RL process.

Overall, research question (RQ3) was comprehensively answered in this thesis. A comprehensive investigation of this stature to assess each players responsibilities and relationship nature of EoL car RL process in the automotive sector has not been undertaken previously and therefore it significantly adds to the research contribution of this study.

<u>Research Question 4</u>

RQ4: What are the drivers and barriers for implementing the reverse logistics process for EoL cars for individual car making and car recycling sector stakeholders and their perceived importance/relevance?

The important RL drivers identified in this study are legislative pressure, economic gain, stakeholder pressure and corporate social responsibility concern. These drivers were found not only to influence stakeholders to get involved with the EoL car RL process, but also influenced them to get involved with a systematic EoL car RL process.

The importance of legislation pressure, in general, was found to be (relatively) high among almost all the players, especially for car manufacturers (CM) and Authorised Treatment Facilities (ATF) but in a different way, legislative pressure forcing CMs to get involved with the EoL car RL process and forcing ATF companies to implement a systematic EoL car RL process or, in other words, to follow regulatory bodies (government agencies) guidance for the EoL car collection to disposal process. Legislation pressure was found to have a moderate impact on Car Dealers (CDs) and Official Scrap Car partners (OSCPs). The importance of economic gain as a driver only had high impact on ATFs both ways (to get involved with EoL car collection to disposal process and to implement systematic procedure for more effective recovery).

Stakeholder pressure was only found to influence ATF and OSCP to implement more systematic procedure to process EoL cars. Competitive pressure was found to mainly influence ATF companies significantly to improve and implement a systematic process, and car manufacturers moderately to get more involved with the EoL car RL process. Corporate Social Responsibility CSR concern for the environment and society was found to have a strong influence on almost all the players. These include the environmental commitment of firms and enhancing reputation/brand image, which was found to vary considerably across stakeholders. Overall, the legislative pressure and CSR concern drivers were found to be the strongest drivers for car manufacturers to get involved with the EoL car RL process. On the other hand, legislative and CSR pressure has strong influence mainly on implementing a systematic RL process for EoL cars. Although the importance of economic gain was relatively low across stakeholders, it was found to be strongest among Authorise Treatment Facilities (ATFs).

The important barriers identified in this study are costly process, lack of expertise, lack of stakeholder support, lack of technology and lack of effective disposal system. Costly process was found to produce barriers strongly relevant to Authorised Treatment Facilities, though the barriers were relatively less significant for other stakeholders. For lack of expertise, CM, ATF, HRC and WMC were found to be failing moderately, while in the case of other stakeholders it was relatively low.

The findings provide practitioners and policymakers in the UK and elsewhere with a potential stock of RL drivers, affecting the involvement and implementation of a systematic EoL car RL process. Also the barriers faced by stakeholders affect involvement and improvement of the EoL car RL process. The RL drivers and barriers identified also include several new drivers and barriers which have not been identified previously in the automotive RL literature. These include stakeholder pressure and competitive pressure and therefore add to the automotive RL literature.

In terms of research contribution, this study has validated RL drivers and barriers not only for why and why not stakeholders are getting involved with RL process but also why they are implementing a systematic RL process and why they are not improving the RL system.

With regard to the theoretical contribution, the study proposes established/emerging theories, namely institutional theory, to understand the RL drivers and barriers affecting the implementation of RL practices. Specifically, drivers are understood through the lens of institutional isomorphism (coercive, normative and mimetic) theory, and barriers through the lens of knowledge-based view theory. The application of several established/emerging theories to understand the various RL drivers and barriers has not been undertaken previously in the automotive sector and hence constitutes a novelty.

Overall, this research question (RQ4) was comprehensively answered in this thesis. No previous study in the automotive sector has conducted a comprehensive investigation to understand relevant drivers and barriers affecting the implementation of RL practices across stakeholders and therefore this adds to the research contribution of this study.

9.4 Each case-category player's contribution to EoL car RL practice

While answering research questions RQ1-RQ4, some of the key contributions of each individual players identified towards EoL car RL practice are as follows.

Car Manufacturers (CM) – Case-Category (CC1)

As Car Manufacturers are the stakeholder mainly responsible (producer responsibility regulation) for their own produced cars for proper recycling, they were found to have an influence on other stakeholders. This has a strong impact on overall EoL car RL process performance. This study found that the goals of the EoL cars RL process are defined by car manufacturers at the EoL car collection stage. For example, it is car manufacturers who decide to have collection points within a 10-mile distance for only 75% car owners or more. Similarly, they are the ones who decide their car recovery percentage target in terms of their car design and innovated technology for the EoL car recycling process. Therefore, the entire EoL car RL practice is influenced by car manufacturers. This study found that EoL car collection network design with free take back collection has a direct contribution in terms of increasing the number of EoL car collections. Given the EoL stage of car considerations made during the design of cars (using renewable materials, ease recycling sign in components) makes a significant contribution to increasing recovery from EoL cars, this reduces waste generation from EoL cars, therefore reducing CO2 emission. Similarly, involvement of recycling technology development (shredding technology) makes a significant contribution in terms of recovering more materials from ASR dust, which reduces waste for landfill.

Also, the decision made by car manufacturers to reuse recycled materials in the production of new cars was found to have an impact on the overall environmental performance, as it reduces resource scarcity of raw materials and saves energy when processing new raw materials.

Therefore, the role of Car Manufacturers is significant in minimising the environmental impact of the EoL car RL process. For instance, car manufacturers could decide the collection recovery target of EoL cars by designing more recyclable cars and innovating recycling technology where no waste goes to landfill and a carefully planned collection process maximises the collection of EoL cars.

Finally, if car manufacturers get involved with the EoL car RL process more, the other stakeholders will have no option but to comply with the requirements, as any failure to do so may lead to them losing the partnership in the first instance, being barred from the project or blacklisted from future projects. Therefore, Car Manufacturers emerged as the most important stakeholder in EoL car RL practice in the automotive industry.

Car Distributors (CD) – Case-Category Two (CC2)

As mentioned earlier, the EoL car network setup is one of the most important activities in the EoL car collection stage. This network was mainly setup according to the car owners' location and these location formations were mainly provided by Car Distributors, as they were mainly selling cars. Also, Car Distributors are working as non-ATF collection points for EoL car collection who are accepting EoL cars and distributing them to the nearest ATF for further treatment. So, to meet the target of collection point setup according to regulation (75% car owners should be within 10 miles and the rest should be within 30 miles) Car Distribution was found to make a significant contribution.

As discussed in chapter 4, most of the individual consumers prefer to dispose of their cars to Car Dealers, as most of the time car dealers are the nearest collection point (car dealer numbers are greater than other collection points), so car owners prefer to drop the car to the nearest dealer. Therefore, car dealers are the key collection points mostly for age related EoL cars (from individual consumers).

In terms of promotion of free takeback, car scrappage schemes encourage EoL car owners to dispose of their cars through an authorise treatment centre. Car Distributors play an important role by informing each new and existing customer in person and via email and this information is also available on Car Dismantler websites.

Furthermore, Car Dismantlers were found to be one of the important stakeholders in this reverse chain for EoL cars, making a positive impact on environment in terms of increasing the number of EoL car collection, which means more EoL cars are disposed of in an environment friendly way.

Official Scrap Car Partners (OSCP) – Case-Catagory three (CC3)

Laws make car makers responsible for what happens to cars of their brands when they reach the end of life. This means Car Manufacturers have to provide a legal, environmentally friendly way to dispose of their cars at the end of life. As the official scrap car partner to the car makers, these companies take the responsibility to achieve the high standards of Car Manufacturers' demands through their hundreds of authorised treatment facilities (ATFs) within easy reach of car owners throughout the UK.

With the help of OSCPs, their network of ATF managed to collect EoL cars locally (the OSCP online link directing car owners to the nearest collection point), which saves on fuel consumption and reduces CO2 emission.

Furthermore, OSCPs provide external training and auditing activities, which were found to improve the EoL car overall treatment process, especially for on-time collection of EoL cars and proper storage systems and hazardous component removal, which has a positive impact on further stages and overall recovery rates of EoL cars.

Finally, OSCP involvement with the EoL car RL process gives no option for ATFs but to comply with the requirements of car manufacturers in terms of the EoL car collection process and recovery target, as any failure to do so may lead to them losing the partnership with OSCP in the first instance; furthermore, this can lead to ATFs losing their licence due to lack of standard policy and procedure. Therefore, OSCPs were found to be one of the most important stakeholders in EoL car RL practice in the automotive industry.

Authorised Treatment Facilities (ATF) – Case-Category four (CC4)

ATFs are the players who mainly execute EoL car RL activities from collection to disposal and this is has a strong impact on overall EoL car RL process performance. This study found that EoL cars recovery percentage, materials quality and overall speed of the process depend on ATFs. For example, it is ATFs who remove hazardous and marketable parts; therefore, their careful consideration of hazardous removal, storage and on-time distribution to hazardous recycling centres can help in quality recovery of materials from hazardous components and at the same time can save the marketable parts from toxic damage. Similarly, they are the ones who are involved with the shredding process to recover materials and separate waste for disposal. Therefore, the entire EoL car RL practice is influenced by ATFs, especially for recovery rates and environmental impact. This study found that the standard process of EoL car collection to disposal done by ATF makes a direct contribution in terms of increasing recovery rates and reduction of CO2 emissions by sending less waste to landfill. The careful considerations made during the hazardous components removal by using proper drainage and storage facilities has a significant contribution to reducing water and land pollution from hazardous components toxic leakage. Similarly, involvement of recycling technology development together with car manufacturers (shredding technology) also has a significant contribution in terms of recovering more materials from ASR dust, which reduces waste for landfill.

Therefore, the role of ATFs is significant in minimising the environmental impact of the EoL car RL process. Therefore, if ATFs become more careful with the EoL car RL process in terms of strict policy and procedure from collection to the disposal process and meet the challenges they are facing (as they are the ones who are executing each activity) to increase recovery from EoL cars and seek other stakeholders' help, this can direct other stakeholders' attention to finding solutions to these challenges. For example, this study found that ATFs identified and reported that newly developed lighter materials used in cars are complex to separate from the shredding process; as a results car manufacturers developed new technology together with ATFs for further shredding of ASR dust coming from auto shredders, which managed to recover most of the lightweight materials.

Therefore, ATFs were found to be very important stakeholders in EoL car RL practice in the automotive industry.

Hazardous Recycling Centres (HRC) – Case-Category five (CC5)

Hazardous Recycling Centres were responsible for recycling hazardous components separately, as this component required special treatment to separate CFC chemicals. As discussed in the chapter 5 in this thesis, CFC contain only carbon, chlorine, and fluorine, produced as volatile derivatives of methane, ethane, and propane. These chemicals can destroy the ozone layer and contribute to Global Warming (through "the Greenhouse Effect") and are harmful to human health. Therefore, these components require suitable equipment for handling and all individuals involved with recycling these components are required to attend a suitable training course.

Hazardous recycling companies took the responsibility of disposing of all the associated components. This was found to be a challenge for HRC companies in the automotive industries. To dispose of and recycle these waste products in a safe, legal, and environmentally compliant manner, they need to consider all existing legislation and safety recommendations. They were qualified and accredited specialist hazardous recycling centres, including airbag, battery and other hazardous component disposal. Additionally, their facilities are approved by the Environment Agency to safely decommission and recycle all hazardous components.

