CRANFIELD UNIVERSITY

Eva Faja Ripanti

A Framework to Design Reverse Logistics Operations based on Circular Economy Values

School of Aerospace, Transport and Manufacturing
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Doctor of Philosophy (PhD)
Academic Year: 2013 - 2016

Supervisors: Dr Benny Tjahjono& Dr Ip-Shing Fan
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Abstract

Reverse Logistics (RL) is complex to be managed due to the uncertainty involved e.g. the quality range of products, timing of product returns, and volume of returns. A robust RL design can contribute to increase the effectiveness of RL operations. Therefore, an RL design framework needs to be formalised. Circular economy (CE) focuses on supporting the separation of treatments between technical and biological materials in maximising the design for reuse to return to the biosphere and retain value through innovations across fields. The aim of the research is to develop a new framework to design RL operations based on CE values that can increase the effectiveness and efficiency of RL operations. This research has been conducted through the qualitative research involving cases in product recovery (PR) options that are analysed in-depth. Literature review and interview are the main methods of this research. A test was conducted by interviewing expert and respondents to obtain the expert view and test the research result which is a developed framework to design RL based on CE values. The testing engaged five criteria (usability, feasibility, consistency, effectiveness, and utility). The formal RL design framework, 15 CE values, framework to design RL based on CE values specifically PR options (repair, refurbishment, remanufacturing, and cannibalisation) are main research findings. The research contributes academically to the development of a formal RL design framework and to the identification, reformulation, redefinition, and implementation of CE values. The research can be used as a basis for an effective design of RL that takes into account the economic, environmental, and social impacts. The research can be used as a guideline or an appraisal tool in designing/modifying RL based on CE values that can support the implementation of a single RL operation and also RL based on CE.

Keywords: Circular economy; Circular economy values; Framework; Product recovery; Reverse logistics; Reverse logistics design

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ABBREVIATIONS

CE	Circular Economy
CLM	Council of Logistics Management
CSR	Corporate Social Responsibility
EoL	End of Life
EMF	Ellen MacArthur Foundation
ERN	European Remanufacturing Network
HR	Human Resource
IS	Information Systems
IT	Information Technology
OEM	Original Equipment Manufacturer
OER	Original Equipment Remanufacturer
PR	Product Recovery
PRM	Product Recovery Management
RL	Reverse Logistics
RLRS	Reverse Logistics and Repair Service
SCM	Supply Chain Management
UML	Unified Modelling Language
WM	Waste Management

LIST OF PUBLICATIONS

Journal

Bernon, M., Tjahjono, B. & Ripanti, E.F. (2016) Aligning retail reverse logistics practice with circular economy values: An exploratory framework. *Journal of Production Planning & Control*. *(Undergoing First Revision)*

Conference Papers

Ripanti, E.F., Tjahjono, B. & Fan, I. (2015) Circular Economy in Reverse Logistics: Relationships and Potential Applications in Product Remanufacturing. *20th Logistics Research Network (LRN) Conference, Derby, UK.*

Ripanti, E.F., Tjahjono, B. & Fan, I. (2016) Circular economy in reverse logistics: formulation and potential design in product refurbish. *Production and Operations Management Society (POMS) Conference.* Florida, USA.

Ripanti, E.F., Tjahjono, B. & Fan, I. (2016) Maximising the retained value of product cannibalisation based on circular economy principles. *23rd International Annual Euroma Conference*. Trondheim, Norway.

Presentations

Ripanti, E.F. (2015)A circular economy based decision support system design, implement, and control reverse logistics operations. *20thDoctorate Workshop European Logistics Association (ELA).* Schindellegi, Switzerland. (Presented)

Ripanti, E.F. (2015) A circular economy based decision support system for designing reverse logistics operations. *Disruptive Innovation Festival (DIF)*. (Presented)

CHAPTER 1

INTRODUCTION

1.1 Research Background

Product returns have been common since the early days of commerce, initially designated as a starting point of reverse logistics (RL). In the 1980s, many researchers (Murphy, 1986; Lambert and Stock, 1987; Murphy and Poist, 1989) attempted to formulate definitions of RL, although they defined RL in a rather limited manner, i.e. in material movements from customers to producers, meaning that it was only from the aspect of product returns. RL itself has only attracted academics' attention since the early 1990s. Since then, various definitions of RL have been proposed by researchers (e.g. Stock, 1992, 1998; Kopicki et al., 1993; Carter and Ellram, 1998; Rogers and Tibben-Lembke, 1999). Rogers and Tibben-Lembke (1999) defined RL as the management action that relates to several keywords, for instance logistics activities/roles, recovery/reuse activities, disposal, recapturing values, management, channel distributions, reverse flow, cost, etc.

RL is considered to be much more complex than the traditional supply chain (Meyer, 1999; Tibben-Lembke and Rogers, 2002). This is because RL encompasses product returns, source reduction, recycling, materials substitution, reuse of materials, waste disposal and refurbish, repair and remanufacturing (Stock, 1998). RL is also considered to be more complex to be managed than forward logistics (Rosen, 2001; Tibben-Lembke and Rogers, 2002; Amini et al., 2005) because the detailed activities in RL involve size, scope, and impact on industry and channel position, and the types of distribution channel are varied (Rogers and Tibben-Lembke, 2001).

Consequently, planning an RL network is logically more challenging than the forward logistics due to the higher uncertainty involved (Flapper, 1995; Guide et al., 2000). Such uncertainties were aired by Meyer (1999), highlighting the fact that products have their own life cycles and each return may require different treatments, depending on whether the product is defective, damaged, recyclable, or 'repackageable', causing increased complexity in the planning process. Fleischmann et al. (1997) concurred, and further added the uncertainty aspects, such as timing of product return, quantities of returns, and the quality of used products returned by customers.

In addition, Rogers and Tibben-Lembke (2001) surveyed implementing RL strategies by interviewing numerous logistics managers. The results conveyed that 35% of 311 managers said that their companies did not implement an RL system properly. So, the difficulty of RL strategies implementation was envisaged due to lack of systems. Regarding implementation, Meyer (1999) also emphasized that RL needs a robust system that represents an opportunity to cut costs, improve operations and customer service, and increase revenues.

On the other hand, the RL formal design method is rarely described by researchers. Most of them focus on the design of the RL network (e.g. Fleischmann, 2001b; Bostel et al., 2005; Daaboul et al., 2014). Indeed, the design of an RL network is important. However, before designing it, the RL design method or framework should be provided that can be a guide to construct robust RL operations. In fact, RL was stated as a broad concept (Kopicki et al., 1993) and also complex to manage, owing to the uncertainty described above.

The term Circular Economy (CE) describes an industrial economy that is restorative and encompasses minimisation of the consumption of finite resources and raw materials in the manufacture of products (EMF, 2013). Unlike the linear economy model of 'take, make, dispose', CE emphasises the circulation of the content of products back to the point of production after their end of life (EoL). The basic premise of the restoration and recirculation of EoL products is the distinct treatment of both the technical and biological materials, so that if needed, these biological materials can safely be released to the biosphere. Therefore, the ultimate goal of CE is to minimise the contents that could end up in landfill or incineration.

CE, as an industrial system, supports a restorative concept through intelligent design of materials, products and systems, and the business model. Preston (2012) interpreted it as the redesign of global production and consumption systems which combine the environmental, resources, technology and consumer demand. CE strives for maximisation of the ‘design for reuse’, thus aiming to retain the intrinsic value of the materials being recirculated through innovations across the various fields (Lacy and Rutqvist, 2015; Webster, 2015), represented by EoL processing and product recovery (PR) activities, such as repair, reuse, refurbish, remanufacture and recycle. To support this representation, CE needs to be operationalised using lower level tenets, principles, values or other related terms. Furthermore, temporarily, CE principles and values terms will be used alternately; even though the original intention is to reveal the fundamental truth, which is a principle, it needs to be proven further.

The identification of CE principles is critical to be reformulated with the ultimate goal being to provide readily available CE principles in a format/structure that can be used for specific implementation purposes in order to support the EoL processing, recovery or RL activities. Researchers have tried to describe CE principles, for instance Feng (2004) in Yuan et al. (2006), Pintér (2006), Yuan et al. (2006), Yong (2007), Geng et al. (2012), EMF (2013), Stahel (2013), EMF (2015), Pan et al. (2015). However, none of them used CE principles as a framework to design RL operations. The principles will be clearly reformulated in this research by extracting many sources, comparing some cases, exploring the existing CE principles, identifying the characteristics of CE, and reformulating them into readily available principles in a format/structure that can be used for RL design.

The idea of RL apparently shares similarities to CE activities – repair, refurbishment, remanufacturing, recycling and disposing (Thierry et al., 1995; Stock, 1998; Rogers and Tibben-Lembke, 1999; Alwood et al., 2011; EMF, 2013). The aim of RL is to reduce raw material, reuse material, and respect the environment (Thierry et al., 1995; Carter and Ellram, 1998) which fits in with some CE activities and purpose, even though in a broader concept. Researchers have also looked at RL and CE in having relations each other, i.e. Xiangru and Wei (2009), Chen and Chen (2010), Ripanti et al. (2015, 2016).

Taking into account the need to formalise the RL design framework, the complexity of RL management, similar activities between RL and CE, and the broader concept of CE, are taken into account. The CE concept itself offers to keep products, components and materials at their highest utility and value at all times. For those reasons, a framework for designing RL based on CE values is developed. Furthermore, PR options are chosen so that the implementation of research is measured and realistic in terms of time. Repair, refurbishment, remanufacturing, and cannibalisation are the research focuses to implement RL based on CE values.

1.2 Research Motivation

The five motivations of the research are presented. *First*, RL, as described before, is complex to be managed due to some uncertainties, for instance the quality of the range of products, different treatment needed, and volume of returns (Flapper, 1995; Meyer, 1999; Guide et al., 2000; Rosen, 2001; Tibben-Lembke and Rogers, 2002; Amini et al., 2005). Additionally, Rogers and Tibben-Lembke (2001) surveyed the implementation of RL strategies where some companies have not yet implemented the RL system properly. Difficulty with this RL strategy implementation was envisaged due to lack of systems. The study regarding the uncertainty and complexity that relates to RL is an interesting and challenging area to be researched more.

Second, the CE concept offers the optimum use of resources, minimum emission and waste in production and consumption activities through being restorative and regenerative. Its aim is to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles (Marion, 2012; EMF, 2013). CE is also an academically motivating area to be studied in greater depth.

Third, a robust system is useful for a mechanism to become more effective and efficient. Also, a robust RL design will influence the effectiveness of RL, and can be one of the solution alternatives to address the complex problems of RL. Thus, a study concerning a robust RL design is a scientifically fascinating aspect to look into and study more deeply.

Four, the implementation of RL and CE by combining both systems using a specific method optimistically can produce an effective RL operations system that can provide a longer life system for RL. A combined and interconnected research area between RL and CE is envisaged so that it will produce several useful findings and solve problems that relate to both areas.

Five, the specific case, which is PR options, was chosen as the research case. It is expected that the implementation will be more applicable and realistic. The reason why PR options was chosen as a research case, in which the framework is implemented, is because the PR options are the main activities in RL operations; they are critical in the daily activity of practical RL.

1.3 Research Aim and Objectives

This research aims to **develop a framework to design reverse logistics operations based on circular economy**. To achieve the research aim, the objectives are to:

1. Formalise an RL design framework. The framework is prepared as a guide in designing RL operations and will be provided in different stages.
2. Reformulate the CE principles. Providing readily available principles in a format/structure that can be used for specific implementation.
3. Embed CE in RL operations. The existing cases will be taken as PR options.
4. Formulate mathematical formulation in the embedding process for quantitative analysis.
5. Test the framework to design RL based on CE. This is conducted through confirming the quality of the framework to general industrial practitioners.
6. Validate the research results to evaluate trustworthiness.

The objectives above describe structurally the research direction. Fundamentally, the first and second objectives can be conducted in parallel or separately. However, objectives 1 and 2 are prerequisites for objective 3. Objective 4 is a part of embedding process which is continuing process of objective 3. Objective 5 must wait for the previous ones to be created. The validation will be conducted after finishing the objective first until fifth.

1.4 Scope of Research

This research mainly focuses on the CE and RL concept. The scoping is done based on comparing some other related concepts, such as supply chain management (SCM) and logistics. Through comparing all concepts, the research focus can be decided; it also considers the literature review. The relationship between SCM and logistics has been described by some researchers, such as Stock and Lambert (2001), Christopher (2011), who asserted that logistics is part of the supply chain components. In logistics theory, the RL position was always described, for instance by Johnson et al. (1999) and Stock and Lambert (2001), whereas CE was defined by some researchers from an environmental, economic perspective (Kneese et al., 1970; Ekins, 1989; Pearce and Turner, 1990) in the industrial economy (EMF, 2013). The detailed scoping is illustrated in Figure 1.1. RL and CE relate to each other directly. They are the main concern of the research (bounded by dotted line – box). They will interact to achieve the aim of the research which produces a framework to design RL based on CE. In addition, the RL itself is part of logistics and the larger area supply chain management (SCM); that if it was configured in more detail then, essentially it can be derived to RL operations, PR options, and PR activities.

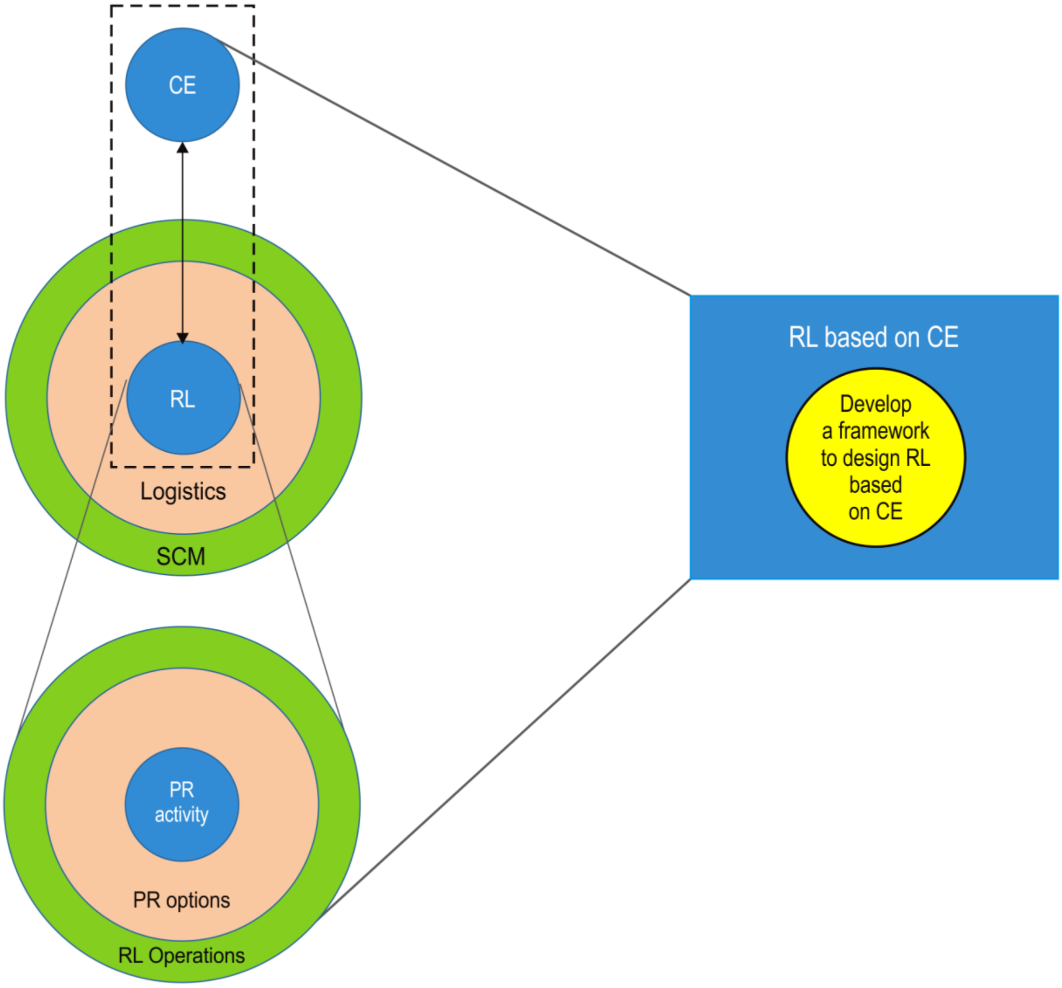

Figure 1.1 – Scope of research

1.5 Organisation of the Thesis

The thesis is organised into eight chapters each consisting of several sections, as illustrated in Figure 1.2. It is divided into four parts; the first boxes (Chapters 1, 2, and 3) indicate the design research programme that will be done first; the second boxes (Chapters 4, 5, and 6) illustrate the results that will be produced through different methods, for instance literature reviewing, synthesising, cases; the third box (Chapter 7) depicts the evaluation process of research through a testing; the fourth box (Chapters 8) show the research conclusions by describing the important parts of each point within the research that can be discussed and concluded.

Each chapter is described in turn in this section so that the understanding of the research is comprehensive from the introduction viewpoint. The explanation starts with Chapter 2, which will describe the extensive literature that focuses on the research's main concepts and other related concepts. Chapter 2 will not only illustrate the theory but also the relation between each concept that can depict the state of the art. This chapter will formulate justification for research.

Chapter 3 will construct the research outline that can direct the researcher to achieve the research aim and objectives. It will produce a research design that leads the technical and non-technical research activities. Chapter 4 is the first implementation of the first objective; it will produce a step-by-step RL design method. Chapter 5 will provide the CE principles, including the definition for each value. It will also produce the configuration of CE.

Chapter 6 produces some stages to implement CE values into RL cases for PR and provides some examples. Chapter 7 is the testing stage in which the research results will be tested through interviewing several industrial practitioners and validated through trustworthiness evaluation. This chapter will also provide the recommendations. Chapter 8 establishes the discussion space for all the objectives' achievements and concludes with all research activities, findings, contributions, and also suggestions for further research.

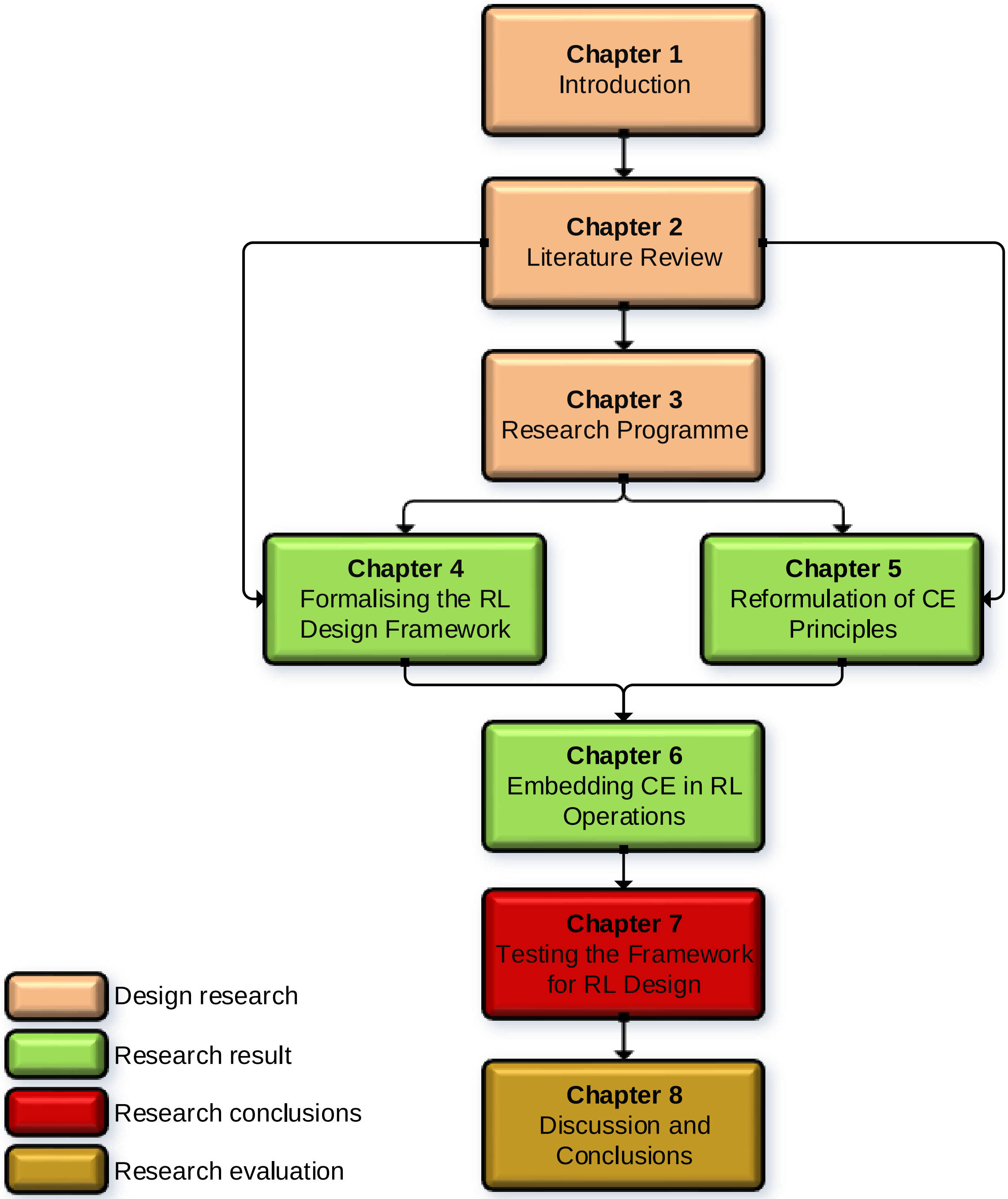

Figure 1.2 – Organisation of the thesis

1.6 Summary

This research is conducted for several reasons related to both background and motivation. The complexity of RL management, the lack of a formal design of RL method, and the usefulness of a combination of both concepts are the main arguments used to conduct the research. The purpose of the research is to produce a method for designing RL based on CE values. To achieve the purpose, six objectives were prepared. The scope of the research depicted the interaction of research components that the research can be figured clearly. It also illustrated how RL relates to CE and other concepts for achieving the research aim. The organisation of the thesis has described each chapter and how they interact. The thesis consists of nine chapters that can be divided into four main parts: planning of research design, results, evaluation, and conclusions.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The purpose of this chapter is to exhibit the state of the art of the theories that are used in this research, for instance RL and CE, and other theories surrounding them, e.g. logistics. A literature review was conducted to acquire an understanding of the concepts that can correlate one theory with another, map the need for research, find gaps, and make justifications for the research.