Similarly, HRCs' professional and highly trained teams were found to capably handle unlimited quantities at any time and their transport was GPS tracked and each container was equipped with 'tamper proof' locking systems to ensure all waste units arrive safely back on site in the original state. This protects the environment and human health from hazardous chemicals.

Furthermore, HRCs also managed to recover more than 95% of hazardous components and only 3 to 5 % waste ended up in landfill. HRCs were trying to develop a policy named "nil waste to landfill" which aims to recover 100% and generate 0% waste for landfill.

Therefore, HRC were found to be another important stakeholder in this reverse chain to recycle EoL cars where they make a significant contribution in terms of waste reduction to landfill and protecting the environment and human health from dangerous CFC and other chemicals contained in car components.

Waste Management Companies (WMC) – Case-Category five (CC5)

Waste Disposal Companies were found to be disposing waste in two ways: incineration and landfill. Any EoL car waste coming to them from ATFs and HRCs are treated as non-hazardous waste. WMCs play a vital role here in terms of making decisions to send the waste straight away to the landfill or apply the incineration process to reduce waste for landfill. This study found that WMCs assess the waste if it is already coming after incineration, meaning the waste is for landfill only, but, if not, then they first place the waste in the incineration process, which not only reduces waste for landfill but also produces energy for reuse.

Furthermore, their landfills are modern and designed to protect the environment by keeping the waste material separate from the surrounding soil, groundwater and air. This offers much more protection for the environment and for local people than traditional 'dumps'.

Government Agencies (GA) – Case-Category six (CC6)

Government agencies play the most important role here for overall improvement of the EoL car RL process in the UK. Their strict regulation, guidance and auditing for producer responsivity regulation for EoL cars forces car manufacturers to become involved with the EoL car RL process and car manufacturers involvement was found to have a very positive impact on the overall EoL car RL process (as discussed above). Also, strict regulation for use of materials restriction for car manufacturing enables more recovery, meaning less waste for landfill, and free take back facility, which helps with collecting more EoL cars, recycling target restrictions, increasing recovery and reducing waste for landfill.

Furthermore, there is increasing tax for waste coming to landfill and the main aim here is to influence recycling companies to recover more to reduce the waste for landfill.

Overall, development and monitoring of strict regulations was found to give no option to ignore the implementation of EoL car reverse logistics process activities according to regulation and guidance from GA for all the stakeholders involved in the EoL car RL process. This making a huge contribution in reducing CO2 emission.

Local Councils (LC) – Case-Category seven (CC7)

Local councils remove abandoned cars from land in the open air and roads (including private roads) and when owners do not dispose of their cars via the OSCP network. This way abandoned cars are disposed in an environment friendly way.

Also, local councils' "Report an Abandoned vehicle" and "Vehicle Surrender Scheme" publicity via their website helps to clear the land and roads of abandoned cars and reduces abandoned cars, as car owners surrender their cars rather than dumping them, as this scheme provides free take back facilities.

Therefore, local councils were also found to play an important role to reduce environmental pollution from abandoned cars volume reduction and proper disposal.

9.5 Research Contributions

Numerous specific contributions of this study are discussed throughout the thesis as well as during the discussion on research questions in the previous section. Here some of the main research contributions of this study towards theory for policymakers and practitioners are presented.

9.5.1 Theoretical Contribution

This research makes a valuable contribution in developing an empirically informed and theoretically grounded understanding of EoL car RL practices by adapting and operationalising the key aspects of RL in the context of twenty-one companies operating in the car making and car recycling sector of the UK automotive industry. This study is the first comprehensive attempt to understand the key aspects of EoL car reverse logistics. As concepts are regarded as the building blocks of theory (Voss et al., 2002), this study contributes towards the conceptual understanding of EoL car RL practices in the UK, ultimately contributing towards theory development in this field. Specifically,

- This study extended the key aspects particulars of RL, which were initially developed by De Brito and Dekker (2003) and adapted by Xie and Breen (2014) and Salvador (2017). This research generates new insight in RL from the detailed perspective of each RL aspect, i.e. EoL car return reason and nature; EoL car RL process in terms of how, where, when and its performance; players involved in EoL car RL practice and their relationship nature; drivers and barriers influencing EoL car RL practice which provide several validated concepts, and underlying concepts discussed in the earlier sections. This itself is a significant theoretical contribution given that construct development and validation is at the heart of theory building.

- In regard to the EoL car return reason and nature, this study has identified several novel factors. For instance, in terms of return reason and return nature of EoL cars, the previous literature only mentioned that EoL cars are the reason for return (Cruz-Rivera & Ertel, 2009; Zhang et al, 2010; Zarei, et al. 2010; Merkisz-Guranowska, Chan et al., 2011) but details of the nature of the EoL cars was not discussed. The study provides a detailed understanding of each of the reasons why cars become EoL and are sent for disposal and details of the return cars' nature with the impact on the EoL car RL process, particularly the nature of car composition's impact on the recycling process. Car composition in terms of use of dismantle marks in cars which contain V-shaped grooves at the points in the bodywork where the instrument panel is attached. This was found to have a very positive impact in the EoL car RL process, specially for the hazardous and marketable parts removal stage. On the other hand, this study also found that composition nature also has some negative impacts, such as use of lightweight material parts' negative impact on the shredding stage, the use of greater number of electric devices and batteries' negative impact on hazardous collection and the recycling stage, which has not received attention in previous RL research. Therefore, it adds novelty, and further, the automotive industry, specially car manufacturers (CM), should focus on the development of lightweight materials in terms of recyclability and ATF should plan and accelerate the storage, collection and recycling facilities for hazardous materials.

- With regards to the EoL car RL process, details of each stage with detailed aspects, including regulatory restrictions, detailed activities, location and time related issues, reuse and redistribution and performance, have not been covered in the automotive RL literature and have only received limited attention in the generic RL literature (Xie & Breen, 2014; Agrawal et al., 2016; Salvador, 2017). This research provides details of each stages of the EoL car RL process in terms of regulatory restrictions, detailed activities, location and time related issues and performance of each stage (collection of EoL cars; assessment of EoL cars; hazardous removal of EoL cars; marketable parts removal of EoL cars; hazardous components recycling; shredding and disposal of EoL cars). This provides detailed understanding of how government's strict regulation influences the EoL car RL process at each stage from collection to disposal; who and how the EoL car collection network is managed and its impact; how EoL cars are assessed for further treatment and details of their conditions and what are the important facts identified here in terms of the assessment process time, expertise, location and its impact; how hazardous and marketable components are removed and processed with details of each component's storage system, technology used, processing time, location and its impact; similarly how the car shell is processed/shredded with details of technology used, time and location related issues and their impact; finally what continues to the disposal stage and what the disposal stage processes are in terms of technology used, time taken, location and its impact. This in-depth understanding presenting each detail underlines how the automotive industry in the UK managed to recover 95% from their EoL cars to save landfill cost and CO_2 emission. This detail can help other industries and countries to identify gaps in their RL practice and implement some action to improve RL practice. Therefore, this understanding significantly adds to the novel contribution to the automotive sector and to the generic RL literature as well.
- With regards to RL performance, the study, in general, addresses the performance indicators but there is a lack of actual performance measure of the RL process in terms of who are measuring these performances, why and what the performance is. In addition, connecting to the RL performance in general discussed in phase one of chapter 2, not all the environmental and social perspective performance indicators are acknowledged in the automotive industry literature. This study found that in the EoL car RL process almost all the players invest in performance but different players focus on different EoL car RL stage performance and this is because not all the players are responsible for the same stage. Here, only car manufacturers are keen to measure performance for the EoL car collection stage where car manufacturers found saving the environment and meeting regulation by establishing the right network in terms of location and number and systematic processes for EoL car collection. For the hazardous components removal stage only, ATF were found to measure performance to make sure their hazardous removal process policies are operative and competent. ATF companies were also keen to measure performance for the marketable parts removal and shredding stage. All ATF companies identified measuring economic and environmental performance of the marketable parts removal and shredding stage to detect profit and protect the environment and meet regulation by establishing the right process. WMC were found to measure performance for the disposal stage mainly in terms of environmental impact of the disposal process, where they found that landfills produced landfill gas, which is about 40% to 60% methane. On the other hand,

incinerators do not produce or release any methane but generate energy which prevents the harmful environmental effects of mining coal and drilling for oil and gas. It uses a fuel source that is available essentially everywhere that humans live, does not need to be mined or refined, and avoids fuel and materials supply depletion problems associated with fossil fuels and nuclear power. This is the reason any waste coming from cars goes through the incineration process first. Performance measurement was found to help players to align their resources, and systems to meet their strategic objectives for EoL car RL practice. It works as a control panel too, providing an early warning of potential problems and allowing knowledge of when they must make adjustments to keep each activity on track. All these performance measurement issues, in terms of who, why and what, have not been undertaken previously in the EoL car RL process literature and not even in the general RL literature and therefore add to the novelty of this study.

- Furthermore, an in-depth understanding of the relationships between players involved in the RL process, relationship nature between players, relationship drivers and barriers, has not been undertaken previously in the EoL car RL process literature and therefore adds to the novelty of the study, as a comprehensive understanding of each player and their role/activities in the RL process, relationships between them to manage activities, and related issues, can guide practitioners and policy-makers with a solid understanding of stakeholders' contributions in implementing the RL process, which could ultimately lead to greater RL practices adoption across the sector.
- Another contribution of this study is that it addresses the lack of theoretically grounded research in RL in the automotive industry. This study uses the application of several established and emerging theories in the conceptualisation of EoL car RL practice.
- This study also proposes a comprehensive framework for RL key aspects details and government regulation details for EoL car RL practice. Future researchers could use/adapt this framework and regulation details in their respective settings in the automotive or other sectors. A comprehensive and validated RL key aspect framework of this depth and breadth has not been identified previously in any sector, let alone the UK automotive sector, and therefore contributes significantly to the theoretical advancement of the field.

Finally, this study could be considered as a first comprehensive step towards the precise identification of a coherent conceptual base for the RL field to grow as a legitimate management discipline, not only in the automotive industry but also in general.

9.5.2 Practical Contributions

This thesis provides many implications for practitioners in the automotive supply chain network. This knowledge is important for the automotive industry because previously practitioners across each stakeholder group had limited understanding regarding the key aspects empowering EoL car RL practices they could have implemented in their respective firms. It identified that the successful implementation of EoL car RL practices, and related improvement initiatives are dependent on the cooperative commitments of all automotive sector stakeholders directly and indirectly involved in EoL car RL processes. They include the car manufacturers, car component manufacturers, raw material suppliers, car dismantlers and shredders, waste management companies, and membership bodies for scrap car recycling.

They have a mechanism to facilitate and to connect the required commitment for processing EoL cars where the centre point is official scrap car partners (membership body). Therefore, most of the work involves discussions and negotiations with terms and conditions for both sectors (manufacturing and recycling).

There is a combined approach where the community sectors, such as local councils, work together for local solutions for abandoned cars for best RL practice. This is achieved through the prioritisation of RL practices both by governmental institutions and industry, investment in RL research, especially in the recycling technology, and availability of data for car making and recycling.

Annual review and update of regulatory policies governing of EoL car RL practices in terms of recovery rate and systematic recycling process was identified as satisfactory in the UK automotive industry where players comply with fulfilling their duties. Here, stricter supervision and enforcement by government plays a key role in facilitating good RL practices in the UK like those implemented in other countries in Europe, like Belgium. This was achievable through periodic auditing of companies involved in the RL processes.

Therefore, the success of an RL system requires cross-boundary cooperation among the actors within the whole reverse chain. Hence, close strategic level collaboration between suppliers is to be encouraged in order to establish a more robust term that is both realistic and agreeable to the parties involved. This type of collaboration will go a long way to improving the efficiency of the RL processes and making it error-free.

However, there is still a small percentage (about 5%) of EoL cars which does not come to authorised treatment facilities. Hence, industry and government should consider increasing investment in public awareness campaigns across the whole country about the environmental effect of improper car disposal, and the enormous socio-economic benefit of returning cars into the authorised network.

Finally, this research suggests, the consideration and implementation of these highlighted RL good practice identified in the UK automotive industry and recommendations for some limitations identified by industry and government to facilitate RL best practices. However, overall RL practice in the UK automotive industry found a sustainable RL practice which can be adopted in other industries and countries as well. So, the table 9.1 bellow presents best practices identified in the study which can be seen as a benchmark and can be used by automotive sector in other countries and also can be adopted by other sectors as well.

Table 9. 1 RL best practice identified in the UK automotive sector and its utilization in other countries and sectors

Sustainable RL practice in the UK automotive industry		**Can be adopted in automotive sector in other country**	**Can be adopted in other industry**
Car design to improve recyclability (Car design was one of the most important factors for UK automotive industry to manage to recover 95% of a car's weight).	• UK government strict regulation initiative to make cars more recyclable forcing UK car industry to work together for more recyclable cars to reduce pollution. • Strategic level collaboration between CMs facilitated the development of innovative technology for more recyclable cars where they share investment and ownership of innovated technology • Changes in car design - more thinking about recycling found; - **Change of material:** to make parts that can be reused as parts/materials, common materials identified are Magnesium, Carbon Fiber, Aluminum, Titanium, Glass Fiber, High Strength Steel which is mainly to protect the environment and address resource scarcity. - **Use of dismantle mark:** cars contain V-shaped grooves at the points in the bodywork where the instrument panel is attached, making it easier to remove. This design is to make recycling easier when the car reaches the end of its useful life by helping to reduce its lifecycle carbon emissions and also permits more efficient recycling of some of the useful materials it contains. - **Use of recycling materials in new cars:** to make new cars mainly interiors, including seat fabrics, under hood parts, carpets, sound absorption materials, bumpers, headliner fabrics are used as materials from EoL cars. This Consumes less energy and water compared to creating new (virgin) materials, and it creates fewer emissions.	• In Australia car design for more recycling is not governed by strict regulations, therefore, the EoL car recycling performance in Australia is poor. To improve this the Australian government should focus on this matter as legislation has a significant impact on EoL car RL practice. In countries where car manufacturers are governed by strict regulations, they are constantly pressured to improve car design for recyclability. • In China there is internal pressure from within the industry, which prioritises quantity of cars produced and ignores recyclable car design practices thus generating more CO2 emissions and increasing global warming. To improve the situation the Chinese government could take the initiative to introduce strict regulation for more recyclable car design like UK government. Car manufacturers in China could opt for close collaboration relationships between them to help to reduce the internal industrial pressure for car quantity and allow more focus on making recyclable cars.	• As product design impacts throughout the lifecycle, including recycling of products, other industries like electric and carpet are still facing problems to manage their return. This can be solved through product re-design or new product design. If a manufacturer increases the availability of recycled production inputs by increasing the products' recyclability rather than increasing return flows, this will have a positive effect not only on the availability of recycled production inputs but also on the RL system's efficiency, such as transportation, waste etc.
EoL car collection process	• Government's strict regulation on EoL car collection network forces CMs to create the network and collect their EoL cars with free takeback facilities. Therefore,	• In developed countries like Australia there is a lack of a proper collection system which gives opportunities for unauthorized recycling facilities to compete with legitimate recycling	• The need for the setting up of collection centres was realized in the electric industry in India because of the uncertainty involved. To reduce the uncertainty,

	- CM and OSCP's strategic alliance with strategic level collaboration relationship managing to build the network - This network managed to minimize the distance between car owners and collection points which helps to reduce fuel consumption and saves the environment - This network also managed to collect about 95% of EoL cars through an authorized treatment facility	sectors in acquiring EoL. Therefore, government should come up with strict regulation for EoL car collection like the UK and at the same time the automotive industry in Australia also should follow the networking strategy like the UK where car manufacturers and car recyclers can work together to collect EoL cars. • Developing countries like China and India where the automotive industry is huge, but they are struggling to collect EoL cars for recycling. Like in the UK, governments from these countries should enforce strict regulations to encourage the creation of an EoL car collection network which can solve the problem.	the electronic industry can implement the collection point network strategy where the location and number of collection sites must be according to product distribution area and volume in order to make it effective.
Hazardous component removal	• Government strict regulations on hazardous component removal before marketable parts from EoL car and careful consideration for process, storage, location and time forcing each player to get involved with different responsibilities at this stage. Thus providing; - Removal of hazardous materials and components in a selective way which managed to avoid contaminating subsequent shredder waste from the EoL car. - This also ensures the suitability of car components for reuse and recovery, and, in particular, for recycling.	• In countries like Mexico, the automotive industry is facing barriers to manage RL of their cars due to lack of strict legislation for hazardous component removal, RL operations for EoL car management are not standardized. Poor practices in EoL car management activities, which lead to negative effects on the recovery value from EoL cars, such as contamination of shredder material by operative fluids and not following RL procedure, such as ignoring removing of fluid before sending the car to the shredder. The government should introduce strict regulations for hazardous components removal like	• Electric products like fridges and computers also contain hazardous components but still there is no strict regulations to remove them before starting the separation of other components. This is contaminating the waste coming from electric products. For each electric product which contains hazardous waste, there should be strict regulations to remove and recycle separately, like EoL cars, to save electric products with good condition parts and reduce waste.

		the UK to manage the entire EoL car RL process.	
Hazardous component recycling	• Government strict regulations on hazardous component recycling process, storage, location and time, forcing hazardous component manufacturers to get involved and take the responsibility for recycling. Therefore, - Collaborative innovation of CM and ATF on hazardous component recycling technology and systematic process managed to recover up to 97% of hazardous components, where 30% of materials were of reusable quality for new auto products - Only 3% waste went to landfill from hazardous, which is 30% less than 7 to 10 years before	• Countries like China and India are not focusing on automotive hazardous components recycling because they do not find any direct economic value from hazardous recycling, whereas in the UK, EoL car hazardous component recycling was found to provide direct economic value as up to 30% waste coming from hazardous are of reusable quality for new auto products. Other countries governments should take initiatives like the UK to force the auto industry to recycle hazardous components separately.	• For medicine recycling, the UK government should take initiatives as well, as medicines are hazardous products and there are no such government initiatives found for old medicine take back for the recycling process in the UK.
Marketable component removal from EoL cars	• The stage was identified as several times easier than before due to the cooperation of car manufacturers (CM) in terms of design of car with ease of recycling signs in the parts and providing car making information. • 15% of car weight was recovered as reusable parts at this stage (excluding hazardous components) which was only 5% about 7 to 10 years ago	-	-
Shredding and sorting of EoL cars	• ATFs are regulated for shredder machine requirements, which controls and converts the hazardous ASR dust to non-hazardous. • Collaborative innovation of CM and ATFs post-shredder machine managed to recover up to 95% of materials which was only 75% just a few years before	• Countries like China, where the automotive industry is struggling to recover components and materials from EoL cars due to lack of technology. The Chinese government should introduce strict regulations for shredder technology like the UK and encourage automotive manufacturers to work together with recycling industry players to manage EoL car recovery.	-
Disposal process	• The hi-tech plant, where the materials are placed in a four-store-tall rotating box which is heated up and	• In countries like Australia 25% of an EoL car still ends up in landfill for	-

	converts them to gas. This gas is used to generate steam for electricity, with two tones of waste creating enough power to run the average house for a year • Odor monitoring, landfill gas controlling process reducing CO_2 emission impact • Only 5% of an EoL car goes for disposal in the UK	disposal. The Australian government should introduce strict regulations like the UK for EoL car recovery percentage to reduce waste for landfill and CO_2 emission.	
Relationships between stakeholders	• As RL of EoL car has number of stages and almost each stage is regulated by strict regulation, it is almost impossible to manage by one stakeholder. Therefore, a close collaborative relationship among all stakeholders managed to not only meet the regulations but also minimizing cost, managing of resources and recovering up to 95% of an EoL car weight which is reducing CO_2 emission • UK auto industry stakeholders believes this relationship will go a long way to improving the efficiency of the RL processes and making it error-free.	-	• Hence, close strategic level collaboration between stakeholders is to be encouraged in order to establish more robust terms that are both realistic and agreeable to the parties involved. This type of collaboration can be helpful for the pharmaceutical and household industries as there is a lack of collaboration identified as the success of an RL system requires cross-boundary cooperation among the actors.

9.6 Limitations and Future Research Directions

There are some limitations to this thesis, which leave enough scope for future research. The most notable limitations and their corresponding future research directions are as follows:

- The automotive industry considered in the study includes only a specific product of automotive in EoL car RL practice. The general automotive industry includes products such as vans, motorbikes and parts as well. Future studies could also consider the other products in their investigation.
- The study may not have covered every aspect of RL practice. For instance, there could be additional (unknown) country-specific aspects that may not have emerged in these exploratory interviews. Also, some aspects which are not relevant to the UK that were excluded from the analysis could be of interest in other country settings. For example, lack of government initiatives, which was excluded from this study because of its non-relevance to the UK for EoL car practice, could be an important barrier in another setting.
- From an industrial perspective, this research explored RL practices within the context of the automotive industry. There is scope to conduct similar RL research in other industries in the UK, such as the food and beverage industry, electronics industry etc., as well as a comparative study of two or more industries.
- The themes/sub-themes (constructs) proposed in this study may require further refinement and validation across different countries.
- The lack of availability of published data in this area, especially relationship nature in reverse logistics practice between players can be considered as a limitation. If the data becomes available, future research can focus on using more objective data on relationship nature between players in RL practice.
- The theories presented here are by no means complete and could be biased based on the author's familiarity and disposition. Future research could utilise this theoretical understanding either directly in their research contexts or as a basis for cumulative theory building and testing.
- Future research could utilise the multimethodology pragmatic approach used in this thesis for conducting a comprehensive investigation in the respective settings in the auto or other sectors. Also, researchers could utilise the pre-tested and validated survey instrument for empirical investigation in their respective settings.

Despite the limitations, in light of the findings of this comprehensive investigation along with its contribution, a heightened interest among automotive industry companies, practitioners and policymakers in the application of EoL car RL practice in the automotive sector can be foreseen. Also, the study is expected to generate significant interest within the research community that could further lead to the theoretical advancement of RL practice in the automotive sector and in general.

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Appendices

Appendix 1: RL key aspects across industry

Studies considering key aspects (return reason, return nature, RL process, location of RL process, time related issues in RL process, players, relationship nature between players, driver and barriers in RL practice) of reverse logistics across industry (apart from the auto industry, as it is presented separately in the Appendix 2).