The research focuses on designing an RL operations framework based on CE values. The topic's purpose is to support users (e.g. company, scientist, or others) in designing RL through a formal framework that can be used a guide in the designing process of RL. The framework that will be proposed will embed CE into RL.

The constructing of a literature review is started by describing the logistics concept, followed by RL definitions, activities, and design. In the next section CE and its principles will be explained. At the end of the literature review, the relationship between both concepts are revealed. Those concepts and the relationships between them need to be analysed to identify the research gap.

Through conducting the activities mentioned above, some conclusions are made. For example, based on the literature, there is a relationship between the RL and CE concepts. Some conclusions will produce other findings which can be identified as the gaps in knowledge and formulated as research justification.

2.2 Search Strategy

An extensive Literature review was conducted by preparing some relevant keywords and sources to run the search strategy process effectively. Phrases related to reverse logistics and circular economy were prepared such as “reverse logistics AND product recovery”, “reverse logistics AND circular economy” by using some search engine databases (Google scholar, Scopus, and EBSCO). The detailed searching results are illustrated in Table 2.1 where, there are 3,236 journals and 1,584 conference papers found. Furthermore, other sources for instance books entitled *Strategic Physical Distribution Management* (Lambert and Stock, 1987), *Going Backwards: Reverse Logistics Trends and Practices* (Rogers and Tibben-Lembke, 1999), and *A New Dynamic Effective Business in a Circular Economy* (Webster et al., 2013) were also used.

Table 2.1 – Literature review search strategy

No	Database	Search string	Result	
			Journal	Conference paper
1	Google Scholar	Reverse Logistics	624	391
		Reverse Logistics AND Product Return	1	1
		Reverse Logistics AND Product Recovery	6	1
		Reverse Logistics AND Design	65	50
		Circular economy	602	138
		Circular economy AND Principle	3	0
		Reverse Logistics AND Circular economy	4	7
2	Scopus	Reverse Logistics	572	595
		Reverse Logistics AND Product Return	2	5
		Reverse Logistics AND Product Recovery	7	7
		Reverse Logistics AND Design	84	75
		Circular economy	167	266
		Circular economy AND Principle	18	40
		Reverse Logistics AND Circular economy	0	8
3	EBSCO	Reverse Logistics	747	-
		Reverse Logistics AND Product Return	3	-
		Reverse Logistics AND Product Recovery	7	-
		Reverse Logistics AND Design	77	-
		Circular economy	241	-
		Circular economy AND Principle	5	-
		Reverse Logistics AND Circular economy	1	-
Total			3236	1584

The relevant keywords searching in the Table 2.1 was done without limiting the year of the publication. Each keyword represents each the title of the papers. For reverse logistics keyword, the result that was produced through three databases above shows approximately 600 journals in average. It means that the publication in this area is not too extensive. It is likewise for circular economy, the result averagely 300s articles. Nevertheless, the combination of those strings, for instance “reverse logistics AND product return” or “circular economy AND principle”, shows findings less than the average results.

The selection process of the result above (Table 2.1) was done by filtering the relevant title and then continuing to the checking of the abstract. The selected papers were then reread more deeply. There were 70, 22, and 7 papers reviewed for keywords associated to reverse logistics, circular economy, and reverse logistics and circular economy, respectively. The relevant contents were cited to support the construction of the research in the literature review sides. The literature review construction process was constructed initially based on the two main concepts, which are RL and CE. In RL, the broader concept needs to be looked at, such as logistics, to see the position of the RL itself. RL definition, activities, characteristics, and design are the most important aspects to establish research justification. Additionally, collecting some RL issues are also needed to identify the extent to which RL research has been done.

In CE, the literature review constructing was started from exploring the understanding of CE through searching the definition, activities, characteristics, principles, and case studies. Furthermore, in the relationship between RL and CE was obtained through reviewing result of RL and CE concepts, and the relationship between RL and CE itself. The number of articles that exactly describe the relationship between RL and CE were limited. In addition, the papers reviewed have been used, besides to acquire the understanding of those concepts, also to find the research gaps that can contribute to the knowledge clearly.

2.3 Logistics

Logistics is explained in many ways, such as business logistics, physical distribution, material management, distribution engineering, logistics management, and SCM (Johnson et al.,1999). Comparing the various terms of logistics, the most familiar term is logistics management (Langley Jr, 1986; Lambert and Stock, 1993).

In attempting to find a logistics management definition, it is necessary to understand logistics itself. Logistics started to be defined in military use (Lummus et al., 2001). According to the Dictionary of Modern War (Luttwak, 1971), logistics is defined as follows: "*Since in modern conditions a wide range of equipment and supplies is employed in widely varied "mixes", logistics involves a great deal of planning and calculation as well as physical activities. The aim is to provide each echelon of the armed forces organization with the optimum quantity of each supply item, in order to minimize both overstocking… and shortages of essential equipment*".

In the context of business, Cavinato (1982) describes logistics as an integrated process of inbound/outbound products, where logistics handles some activities on a functional basis, e.g. purchasing, transportation and storage. Logistics can be applied to pre-production, in-production, and post-production channels; additionally, physical distribution only applies to the post-production channel. The Council of Logistics Management (CLM, 1989) defines logistics as "*the process of planning, implementing, and controlling the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements*".

Logistics is also understood in SCM. There are four perspectives to describe the correlations: traditionalist, which indicates SCM as being a part of logistics; relabelling, which describes how logistics is the same as SCM; unionist, which means logistics are a part of SCM; inter-sectionist, which indicates logistics and SCM are intersected (Larson and Halldorsson, 2004). In the supply chain system, logistics was described by Krumwiede and Sheu (2002), as consisting of forward and reverse logistics; similarly, Thierry et al. (1995) illustrated the integrated supply chain as being divided into forward and reverse flows. Forward logistics was defined as the flow of material in the normal movement from raw material to finished goods that are eventually received by customers (Krumwiede and Sheu, 2002).

In addition, forward and reverse flows were described to have different activities significantly one another, even though they can work in synergy manner (Fleischmann et al., 2000). Tibben-Lembke and Rogers (2002) also compared forward and reverse logistics, and found that between them, they have a significant difference in terms of information flow. Furthermore, El-Sayed et al. (2010) illustrated the direction of forward logistics encompasses suppliers, facilities, distributors, and customers entities, while reverse logistics flow has disassembly, disposal, redistribution, and second customer entities.

2.4 Reverse Logistics (RL)

RL is part of the logistics area, which is a focus of this research. Thus the definition of RL needs to be mapped well. The understanding of RL itself is robust. Indeed, this research has identified its definition from several researchers, such as in the 1980s, Murphy (1986), Lambert and Stock (1987) and Murphy and Poist (1989). They defined RL as a converse movement flow within a channel distribution. They focused on the flow of movement of product from the reverse side. However, in the 1990s other researchers (e.g. Stock, 1992, 1998; Kopicki et al., 1993; Carter and Ellram, 1998; Rogers and Tibben-Lembke, 1999) not only described the reverse side, but also explained the activities within the flow, such as recycling, reusing, disposing, etc.

Table 2.2 identifies some RL definitions from which it can be concluded that RL theoretically is discussing the management action, logistics activities/roles (Kopicki et al., 1993; Stock, 1998; Rogers and Tibben-Lembke, 1999), recovery/reuse activities (Stock, 1992; Kopicki et al., 1993; Carter and Ellram, 1998), distribution channel (Murphy, 1986; Murphy and Poist, 1989), recapturing values (Rogers and Tibben-Lembke, 1999), reverse flow (Murphy, 1986; Lambert and Stock, 1987; Murphy and Poist, 1989), and also cost (Rogers and Tibben-Lembke, 1999).

Table 2.2 – Identification of the definitions of reverse logistics

Reference	Definition of RL
Lambert and Stock (1987)	"Going the wrong way on a one-way street because the great majority of product shipments flow in one direction."
Murphy (1986); Murphy and Poist (1989)	"Movement of goods from a consumer towards a producer in a channel of distribution."
Stock (1992)	''… the term often used to the role of logistics in recycling, waste disposal and management of hazardous materials; a broader perspective includes all issues relating to logistics activities carried out in source reduction, recycling, substitution, reuse of materials and disposal.''
Kopicki 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."
Stock (1998)	"The role of logistics in product returns, source reduction, recycling, materials substitution, reuse of materials, waste disposal and refurbishing, repair, and remanufacturing."
Carter and Ellram (1998)	"The process whereby companies can become more environmentally efficient through recycling, reusing, and reducing the amount of materials used."
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."

In addition, based on the highlighted key points in the definition above, researchers such as Govindan et al., 2012; Ravi and Shankar, 2005; Horvath et al., 2005; Tibben-Lembke, 2001; Ravi and Shankar, 2005; Lu and Bostel, 2007; Du and Evans, 2008; Meade and Sarkis, 2002; Daugherty et al., 2005; Lambert et al., 2011 respectively supported the management action of logistics functions, recovery/reuse activities, distribution channel, recapturing values, reverse flow, and cost.

On the other hand, product return, the common term within RL, needs to be defined clearly to avoid confusion between them. Returned product, as defined by Guide et al. (2003), is a product that is returned for refund by a customer, because it has not fulfilled their needs or standards. The process of product return was described by Blackburn et al. (2004) as starting from the process of recovering value, until reuse or resale. They stated that there are five key processes within the return process:

product acquisition, receiving returned product from customer; *reverse logistics*, transporting for assessment; *inspection and disposition*, assessing and deciding the quality of product; *remanufacturing or refurbishing*, recovering the product to its original condition; and *marketing*, selling recovered product. Logically, product return is an activity that is started from when the customer returns the product, new or used, for any reason. The product will be treated according to the quality of the product; it might be directed to reuse, repair, refurbish, etc. In addition, Rogers and Tibben-Lembke (1999) and Tibben-Lembke and Rogers (2002) described the area of RL that covers the processing of returned product for reasons such as damage, unwanted, etc. Guide and van Wassenhove (2001) also explained the return of used products as being the basic input to a reuse option, where there are two methods to acquire used product in a product return – waste stream and market-driven system.

2.4.1 Reverse Logistics Activities

The activities of RL need to be identified, according to the RL definitions so that the process of identification can be started. As concluded from the RL definitions above, RL focuses on several points such as reuse, recovery, recycle, and disposal. Based on those points, other researchers also described RL activities, such as Thierry et al. (1995) who illustrated the reverse flow in the integrated supply chain, and Krumwiede and Sheu (2002) who depicted the basic RL activities. The RL activities from both of them are depicted in Figures 2.1 and 2.2. Figure 2.1 shows the reverse flow that has three main parts: direct reuse, product recovery management (PRM), and waste management (WM). Its process can be started from users returning their product until the processing as raw material. In addition, Figure 2.2 depicts activities involved in reverse flow. Within reverse flow, there are several activities involved, e.g. test, repair, refurbishing, service, disassembly, where the flow is initiated by sending used product from customers to become raw material. Comparing both figures, fundamentally, they illustrate similar activities. The detailed RL activities will be described further based on Figure 2.1, in the following sections.

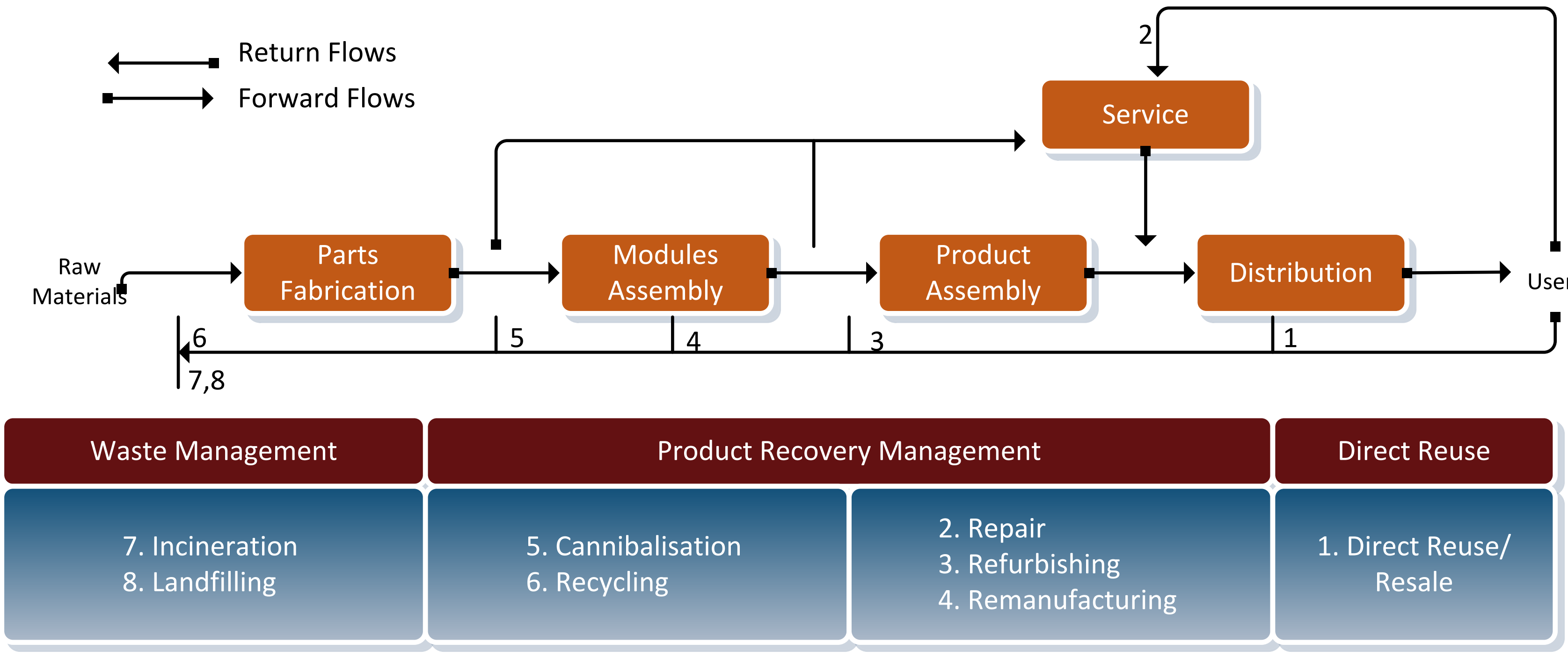

Figure 2.1 - Integrated supply chain (Thierry et al., 1995)

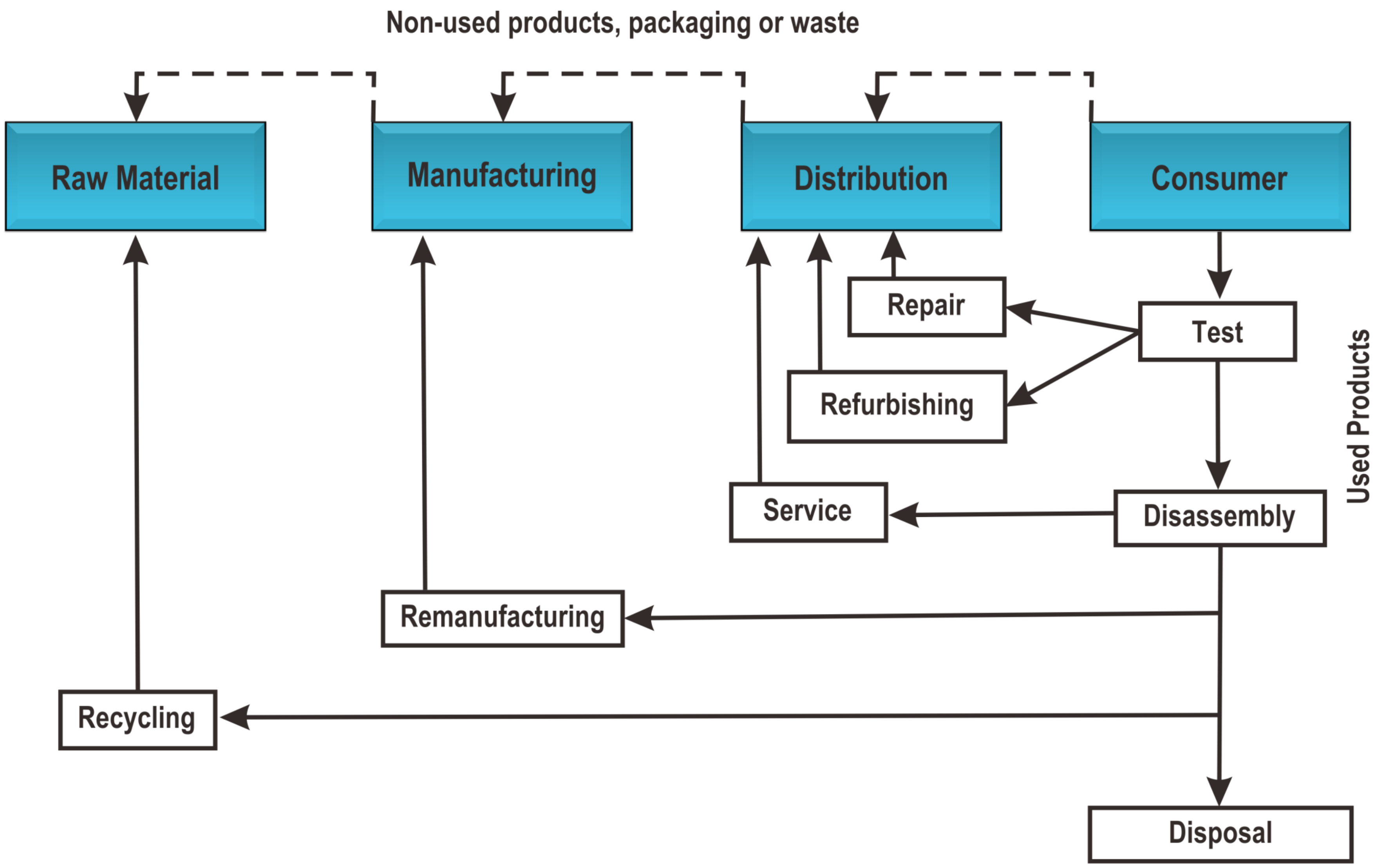

Figure 2.2 - Basic flow diagram of reverse logistics activities (Krumwiede and Sheu, 2002)

A. Direct Reuse

Some researchers have described direct reuse as one of components or activities in RL; for instance, Kopicki et al. (1993) communicated it as the use of product or component parts without changing their form and passing through the remanufacturing process. Thierry et al. (1995) also illustrated it as the first alternative before other activities to recover the return product, for instance repair, refurbishment, etc. In addition, Fleischmann et al. (1997) described how the returned product is possible to be reused without a product process as it might be able to be cleaned or have a small repair. Hazen et al. (2011) explained it as being an alternative to unused product from the customer who returns the product to the purchasing outlet or retailer. The product is possible to be inserted into the supply chain.