Study	Country	Industry	Metho-dology	Reverse logistics key aspect													Details
				Return Reason	Return product nature	Product design	RL process	Location of RL process	Time of RL process	Players	Performance	Relationship between players	Drivers	Barriers for not being involved	Barriers - to improvement	Others	
Carter and Ellram, 1998	Generic	Generic	Content analysis			√	√			√		√	√				**Product design** • Minimisation of materials to design products **Process** • Reuse the product, materials and energy • Recycle the product • Disposal by incineration to recover energy or landfill **Players** • Supply chain members **Relationship between players** • There is a need for logistics managers to work with supply chain members to ensure quality of environment friendly input/design to enhance RL activities. • Impact of the relationship**:** the greater the relationship, the higher the level of RL activities in

																	terms of reducing uncertainty between demand and supply. **Drivers** • Govt. Regulation pressure for proper disposal of return product • Stakeholder pressure from suppliers & buyers for take back policies • Competitive pressure for environmental performance
Rogers and Tibben-Lembke, 1998	US	Multi	Mix method	√			√						√		√		**Return reason** From supply chain partner • Stock Balancing Returns • Marketing Returns • Transit Damage From users • Defective/Unwanted Products • Warranty Returns • Recalls • End of Life **Process** • Collection/acceptance of products • Assessment and sorting of return products • Direct reuse of product as new/discount/sell to outlet/secondary market/donate to charity • Repair, refurbishing, remanufacturing • Shredding and material recycling • Disposal (incineration and landfill). **Drivers** • Competitive pressure to satisfy customer • Clean channel to sell new product • Regulation: strict non-compliance penalties, increase price to landfill waste **Barriers** • Return arriving faster than processing/lengthy processing cycle time • Cost of return process • Customer perception of poor-quality repaired product • Lack of management attention
Gungor and Gupta, 1999	Generic	Multi	Content analysis			√							√				**Design** • Product design impact throughout the lifecycle including recycling of product

																	Drivers • Regulatory pressure by government for environmental issues • Customer pressure for environmental awareness
Fleischmann et al., 1997	Generic	Generic	Survey	√			√			√			√				**Return Reason** • End of use/life return • Commercial returns from retailer to manufacturers • Warranty returns • Production leftover return • Packaging **Process** • Reuse directly may sometimes require cleaning & minor maintenance • Repair and remanufacture and make as new • Shredding and recovering materials • Disposal by incineration or landfill **Players** • Forward chain players (manufacturers) • Reverse chain players (remanufacturers) **Drivers** • Direct Economic value for recovery product which provides cheap resources rather than virgin materials • Indirect economic value by managing/taking back returns working as marketing trigger for green profile. • Environmental regulations for own product responsibility • Assess protection of sensitive components
Fuller and Allen, 1997	Generic	Generic	Content analysis							√							**Players** • Forward chain players (manufacturer, wholesaler, and retailer) • Reverse chain players (recycling specialist companies/Third parties) • Government/government agencies (organisations responsible for compliance) • Opportunistic players (charity organisations) • Senders (who return the products)
Yang and Wang (2007)	Generic	Generic	Survey				√			√	√		√				**Process** • Gatekeeping assess customer returns. If its within time frame accept, if not cannot accept, but record customer feedback about product problem.

																	• Collection/acceptance: Accept the product and refund or exchange or repair or send for recycling, depends on customer demand and company policy. • Repair: if the product condition is repairable, product gets repaired and goes back to customers. • Hazardous Recycling: If the product is end of its life and contains toxic or harmful materials • Shredding and disposing: shredding and disposing End of life products and recovering materials **Players** • Manufacturers: reuse the materials coming from recycling products • Suppliers: supply the materials coming from recycling products • Recycling collectors: collect products for recycling, recycling them and redistributing recovered materials. **Drivers** • Direct govt. regulation: environmental laws are increasingly forcing manufacturers to engage in recycling activities. **Performance** • The proposed framework identified that the use of sensor agents and disposal agents can improve reverse logistics performance in terms of repair time and recycling process by increasing information transparency regarding customer feedback, demand, product problems and best possible recovery options.
Bai and Sarkis, 2013	Generic	Generic	Survey				√			√	√						**Process & players** • Collection of waste, used & returned product by manufacturers, retailers & third party • Separation by quality control team of manufacturers • Storage by warehousing and inventory management • Dismantling and compacting by dismantler • Recycling by recycler • Disposal of waste by waste management company • Redistribution by distributors **Performance**

																	• Flexibility is important to manage uncertainty in reverse logistics to improve RL performance • A third-party reverse logistics provider can help to have successful reverse logistics continuous process by providing flexibility to managing uncertainty
De Brito and Dekker, 2003	Generic	Generic	Content analysis	√	√		√			√			√				**Return reason and source of return** • **r**eimbursement guarantees**,** warranty and service return, end of use return and end of life return by consumers • commercial return for defective, damaged, expired, unsold/in excess; product recalls; carrier and packaging; stock adjustment for redistribution of items between warehouse or stores by distributors. • Excessive raw material and defective raw material, such as transitional or final products failing quality checks by manufacturers **Return feature** • Configuration– number of components and materials contained in the return product; how they are put together; the presence of hazardous materials; material heterogeneity; size of the product • Functionality – product age, components/parts age, market value (demand/law). • Use pattern – single/multiple, duration of use, consumption level. **Process** • Collection/acceptance of products • Assessment and sorting of return products • Direct reuse of product as good as new • Repair, refurbishing, remanufacturing • Shredding and material recycling • Disposal (incineration). **Players** • Forward chain players: Suppliers, manufacturers and retailers • Reverse chain players: recovery companies and municipalities • Opportunistic players: charity organisations **Drivers**

																	• Direct economic gain by reusing return product, parts, raw materials and reducing disposal cost. • Indirect economic gain by accepting returns with speedy process improving customer service and anticipating legislation to protect environment providing green image, also accepting own product return, protecting asset from stealing knowhow by brokers. • Govt. environmental regulation for taking back returns and recycling of return products. • Environmental protection awareness and responsibility towards society to protect from pollution.
Nikolaou et al (2013)	Generic	Generic	Survey								√						**Performance** • Economic: Enhanced resell value from recovery products, less costly recovery products/materials, less tax on recovered products • Environmental: Waste management reduction, emission impact, minimising the use of natural resources. • Social: Health & safety, training, education, & policies for human rights for employees; policy to manage impact on community in areas affected by RL activities & preventing customer health and safety; award received for environmental performance donation to community.
Joshi, 2013	India	Electronic	Survey										√				**Drivers** • Customer satisfaction to sell new products by providing return policy • To sell new product by clearing old product
Korchi and Millet (2011)	Generic	Remanufacturing of electric-and-electronic equipment	Case study								√						**Performance** • Transportation cost is main cost in the network so to reduce transportation the location of treatment activities in the reverse logistics channel may be a major determinant of performance of a remanufacturing system considering the use of current forward logistics facilities and more interaction between product and reverse logistics channel design decisions. • No negative environmental impact due to the use of limited chemical (treatment process is mostly done manually)

																	• Social impact in terms of local job creation
Goggin and Browne, 2000	In-general	Electric and electronic	Content analysis		√		√										**Return feature** • Composition - Product size (large/small). Products recovery complexity depends on products size. **Process** • Remanufacturing: remanufacturing involves disassembly, test, repair, upgrade and re-assembly. • Dismantle: The functions that are performed in the reclamation of components are product disassembly, component module assessment and testing, and possibly component module repair. • Shredded: Shredding, melting and material recovering • Redistribution: Remanufactured products redistributed in the secondary market. recovered components redistribution depends on component type and materials, market in which materials are sold is a global one, with prices set globally on the basis of supply and demand.
Agrawal et al., 2016	Generic	Electronic	Survey								√						**RL process performance index based on TBL** • Economic: Return on investment, maximum value recapture, logistics cost optimisation, recycle efficiency, annual cost, disposal cost • Environmental: Minimum energy consumption, best use of raw materials, transportation optimization, reduced packaging, use of recycled materials, waste reduction. • Employee benefits, stability; customer health & safety; donation for community, community complaints, stakeholder participation
Malik et al 2015	India	Electronic	Mix method				√										**Process** • Collection: the need for the setting up of collection centres was realized because of the uncertainty involved. To reduce the uncertainty, the returned products are collected into collection sites. Hence, for an efficient reverse supply chain, the location of collection sites must be appropriate in order to make it profitable for the organization.
Thierry et al., 1995	Europe	Electronic	Case study			√	√										**Design**

																	• Design for recycling by reducing multi material use and replacing non-recyclable materials for copy machine **Process** • Direct use • Repair/refurbish/remanufacturing of product & retrieval of parts • Shredding and recovery of materials disposal (incineration and land filling).
Kumar and Putnam, 2008	US	Multi	Interview				√						√				**Process** • Collection/acceptance • Hazardous removal • Hazardous components recycling and recovery • Dismantling product and recover components and parts • Compacting rest of the product • Shredding and recover materials • Disposing shredder dust by incineration/landfill **Drivers** • Market competition desire green product • Govt. Regulation to manage wastes • Globalising growth for recycled and remanufacturing product
Li and Olorunniwo, 2008	USA	Multi –	Interview				√			√		√					**Process:** • Collection/acceptance of products • Assessment and sorting of product according to product condition and market value • Product repair • Resale in secondary market • Recycle (if law allows) • Disposal **Players** • Forward and reverse logistics service providers • Manufacturers (consumer electronic) **Relationship between players** • Relationship type: Collaboration • Type of IT needed to share in collaboration: Use of internet, electronic data interchange, enterprise resource planning (ERP), radio frequency identification

																	• Resource commitment needed: leadership support, financial and personnel resources, as well as investment in technology innovations in RL • Drivers of collaboration: To minimize cost while achieving some desired customer service level consistent with industry standards. • Barriers to collaboration: The whole supply chain of returns is sometimes decentralized in the sense that each supply chain member is self-serving which hinders collaborative planning, forecasting and replenishment.
Xie and Breen, 2014	UK	Household batteries & medicines	Mix method	√	√		√	√		√			√		√		Return reason • End of use and end of life return due to environmental concern Return nature • The products entering the RL network (in) • Composition: household batteries which contain hazardous materials need to be handled separately and waste batteries are small and easy to store in household • Deterioration: Household medicine expired or not expired (functionality) • packaging: package size (multi-size available) • The products leaving the RL network (out) • Materials from batteries lithium, zinc, lead as raw materials • UK-registered charity which collects unused medications from general practitioner (GP) surgeries in the UK and then delivers them free of charge to more than 100 health centres in 7 countries in sub-Saharan Africa Process and activities • Collection: medicines are accepted by pharmacies and GP (general practice) and batteries collected by household waste recycling centres and local authorities • Direct reuse: medicines which are not expired • Shredded: batteries are shredded and plastics recovered • Disposal: The waste medicines are made safe by clinical waste incineration at an authorised incinerator

																	Players and their roles • Environment agency, battery producers, recycler and others like schools for batteries and for medicine pharmacies, NHS • Relationship between players • total involvement and cross section collaboration needed to fulfil RL duties to recycle household batteries and medicine RL. **Location (where)** • easily accessible collection points across UK together with recycling points provided by other compliance schemes and Household Waste Recycling Centres operated by local authorities. **Drivers** • what is the driver: regulations enforce certain responsibilities on all the actors in the battery RL system except individual customers, requiring producers to incorporate waste management practice at the three levels: reduce, reuse and recycle? • what players are doing for that: The five battery compliance schemes in the UK are working together to achieve the target recycling rate (Environment Agency, 2013), and they have launched publicity campaigns which aim to educate the public reducing resource costs and protecting the environment, while facilitating producers setting up corporate green images. • what is the result/ impact: The success of the publicity campaigns is demonstrated by significant behaviour change in the recycling of household batteries, with two in five people (42 per cent) having recycled a battery? **Barriers** • no government initiatives for medicine recycling • no economic value incentives for medicine recycling
Silvenius et al., 2013	Europe	Household food	Mix method		√												**Return feature and its impact** • Packaging size, shape and materials used Impact • Can minimise the household waste and for forward chain it can reduce environmental impact

Morgan et al., 2016	US	Retail	Survey							√		√					**Players** • Retailers and IT firms **Relationship between players** • Collaboration (sharing IT) Relationship Drivers • To achieve RL competency (collaboration with IT expertise is needed for information support to manage returns, as retailers do not have IT expertise) Relationship impact • Collaboration with IT expertise increasing information support between partners, which empowers the partners to be more responsive to each other to achieve RL competency.
Biehl et al., 2007	US	Carpet	Quantitative			√	√	√									**Design** • The availability of recyclables within the carpet industry can be increased through product re-design or new product design. If a manufacturer increases the availability of recycled production inputs by increasing the products' recyclability rather than increasing return flows, this will have a positive effect not only on the availability of recycled production inputs but also on the RL system's efficiency (e.g., transportation, waste generation, etc.). **Process details** • Importance of technology; Investment is better placed in recycling technology or product R&D that increase recycling rates. **Location (where)** • Increasing the number of collection centres and easily accessible locations providing more convenient opportunities for residents and contractors to turn in their carpets for recycling.
Somuyiwa & Adebayo, 2014	Nigeria	Food and beverage	Survey								√						**Performance** • Improve customer satisfaction, minimizing environmental impact of returns through appropriate disposition strategies. • Compliance with environmental regulations • Extracting and recovering raw materials for use in the production of new products.