B. Product Recovery Management (PRM)

PRM was illustrated by Thierry et al. (1995) who described it as the management of used and discarded products/components/materials where the objectives are to recover economically and ecologically maximum retained value. Thierry et al. (1995) divided PRM into five options (Table 2.3): repair, refurbishment, remanufacturing, cannibalisation, and recycling. Each activity has requirements to describe it. The requirements are level of disassembly, quality requirement, and resulting product.

Furthermore, Klausner et al. (1998) expressed that the strategic PR activities encompass repair, refurbishment, remanufacturing, reusing, recycling, and disposal. Those activities are similar to those of Thierry et al. (1995) illustrated above. Fleischmann et al. (2000) described some processes in the PR chain where there are two directions (forward and reverse flow). The process is started from supply, production, and distribution in which a product can be used, and the reverse flow process can be started from a used product that can be collected, selected, reprocessed, redistributed until the product can be reused, or the choice is made to dispose of it. Guide et al. (2003) emphasized that PR refers to the parts and materials in the returned product that possibly can be recovered.

Table 2.3 – Comparison of product recovery options (Thierry et al., 1995)

PRM Activity	Level of Disassembly	Quality Requirement	Resulting Product
Repair	To product level	Restore product to working order.	Some parts fixed or replaced by spares.
Refurbishment	To module level	Inspect all critical modules and upgrade to specified quality level.	Some modules repaired, replaced; potential upgrade.
Remanufacturing	To part level	Inspect all modules and parts and upgrade to 'as new' quality.	Used and new modules/parts combined into new product; potential upgrade.
Cannibalisation	Selective retrieval of parts	Depends on process in which parts are reused.	Some parts reused; remaining product recycled/disposed.
Recycling	To material level	High for production of original parts; less for other parts.	Materials reused to produce new parts.

The detailed activities of PR can be divided into the following:

1. Repair

The repair activity was discussed by some researchers, such as Blumberg (1999) who described the reverse logistics and repair service (RLRS) market. The explaination is the functions within the RL and repair process as being storage and warehousing, collection and sorting, substitution, transportation and distribution, disposal, depot repair and remanufacturing, and recertification. Blumberg (1999) also illustrated the repair activity, where the process could be started from end users that recover their EoL product, and how the recovery process depends on the quality of EoL product, whether the product needs repair, refurbish, or disposal. Guide et al. (2003) described some considerations when undertaking repairs, such as cost, lifetime, and warranty. Similarly to Guide et al. (2003), King et al. (2006) explained that repairing is a minor correction when the product is still under warranty.

2. Refurbish

Some researchers who focused their research on refurbishment gave its definition and requirement. Thierry et al. (1995) illustrated refurbishing as a recovery level where some modules are possible to repair and replace, and also to have a potential upgrade. White and Naghibi (1998) explained that the requirements of a refurbishment product are when the product can fulfil the manufacturing standard; this is in line with Vorasayan and Ryan (2006) who described refurbishment as a product that has been undertaken and verified by the manufacturer, and can function as a new product.

Research this area also were conducted by for instance Piplani et al. (2007), they focused on optimizing the repair and refurbish network, where the purpose of the research was to decide facility locations and product flow to support a repair network for faulty products and refurbishing network for commercial returns. Zikopoulos and Tagaras (2007) conducted a research that concerned the impact of the uncertain quality refurbishment of used product returns.

3. Remanufacturing

Remanufacturing was identified as the process of restoring used products to become new products using several steps, e.g. refurbish and clean to obtain the same as, or better quality, i.e. up to a new product standard (Lund, 1983). Furthermore, the type of remanufacturers were then identified to provide a clear process within manufacturing, i.e. they are the *original equipment manufacturer/remanufacturer*, where the remanufacturing process will be done by the company that produces their own product; *contracted remanufacturer*, a company that has a contract to remanufacture a certain product on behalf of a company; *independent remanufacturer,* the remanufacturing process is performed with a limited or without a contract with the original equipment manufacturer (OEM) (Lund, 1983; Jacobsson, 2000; Sundin and Bras, 2005; ERN, 2016).

Steinhilper (1999) explained that the remanufacturing process depends on the type and functionality of the product. He divided the process into five steps for mechanical systems: *disassembling,* including sorting the parts that cannot be reused or remanufactured; *cleaning,* degreasing, deoiling and derusting; *classifying* according to the ability to be remanufactured or reconditioned (reusable without reconditioning, reusable after reconditioning, not reusable/to be exchanged); *reconditioning* or exchanging worn parts; *reassembling*. Freiberger (2007) illustrated the remanufacturing process for mechatronic and electronic products which has six steps: diagnosis, disassembly, cleaning, inspection and sorting, reconditioning and/or replenishment, and reassembly. In addition, ERN (2016) depicted the general remanufacturing process as documentation, collection, inspection, disassembly, component remediation, replacement, reassembly, testing, and warranty.

Östlin et al. (2008) and ERN (2016) identify the types of used product in remanufacturing. They are *ownership-based*: where the product is operated by the customer, even if the owner is the manufacturer; *service contract-based*: the relationship is based on a contract between manufacturer and customer; *direct-order-based*: the customer can possibly return the used product for remanufacture and can take the same product back; *deposit-based*: the customer can return a similar used product; c*redit-based*: the customer can receive a discount when they are buying a remanufactured product when they return a used product; *buy-back-based*: the remanufacturer buys the wanted used product from a supplier; and *voluntary-based*: the supplier provides a used product to the remanufacturer.

In addition, Kim et al. (2006) proposed a general framework and a mathematical model for a remanufacturing system in an RL environment. They illustrated the remanufacturing system, describing the process from when the customer sends the returned product to the collection site. The collection site is like a pool of returned products that are then sent to a disassembly site or remanufacturing subcontractor. In the disassembly site, the product is assessed and considered before going to a refurbishing site to be refurbished to become a new part and sent to a new part inventory. The other result of the process in disassembly sites is possibly waste that must be sent to a disposal site. Also, the product will become new parts after the process at the remanufacturing subcontractor, and sent to inventory. By adding several parts from external suppliers, all parts are sent to manufacturers. Demirel and Gökçen (2008) discussed the optimal values of the production and transportation of quantities of manufactured and remanufactured products, and Kizilboga et al. (2013) developed a remanufacturing process in an RL network.

4. Cannibalisation

Thierry et al. (1995) explained the process of product cannibalisation where they indicated it is a simple process in which less than 10% can be cannibalised in used product. Cannibalisation was defined by some researchers such as Copulsky (1976) as “the extent to which one product’s customers are gained at the expense of customers of other products offered by the same firm”; and Heskett (1976) explained it as “the process by which a new product gains sales by diverting them from an existing product”. Furthermore, Lomax et al. (1996) described the measurement of cannibalisation with three methods: gains loss analysis; duplication of purchase tables; and deviations from expected share movements. Cravens et al. (2002) also illustrated a framework for a proactive cannibalisation that responds to changing customer value in the process of building appropriate innovation strategies for the new competitive and technological environment. Those cannibalisation researches above are used in the marketing context, except for Thierry et al. (1995), who were concerned with PRM.

5. Recycling

Recycling was defined by Wiard and Sopko (1989) as the series of processes that involves collecting, sorting, decontaminating and returning waste material as a commodity. Recycling also can be seen as a process which is disassembling, shredding, incineration and landfilling (Gerner et al., 2005). In addition, Pohlen and Farris (1992) identified a number of municipal solid wastes where the identification focused on plastics recycling. They also illustrated the diversity of the recyclable material path from producer to end user. Several possibilities involved within recycling entities are: customer/industrial producer, material recovery facility, municipal pick up, broker, intermediate processor, and end user. Kroon and Vrijens (1995) conveyed a burden to the environment from one way packaging material, where they focused on returnable containers.

C. Waste Management

Thierry et al. (1995) divided WM in RL into two activities: incineration and landfilling. WM’s purpose is to conserve natural resources, and protect the environment using a sustainable development approach (El-Haggar, 2007). To achieve this purpose, suitable techniques, technologies, and a management programme need to be used (Tchobanoglous et al., 2002). Incineration is translated as a thermal treatment process of solid/liquid waste (El-Haggar, 2007), and landfilling is described as the physical facilities used for the disposal of solid waste and solid waste residuals into the surface soils of the earth (O’Leary and Tchobanoglous, 2002).

2.4.2 Reverse Logistics Characteristics

RL characteristics will be identified based on information surrounding RL definitions and activities. Murphy (1986), Lambert and Stock (1987), Murphy and Poist (1989) and Kopicki et al. (1993) all used a similar term for RL – it is a backward flow; the terms that they used such as wrong direction and movement of goods from customer to producer. In terms of RL activities, there are comparable activities; for instance they can be recycled, disposed of, refurbished, repaired and remanufactured (Stock, 1992, 1998; Thierry et al., 1995; Carter and Ellram, 1998; Krumwiede and Sheu, 2002); those activities are identified as characteristics of RL.

There are some features of RL that can be identified based on definitions or activities. Stock (1992) stated that RL typically constitutes recycling, waste disposal and management of hazardous materials. Kopicki et al. (1993) recognized that RL refers to logistics management and disposing of hazardous or non-hazardous waste from packaging and product. Features from RL activities encompass direct reuse, PRM and WM (Stock, 1992; Kopicki et al., 1993; Thierry et al., 1995; Rogers and Tibben-Lembke, 1999; Fleischmann, 2001a). Additionally, Rogers and Tibben-Lembke (1999) divided RL activities based on two types of material in the RL activity: product (return to supplier, resell, sell-via-outlet, salvage, recondition, refurbish, remanufacture, reclaim materials, recycle and landfill) and packaging (reuse, refurbish, reclaim materials, recycle, and salvage).

Other characteristics of RL are further explored by Murphy (1986), Murphy and Poist (1989), Pohlen and Farris (1992) who asserted that the RL characteristics are concerned with used products; backward flows; direct reused, recovered and disposed products (Kopicki et al., 1993; Thierry et al., 1995; Rogers and Tibben-Lembke, 1999; Fleischmann, 2001a); and product return (Stock, 1992). Tibben-Lembke and Rogers (2002) defined some characteristics of RL by comparing forward and reverse logistics in the retail environment (Table 2.4). As can be seen in Table 2.4 RL has specific characteristics, such as more difficulty in forecasting, and the product quality is not similar. Those specific characteristics support the statement regarding the complexity of RL.

Table 2.4 - Differences between forward and reverse logistics (Tibben-Lembke and Rogers, 2002)

Forward	Reverse
Forecasting relatively straightforward	Forecasting more difficult
One to many transportation	Many to one transportation
Product quality uniform	Product quality not uniform
Product packaging uniform	Product packaging often damaged
Destination/routing clear	Destination/routine unclear
Standardized channel	Exception driven
Disposition options clear	Disposition not clear
Pricing relatively uniform	Pricing dependent on many factors
Importance of speed recognized	Speed often not considered a priority
Forward distribution costs closely monitored by accounting systems	Reverse costs less directly visible
Inventory management consistent	Inventory management not consistent
Product lifecycle manageable	Product lifecycle issues more complex
Negotiation between parties straightforward	Negotiation complicated
Marketing methods well-known	Marketing complicated
Real-time information readily available	Visibility of process less transparent

In addition, other identification is found by looking at the work of some researchers. Murphy (1986) and Murphy and Poist (1989) have been concerned with the movement of product from customer to producer. Indirectly Thierry et al. (1995) and Krumwiede and Sheu (2002) described a similar flow. They explained product delivery as being where the product has been delivered by producer to customer. This means the context of a product in RL is a product that has passed the delivery process. Rogers and Tibben-Lembke (1999) conveyed management actions, such as planning, implementing and controlling; this means such management actions are also taken into account in RL as part of company management. Stock (1992, 1998), Carter and Ellram (1998) highlighted product return; source reduction; substitution; and reuse of material reduction. And Stock (1992, 1998), Kopicky et al. (1993), Rogers and Tibben-Lembke (1999), revealed that RL relates to logistics management.

2.4.3 Identification of Reverse Logistics Issues

RL has been described as a broad concept and complex to be managed (Meyer, 1999; Tibben-Lembke and Rogers, 2002). Identification of RL issues can inform the type of RL research implementations that have been done. The research was undertaken randomly; it will compare one with another. Firstly, for RL in the recycling activity, Pohlen and Farris (1992) focused on RL for plastic recycling. They described how RL is not similar to forward logistics flows where RL flows, especially in recycling, have their own activities such as collection, transportation, and the remanufacturing of the material process. Barros et al. (1998) focused on recycling issues as well, especially for construction waste, i.e. sand. They produced a recycling network. According to both these researches, the recycling activity has been implemented for different products and in its implementation as well. Regarding the RL flow in recycling, the activities within the flow are different *(*Pohlen and Farris, 1992); this is similar to Tibben-Lembke and Rogers' (2002) findings as already explained.

Other RL implementations have also been provided by researchers, e.g. Kroon and Vrijens (1995) described reusing returnable containers. They asserted that the returnable container is one of the attempts made in RL activities. Wang et al. (1995*)* highlighted the importance of transportation in material recovery management, specifically the WM system. Autry et al. (2001) were concerned with RL performance and satisfaction, where their implementation is effected by size/sales volume, and industry, respectively, in the electronics industry. Minner (2001) combined the supply chain and RL, specifically safety stock planning, and RL activities such as return and reuse. Realff et al. (2004) described the appraising uncertainty both of collected and price of product in the reverse production system. Salema et al. (2007) focused on a recovery distribution network that considered the capacity, multi-product management, and uncertainty of demand and return. Bai and Sarkis (2013) described the determination and management of third party RL providers. The broad implementation in RL can therefore be seen, for instance Kroon and Vrijens (1995), Autry et al. (2001). Realff et al. (2004) focused on various products such as returnable containers, the electronics industry, and carpets. Those researches also asserted the broad area and complexity of RL (Lambert and Stock, 1993; Meyer, 1999; Tibben-Lembke and Rogers, 2002).

2.5 Reverse Logistics Design

There are several researchers who have described the RL design e.g. Amini et al. (2005), Dowlatshahi (2010a, b), and Pochampally and Gupta (2012). Amini et al.

(2005) focused on the service management activities specifically for repair. The effectiveness and profitability increase through minimising total capital and operational cost is the decision results. Dowlatshahi (2010a) concerned on return process of products or parts related to cost-benefit. Dowlatshahi (2010b) focused on the transportation system in RL operations where he identified sub-system, proposition, and the effectiveness of framework of transportation system. Pochampally and Gupta (2012) described that the term design in RL is similar with strategic planning where the design can address some crucial issues surrounding it such as selection a collection centre effectively, and evaluation of repairing EoL product.

The logistics design network is described as a relationship among suppliers, production, distribution centres and the channels between them and customers in an efficient manner (Pishvaee et al., 2009). Fleischmann (2001b) illustrated the RL network structure (Figure 2.3) in two parts which are convergent (linked from individual sources process to recovery facility), and divergent (linked from recovery facility to individual customer). Daaboul et al. (2014) described some characteristics in designing an RL network: integration of environmental consideration; company facilities (collection, remanufacturing facility); and recovery route of sources.

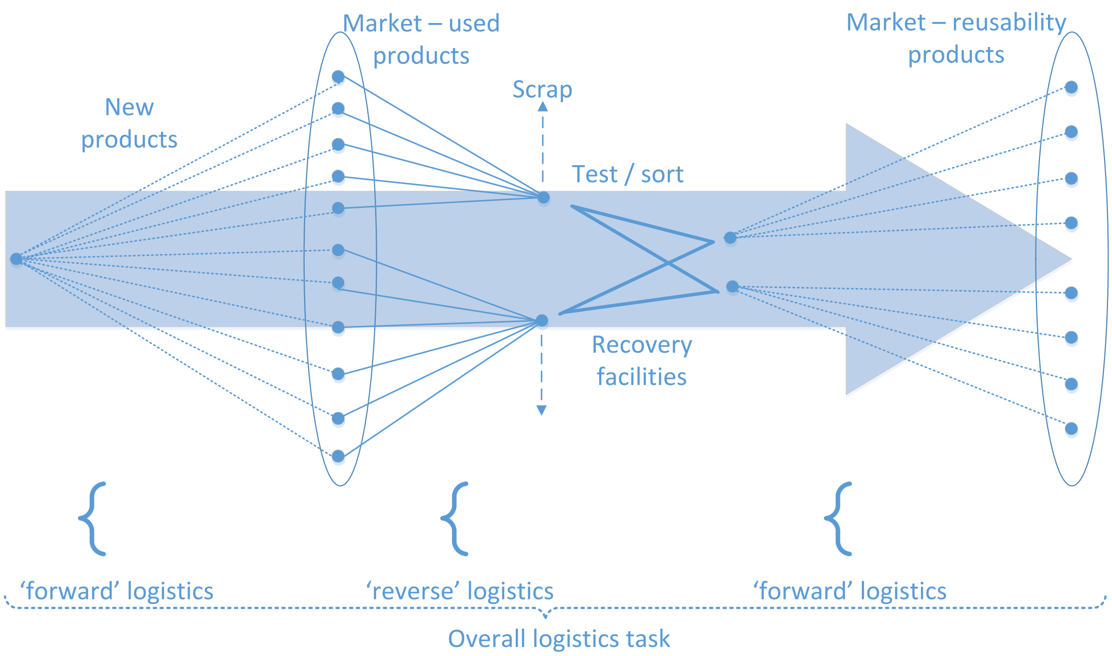

Figure 2.3 - Reverse logistics network structure (Fleischmann, 2001b)

Researchers who focused on the RL network are Bostel et al. (2005) and Srivastava (2008); both of them have a similar focus on designing a logistics network for optimising a facility that considers environmental and economic efficiency. Bostel et al. (2005) added an integrated logistics system framework (Figure 2.4) which consists of forward and reverse flow. It also engages supplier, production, distribution, and customer as the entities, by undertaking several activities: collection, intermediate-processing, recovery, and material recycling. The detailed process of designing RL is also described by Bostel et al. (2005); it illustrates designing steps, including identifying the actors, identifying the relationship, identifying the recovery option, applying economic and ecological evaluation, and identifying the entities/activities involved. Daaboul et al. (2014) describe how there are five steps in designing an RL network: context definition, parameter definition, scenario definition, modelling and assessment of the identified RL scenario, and analysis of assessment results/definition of the best RL scenario.

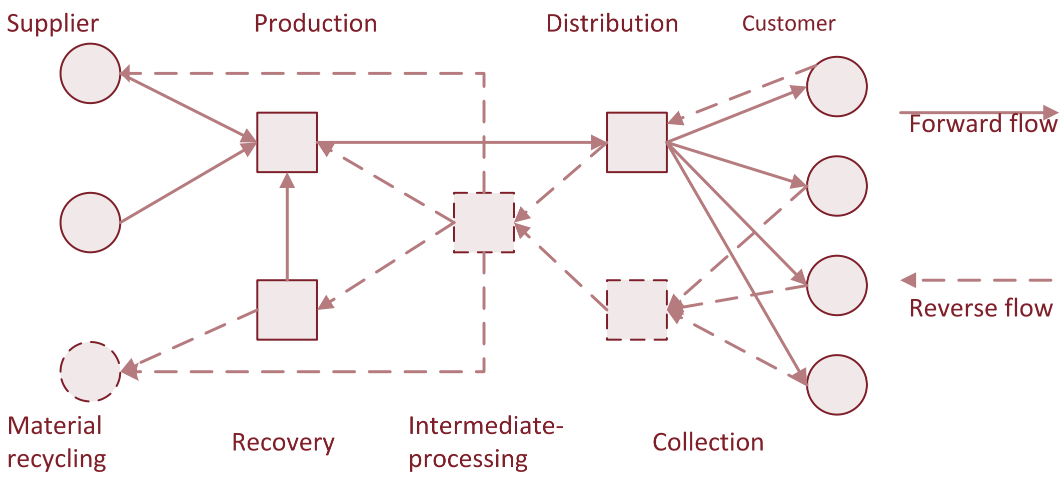

Figure 2.4 – Framework of an integrated logistics systems (Bostel et al., 2005)

2.6 Circular Economy (CE)

CE is a term used by some researchers such as Leontief (1928), Boulding (1966), Kneese et al. (1970), and Stahel and Reday-Mullvey (1981). However, the CE term was also raised by Ekins (1989) and Pearce and Turner (1990). Wassily Leontief wrote his thesis entitled “The Economy as a Circular Flow”. He explained the causal relationships between individual elements and economic processes. There are two basic components in production; they are costs and returns that correspond to input and output (Leontief, 1928).