																	• Companies have been moderately effective in achieving reverse logistics objectives related to cost control and improved profitability.
Bansia et al. 2014	India	Battery	Mix method								√						**Performance index based on BSC** • Return on Investment: Setting up a big battery recycling plant with all the high technology machines is a capital-intensive process. Every firm aims at achieving high return on investment. • Profit: Profit reflects how much the operations are earning, in absolute terms. Needed apart from ROI. • Buyer Supplier Relationship: In the case of the reverse cycle, the distributor is the supplier and the company purchasing the scrap battery is the buyer. • Fuel Consumption: Saving on fuel is a means to increased profitability and safeguarding the environment. • Cycle Time: Cycle time of each machine, the bottleneck process affects the cycle time of the complete process and reducing the cycle time enhance the productivity. Thus, it is also a contributing factor for PM system • Machine Availability: Not only in high tech machines availability is equally important i.e. the probability that the machine is available for use at required time. • Recovery: The amount of lead recovered as a percentage of the input lead is both a factor with environmental as well as monetary significance.

Appendix 2: RL key aspects in the automotive industry

Studies considering key aspects (return reason, return nature, RL process, location of RL process, time related issues in RL process, players, relationship between players, driver and barriers in RL practice) of reverse logistics in the automotive industry

Study	Country	Product	Method-ology	Reverse logistics key aspects in auto industry													Study Details
				Return Reason	Return product nature	Design of products	RL process	Location of RL process	Time of RL process	Players	Performance	Relationship between players	Drivers	Barriers to involvement	Barriers to improvement	Others	
Ravi and Shankar, 2004	India	car	Survey												√		**Barriers:** • Lack of awareness of RL • Lack of commitment by top management • Lack of strategic planning and company policy • Financial limits • Product quality • Lack of training and education • Lack of IT systems • Lack of stakeholder support • Lack of appropriate performance metrics
Schultmann et al., 2006	German	ELV	Survey	√		√	√					√					**Return reason** • End of life Vehicles (ELVs) due to accident and age **Design** • As automotive manufacturers attempt weight reduction of cars, plastics are replacing metal applications in new cars to an increasing extent **Process**

																	• Depollution of fuel, oil, coolants etc to avoid danger of spilling harmful substances during further dismantling activities, draining protects the latter shredder output from being contaminated and thus from losing sale value resp. from rising deposition cost • Dismantling valuable components • Recycling hazardous components and recovering valuable materials • Compact ELV • Shredding and recovering ferrous, non ferrous & shredder fluff • Landfilling shredder fluff **Players** • 1200 dismantlers • 5 with shredding and cleaning technology (Shredding and cleaning technology is currently used for similar thermoplastic material originating from other waste streams
Gehin, et al. 2008	Europe Generic	Car	survey			√							√				**Design** • Presents different strategies for designing a car with increased recyclability and explains why "remanufacturing of products" is considered the most promising approach. Also presents limitations and suggestions for a new tool for helping firms to coordinate the modified supply chain, and for product designers to develop the appropriate products. **Driver** • Regulation: Regulations put pressure on firms and tend to make them responsible for the End of Life (EoL) of their products • Environmental consciousness: Different norms have encouraged companies to reconsider their ways of producing to protect the environment
Mansour and Zarei 2008	Iran	Car	Quantitative mathematical model				√			√							**Process** • Collection: Car manufacturers are responsible for setting up collection centre network with minimum distance to car owners. Proposed model suggests

																	manufacturers join with EOL collectors and dismantlers to minimise collection point setup and transportation cost • Depollution: Upon the arrival of ELVs at the dismantlers, their environmental hazardous substances, such as batteries, fluids, etc. are discarded which is referred to as ‘depollution’ • Dismantling: The valuable parts for reuse or remanufacture are removed • Shredding: The remaining portion of an ELV, which is called the ‘hulk’, is sent to the shredders • ASR recycling: After shredding the hulk, the ferrous metals are separated and sent to the recyclers. The remaining material is divided into non-ferrous metal fraction, which will be sent to the metal separators and the relevant recyclers and the non-metal fraction • Disposal: The light automobile shredder residues (ASR) will be land filled/incineration **Players** • Car manufacturers, Collectors, Dismantlers, shredders, ASR recyclers and landfill
Cruz-Rivera & Ertel, 2009	Mexico	Car	Survey				√			√					√		**Process** • Collection: ELV collected by scrap yards, repair body shops and dismantlers • Dismantling: Dismantling by above players to recover parts • Repair/refurbish/remanufacture: Refurbished and remanufactured spare parts by above players. • Shredding: Shredding body shell and unsold parts by shredder and recovering ferrous and nonferrous metal scrap, which is further recycled to recover materials • Disposal: ASR dust disposed by landfill **Players** • Small body shop, scrap yard, dismantlers, shredders, material recycling companies. **Barrier** • Due to lack of strict legislation, operations for ELV management are not standardized. Poor

																	practices in ELV management activities, which lead to negative effects on the recovery value from ELV, such as contamination of shredder material by operative fluids and not following RL procedure, such as ignoring recovery of fluid before sending the car to shredder .
Zhang et al, 2010	China,	Automotive, components	Conceptual										√				**Barriers** • Lack of remanufacturing technology • Lower number of ELV collection • Restricted regulation on remanufacturing (cannot remanufacture all parts coming from dismantlers and does not permit the import of scrap cars for remanufacturing) • No value added tax refund policy • No maturing technology standards to control the quality and reliability of remanufactured products • Poor quality perception on remanufacturing products
Zarei, et al. 2010	Generic	Auto	Survey				√										**Process** • Collection: A network for ELV distribution-collection (new vehicles will be distributed and ELV will be collected from same points) can minimise cost and environmental impact.
Merkisz-Guranowska, 2011	Poland	Auto, ELV	Quantitative								√						**Performance indicator** • Network setup cost was the performance indicator here and it was identified that 93% of the cost is the operation cost of the network and only 7% transportation cost including ELVs' collection, transport to return station, dismantler, shredder and ASR recycling centre. **Actual performance** • The results indicate that the transport of waste does not play a significant role in the total costs of the functioning of the system. What is important is that the use of all entities be optimized in the network.
Harraz & Galal, 2011	Egypt (developing	Auto	Quantitative					√			√						**Location of RL process** • Suitable location for ELV collection and dismantlers: For collection, the main criterion

	country perspective)																for selecting the location was identified as proximity to end users to encourage and facilitate the process of delivering old vehicles. • Location for refurbishing centre: Refurbishing activities should be performed by existing manufacturers involved in the car feeding industry. **Performance of RL process** • This proposed framework implementation can give three dimensions of sustainability: economic (recovery of parts and materials), environmental (reducing waste for disposal) and social (creating jobs)
Chan et al., 2012	Generic	Automotive, car	Case study				√						√			√	**Process** • Assessment and sorting: sorting according to recovery options of EoL car • Repair/refurbish/remanufacture and resale of cars in good condition • Dismantling: removing parts and repairing and refurbishing parts in good and fairly good condition • Shredding: shredding car shell and non-repairable parts to recover materials **Drivers** • Direct economic value from return parts and components • For high level customer service, companies deal with warranty returns and recall for cars quality conformity. • Government regulation for disposal requiring environmentally friendly practices **Others** • High number of players makes reverse chain complicated and it is difficult to transport the product back to manufacturers • The use of several thousand parts makes the disassembling/dismantling process complicated • Due to safety and customer perception of remanufactured parts, manufacturers avoid the use of remanufactured materials.

Shaan and Subramoniam, 2012	Multi	Automotive, parts	Conceptual												√		**Barriers** • Core acquisition: return managed by third parties • Consumers' negative perception on quality • Lack of strict legislation • Availability of cheaper new products • Performance on remanufacturing practice based on countries • UK: Efficient use of resources through lower water consumption and reduction in landfill waste • Japan: Original Equipment Manufacturers' (OEMs) negative attitude towards the use of recycled materials, which may affect the sales of new products. • Turkey: Lack of knowledge about remanufacturing practices and absence of strict legislation. • China: Internal pressure from within the industry, which prioritises quantity of products over green practices. • Malaysia: Customer awareness about greening environment is a good sign for remanufacturing practices in the country. • India: Rapid increase in the use of remanufactured products & Availability of used products & High price sensitivity.
• Focusing on parts remanufacturing																	
Gonzalez-Torre et al, 2010	Spain	Automotive, generic	Survey				√										**Barriers** • Lack of RL awareness (government, society, customer and competitor's attention) • Customers perception of remanufacturing products as poor quality • Lack of expertise • Lack of top management support • Lack of IT systems • High operational cost to manage returns
Blanas et al, 2012	Europe	Automotive, parts remanufacturing	Survey				√										**Barriers** • Extended producer responsibility (govt. Regulation) in EU is a strong barrier for Non-EU auto manufacturers who do not have such huge networks for RL practice.