Kneese et al. (1970) mentioned CE from an environmental economic perspective based on a material balance principle that all material flows can be accounted for; however, it will be the economic values, not the physical flows that guide their management. Stahel and Reday-Mullvey (1981) described CE as an economy in loops, and the four impacts were job creation, economic competitiveness, resource savings, and waste prevention. Ekins (1989) explained the CE model from an economist and general public point of view but this was still relevant to other models. It depicted the life-processes of living systems that were derived from the countryside with which his research was concerned. The model illustrated in Figure 2.5 has the objectives of minimum production of wastes, renewing of renewable resources, sparing use of non-renewable resources, and production growth within these constraints.

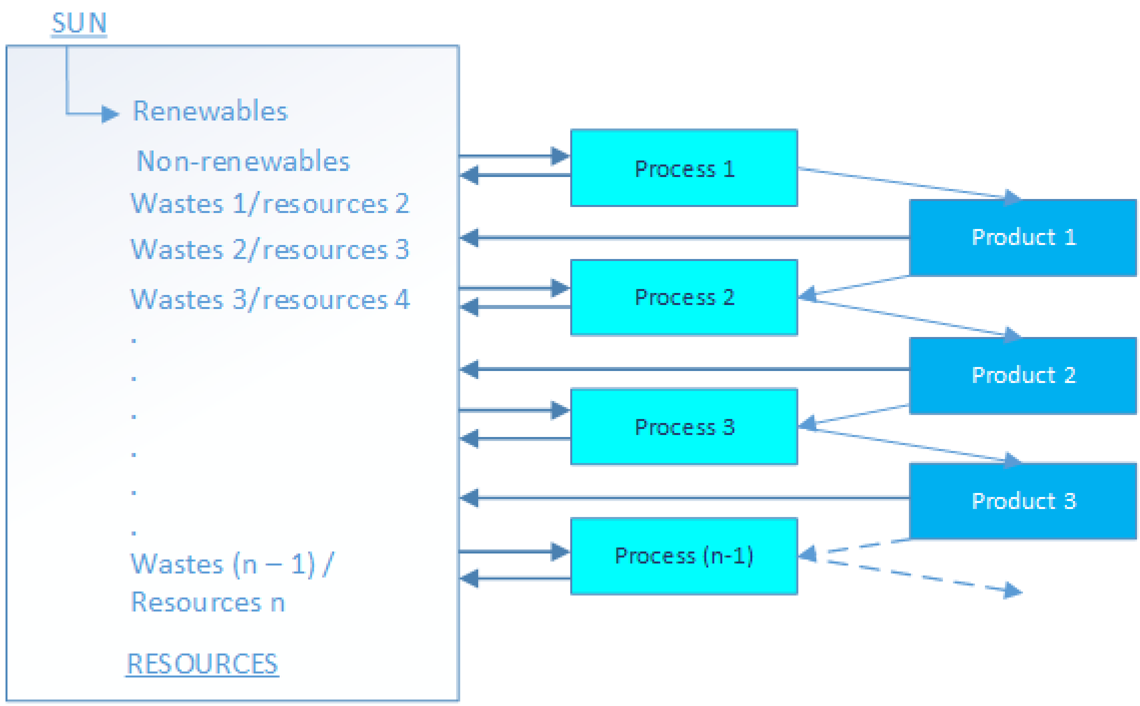

Figure 2.5 - Circular economy model (Ekins, 1989)

Pearce and Turner (1990) divided the CE into four functions: amenity values, a resource base for the economy, a sink for residual flows, and a life support system.

These are illustrated in Figure 2.6, where the CE is depicted as a flow of various entities, namely P (production), C (consumption), K (capital goods), U (utility), R (natural resources), r (recycling), W (waste), ER (exhaustible resources), RR (recyclable resources), A (assimilative capacity), h (harvest) and y (yield).

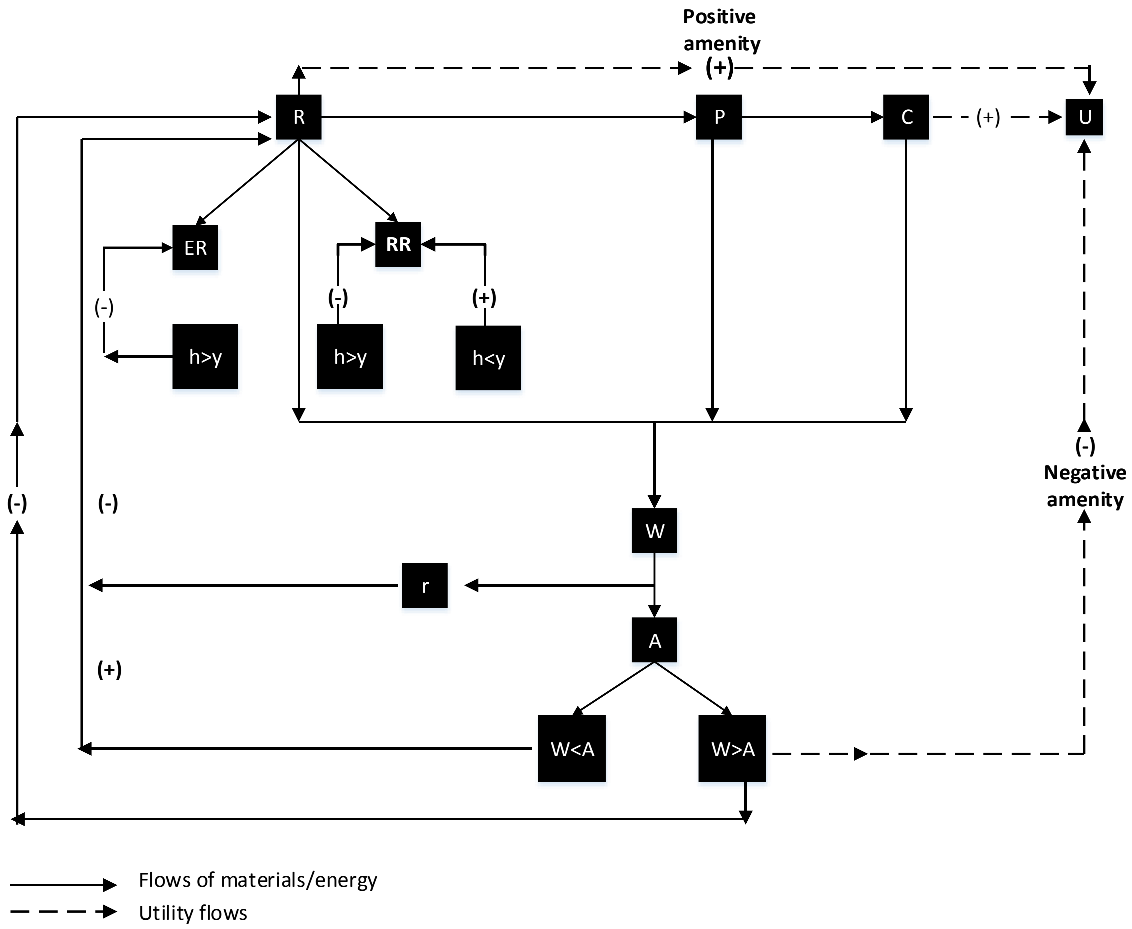

Figure 2.6 - The circular economy (Pearce and Turner, 1990)

In addition, Hu et al. (2011) described CE in the industrial and economic system as needing to collaborate with all the components involved, including stakeholders and energy flow management so that they can minimise use of the finite resources and energy input. To increase circularity of resource flows, these are switching to longer-lasting products, modularisation and remanufacturing, component reuse, and designing products using less material (Alwood et al., 2011). Preston (2012) interpreted CE as the redesigning of global production and consumption systems which are a combination of environmental, resources, technology, and consumer demand. Furthermore, IMSA (2013) highlighted the importance of CE that focuses on the bio cycle and techno cycle; system thinking and inspiration from nature; collaboration and partnership; and reduction in the need for virgin raw material.

Recently, the Ellen MacArthur Foundation (EMF) actively conducted CE activities. Some technical reports from those activities also provided a definition. Principally, CE is defined as a global economic model to minimise the consumption of finite resources that focuses on the intelligent design of materials, product, and systems (EMF, 2013). It also supports the separation of treatments between technical and biological materials in maximising the design for reuse to return to the biosphere and retain value through innovations across fields (Lacy and Rutqvist, 2015; Webster, 2015). EMF (2015) described the CE in an industrial system which is depicted as a system that has biological nutrients and technical nutrients process (Figure 2.7).

On the other hand, China is one of countries that has incorporated the CE into the government as a new development strategy since 2002 (Yuan et al., 2006). CE is defined by China's National Development and Reform Commission as "CE may be interlinked manufacturing and service businesses seeking the enhancement of economy and environmental performance through collaboration in managing environmental and resource issues. The theme of the CE concept is the exchange of materials where one facility's waste, including energy, water, materials - as well as information - is another facility's input" (Pintér, 2006).

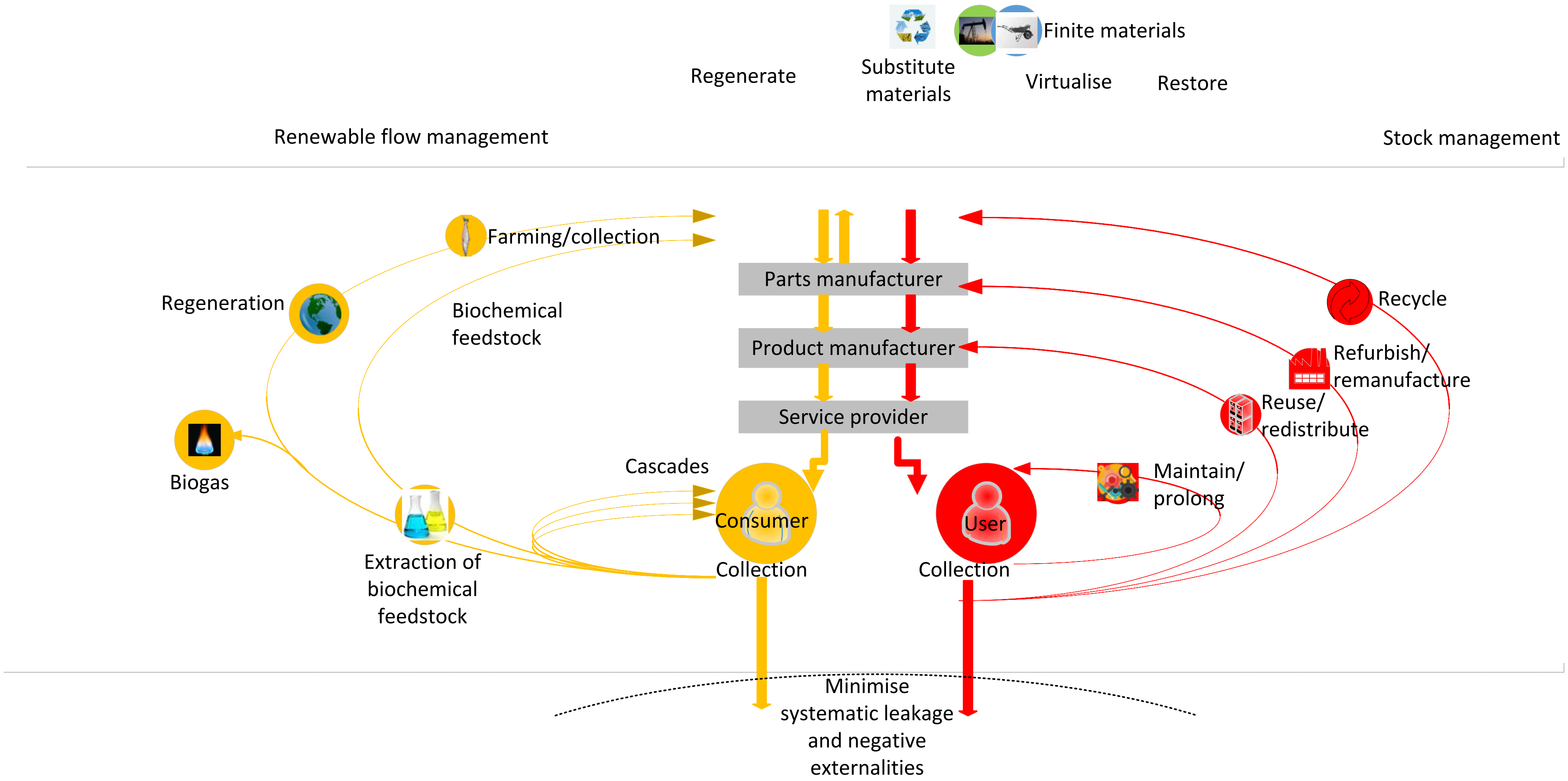

Figure 2.7 – Outline of circular economy (EMF, 2015)

Several researchers have studied CE as a case study in China, such as Yong (2007), Geng et al. (2012), and Ma et al. (2014). Yong (2007) described how China has three levels of CE: enterprises, eco-industrial parks, and regions. Yong (2007) also distinguished between the CE implementation in developed and developing countries. Germany started to implement CE with "the waste economy" that was supported by reduce, reuse, and recycle, where China was implementing CE for mitigating the amount of industrial pollution and consumption of resources and energy in the production area. Geng et al. (2012) evaluated the benefits and challenges of the indicator system of CE. They highlighted that the indicators might be integrated to the methodology for decision making to achieve the goals of the CE effectively, whereas the indicators have some positive benefits, such as benchmarking, improvement of environmental performance at multiple levels, identification of problem areas, cost-benefit analyses, policy direction, business investment decisions, and many other applications. Ma et al. (2014) examined the CE in the Wu'an Iron and Steel Group, where the result is positive where the CE was implemented, which can provide some improvements in resource consumption, and environmental quality. Even so, there are still some problems such as the upgrading process of product.

2.7 Circular Economy Principles

The Oxford English dictionary defines a 'principle' as "*a fundamental truth or proposition that serves as the foundation for a system of belief or behaviour, or for a chain of reasoning*". The principles of the CE can therefore be interpreted as fundamental truths of CE that represent its behaviour for the purpose of further analysis or reasoning. Although these truths of the CE are not often explicitly discussed in academic literature, five principles of CE have so far been widely publicised by the EMF in many of their reports, for instance EMF (2013). These principles include: *1)design out waste*, meaning that when a product is designed, the designer needs to consider the biological or technical material cycle that can be reprocessed; *2) build resilience through diversity*, meaning that there is a need to build a system resilience covering several aspects within CE; *3) work towards using energy from renewable sources*, meaning that energy usage per unit of output needs to be reduced and the shift to renewable energy needs to be accelerated by design, and treated in the economy as a valuable resource; *4) think in system*, meaning a set of components or objects that interact with each other to achieve the goals in real-world, non-linear, feedback-rich systems, particularly living systems; and *5) think in cascades*, meaning that maximisation of the retained value of product can contribute optimally before going back to the biosphere or continuing loops. Later on, the EMF updated their views on CE principles by simplifying them into three (EMF, 2015), each of which addresses different challenges that the industrial economy faces. The principles are: *1)control finite resources and balance renewable resource flows*; *2)circulate products, components and materials at the highest utility at all times*; and *3) design out waste*.

Other researchers considered the principles of CE from different perspectives and the processes incorporated within it. Yong (2007), for instance, considered reduce, reuse, and recycle (the 3Rs) as the three guiding principles on how to implement CE. Clearly, the use of resources and energy in production has to be reduced, products should be used for as long as possible, and EoL products should, as much as possible, be converted into new resources. Yuan et al. (2006) asserted that the core of CE is the loop of materials and energy, continuously circulating in multiple steps, through what Feng (2004) in Yuan et al. (2006) cited to describe the three possible practices of CE, which are the 3Rs principles, i.e. reduce, reuse and recycle of materials and energy. Geng et al. (2012) considered CE as *an accounting system* in an economy, where inputs of a process (extractions + imports) are equal its outputs (consumptions + exports + accumulation + wastes). Therefore, many CE measures have been derived from this fundamental principle of the *mass balances,* with material flow analysis and accounting being used as an input-output analysis mechanism (Pintér, 2006). Stahel (2013) argued that CE is about economics, although it is characterised by five governing principles that are not exhibited in traditional economics. These principles are *1) the smaller the loop, the more profitable and resource efficient it is*, *2) loops have no beginning and no end*, *3) the speed of the circular flows is crucial*, *4) continued ownership is cost efficient*, and *5) CE needs a functioning market*.

Despite the generality and perceived ease of understanding, the above principles are purposely put forward to elaborate the fundamental truths, and arguably, it is what they were meant to be used for, i.e. to conceptually deliberate the CE. The truths, however, do not seem to sufficiently reflect the operationalisation of the CE, especially in describing the low level activities, such as PRM. As it stands, the above principles have also not been elaborated in such a way that they can be readily used in the operationalisation of particular cases. It is therefore believed that without further denominating or deriving of these high level principles into the lower level tenets or values that correspond to the measurable benefits from CE implementation, those principles would indeed remain conceptual, as they are inherently elaborated from where they originated and thus how those principles are claimed. Therefore, there remains a compelling need to reformulate the principles and operationalise them at the right level and to derive those principles into lower level values and, if necessary, the design process parameters.

2.8 Relationship between Circular Economy and Reverse Logistics

At the beginning of this chapter the logistics concept has been described as an integrated material and product moving process from within and out of a firm (Johnson et al., 1999). It was also correlated to SCM (Larson and Halldorsson, 2004). Krumwiede and Shue (2002) divided logistics into forward and reverse logistics. On the other hand, CE has been described as an industrial economy concept that handles technical and biological material within the circulation (EMF, 2013). CE strives to maximise the “design for use” (Lacy and Rutqvist, 2015; Webster, 2015).

RL and CE have similarities in activities. EMF (2013) illustrated some CE activities such as maintenance, collection, repair, refurbishment, remanufacturing, recycling, etc., while RL also has been illustrated by direct reuse/resale, repair, refurbishment, remanufacturing, cannibalisation, recycling, etc. (Thierry et al., 1995). RL’s purpose is to produce an efficient and effective process of planning, implementing, and controlling the flow of material to recapture the values of proper disposal (Rogers and Tibben-Lembke, 1999). The CE purpose is to keep products in their highest utility and value in the circulation by distinguishing between biological and technical materials (EMF, 2013).

The relationship between CE and RL has also been described by researchers such as Xiangru and Wei (2009), Chen and Chen (2010), Ripanti et al. (2015, 2016). Xiangru and Wei (2009) described that CE based on RL can provide some positive impacts, such as developing a cycle of economy, contributing to RL efficiency, specifically in electronic enterprises. Chen and Chen (2010), asserted that RL has an important role in the CE development through implementing the CE principles (reduce, reuse, and recycling), especially in the circular process that can keep the material flow at a low cost. Ripanti et al. (2015, 2016) explained how CE and RL have a strong link through the implementation of CE principles in refurbishment, and remanufacturing activities.

2.9 Justification for Research

The literature review was conducted to find the fundamental understanding of this research. The literature reviews also highlighted some research gaps. The main research area of this research is RL and CE. In the RL area, some issues are raised, such as more complex to be managed than forward logistics (e.g. Rosen, 2001; Tibben-Lembke and Rogers, 2002; Amini et al., 2005); uncertainty involved, e.g. the quality range of products, timing of product returns, and volume of returns (Flapper, 1995; Guide et al., 2000); efficiency and effectiveness of flow of product from point of consumption to the point of origin (Rogers and Tibben-Lembke, 1999). In addition, Rogers and Tibben-Lembke (2001) surveyed where the results showed that an RL system has not been implemented yet, or in other words, some companies have not implemented it well. To increase the efficiency and effectiveness of RL operations, managing the uncertainty involved and implementing an RL system properly surely need to be done, where the literature review focused on the RL design. In fact, literature that discussed RL design is scarce. The most frequently result in the RL design searching was directed to RL network design (e.g. Fleischmann, 2001b; Bostel et al., 2005; Salema et al., 2007; Mutha and Pokharel, 2009; Pishvaee et al., 2009; Daaboul et al., 2014). Indeed, RL design and RL network design are different. RL design might exist in the literature but informally. The formal RL design method is required to be constructed to be a guide for RL operations and to produce effective and efficient RL.

CE principles need to be reformulated into a format that can be implemented for specific purposes, such as in RL specifically in PR. Researchers have declared the CE principles, for instance Pintér (2006), Yuan et al. (2006), Yong (2007), Geng et al. (2012), EMF (2013, 2015), Stahel (2013), and Pan et al. (2015). However, they described the CE principles at a greatly conceptual level, and were not implementing them in RL operations, specifically PR options cases. In addition, by conducting the literature review for both concepts, the relationships between them through similar activities were found, such as collecting, maintaining, reusing, recovering, recycling, and disposing. There were researchers who tried to describe the relationship between RL and CE (Xiangru and Wei, 2009; Chen and Chen, 2010); however, they have not been described in the operational implementation yet as an integrated RL based CE. The potential of RL and CE is high. RL focuses on the effectiveness of logistics, reuse/recovery flow, cost, and recapturing values of the retained product, while CE focuses on keeping the material longer in circulation to obtain the highest utility and values. A method to design RL based on CE values strongly needs to be proposed, even though there is little evidence in the literature to develop an RL based CE method.

The literature review results show that there is a crucial need to conduct this research due to reasons as follows:

- RL design framework is the first formal framework to design RL that can increase effectiveness and efficiency of RL operations. Formal RL design framework is also required to design other applications such as RL network design.
- Reformulation CE principles are necessary as the existing CE principles are formulated differently with the different understanding. The principles were described at the strategic level. The CE principles also are not described in the specific purposes such as RL.
- The implementation CE into RL or conversely is still rare that the embedding process that is described in this research can be a guide to applying both concepts.
- There are some researchers that described RL design method or framework (e.g. Amini et al., 2005; Dowlatshahi, 2010). However, they are not discussing the RL design framework. Even less, a framework to design RL based on CE.

2.10 Summary

A literature review is a starting point of the research activity; through conducting a review, it will open up, understand, provide, and reveal some opportunities to continue this research. This chapter consists of three main parts: describing the RL, the CE, and the relationship between them. Each part attempted to describe the theoretical framework until state of the art that can justify for the research. The literature search strategy by using search engine databases and others sources have been adopted to obtain the comprehensive result. The searching results showed that research publications for both concepts are not extensive, especially CE. In RL, some issues surrounding it were revealed, such as the uncertainty involved of the quality of product return, the formal RL design framework was described in the limited manner. CE principles have been discussed by researchers in the strategic level. RL and CE literature review revealed that both concepts have a relationship. Those aspects are reason to develop a framework for designing RL based on CE.

CHAPTER 3

RESEARCH PROGRAMME

The research programme describes how this research was designed through research methodology and methods. Each of them was constructed based on research context, paradigm, and design. Those are a basis to justify research methodology, and method in this research.

3.1 Research Methodology

3.1.1 Research Context

The area of this research is RL that is combined with CE. The combination of those areas represents the relationship between them. This research is focused on RL and CE specifically to formalise an RL design framework and reformulate CE values. A framework to design RL based on CE values is proposed to increase the effectiveness of RL operations through CE as an implementation stage for both areas.

3.1.2 Philosophical Paradigm of Research

A research paradigm is defined as "a set of beliefs about the world and about gaining knowledge that go together to guide the actions as to how to go to do research" (Wilson, 2001). A worldview term is also used to represent the paradigm. It was defined as "a basic set of beliefs that guide action" (Guba, 1990). Theoretically, the philosophical worldview was divided into four worldviews (Creswell, 2009): post positivism, constructivism, advocacy/participatory, and pragmatism, as depicted in Table 3.1.

Table 3.1 – Worldviews (Creswell, 2009)

Worldviews	
Post-positivism	**Constructivism**
• Determination • Reductionism • Empirical observation and measurement • Theory verification	• Understanding • Multiple participant meanings • Social and historical construction • Theory generation
Advocacy/Participatory	**Pragmatism**
• Political • Empowerment issue-oriented • Collaborative • Change-oriented	• Consequences of actions • Problem-centred • Pluralistic • Real-world practice oriented

3.1.3 Research Design

Cresswell (2009) illustrated that research design consists of three main components; philosophical worldviews, selected strategies of inquiry, and research methods. Research design itself can be categorised into qualitative, quantitative, and mixed methods. Qualitative research is "an approach to social science research that emphasizes collecting descriptive data in natural settings, uses inductive thinking, and emphasizes understanding the subject's point of view" (Bogdan and Biklen, 2007); quantitative research is described as focused on quantification in the collecting and analysing data process (Bryman, 2001); and mixed method is combining quantitative and qualitative forms with the philosophical assumption from both approaches (Creswell and Clark, 2007). Saunders et al. (2012) also grouped research design based on exploratory and conclusive research. They defined research design as a general research plan that can be directed to answer research questions. Exploratory is exploring process of research where the results are not the final answer. Differently from conclusive research, it is a research that is usually used for quantitative technique that provides numerical results (Nargundkar, 2008).

In addition, Bryman (2001) used the term 'research strategy' to distinguish between quantitative and qualitative research. He described qualitative and quantitative research based on theory and research roles (deductive and inductive), epistemology, and ontology (Table 3.2).

Table 3.2 – Identification of quantitative and qualitative research (Bryman, 2001)

Fundamental differences between quantitative and qualitative		
	Quantitative	**Qualitative**
• Principle orientation towards the role of theory in relation to research	• Deductive; testing of theory	• Inductive; generation of theory
• Epistemological orientation	• Natural science model, in particular positivism	• Interpretivism
• Ontological orientation	• Objectivism	• Constructionism

Deductive here means that theory drives research and conversely with inductive. While epistemology is focused on the questions linked to "what is or should be" in specific knowledge in a discipline. Ontology is described as the nature of social entities (Bryman, 2001).

3.1.4 Research Methodology

The popular research methodology, or s*trategies of inquiry,* in qualitative research are ethnography, grounded theory, case study, phenomenological research, and narrative research. Ethnography is where a research focuses on the cultural community in its natural background. It is usually done over a long period (Creswell, 1994). Sharing cultural behaviours of communities/people, exploring insider perspectives, observing and learning about the community, not using additional data collection, preparing to change the central focus and detailed research questions, and prolonged data collection, are all features of ethnography (Robson, 2011). Grounded theory is a process of constructing a theory based on structural data (Denzin and Lincoln, 1994).

The case study is "an empirical enquiry that investigates a contemporary phenomenon (the "case") in depth and within its real world context especially when the boundaries between phenomenon and context may not be clearly evident" (Yin, 2014). Phenomenological research is described as a research that can be started from the perspective of hypotheses (Husserl, 1970). Furthermore, narrative research focuses on collecting the experience of personal and human dimensions which can be correlated between cultural context and individual experience (Connelly and Clandinin, 1990).

The qualitative research methodology was identified based on five types of methodology (grounded theory, case study, phenomenology, ethnography, and narrative), common paradigm and data collection (Table 3.3).

Table 3.3 - Identification of qualitative methodology (Adapted from Petty et al., 2012)

Methodology	**Common Paradigm**	**Common Data collection**
Grounded theory	• Positivist/post-positivist • Constructivist	• Interview • Observation • Documentary data
Case study	• Positivist/post-positivist • Interpretivist	• Interview • Observation • Documentary data
Phenomenology	• Positivist/post-positivist • Interpretivist	• Interview
Ethnography	• Positivist/post-positivist Interpretivist	• Interview • Observation
Narrative	• Positivist/post-positivist • Interpretivist	• Interview • Observation • Documentary data

In addition, Punch (2005) identified the characteristics of research methodology for case study and ethnography (see Table 3.4).

Table 3.4 - Identification of characteristics of research methodology (Adapted from Punch, 2005)

Case study
• Case has boundaries • Case is a research focus • Multiple sources and methods for collecting data
Ethnography
• Engaging a group of people • Needs to understand behaviour, event, actions surrounding the research focus • “Natural setting” • An unfolding of study • Fieldwork as necessary in the data collection • Prolonged and repetitive data collection

3.1.5 Research Method

Some research methods that have been illustrated by Creswell (2009), such as data collection, data analysis, and validation, are used in this research.

A. Data Collection

This section will describe some popular data collection methods, for instance literature review, interview, focus group, and document analysis, as follows:

1. Literature Review

This has some systematic processes and is defined as an activity to identify, classify, evaluate the existing documented work by researchers, scholars, and practitioners that is done systematically, clearly, and reproducibly (Fink, 1998). Hart (1998) also described the reasons to conduct a literature review: to distinguish what has been done and what needs to be done; discover important variables; synthesise and gain a new perspective; identify relationships between ideas and practices; establish the context of the topic or problem; rationalise the significance of the problem; enhance and acquire the subject vocabulary; understand the structure of the subject; relate ideas and theory to applications; identify the main methodologies and research techniques that have been used; and place the research in a historical context.

2. Interview

This requires eliciting perceptions, meanings, definitions, understanding of people in a certain situation through asking and questioning (Punch, 2005). Interviews can be grouped into the structured interview, which uses the same context of questioning; the semi-structured interview, which provides opportunities for the interviewer to ask further questions in response to significant feedback from the interviewee, even though it relates to a series of ready-made questions; the unstructured interview, the style of questioning is informal, it also usually only has an interview guide (Bryman, 2001).

3. Focus Group

This activity usually engages a group for discussing of a specific topic where the format can be structured, semi-structured, or unstructured (Petty et al., 2012). Robson and McCartan (2016) explained the advantages and disadvantages of the focus group method. The advantages are such as highly efficient, natural quality control, group dynamics, relatively inexpensive and flexible participants encouraged to provide comments, and no discrimination regarding participant limitation.

Disadvantages are limited questions, needs an expert facilitator, conflicts may arise, and difficulty in generalising the results.

4. Documentary analysis

This can include various sources, such as letters, magazines, photos, and other relevant documents that have the following criteria: readable, available, preserved, and relevant Bryman (2001). Documents can be from a wide range of sources, for instance personal, official, mass media output, and virtual output documents. Scott (1990) suggests filtering the quality of the documents for the following criteria: authenticity, credibility, representativeness, and meaning, which respectively mean genuine, free from error, evidence is typical, and clear.

B. Evaluation

In qualitative research, the quality can be evaluated by using two assessing criteria: trustworthiness and authenticity (Lincoln and Guba, 1985; Guba and Lincoln, 1994). Trustworthiness was developed from four criteria: credibility, transferability; dependability, confirmability, which are related to internal validity, external validity, reliability, and objectivity, respectively (Bryman, 2001), while authenticity was raised for broader issues, such as political concerns (Guba and Lincoln, 1994).

In fixed design research, trustworthiness considers validity and generalisability. In flexible design research, validity was described as accurate, correct, or true (Robson, 2011). There are threats to validity such as in description, interpretation, and theory (Maxwell, 1996) and bias and rigour issues, for instance reactivity, respondent and researcher bias (Robson, 2011). The strategies to minimise the threats to validity were described by Robson (2011) as:

1. Prolonged involvement, developing connection between respondent and researcher, understanding the culture, and spending time in the research setting.
2. Triangulation, adopting a wide range method of data collection.
3. Peer debriefing and support, involving researchers in the debriefing.
4. Member checking, obtaining feedback from presenting research results.
5. Negative case analysis, searching cases to elaborate the theory.
6. Audit trail, documenting all the research activities.

7. Research dissemination, involving actively in research publication that can provide the opportunities to refine the research.

3.2 Research Method Selection and Justification

This requires selecting and justifying the specific research design, approach and technique.

3.2.1 Selected Research Design: Exploratory

An exploratory research design was selected to undertake this research for several reasons, including the research aim and objectives, and research context. The first objective is to formalise the RL design method. Indeed, understanding and exploration were needed to construct the method. The result of a formal RL design method is that it is flexible and adaptable to be modified. It provides opportunities to lead, continue and modify the studies. Similarly to the first objective, reformulation of CE principles/values also need to be understood and explored. In fact, the existing CE principles have limited information regarding specific implementation in certain cases. The results from this finding do not provide a final conclusion. The CE embedded in RL operations became challenging as the implementation of CE in RL or RL in CE are only a few. The CE in RL embedding produced a framework to design RL based on CE, which is objective three. This might be a new study for both areas. For these reasons, an exploratory design was chosen for this research.

3.2.2 Selected Research Approach: Qualitative

A qualitative approach for this research is used for several reasons. Firstly, this research was conducted mainly through a desk-based research approach where the research started by analysing the literature review as a main source of information. However, some other sources were also used, such as videos, presentations, discussions, etc. to obtain an in-depth understanding of direction, topic and context. Those activities were used specifically for the first, second, and third objectives, while the fourth objective was covered by interviews. Those objectives were represented systematically using rich data to express the exploratory results through providing in-depth understanding. This research was also done based on words rather than numbers, even though one of steps in the method design of RL CE uses some mathematical formulations. It cannot claim to be a mixed method since the mathematical formulation was used only as an example to represent a specific condition.

3.2.3 Data Collection Technique: Literature Review and Interview

In the primary and secondary data collection, a literature review and interviews were conducted for this research. The literature review was used as a secondary data collection to find and assert the argumentation. However, those data were also used as a primary technique to investigate the phenomenon based on the literature specifically. The interviews were used as a secondary data collection as they were used to confirm and obtain practitioners' views. Turner (2010) described how the interview can support receiving detailed information from the experiences and views of respondents in specific cases. To conduct a robust quality interview, a pilot interview was conducted. It provided the opportunity for the researcher to improve the interview practice (Hill et al., 2005). The semi-structured interview format was adopted here, as it can provide the opportunity to explore respondents' knowledge while still preparing a clear interview guide (Wilson, 2013).

3.3 Research Methodology Development

The integrated research activities are described by research outline (Figure 10) which will direct the well organised research planning of the research. The research outline represents the detailed activities within this research. The outline encompasses the research background and can describe the argument regarding why the research needs to be conducted. The background was described in section 1.1; research motivation, which can be connected to the background that can be asserted by conducting a preliminary literature review; then formulating the aim and objectives will determine the research direction. Research motivation was shown in section 1.2.; research aim and objectives, which determine the research direction. Through this stage research objectives can be specifically correlated to the research methodology.

The research methodology will also produce a detailed stage/phase of research and support the next process of the research outline; based on the aim and objectives, the research scope will be constructed to limit the research area on which the research will focus. Research scope was illustrated in section 1.4; literature review, which needs to be conducted to find the state of the art that can support the next step, specifically discovering research gaps; research findings can be found through literature review results and/or research methodology; testing, this is needed to measure or confirm the validity of research results; conclusions, the conclusions are provided in detail to report the research activities, including providing the research findings and contribution. In addition, the research methodology in the research outlined has some specific stages that need to be described clearly as technically this research has specific sub-activities that have been formulated in the research objectives.

Based on the research outline (Figure 3.1), the research methodology was constructed (Figure 3.2) which is divided into two parts: research methodology and research method). Research methodology consists of four stages: formal RL design method, reformulate CE principles, embed CE in RL operations, and test the framework RL based on CE principles; these are discussed in detail below. Each stage has several activities. In addition, the research method describes the detail of the techniques required to conduct the research stage.

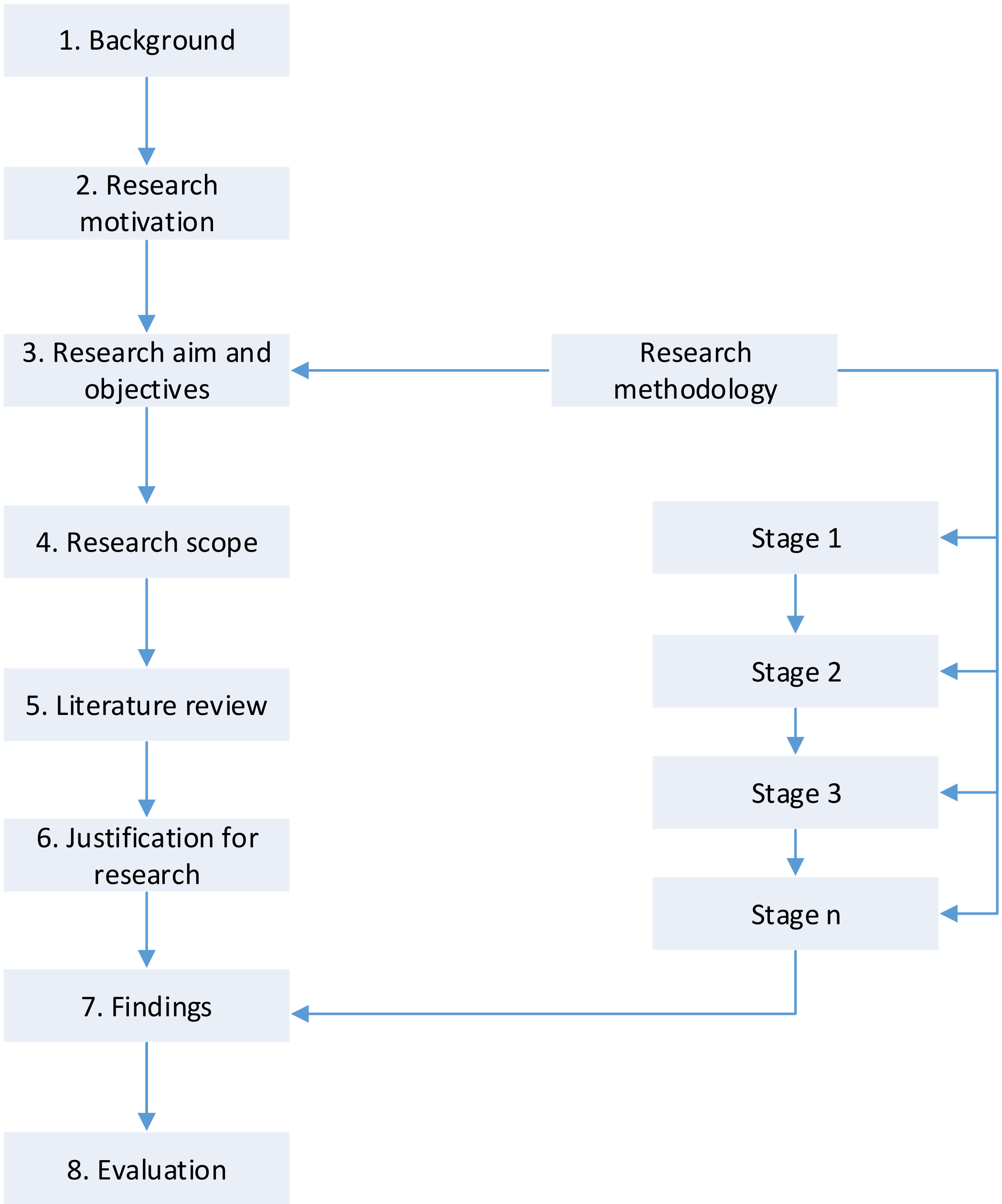

Figure 3.1 - Research outline

Stage 1: Formalise RL design method

This stage correlates with the first objective of the research; its purpose is to construct the RL design framework formally that will be a guide to design RL operations. An understanding of RL activities, RL flow, and effective RL operations is required, through having conducted the literature review. They are necessary to observe the ideal RL system and operations and through understanding them, synthesising can be done effectively. Through reviewing the literature and synthesising, an RL flow diagram was developed, where the RL flows and activities involved are illustrated clearly. In constructing the design of RL, exploring how RL was designed based on existing literature is necessary. Some keywords were used to do so, such as “reverse logistics design”, “reverse logistics network design” and “reverse logistics model”. Each keyword was used to identify the design process, parameter, and method that can be synthesised in the systematic stages of RL design. Those stages need to be analysed to consider the effectiveness and efficiency of flow logically and also based on implementing the process into some PR option examples. After obtaining a logical and robust process, the formal RL design method is depicted structurally.

Stage 2: Reformulate CE principles

This stage relates to the second objective of this research, where the intention is to provide the available CE principles that can be implemented for specific purposes. The stage was started by conducting a literature review. The CE purposes, activities, flows, characteristics, principles and the extent to which CE is implemented in the real world were sought in order to obtain a general CE understanding. Identifying the existing CE principles was expected to provide a representation of the whole CE. Based on the understanding of CE and CE principles through the literature review, the analysing, specifically the need for CE reformulation, was conducted. The analysing process was done by synthesising literature on both CE and CE principles.

Reformulation of CE principles was conducted by systematic literature review. It was defined as “identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest” (Kitchenham and Charters, 2007). The reformulation was started by collecting CE sources. Some keywords are provided, such as “circular economy”, “circular economy + principle”, and other relevant keywords such as “circular economy + repair”, and “circular economy + refurbishment” were included. The collecting produced many CE sources. A filtering processed is needed then to select the relevant content of sources for the research objective. The selected literature was analysed to find the main keywords that can describe the CE principles as a representation of CE. After producing keywords, the keywords were processed become CE themes. The themes will be initial CE principles. Based on the collected CE themes, there is correlation then between the themes and CE literature to provide the CE principles.