Daugherty et al., 2005	US	Automotive, components	Survey								√						**Performance** • Information technology capability can improve customer satisfaction, achieving compliance with environmental regulations as well as in extracting and recovering raw materials for use in the production of new products by authorising, tracking and handling returns
Aitken and Harrison, 2013	UK	Automotive, components	Case study							√		√					**Players and their relationships** • Insurers • Repair centres • Dismantlers **Relationships between players** • The greater collaboration between insurer and parts supplier capability coupled with higher levels of knowledge and information codifications were shown to be important factors in the establishment of a reverse logistics system. Supplier capability, knowledge codification and transaction complexity were found to be moderating variables which can enrich the traditional models on buyer-supplier relationships based on trust and ongoing commitment.
Richey et al , 2005	USA	Automotive, Components	Mix method								√						**To improve RL Performance** • RL programme formalisation (taking decisions of what to do with the product scraped/discarded/sold in secondary market) • Return policy restrictiveness • Innovation in the process (developed in-house or outsourced) **Actual performance/impact** • Policy restrictiveness has highest positive impact in RL process effectiveness • Formalisation has little positive impact on RL cost effectiveness • Revolution for outsourcing reverse logistics software is the best strategy rather than developing it in-house
Olorunniwo and Li, 2011	US	Automotive,	Qualitative, Interview	√			√				√					√	**Return reason** • Wrong product being ordered • Followed by customers changing minds

		aftermarket															• Shipping damage and quality complaints • Shipping to wrong destination **Process** • Mostly processed and put back on the shelf without any or with little repair, or refurbishing • Restore, remanufacture and remarket parts • Dismantle and shredding parts • Landfill **Performance indicators based on IT impact** • Customer satisfaction • Time to obtain return authorisation • Time for credit processing • Time of repair/refurbishment • Total inventory savings • Stake of obsolete item reduction • Manufacturing, transportation and cost of goods sold savings • Revenue from RL **Actual performance** • Revenue generation identified has little positive impact. Time aspects and cost savings also had limited impact; only customer satisfaction identified as very positively impacted **Others** • Use of IT • Internet • Information system where all organisational facts are integrated on a common database • Electronic data interchange system • Radio frequency data communications • Bar code • IT impact • IT viewed as a critical enabler of firms' operations which contribute to company's corporate image because the efficiency and effectiveness of the RL operations promote longer-term inter-firm relationships.
Subramanian et al., 2014	China	Automotive, parts manufacturing	Multiple case study				√			√			√		√		**Process** • Collection (Collection points): scrap centres, appointed retailers, ELV testing centres, third parties

																	• Assessing and sorting ELV • Dismantling and recovering parts • Shredding and recovering materials • Parts and materials resale in secondary markets • Disposal of waste **Players** • Consumers, collection points, distribution centres, dismantling and sorting centres, disposal centres, raw material an component suppliers, auto parts manufacturers and data centres **Drivers** • Government regulation requires resource recovery • Recaptured economic value • Increasing demand for green products • Assets protection concerns **Barriers** • Uncertainty with return of ELV • Lack of technology for dismantling and remanufacturing • Lack of human resources and management commitment • Higher tax for RL and remanufacturing related activities.
Soo et al., 2017	Comparative study between Australia and Belgium	Automotive, ELV (Car)	Case study				√			√	√		√				**Process** • Collection: Australian scenario - the lack of a proper collection system gives opportunities for unauthorised recycling facilities to compete with legitimate recycling sectors in acquiring ELVs. On the other hand, in Belgium one non-profit organisation manages the collection, treatment and recycling of ELV. • Hazardous removal: The collected ELVs undergo depollution procedures to remove batteries, fluids and other materials that contain hazardous waste. • Dismantling: Valuable parts are further disassembled to cater for the sale of reused parts.

																	• Shredder: The car hulks are then processed in material recycling facilities to recover valuable materials such as ferrous (Fe) and non-ferrous (NF) metals. • ASR recycling: the remaining ASR is further treated through post-shredder technologies to achieve the set recycling targets in Belgium but in Australia 25% ASR dust goes to landfill rather than further ASR recycling due to lack of strict legislation. • Disposal: The strict recycling targets and scarcity of available landfill space in Belgium have further encouraged minimal ELV waste disposal (only 5%) due to high landfill costs. On the other hand Australia 25% of ASR dust going to landfill for disposal. **Players** • Last vehicle owners, one non-profit organisation managing the RL process, recycling operators, authorised treatment facilities, and authorities. **Drivers** • Economic • In Australia, the voluntary based ELV regulatory framework has led to a profit-driven automotive recycling industry. The types of recovered materials are limited here. In contrast, Belgian recyclers also looked into the potential of recycling non-metallic materials such as plastics to achieve a higher recycled mass fraction. Although plastic recycling is not as lucrative as metal recycling, there is still great potential value for secondary plastic production. Moreover, it provides environmental benefits and allows further reduction of waste being produced for disposal. • Also, the implementation of advanced post shredder technologies is continuously progressing since the associated recycling costs are still below the disposal cost in Belgium. • Legislation

																	• Australia has no formal legislation pressure specifically for end-of-life vehicle (ELV) disposal, whereas Belgium enforces the strict ELV Directive of 95% reuse and recovery, which requires the implementation of authorised collection and treatment of ELV. **Impact/performance** • It is shown that the strict implementation of the ELV Directive in Belgium has led to better environmental performance by a factor of 7.9 in comparison to the Australian scenario. The enactment of strict ELV legislation, adoption of advanced recycling technologies, and improvement of the recycling efficiencies of revenue streams are identified as the major influencing factors for a sustainable ELV management system.
Mohamad-Ali, et al. 2018	Malaysia	Auto parts	Qualitative							√					√		**Players in recovery of parts** • Internal police force, city council, road transportation department, customs, individuals and third-party vendors, parts importer, spare part dealers, individual customers, service centres, insurance companies, scrap metal handlers, remanufacturers and goverment agency. **Drivers** • Demand for spare parts • Quality of spare parts • Value of materials • Barriers • No scrap facilities • Illegal spare parts • No aftermarket infrastructure • Poor maintenance, overage of parts, not usable in other countries • High tax, rapid technology changes, no skilled workers • Difficult to obtain licence to sell parts • Negative customer perception, • Quality difference between local and importer spare parts.

Xiao et al., 2019	China	ELV	Quantitative							√					√	√	**Players** • Collection centres • Dismantlers • Hazardous waste treatment facilities • Metal material recycling facilities • Remanufacturing centres • Barriers • Improper management of ELV • No cooperation between players • Lack of Government support – no tax incentive policy for recycling and remanufacturing products and no strict regulation to use formal recycling channels • Increasing ELVs but number and capacity of recycling facilities are insufficient **Others** Product Flows • ELV from Customers – Collection centres • ELV from Customers – Dismantlers • ELV from Collection centres – Dismantler

Appendix 3: Background for all twenty-eight-case study in terms of RL practice.

1. Case One (C1): Car Manufacturer A (CMA)

CMA is a Japanese multinational automotive company. CMA has automobile (car) manufacturing operation in the UK where they are responsible for automobile sales, marketing, after sales and customer relations since 1989.

EoL car RL practice consider very important at CMA. Therefore, there is procedure in place to manage EoL car RL process. To manage EoL car RL process to make sure 95% of a car is recycled, CMA has a network of more than 150 approved authorise treatment Facility (ATF), working with their recycling partner Official Scrap Car Partner A (OSCPA). OSCPA follow the European End-of-Life Vehicles (ELV) Directive.

If any CMA car has reached the end of its life, they qualify for their free take back scheme. CMA recycling partner OSCPA can advise whether or not the vehicle qualifies and can point the car owner to a nearest take back facility.

Apart of EoL car collection CMA also involved with new car designing including using bio-plastic as organic materials to build cars, developing recycling materials to use in new cars, increase in hybrid car volume, labelling of plastic parts with their material type to support cars RL process to recover more value and reduce waste for landfill.

For future plan for EoL RL process (2020/2021) CMA aim to reduce more waste, promote car recycling, parts reuse and remanufacture.

2. Case Two (C2): Car Manufacturer B (CMB)

CMB is a German multinational automotive company. CMB has automobile manufacturing operation in the UK where they are responsible for automobile sales, marketing, after sales and customer relations since 1980.

EoL car RL practice consider as very important at CMB. Sustainability is a key word at every point of CMB process chain, from the car design to car recycling. They acknowledged that EoL cars are important source of secondary raw materials. Therefore, not only to make sure 95% of a car is recycled but also to contribute to the conservation of natural resources, CMB also working with their recycling partner Official Scrap Car Partner A (OSCPA).

Apart of EoL car collection and recycling, CMB also involved with new car designing including using bioplastic as organic materials to build cars, using olives leaves as renewable materials, labelling of plastic parts with their material type to support cars RL process to recover more value and reduce waste for landfill.

Apart of these, recycled materials are used in various areas such as insulation, boot ventilation and other aspects of the car that are not in direct view or part of a safety feature to protect natural resources.

CMB specialists begin laying the foundations for the end of a cars’s life during the product development process. their engineers and design team work closely with their recycling specialists to analyse the environmental impact of a car’s components.

3. Case Three (C3): Car Manufacturer C (CMC)

CMC is a British multinational automotive company. CMC has automobile (car) manufacturing operation in the UK where they are responsible for automobile sales, marketing, after sales and customer relations since 1948.

CMC has stablished a comprehensive plan to meet EoL car legislation within the European union. As environmentally responsible manufacturers, and in order to meet End of Life Vehicle (ELV) legislation in the EU, CMC take back all EoL car at the end of their life. And to manage this process CMC working together with their recycling partner, Official Scrap Car Partner B (OSCPB).

Also to support EoL car recycling CMC developing ultra-high-strength low-weight steels, engaged in investigation on natural fibre, labelling of plastic parts with their material type, Introducing hybrid and electric cars to support cars RL process to recover more value and reduce waste for landfill.

Apart of these, CMC taking initiatives to increase battery collection and recycling as they are also one of the battery producer in the UK. Therefore, CMC working together with Civic Amenity and Recycling Centres, Local Authority Battery Collection Schemes, Licensed End of Life Vehicle Authorised Treatment Facilities and Licensed Metal Recycling Sites to collect EoL car batteries to make sure no battery waste going to landfill which was banned in the UK from 1st January 2010.

CMC have a closed loop waste recovery and recycling system at their production centre, as well as a trial process where their new all-aluminium car models are manufactured.

4. Case Four (C4): Car Manufacturer B (CMD)

CMD is a US multinational automotive company. CMD has automobile (car) manufacturing operation in the UK where they are responsible for automobile sales, marketing, after sales and customer relations since 1909.

When CMD cars comes to the end of its life they accept it free of charge when through their appointed EoL car collection points which is manged by their partner OSCPB who provide this service, in strict accordance with the Government's Environmental Agency and the End of Life Vehicle regulations (EU Directive2000/53/EC).

Also, to support EoL car recycling CMD developing recycling plastics to use in new cars, labelling of plastic parts with their material type and Introducing hybrid and electric cars.

5. Case Five (C5): Car Dealer A (CDA)

CDA is one of the leading CMA (C1) dealer in the UK. In fact, CDA is one of the biggest dealers of CMA in Britain. CDA company sells the new and approved CMA's used cars since 2003.

CDA is also engaged with EoL car RL practice in terms of EoL car collection. They accept CMA's EoL cars which further get collected by one of the nearest Authorise Treatment Facility

(ATF). EoL car RL practice consider important at CDA as it offers an opportunity for car dealerships to engage positively with customers and build relationships.

6. Case Six (C6): Car Dealer B(CDB)

The CDB was established in 1985 and is an authorised CMB's dealer in the UK. This company country of origin is UK.

CDB is also engaged with EoL car RL practice in terms of EoL car collection. They accept CMB's EoL cars which further get collected by one of the nearest Authorise Treatment Facility (ATF).

Apart of this they also promoting CMB's EoL car recycling policy through their website and Sustainability Group Index. As CMB works hard to ensure that the recycling of cars is at the forefront of its mind from the very beginning. From the development and manufacturing through to use and servicing, which influencing CDB to ensure that they are also supporting CMB as environmentally conscious and friendly as they can be.

7. Case Seven (C7) – Car Dealers C (CDC)

The CDC company was established in 1968 as automotive dealer and is an authorised CMC company dealer based in the UK. The company country of origin is UK.

CDC is also engaged with EoL car RL practice in terms of EoL car collection. They accept CMC's EoL cars which further get collected by one of the nearest Authorise Treatment Facility (ATF).

8. Case Eight (C8) – Car Dealer D (CDD)

The CDD company was established in 1968 as automotive dealer and is an authorised CMD company dealer based in the Kent. The company country of origin is UK.