Furthermore, defining each CE principle based on the understanding of CE and the available CE literature is undertaken. The CE principles then need to be evaluated which was done by correlating and comparing one principle with another; the result of these processes is the regrouping/configuring of CE principles based on the level of the principle itself.

Stage 3: Embed CE principle in RL operation

This stage relates to the third research objective and aims to implement RL and CE through embedding CE principles in RL operations. The first and second stages produced results which are the formal RL design and CE principles respectively. Both results were synthesised to provide the systematic embedding process; the latter was done by inserting the CE values into a formal RL design method. Analysis of the embedding process is required to obtain a logical flow. The analysis used the existing examples to simulate the logic processes, while it was also correlated to the literature. The implementation was done by running some examples of PR options (repair, refurbishment, remanufacturing, and cannibalisation). Evaluation of the systematic embedding process was done by analysing the implementation results. And, refining or improving the process was undertaken during the previous processes by restructuring. Based on the evaluation result, a method to design RL based on CE values is finally proposed.

Stage 4: Formulate mathematical formulation in the embedding process for quantitative analysis

The fourth objective represents the mathematical formulation, the formulation will be constructed based on some parameters that have been identified in the embedding process. The specific PR activity and process in the certain PR options based on CE values are identified. The identification will produce some parameters, for example in the reconditioning process based on oriented to cascades/reverse cycle has such as a number of reconditioned products/parts parameter where the crucial decision is maximising reconditioned products/parts. Based on the decision and the available parameters the mathematical formulation will be formulated.

Stage 5: Test the RL framework based on CE principles

The fourth stage is linked to research objective four. This stage is utilised to validate the research results through confirming some key measurements. The validation was done by interviewing several respondents. The interview aims to test the framework and obtain experts' views. Firstly, interview instruments such as interview protocol, interview questions, and measurement keys (Platts, 1993; Harper, 1994; Krishnan and Kellner, 1999; Rubin and Chisnel, 2008) were developed; evaluation of the instruments was therefore required before conducting the interviews. The evaluation has been completed after discussions with expert and the supervisor. Interviews were initiated by first conducting the pilot interview with two respondents, while the main interviews involved four respondents and one expert. The respondents were selected based on criteria such as experience. The interview results were interpreted, coded, and analysed (Kvale, 2007; Creswell, 2009). Analysis of the interview results was undertaken based on some measurements. Each measurement for each respondent was analysed and then the complete set of interview results was reported comprehensively.

Stage 6: **Validate the research results to evaluate trustworthiness**

The research results need to validate. The sixth stage accommodates validation process. There are five strategies (triangulation, peer debriefing and support, member checking, audit trail, and research dissemination) will be conducted. The six stages are done step by step in each objective. However the comprehensive validation is concluded after finishing the whole objectives.

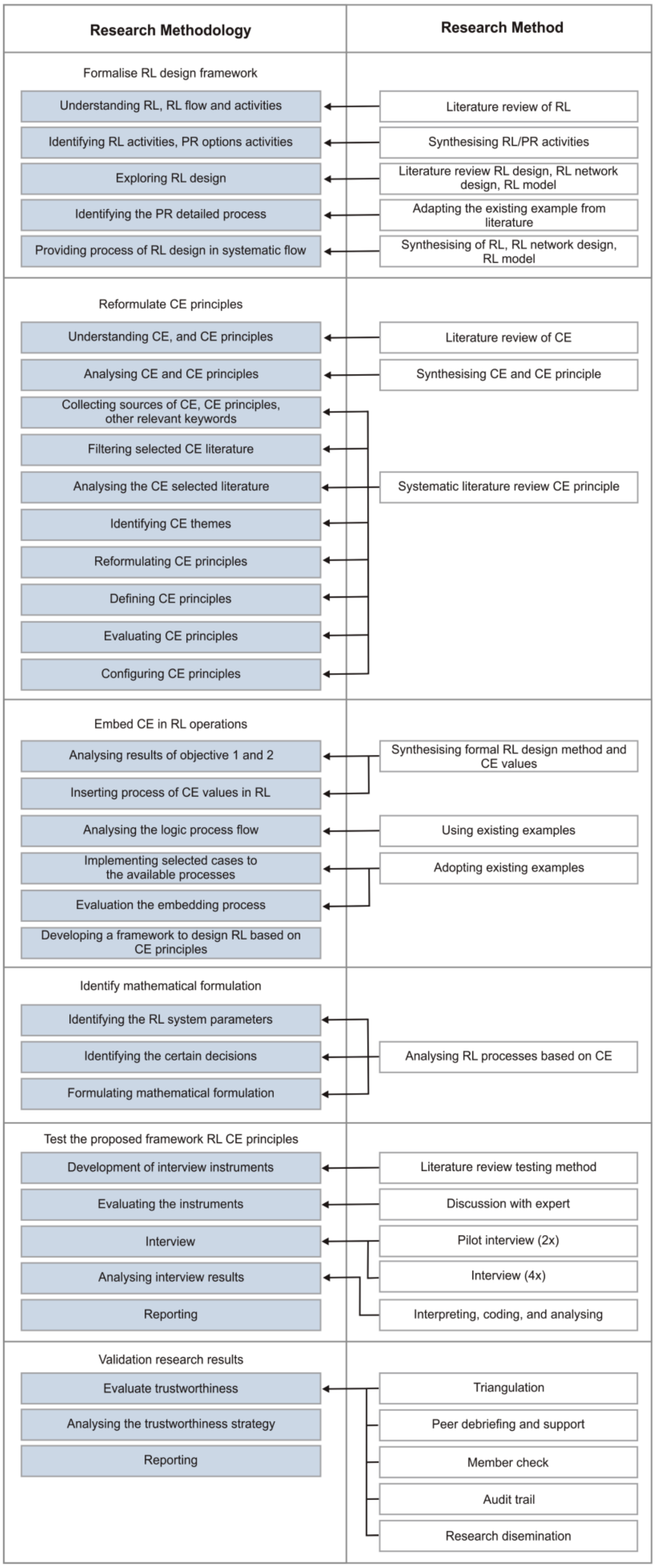

Figure 3.2 – Structure of research methodology

3.4 Summary

The research design was constructed to guide the research direction. This chapter provided a detailed explanation of each method that was adopted in this research. The explanation started by constructing the research method after considering the objective. Each part of the research method was then derived. The methods described were then used to design the specific approach required to achieve the aim of the research. Some methods, for instance the literature review, and interviews were described in detail.

The selected research method was justified after analysing and considering the research context, and aim and objectives. This research selected exploratory as the type of research design due to one the reason that the implementation of RL and CE is rare. The research approach is qualitative where this research provides narrative results dominantly. The research method is case study, and data collection is mainly coming from conducting the literature review and interview.

CHAPTER 4

FORMALISING THE REVERSE LOGISTICS DESIGN FRAMEWORK

4.1 Introduction

RL is more complex to be managed than forward logistics (Rosen, 2001; Tibben-Lembke and Rogers, 2002; Amini et al., 2005) which is one of reasons for designing a formal RL framework, besides the lack of research in providing such a framework. Most researchers have focused on the design of an RL network (Fleischmann, 2001b; Bostel et al., 2005; Srivastava, 2008; Pishvaee et al., 2009). A formal RL design framework is necessary to be formulated, as it is considered to provide a guide to designing an RL. By following a guide, a developer can have sufficient knowledge in the designing process so that it will be easier to modify or increase the effectiveness or efficiency of the RL operations. The RL design framework is a foundation from which to undertake other activities, such as designing an RL network, because the absence of a robust design quality will influence the quality of other activities surrounding RL. The formal RL design framework will be described in the further section. A logical link diagram (Figure 4.1) is constructed to provide the easier way to understand the development process of a formal RL design framework.

Figure 4.1 illustrates the detailed process of constructing a framework as an output of this chapter. The process was initiated from literature review result previously. It is continued specifically to collect the RL design sources with relevant keywords. The filtering process is needed to obtain the comprehensive understanding of RL design framework. In the process of constructing RL design framework, the general RL flows, activities, and entities need to be identified. Furthermore, the filtering relevant literature results are synthesised. It consists of design, RL design, RL network design, and RL model. The synthesising result of the RL design is implemented in some cases. Indeed, the cases are related to PR options (repair, refurbishment, remanufacturing, and cannibalisation). Based on the implementation result, it can be analysed, whether it needs to improve or no. Through some processes above a formal RL design framework constructed.

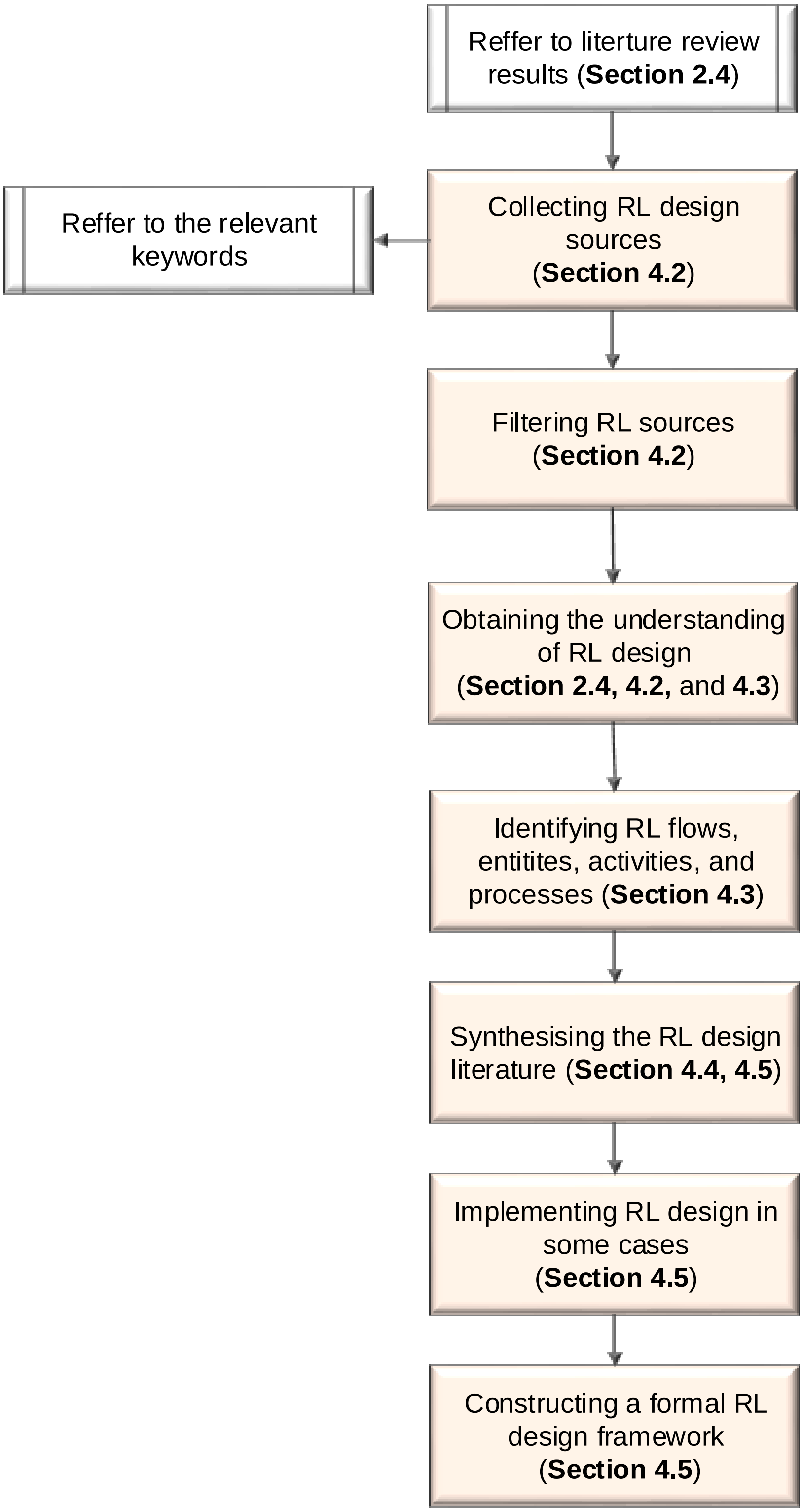

Figure 4.1 Logical link diagram of formalising the RL design framework

4.2 Framework for Formalising Reverse Logistics Design

Literature review is the main method in the process of formalising RL design framework. The process is started from collecting the sources related to reverse logistics design framework. Some relevant keywords are prepared (Table 4.1). The search strategy used search engine databases (Google scholar, Scopus, and EBSCO). Table 4.1 shows, by using the three strings that were found, the average result is less than 100 except for “reverse logistics AND model” in Google scholar and Scopus. The first string (Reverse logistics AND design) is applied to collect information regarding the design process of RL. Even though, the result showed approximately 80% related to RL network design. The second string (Reverse Logistics AND network design) was used to identify the design process of RL network design that might be adopted to formalise the RL design. The third string (reverse logistics AND model) can contribute to inform the ideal RL system through the proposed RL model.

Table 4.1 – Search string for formalising RL design method

No	**Database**	**Search string**	**Result**	
			Journal	**Conference paper**
1	Google Scholar	Reverse Logistics AND Design	88	54
		Reverse Logistics AND Network Design	64	41
		Reverse Logistics AND Model	118	65
2	Scopus	Reverse Logistics AND Design	84	75
		Reverse Logistics AND Network Design	69	55
		Reverse Logistics AND Model	106	110
3	EBSCO	Reverse Logistics AND Design	77	-
		Reverse Logistics AND Network Design	61	-
		Reverse Logistics AND Model	90	-
Total			757	400

Filtering process needs to be applied to the documents retrieved using the above search strings. The filtering of the relevant papers was done by reading the title, keywords, and abstract. The selection process showed some similar result papers specifically for “reverse logistics AND design” and “reverse logistics AND network design” strings. “Reverse logistics AND design” dominantly were resulting in reverse logistics network design. The result describes reverse logistics design in only less than around 20%. The selected papers were reviewed based on the relevant content, it describes the related process of RL design explicitly or implicitly.

Furthermore, “reverse logistics AND model” string was filtered randomly based on the previous strings needs, as the string was searched to find the ideal format of RL in a model. There are 42 selected papers reviewed in detail that can support the formalising process.

The formalising process, the identification of RL operations in general is needed where it describes the flow, activities, and entities of RL. The process can produce an RL design framework comprehensively. The RL operations and PR options will also be described before formalising the RL design framework.

4.3 Reverse Logistics Operations

The term ‘operations’ in RL has been commonly used by researchers (e.g. Krumwiede and Sheu, 2002; Amini et al., 2005; Meade and Sarkis, 2006; Min et al., 2006). It needs to define the exact intent of operations. Based on Dummies (2016) definition, operations is the processes and resources that are used to produce the highest quality of product and service result efficiently. Amini et al. (2005) described RL operations as covering product returns, repairs and refurbishment. Meade and Sarkis (2006) concluded from some literature (e.g. Pohlen and Farris, 1992; Rogers and Tibben-Lembke, 1999; Schwartz, 2000) that RL operations cover collection, packing, storage, sorting, transitional processing, and delivery activities.

In addition, term “integrated” in RL or supply chain also frequently emerges in the RL operations. Thierry et al. (1995) illustrated an integrated supply chain that covers reverse and forward flows. The term ‘integrated’ in this context describes both sides, i.e. forward and reverse flows, although there is still a relationship among some of the entities and processes of each side. Furthermore, an RL activities flow has been visualised by Krumwiede and Sheu (2002) in which they illustrated several activities such as test and disassembly, through to disposal activities, and that those activities are related to other entities, for instance consumer, distribution, manufacturing, and raw materials. Mainly through both the above researchers, an integrated RL flow is constructed (Figure 4.2).

Figure 4.2 depicts the RL operations by describing in detail the relationships between activities, entities and flow that are known holistically; each type of process will be considered for each option/activity within the RL operation. As can be seen, Figure 4.2 has components: RL activities (direct reuse/resale, repair, refurbishment, remanufacturing, cannibalisation, recycling, and disposing); forward entities (supplier, manufacturer, warehouse, distributor, and retailer); reverse entities (inventory, secondary market, WM); and information flow. The processes illustrate the options and conditions of the returned product that will be considered. The detailed flows of the process will go to the reverse entities, such as inventory and secondary market, after that the process can be continued to send the returned product to the forward entities such as manufacturer, warehouse, etc. Nevertheless, the forward entity can relate directly to the reverse flow, for instance the supplier. There are two important entities in Figure 4.2, which are inventory and secondary market. Inventory is needed to stock a “new product” after the recovery process, such as refurbishment (Kim et al., 2006), the secondary market is needed as a place to sell returned product from the customer (Tibben-Lembke, 2002).

The complete process of Figure 4.2 starts from when the customer returns the product, and whether its quality means it can be directly reused or resold, repaired, refurbished, remanufactured, recycled, or disposed. As the customer needs a place to send their returned product to, an entity that has a function to collect and assess the returned product is needed. It could collaborate with entities in the forward flow or create some entities that only focus on reverse flow. Figure 4.2 depicts that there is an entity that has a function as a collector – it is inventory. After the returned product has been treated based on its quality, the product can be sent directly to the customer if it fulfils direct reuse/resale requirements; if not, some specific treatments are required. The finished returned product can be sent to a secondary market, and also sent to the manufacturer; this will depend on the output quality options (repair, refurbish, remanufacture, or others). The returned product could also be sent to WM, if the product/component/part is unusable.

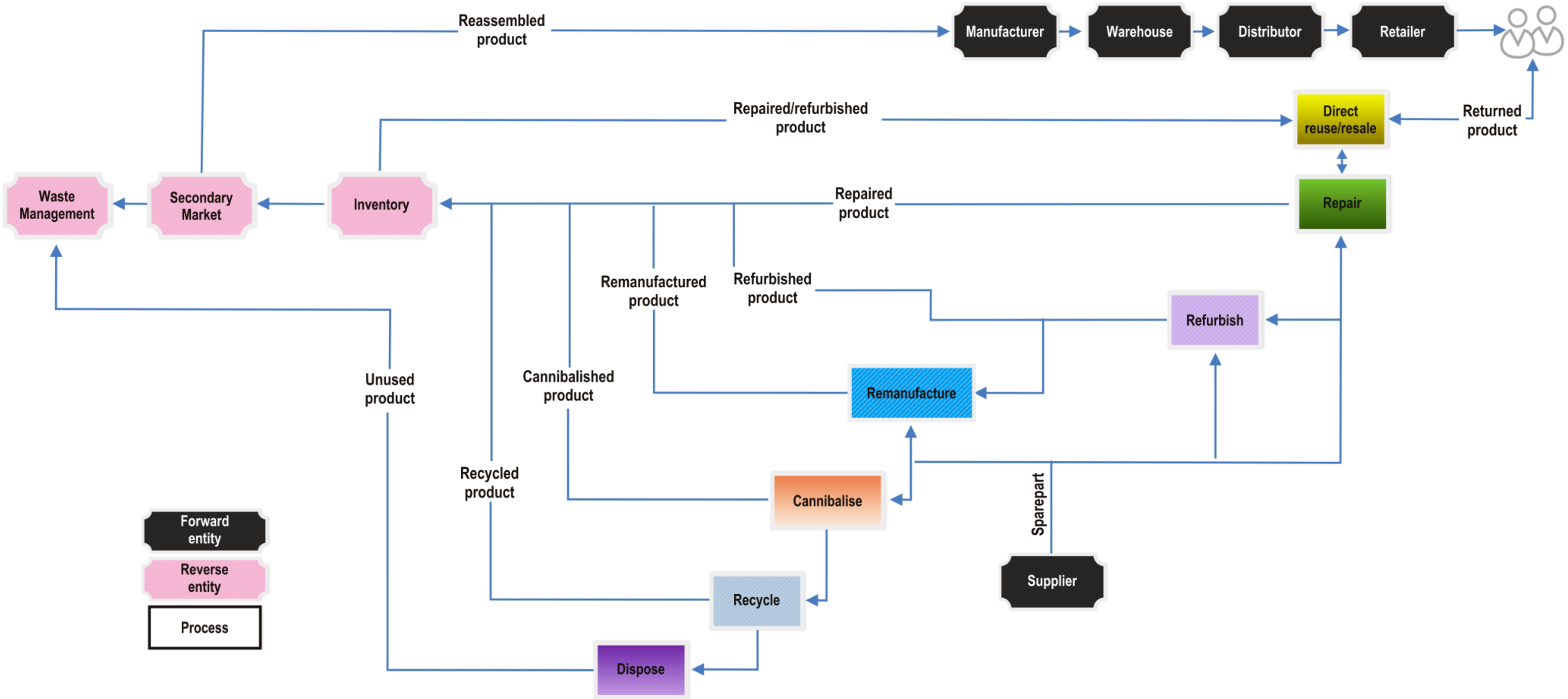

Figure 4.2 - Integrated reverse logistics flow (Adapted from Thierry et al., 1995 and Krumwiede and Sheu, 2002)

4.4 Product Recovery (PR) Options

As stated in several sections previously, this research will focus on PR options. The options chosen are repair, refurbishment, remanufacturing and cannibalisation, which were chosen for several reasons. Firstly, replacement level of PR options that classified (Figure 4.3). The level is arranged based on the activities involved within RL operations. All of the activities need to be categorised, where the level of value of each activity will be determined. Seven RL activities will be classified: reuse/resale, repair, refurbish, remanufacture, cannibalise, recycle, and dispose. Thierry et al. (1995), Fleischmann et al. (1997), and Hazen et al. (2011) described reuse/resale in the reverse flow, saying the product only needed minor treatment, such as cleaning or small repairs (Fleischmann et al.,1997) and then the product can be inserted into the supply chain flow. Thierry et al. (1995) also asserted that this activity is done before treatments such as repair, refurbishment, etc., are needed. The next activity is repair, in which minor activity is also mentioned, as stated by Guide et al. (2003) and King et al. (2006); repair is the small correction to a product that is still under warranty. The refurbish activity is also a level of recovery in which it is also possible to repair, replace, and upgrade (Thierry et al. 1995). These activities are categorised as minor replacement.