Like other car dealers discussed above CDD is also engaged with EoL car RL practice in terms of EoL car collection. They accept CMD's EoL cars which further get collected by one of the nearest Authorise Treatment Facility (ATF).

9. Case Nine (C9) – Official Scrap Car Partner A (OSCPA)

Official Scrap Car Partner A (OSCPA) is membership body for business who are mainly car disposal expert was founded in year 2004. This company's country of origin is UK.

Car manufacturers free car take back schemes for car owners to recycle their EoL cars. This scheme, run by car disposal expert network Official Scrap Car Partner A (OSCPA), offers car owners an opportunity to dispose of their car in an environmentally sound manner. It is also helping manufacturers to increase their vehicle recycling rates target, which requires 95% of a vehicle to be reused, recycled or recovered.

Car owners simply visit the OSCPs website, type in their registration and postcode and receive an instant quote. They can either take their car to their preferred dealership, or it can be collected from their home, for free. OSCP is the approved vehicle disposal partner to numerous vehicle manufacturers, including CMA and CMB who are also inviting owners to obtain a quote via their own websites. Once the vehicle has been handed over, the owner receives a PIN number to enter online, which generates a secure payment of the sum agreed, direct to their bank account. The car is collected for final disposal by OSCP's network of Authorise Treatment Facilities (ATF) for further treatment for proper disposal.

10. Case Ten (C10) – Official Scrap Car Partner B (OSCPB)

Like OSCPA this OSCPB also another car disposal expert network who offers car owners an opportunity to dispose of their car in an environmentally sound manner.

This company founded in year 2002 as a private limited company and its country of origin is UK.

Here also car owners can visit the OSCPBs website, type in their registration and postcode and receive an instant quote. They can either take their car to their preferred dealership, or it can be collected from their home, for free. OSCPB is the approved vehicle disposal partner to numerous vehicle manufacturers, including CMC and CMD who are also inviting owners to obtain a quote via their own websites. Once the vehicle has been handed over, the owner receives a PIN number to enter online, which generates a secure payment of the sum agreed, direct to their bank account. The car is collected for final disposal by OSCPB's network of Authorise Treatment Facilities (ATF) for further treatment for proper disposal.

11. Case Eleven (C11) – Authorise Treatment Facility A (ATFA)

ATFA is local treatment facility for EoL cars, situated in Kent. They are licenced as specialise in the recovery or scrap cars and ferrous and non-ferrous scrap Metals. Established in 1978. They have branches all over Kent and South-East London. They are DVLA and Environmental Agency approved, so they hold an ATF License. ATF stands for Authorised Treatment Facility. It's a scrapyard or scrap car breaker that has been licensed by the Environment Agency, to ensure that it's meeting standards of safety, quality, sustainability and acceptable business practices. ATFs are the only scrap car breakers that are authorised to operate in the UK.

In terms of EoL car reverse logistics process they are involved with EoL car collection, hazardous components removal and marketable components removal stage. In the EoL car collection process, their entire team is committed to ensuring and upholding EoL car owner (customer) satisfaction, because of this they have many regular clients. They deal with all clients direct, cutting out the middleman. They are paying competitive prices for EoL cars and as they regularly update prices.

12. Case Twelve (C12) – Authorise Treatment Facility B (ATFB)

ATFB has been operating since 2012. They have branches all over London. They are DVLA and Environmental Agency approved, so they hold an ATF License. It's a scrapyard or scrap car breaker that has been licensed by the Environment Agency, to ensure that it's meeting standards of safety, quality, sustainability and acceptable business practices.

In terms of EoL car reverse logistics process they are involved with EoL car collection, hazardous components removal and marketable components removal stage. They offer a free local collection/delivery service within a 15-mile radius of their garage.

13. Case Thirteen (C13) – Authorise Treatment Facility C (ATFC)

ATFC has been operating since 2006. ATFC is specialists in scrap car processing throughout the UK. They have three sites in the UK for EoL cars treatment including dismantling and shredding. ATFC is totally committed to meeting their last car owners (customers) and regulatory body requirements across the UK.

ATFC also accept car shells/scrap metal from everyone and whether it's large multi-national companies or individual householders, they always proud to offer a polite, friendly and convenient service to each and every one of their customers.

ATFC attempt to exceed expectations in the scrap metal recycling industry. They achieved by buying competitively and using cutting edge processing equipment, which is complimented by a modern fleet of collection cars, all of which are maintained to exceptional standards. ATFC also constantly reviewing the recycling industry to identify new equipment that will potentially enhance the efficiency of their processing operation.

14. Case Fourteen (C14) – Authorise Treatment Facility D (ATFD)

ATFD has been operating since 1980. Like other ATF companies ATFD also approved by environment agency for EoL car recycling treatment. ATFD not only collecting, dismantling and shredding EoL cars but also, they have total waste management solutions for their ASR that accept ASR from other auto shredder to reduce waste and increase recycling. ASR is automotive shredder residue or automobile shredder residue (ASR). ASR consists of glass, fibber, rubber, automobile liquids, plastics and dirt coming from automotive shredder.

ATFD shredder plant is a high specialised shredder plant in the UK with ASR recycling facility. Though this operation is still developing but they are already delivering the 95% recovery target through a combination of plastic recycling, producing materials for construction industry and fuel to a substitute coal.

15. Case Fifteen (C15) – Hazardous Recycling Centre A (HRCA)

HRCA are a well-established, legally compliant, waste oil collection & recycling company. They recycle cars waste oil into fuels for industry science 2011.

With collection coverage and recycling facilities throughout the UK they ensure that waste oil collection is dealt with efficiently, legally and in the most environmentally friendly manner. HRCA is registered and adhere to the environment agency for waste collection and treatment.

16. Case Sixteen (C16) – Hazardous Recycling Centre B (HRCB)

With over 35 years in the waste management industry, HRCB have the specialist knowledge, professional accreditation and leading-edge facilities to provide the most cost-effective and compliant solutions for the removal, treatment and disposal of Hazardous Waste; whether from demolition and construction or industrial, medical and manufacturing processes.

They have in-house qualified assessors, a large fleet of specialist vehicles and containers for all load sizes – from bags to skips from 14 to 40yd3 ROROs - and state-of-the-art treatment and disposal facilities.

Waste recovery is central to HRCB's business with landfill diversion options not only helping companies find more sustainable solutions for their waste but also make significant savings by escaping high rates of landfill tax. Their state-of-the-art soil washing plant is conveniently located for London and the South East and converts contaminated soils into clean, inert materials suitable for re-use in construction projects or land restoration.

17. Case seventeen (C17) – Waste Management Company A (WMCA)

WMCA is a waste management company in the United Kingdom. WMCA operates two active landfill sites in Essex and continue to monitor and maintain one non-active site. All are highly engineered and managed to stringent Environment Agency (EA) standards. The EA may visit at any time for inspection or monitoring purposes and have full access to their comprehensive site data. Once a landfill site has reached the extent of its planning permit, they are responsible for capping it, or undertaking restoration and providing a programme of aftercare. WMCA work to regenerate natural habitats in a sympathetic manner that will minimise the effect of their operations on the original plants and wildlife and allow it to flourish.

18. Case Eighteen (C18) – Waste Management Company B (WMCB)

WMCB is the leading integrated waste management company in the UK. It provides collection and landfill waste services to local authorities and industrial and commercial clients in the UK. As of 2017 it is the second-largest UK-based waste-management company. It provides disposal and technologically-driven energy generation services across four operating divisions. WMCB service over 2.5 million households and collect 4.1 million bins per week within its municipal division, and has over 72,000 industrial and commercial customers.

19. Case Nineteen (C19) – Government Agency A (GAA)

GAA is a non-departmental public body, established in 1995 and sponsored by the United Kingdom government's Department for Environment, Food and Rural Affairs (DEFRA), with responsibilities relating to the protection and enhancement of the environment in England.

Their purpose is to protect or enhance the environment, taken as a whole" so as to promote "the objective of achieving sustainable development" (taken from the Environment Act 1995, section 4). Protection of the environment relates to threats such as flood and pollution. The vision of the Agency is of "a rich, healthy and diverse environment for present and future generations".

In terms of EoL car reverse logistics practice, cars are regulated by GAA to limit the environmental impact of their disposal, by reducing the amount of waste created when they are scrapped. This is done through various measures to encourage the recovery, reuse and recycling of metals, plastics and rubber.

Responsibility for enforcing the regulations is shared by the Department for the Environment, Food and Rural Affairs (Defra) and the Office for Product Safety and Standards (Safety & Standards).The End-of-life Vehicles Regulations 2003 (as amended) and the End-of-life Vehicles (Producer Responsibility) Regulations 2005 (as amended) are the underpinning legislation. Detail of each legislations are captured in the appendix 4.

20. Case Twenty (C20) – Local Council A (LCA)

LCA is a county council in Kent, UK. he County Council is made up of 84 elected county councillors. The cabinet of country council is responsible for the strategic thinking and decisions that steer how the council is run. It has local board which is local community groups that hold regular public meetings across the county so that the people to voice issues that affect their community. They also allocate funding to local projects. There are 12 local boards of LCA. The work of the Council is organized into departments and divisions such as Strategic and Corporate Services who support supports the work of the directorates by providing specialist expertise and strategic direction. The department also leads and co-ordinates major change and organisational development; Children, Young People and Education which aim for the county to be the best place for children and young people to grow up, learn, develop and achieve; Adult Social Care and Health mainly works with people who need care and support, providing Adult Social Care Services and Public Health Services for the people of the county; Growth, Environment and Transport mainly comprises a range of key frontline, strategic, policy and commercial functions, and plays a major role in making the county a better place to live, work and visit. Under this divisions LCA are also responsible for abandoned vehicles removal from land in the open air roads (including private roads).

21. Case Twenty-one (C21) – Local Council B (LCB)

LCB is a county council in Tower Hamlets, UK. The LCB County Council is made up of 45 elected county councillors. The cabinet of country council is responsible for the strategic thinking and decisions that steer how the council is run. Like LCA it also has local board which is local community groups that hold regular public meetings across the county so that the people to voice issues that affect their community and LCB also organized into departments and divisions such as Strategic and Corporate Services; Children, Young People and Education ; Adult Social Care and Health; Growth, Environment and Transport. LCB also responsible for abandoned vehicles removal from land in the open air roads (including private roads).

Appendix 4: Regulations for EoL car reverse logistics practice in the UK

The ELV directive (2000/53/EC) are applicable for the End of Life Vehicle to scrap cars and vans that have a gross vehicle weight of up to 3,500kg. End of life vehicle is another name for what's normally known as a scrap car, junk car, breaker or salvage vehicle. This research used the term “EoL car” as this research considered only cars in our research.

The regulations were designed to reduce the impact that scrap cars have on the environment. They were introduced in two parts.