Remanufacture and cannibalise activities are categorised at the second level where the replacement is moderate. Remanufacture has the possibility for reassembly after being restored as new product (Lund, 1983). Thierry et al. (1995) describe how the cannibalisation activity has a level of disassembly in the selective retrieval of parts. The recycle and dispose activities are categorised in the third level where the replacement of those activities is major, and the retained value of product is low. Furthermore, as already stated above, this research will focus on PR options, specifically repair, refurbishment, remanufacturing, and cannibalisation, as those activities are included in the minor and moderate replacement area where the values are still high or medium.

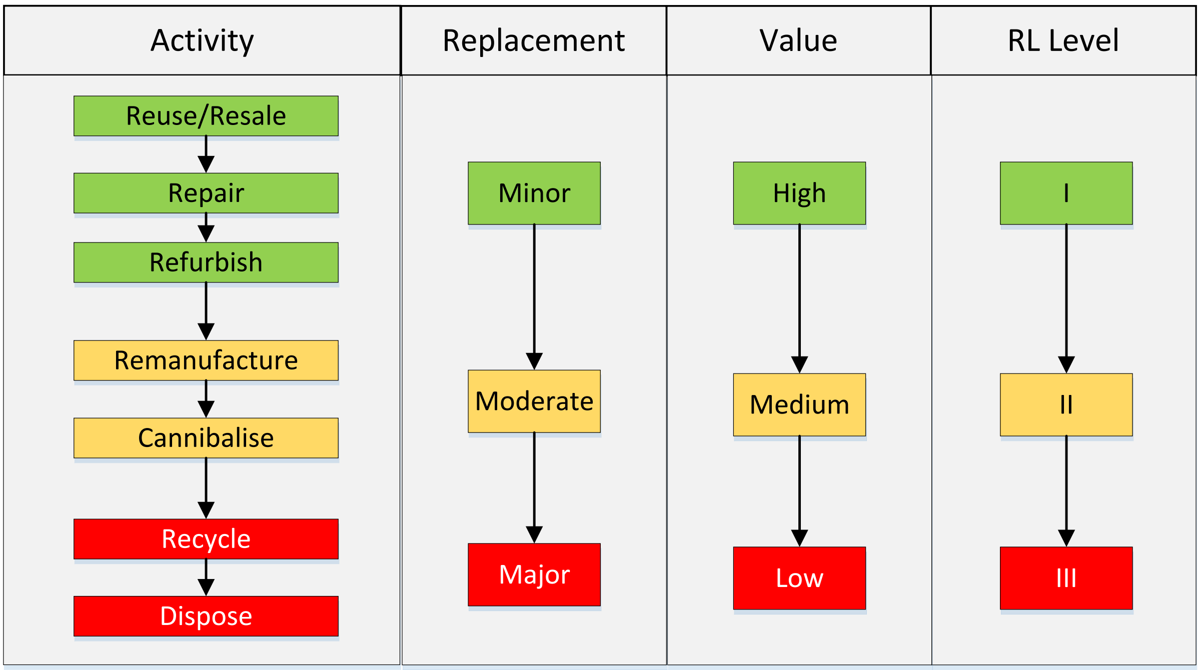

Figure 4.3 - Reverse logistics operation options based on the replacement level (Adapted from Thierry et al., 1995)

4.5 Constructing of the Formal Reverse Logistics Design Framework

The purpose of this chapter is to formalise the RL design framework. The formulation process will be explained in this section. RL design has been described by researchers (e.g. Amini et al., 2005; Dowlatshahi, 2010a, b; Pochampally and Gupta, 2012). They designed RL for specific problem such repair service and transportation system. Pochampally and Gupta (2012) also added the general process of RL design by focusing on crucial problem on RL. Fundamentally, the approaches have been explained by those researchers can be adapted to formalise RL design framework. Nevertheless, the comprehensive reviewing of the literature will support to produce the suitable framework of RL design that can be applied easily. Firstly, search a design definition. It is defined from different perspectives such as instructional, research, and practitioner (software design) (Ralph and Wand, 2009). Therefore, many definitions of design can be used, for instance “Designing is creating a structure that organizes the logic in the system” (Beck, 2000); “Design ... involves the understanding of the studied domain, the application of relevant scientific and technical knowledge, the creation of various alternatives, and the synthesis and evaluation of proposed alternative solutions” (Nunamaker et al., 1991).

Design also is regarded as a process, creation, physical activity system, etc. (Ralph and Wand, 2009).

According to the result searching by using reverse logistics design keyword that the result directed to the RL network design that needs to look at the process of the RL network design. There are some researchers focused on the reverse logistics network design (e.g. Fleischmann et al., 2001; Fleischmann, 2001b; Bostel et al., 2005; Srivastava, 2008; Pishvaee et al., 2009; Daaboul et al., 2014). The RL design network is not similar to RL design, in terms of its purpose. In fact, an RL network design is the next process after having first designed an RL. Logically, the method or framework described in the RL design network can still be used with some adjustments. The framework to design RL possibly exists; however, the framework has not yet been formalised.

RL design model literature in needed as mentioned above to see how RL handle some issues through an RL model. Some RL issues fundamentally were described in the section 2.4.3 in Chapter 2. In addition, Raj et al. (2014), Zaarour et al. (2014), and Choudhary et al. (2015) designed RL model for different scenarios. Raj et al. (2014) used mathematical model to develop inventory system for maximising profit. In this model identified the problem that will be concerned on and some entities involved (e.g. supplier, producer, and retailer). Roghanian and Pazhoheshfar (2014) described a model to optimise RL network with considering uncertainty problem in RL network. Comparing those literatures that can be concluded, RL model design activities could be similar with RL design. However, it is normally to address specific problem by using different method.

The formulation of an RL design framework is started by synthesising the literature. Firstly, as stated previously, the literature review needs to be collected. The literature that can be categorised as an RL design, RL network design, and RL model were collected. The detailed process of synthesising RL network design is accumulated in Figure 4.4 which is divided into four parts: method (Daaboul et al., 2014), activity (Fleischmann, 2001b), sub activity (Bostel et al., 2005), and decisions as examples (Fleischmann, 2001b; Lu, 2003 in Bostel et al., 2005). The linkage of one component to another needs to be analysed. By comparing the components and also using the knowledge that has been taken from the literature, the formal RL design framework can thus be constructed.

According to Figure 4.4, it can be concluded that there are several important activities in RL design. *First*, determining the RL detailed activity itself, such as collection, reprocessing, and testing. *Second*, the actor/entity that can provide the relationship one to another. *Third*, the parameters surrounding RL. *Fourth*, the purpose or decision. These will provide the focus for required information in the area of PR options.

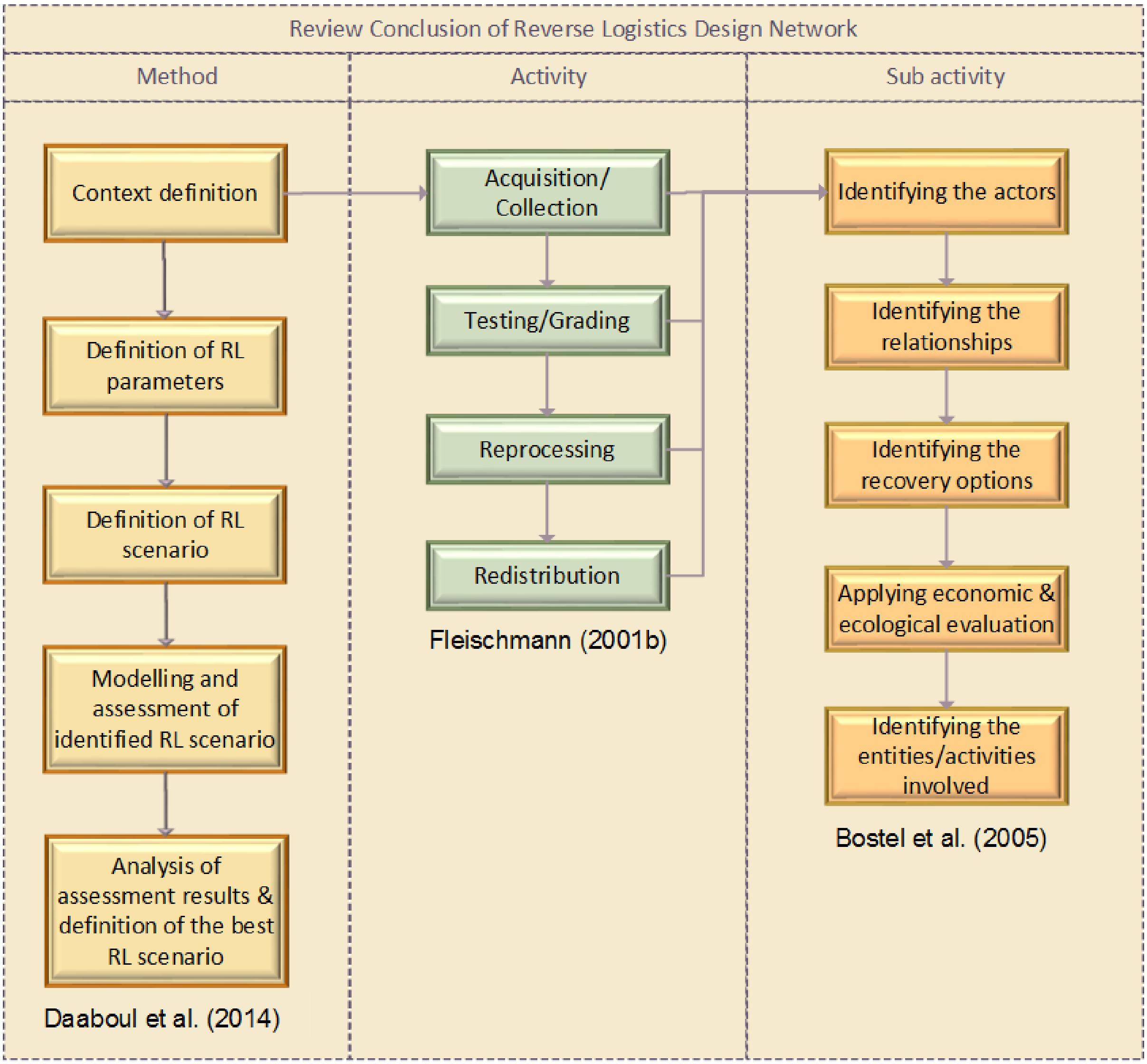

Figure 4.4 – Review summary of current RL design network

There are five steps that have been arranged. Each point is described in detail below:

1. Determining Reverse Logistics/Product Recovery Operation Options

The determining of RL operations options will help to focus on specific activities surrounding the options. As stated above, this research will only focus on PR where the options are repair, refurbishment, remanufacturing, and cannibalisation. The option can be chosen more than once, depending on the needs and facilities surrounding it.

2. Identifying the Reverse Logistics Activities

The identification process starts from considering the logistics and RL activities. RL activities identified are: transport, collect, assess, classify, repair, disassemble, reassemble, store, and test (Lambert and Stock, 1993; Thierry et al., 1995; Krumwiedeand Sheu, 2002; Kim et al., 2006; Vorasayan and Ryan, 2006; Piplani et al., 2007; Zikopoulos and Tagaras, 2007).

The identification results described, there are nine RL activities. (1) ***Transport,*** is the process of moving a product within the channel involved with a minimum of difficulty in time and cost (Lambert and Stock, 1993; Dowlatshahi, 2000). (2) ***Collect***, is necessary to gather the product specifically from the customer to transport it to another centre or point (Pohlen and Farris, 1992; Rogers and Tibben-Lembke, 1999; Schwartz, 2000). (3) **A*ssess***, is allocated to test the quality of the product return that can determine the appropriate treatment for the product (Srivastava, 2008). (4) ***Classify***, is looking at the type, quality, and hazard rate of the product that this activity needs to consider (Pohlen and Farris, 1992).(5) ***Repair***,is a common term to recover a returned product without the disassembling or assembling process (Krumwiede and sheu, 2002; Amini et al., 2005). (6) ***Disassemble***, is covering several processes in the RL that aim to increase the amount of recovered product/material (Srivastava, 2008). (7) ***Reassemble***is needed to reintegrate some components into a new product (Lambert et al., 2011). (8) ***Store***, is the location needed to store returned product (Krumwiede and Sheu, 2002). (9) ***Test***, is the process to ensure that the recovery process has fulfilled the required standard (Srivastava, 2008).

Those RL activities above need to be identified for PR activities, specifically for the four options (i.e. repair, refurbishment, remanufacturing, and cannibalisation). The nine activities of RL above describe the general activity. Indeed, each option has a detailed process, depending on the type of product.

3. Analysing the Detail of the Reverse Logistics Process

After determining the type of RL options and activities involved, identification of the detailed activities is needed. The detailed activity, or so-called sub activity or process, needs to be identified specifically, because different types of product or industry have different processes. Some PR processes are product repair, refurbishment, remanufacturing, and cannibalisation which will be described below. The detailed process for each PR option basically is the example given.

- ***Repair***

The detailed process of repair is arranged; it has been adapted from ERN (2016), where the product is an aerospace product, and the type of remanufacturer is an independent remanufacturer (Figure 4.5). Figure 4.5 has three components: customer/aircraft operator; remanufacturer; and manufacturer/OEM. The process will be started from when the aircraft operator sends the product that has been collected from the manufacturer for repair purposes. There are three conditions; C1 (cycle 1), the engine is stripped down, cleaned, and assessed; C2 (cycle 2), the repairable engine will be having a non-destructive testing process to diagnose the repairing point and then the components will be repaired using chemical electroplating, welding etc.; C3 (cycle 3), the repaired component will be reintroduced back to the main engine (reassembly) before the series of tests (embedded, engine, performance indicator tests) are proceeded with in order to meet OEM performance requirements.

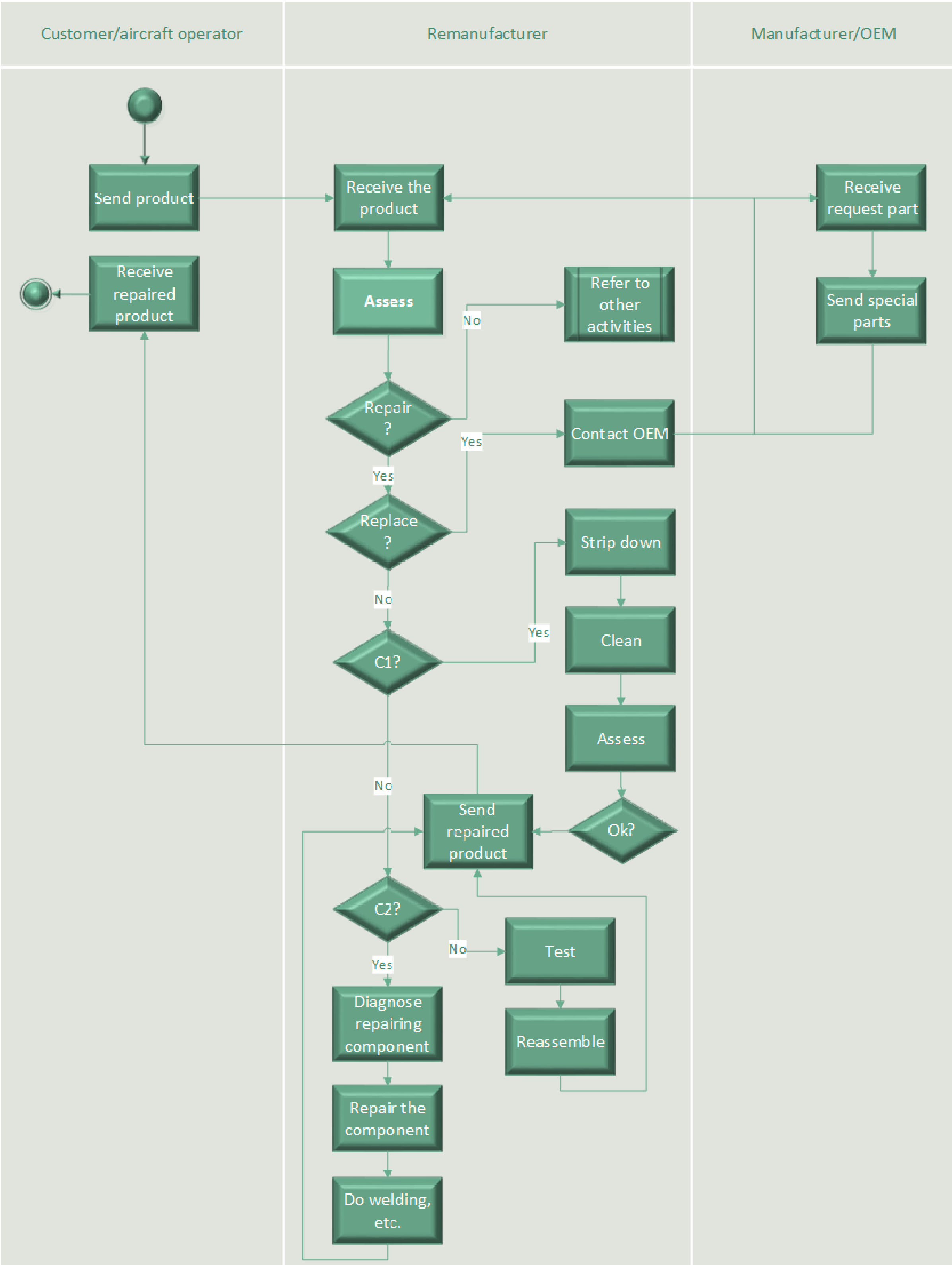

Figure 4.5 – An example of the repair process

- ***Refurbishment***

The product refurbishment process is represented by an electronic product (computer), and the type of remanufacturer is an independent remanufacturer. The process consists of four components: supplier/customer, provider, customer/other customers, and recycling centre. The process starts from the supplier sending the collected product, where the supplier has a function to collect the used product from the customer as well. The detailed process of refurbishment can be seen in Figure 4.6.