- The first set of regulations came into effect in 2003 and require hazardous components removal from scrap cars before destruction. This involves the removal of fluids, tyres, battery and hazardous materials, before any of the remaining parts or materials can be reused or recycled. This treatmnet can only be carried out at Authorised Treatment Facilities (ATFs) holding the appropriate environmental permit. The 2003 regulations also required ATFs to issue last owners with a Certificate of Destruction (CoD), through which scrapped vehicles are deregistered.
- The second set of regulations came into effect in 2005 and mean that both producers (vehicle manufacturers and professional importers) must establish national networks of ATFs to provide “free take-back” of their “own marque” ELVs. For the vehicles dealt with by these networks until 2015, producers had to achieve 85% reuse, recycling and recovery targets, as did ATFs not forming part of a producer’s network. From 2015 onwards, that target has become 95% by weight of the vehicles.
- Apart of ELV detective (2000/53/EC), this also discussed other environmental regulations which has impact on EoL car RL process.
- Failure to follow the regulations and carry out your duties may result in prosecution and a fine (licence revocation/financial penalty)

Regulations	Details	RL process stages	Objective	Responsible
ELV directive (2000/53/EC): Only applicable for vehicles having a maximum mass not exceeding 3,5 tonnes Aim: Minimising the environmental impact of EoL cars (Reduce the final disposal & Improve environmental performance of manufactures and other players involved - economic operator)				
The network for EoL car collection with free take back.	• Regulation requires each car manufacturers to establish a network for the collection and treatment of the vehicles for which he has declared responsibility, when those vehicles become ELVs. • system requires producers to meet all or a substantial part of the costs of providing "free take-back" for EoL cars • system requires 75% of car owner should be within 10 miles from the collection points and rest should not be more than 30 miles away. • Only ATFs are eligible to establish the electronic link with the Driver and car Licensing Agency through which the CoD is issued.	EoL car Collection	• To encourage EoL car owners to scrap their car with authorised treatment facilities • To have a centralised and controlled record system of deregistration cars	Car manufacturers and dealers
Hazardous components removal (depollution)	• Hazardous materials and components shall be removed and separated in a selective way so as not to contaminate subsequent shredder waste from end-of life cars. • Removing operations and storage shall be carried out in such a way as to ensure the suitability of car components for reuse and recovery, and in particular for recycling. • Treatment operations for depollution of end-of-life shall be carried out as soon as possible	Hazardous component removal	• To secure marketable components and shredder materials from toxic • To secure the environment and employee health from the hazard of toxic	ATF and Hazardous Recycling Centre
Dismantle Information availability	• Producers, in concert with material and equipment manufacturers, shall use the nomenclature of ISO component and material coding standards (see detail below) for the labelling and identification of components and materials of cars, in particular to facilitate the identification of those components and materials which are suitable for reuse and recovery. • This information's should be available (in IDIS) of each type of new car put on the market within six months after the car is put on the market	For assessment to disposal process	• To make recovery system more effective in terms of ease of process and recovery percentage	Car, battery and components producer/manufacturers
Design responsibility	• Producers to limit the use of hazardous substances in car production • Producers to design more recyclable car (in order to reach the targets) • Dismantlability, recoverability and recyclability standards in type-approval directive (ISO standard 22628:2002) • Producers to integrate more recycled materials in new cars	Design stage	• To increase recovery percentage and ease the recovery process to reduce waste going to disposal	Car, battery and components producer/manufacturers
Producer responsibility to meet recovery target	• Car manufacturers to achieve reuse, recovery and recycling targets of 95% of total weight of a car	Assessment to Disposal	• To reduce waste going to landfill	Car manufacturers

			• To control resource (raw materials) scarcity	
Financial responsibility	• Producers to cover costs of take-back and further treatment of EoL car • Producer to cover cost of take back and further treatment for battery	Collection to disposal	• To encourage car manufacturers to produce car responsibly • To encourage auto recycling industry	Car and battery manufacturers
Other environmental related regulations to get environmental permit Aim: to protect environment from air, land and water pollution				
Standard rules SR2015 Car storage, depollution & dismantling (authorised treatment facility)	• The activities shall not be carried out within Groundwater / within 50m of any well spring or borehole used for the supply of water for human consumption. • This must include private water supplies. • These rules apply to the recovery (including storage) of all waste motor vehicles. • The total quantity of waste that can be accepted at a site under these rules must be less than 75,000 tonnes a year. • Liquids may be discharged into a sewer subject to a consent issued by the local water company. • Liquids may be taken off-site in a tanker for disposal or recovery. • Clean surface water from roofs, or from areas of the site that are not being used in connection with storing and treating waste, may be discharged directly to surface waters, or to groundwater by seepage through the soil via a soakaway	Depollution, Dismantle, shredding	• Toi protect the emission impact • To protect the ground water	Authorised Treatment Facilities (ATF)
Collect and transport and store hazardous components	Recycler must follow each steps below in order to collects and storage hazardous waste. • Register as a waste carrier. • make sure the waste is classified correctly. • Separate waste correctly during the loading time for transportation. • Storing them to an authorised waste site. • Keep records of all documentation for one year.	Hazardous recycling	• To make sure toxic from hazardous waste are not polluting ground and air • To make effective waste recycling in terms of ease of recycling process and recovery quantity and quality	Hazardous Recycling centres
For treatment of hazardous components	• Recycling centre must follow these steps below to treat or dispose of hazardous waste at premises in UK. • Get an environmental permit or register an exemption for the premises. • Check the consignment note and waste before accepting it – make sure it's classified correctly. • Reject the waste if the consignment note is missing, incorrect or incomplete. • Keep records.	Hazardous recycling	• To have proper control on hazardous wastes treatment to make sure wastes are treated environmentally friendly way	Hazardous Recycling centres

Qualified worker for hazardous recycling	• EU Regulations (EC 307/2008) concerning qualifications for person dealing with hazardous recycling came into force in April 2008. These require relevant operatives to be formally trained and in possession of a duly accredited certificate of competence.	Hazardous recycling	• To assure health and safety in the work environment	Hazardous Recycling centres
Regulation for site and operating standard	• Treatment site should be outside of protected areas (school, public houses, public gathering area, water facilities etc..) and all the components should be removed and storage manually or electrically according to the type of components.	Assessment to disposal process	• To assure community health and safety	All ATF's

Appendix 5. Research instrument employed

Introduction: This semi-structured interview is designed to produce relevant empirical information for the conduct for a research study on “Reverse logistics practices for EoL cars in the UK’’ All responses will be confidential and only aggregate analysis will be presented, along with any relevant quote to support a particular point of view.

1. Introduce interviewer and thank interviewee for agreeing to take part in this 45-60-minute interview;
2. Remind interviewee that the purpose of our study is to explore reverse logistics practices for EoL car in the UK;
3. Advise interviewee that the interview objective is to ask their expert views and opinions about these practices as guided by questions;
4. Assure confidentiality and anonymity regarding any attributed comments;
5. Ask whether the interview can be recorded for the purpose of ensuring the interviewee’s meanings and comments are properly interpreted; and
6. Obtain verbal consent from interviewee to the above and proceed.

Case Profile

1. Job Title:
2. Years in Profession:
3. Years with the company:
4. Company Specialities/major Business:
5. Industry sector classification:

Interview questions

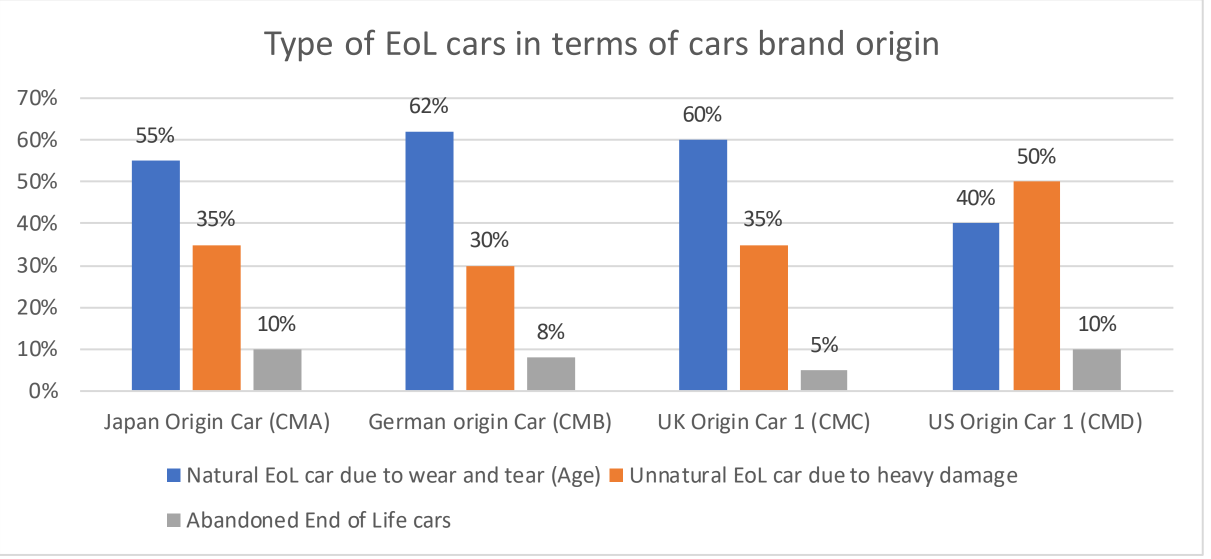
Return reason and nature perspective in reverse logistics

1. Does your company allow end of life (EoL) cars to be returned by customers?
    a. If no, why not?
    b. If yes, in practice, how does your company receive EoL cars back from customers?
2. What is the reason of the EoL cars normally received back from customers?
    a. What is condition of most of the cars coming back for as EoL car? (age, mileage, damage)
3. What does your company do with the return EoL cars?
4. What impact dose these activities have on your company? In terms of [Operational Cost, Legislative Compliance, Environment, Corporate Reputation, Sustainability etc.]
5. What are the key challenges your company faces in managing EoL cars?

6. Why do your customers/partners return cars back to your company?
    a. If customers or partners do not return cars to your company, why don’t they?
7. Why does your company accept cars back from customers/partners? [Economic Reason, In-warrantee agreement, Legislative Reason, Brand protection reason, corporate citizenship Reason, Environmental concern, etc.]
    a. If your company do not, what is the reason?
8. How important are managing EoL car return practices to your company?
    a. Very important; why?
    b. Not important; why not?
    c. Indifferent; why?
9. Are there procedures in place for the collection, sorting, storing and processing of returned EoL cars by your company?
    a. If no, what is the reason?
    b. If yes, please describe the process/procedure;
    c. Are the procedures followed?
    d. If no, what is the reason?
10. Are there better ways of performing these activities (Reverse Logistics of EoL car)?
11. How long does your company keep the returned EoL cars before processing?
    a. What reason account for this?
    b. If your company do not keep the returned cars, which company do the storage and processing?
    c. Are there better ways of performing these activities?
12. what is your key responsibility of your company in managing return EoL cars?
    a. How do you manage the activities? (inhouse, outsources etc.)
    b. b. If inhouse, why and how?
    c. If outsource, why and who do you outsource/which supply chain stakeholder?
    d. What is the nature of your company relationship with these companies?
13. Who are the actors/employees within your company responsible for the day-to-day administration, collection, sorting, storage, re-sell, reporting and disposal of the returned cars for scrappage?
14. Where are the stakeholders located that are involved in the reverse logistics operation of your company?
15. What influence/impact dose the location of stakeholders has on the collection, storage, and processing strategy of returned cars?

16. On a scale of 1-10 how well do you feel your company manages EoL car returns overall?
17. What are the laws governing the handling of EoL car returned?
18. Is your company compliant? What are the factors hindering compliancy?
19. What is your company doing to improve the reverse logistic practices of EoL car?
20. Does your company measure environmental/economic and social performance for these activities?
    a. If yes, what are the performance indicators you consider measuring environmental/economic and social performance?
    b. If yes, to what extent has each of these practices impacted your environmental/economic and social performance?
    c. if no, why not?

Appendix 6: EoL car category for CMs



Apendix 7 : Natural EoL cars age type for CMs