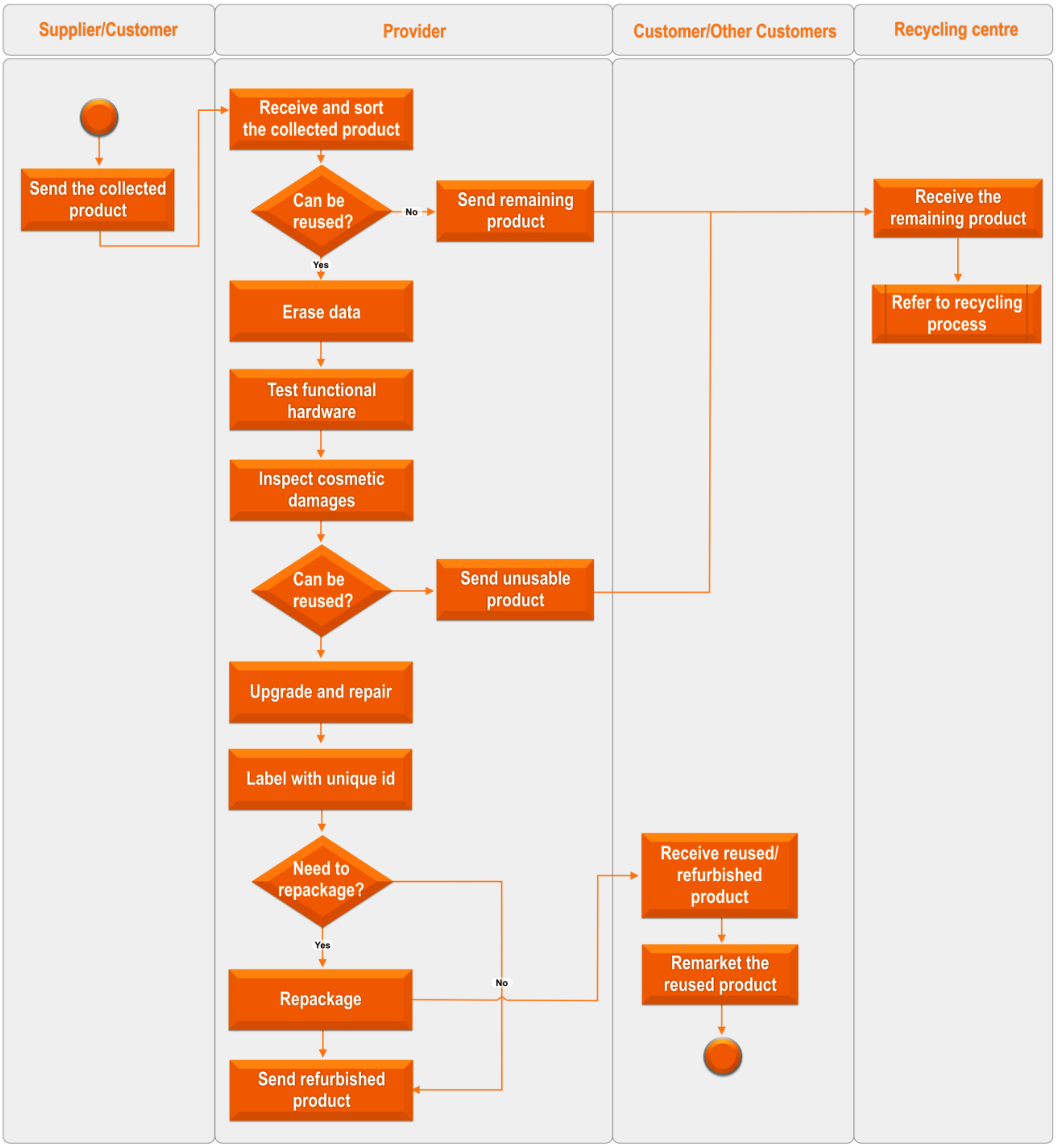

Figure 4.6 – An example of the refurbishment process

- ***Remanufacturing***

The example of the product remanufacturing process is illustrated in Figure 4.7. The type of product is a forklift truck, and the type of remanufacturer is an original equipment remanufacturer (OER). The process engages entities such as market/ rental and OEM. The process is started from when the market/rental sends the product to the OEM. The OEM receives the product for inspection which is done to determine the class of used product; several activities are needed, such as cleaning, repairing, repainting, including changing parts if required. Testing the product is needed after doing all of the above processes.

- ***Cannibalisation***

The cannibalisation process is started from some conditions shown in the flowchart in Figure 4.8, where it only can be done if the designated asset is available. The process in Figure 4.8 is also taken from the aerospace industry. The cannibalisation process in this industry can be done for various reasons, such as if the number in stock is zero, which exceeds the operational schedule. When requesting cannibalisation, the specific requirements of the company need to be followed. The request will be received by the manufacturer/remanufacturer if the designated asset is available. If all of the requirements are fulfilled, several processes will be undertaken: inspection, remove component, install, and the last process refers to the notification procedure before sending to the customer/inventory.

4. Identifying parameters

The parameter here means the attribute of each object of the process. Identifying parameters will provide information regarding the operational level of process or system, for example, in product cannibalisation for the remove component box (Figure 4.8). For this condition there are several parameters to identify, such as type of technology, availability of technicians, and the availability of stock components.

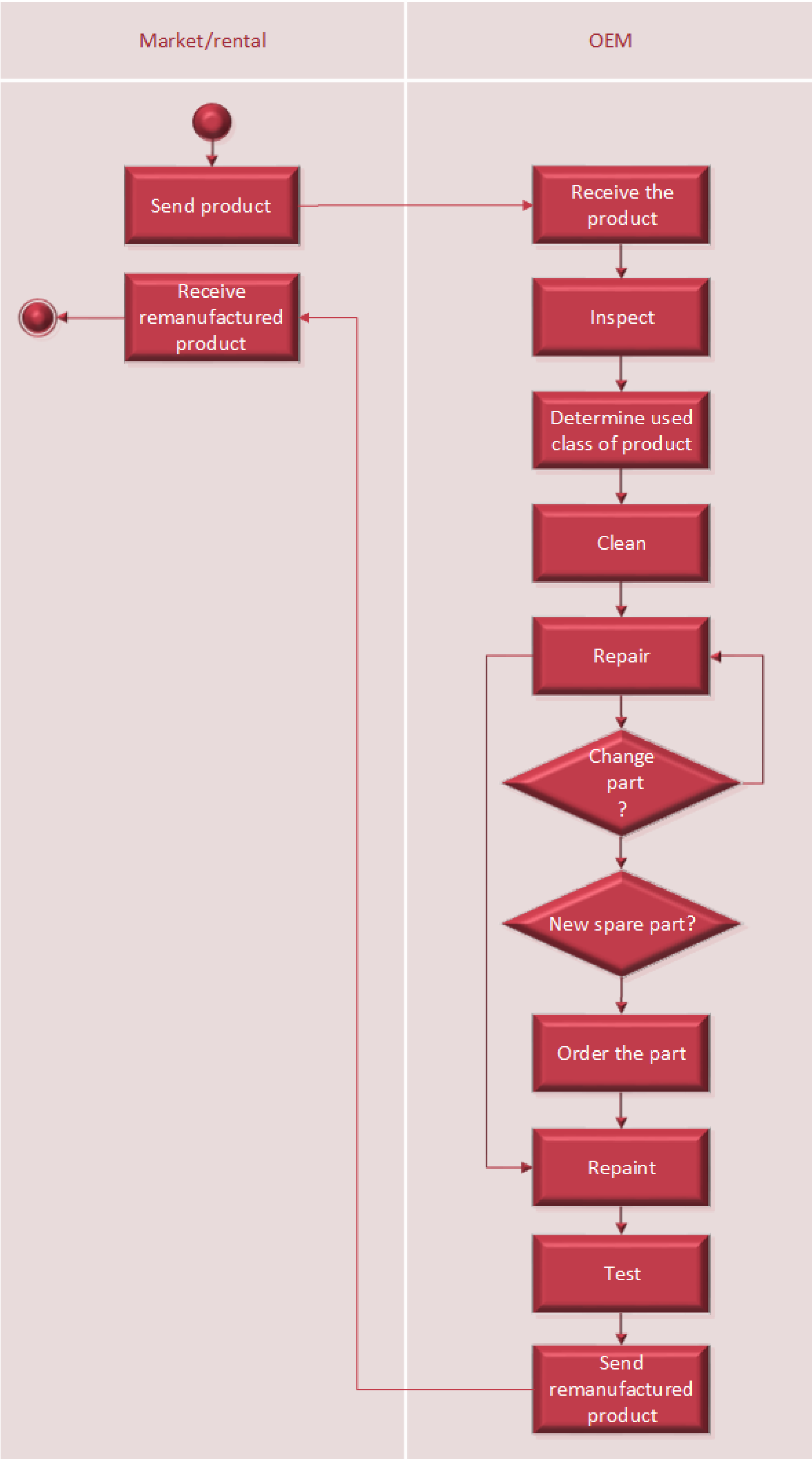

Figure 4.7 – An example of the remanufacturing process

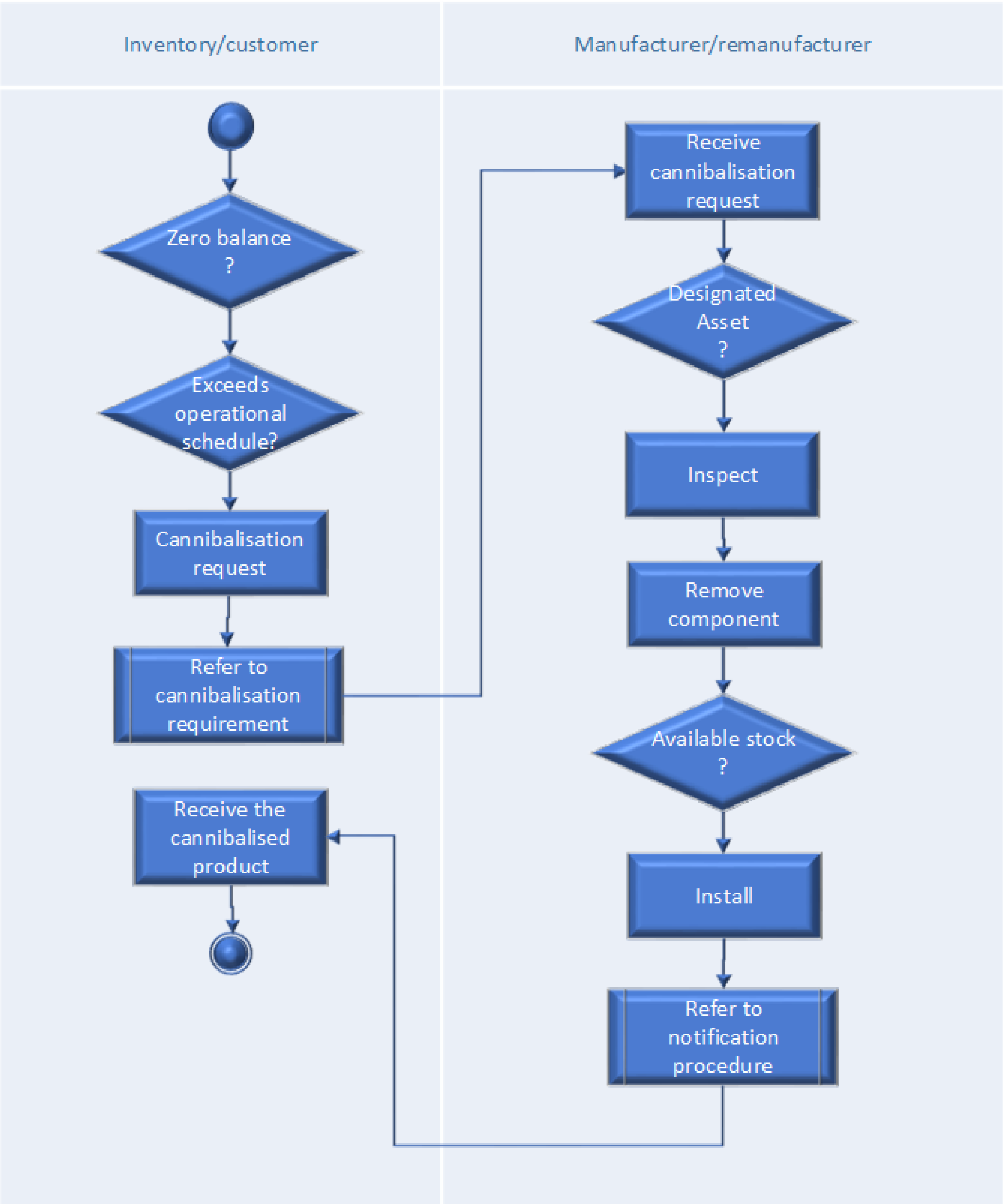

Figure 4.8 – An example of the cannibalisation process

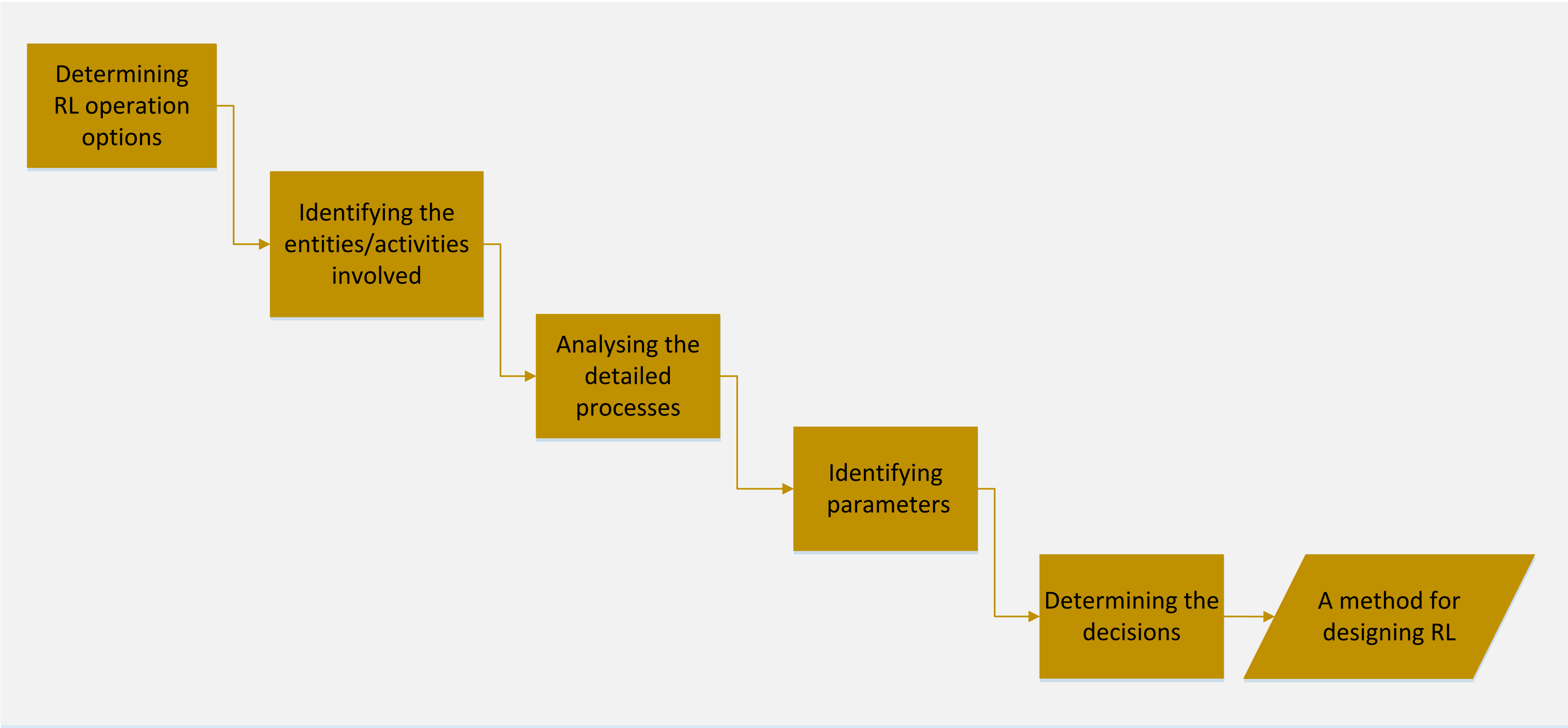

Figure 4.9 – The formalised framework for a reverse logistics design

5. Determining the decisions

Each process in each PR option could require several decisions to be made. The decisions can also lead to various parameters being involved. The decisions can be generated based on the parameters that have been identified, for example determining the optimum transportation, effective testing, etc.

It can be concluded that the formal RL design method consists of five steps: determining RL operation options; identifying the entities/activities involved; analysing the detailed processes; identifying parameters; determining the decision. Those steps are represented in Figure 4.9.

4.6 Summary

The formulation of an RL design was intended to support the high quality of the RL design, and provide proper decisions for the complex problems of RL. The formalising was done by reviewing the literature. There are three main keywords were used to construct the formal RL design framework: reverse logistics design, reverse logistics network design, and reverse logistics model. The formalising was initiated by describing the RL operations, where the describing defines the RL flow, entities, and activities. It was needed to support the quality of formal RL design. Furthermore, the framework has five steps: determining the RL operation options, identifying the entities/activities involved, analysing the detailed process, identifying parameters, and determining the decisions.

CHAPTER 5

REFORMULATION OF CIRCULAR ECONOMY PRINCIPLES

5.1 Introduction

According to the literature review, some researchers have attempted to describe CE through explaining the CE principles from various viewpoints; e.g. Feng (2004) in Yuan et al. (2006), Pintér (2006), Yuan et al. (2006), Yong (2007), Geng et al. (2012), EMF (2013, 2015), Stahel (2013), and Pan et al. (2015). However, all of them were still describing CE at the conceptual level. The formulation of principles literally can support the understanding of the concept; however, the implementation of the principles itself needs to provide readily available CE principles in a format/structure that can be used for specific implementation purposes. The reformulation process was conducted through a systematic literature review, from which the process detail will be described. The process produced several results: the first is the method for reformulation, second is the 15 CE values including their definition, and the third is the configuration of CE.

The reformulation process of CE principles in this chapter will be described structurally to provide the easiness understanding. The sequence diagram depicts in Figure 5.1. First section 5.1 introduction describes generally the argumentation to conduct reformulation CE principles. Section method for reformulation CE principles (Section 5.2) explains the method stages of CE reformulation. The stages consist of five steps that are described clearly through subsections. Section 5.3 will summarise the important points of reformulation CE principles.

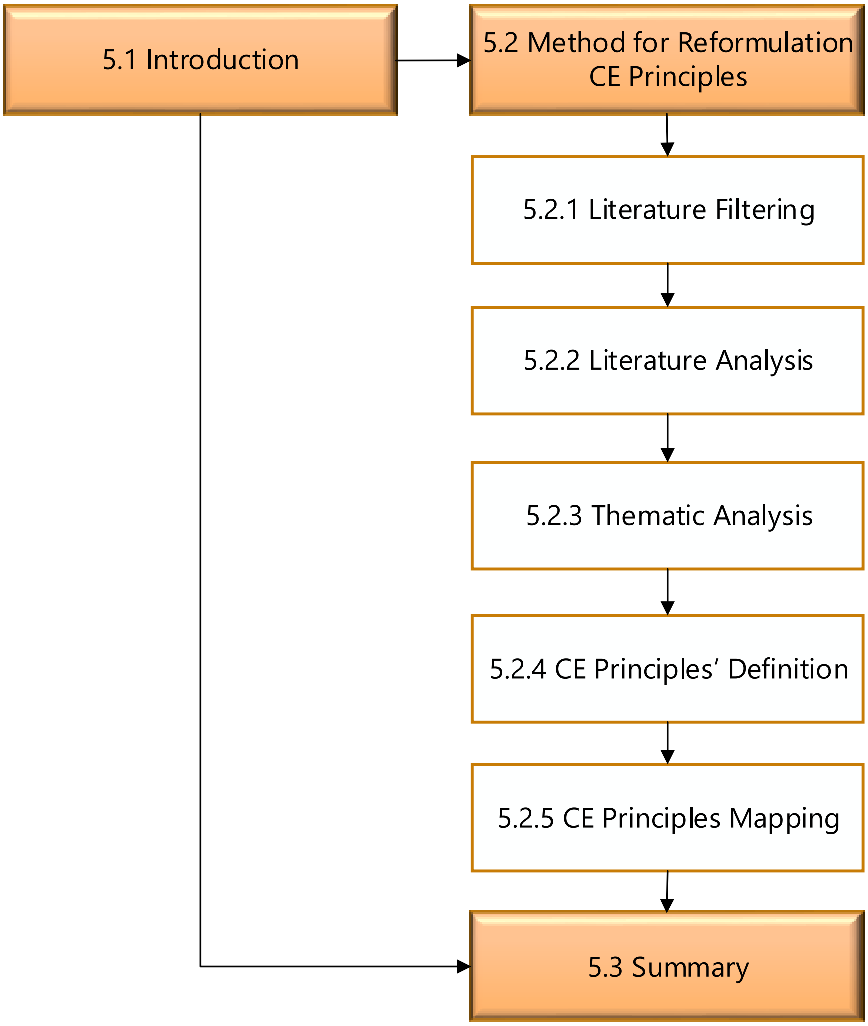

Figure 5.1 Structure of reformulation CE principles

5.2 Method for Reformulation Circular Economy Principles

The approach adopted was mainly through a systematic literature review which was initiated from relevant publication databases and other scientific resources, using a wide range of keywords and phrases associated with CE, and other related keywords, for instance principle, reverse logistics, product recovery, repair, refurbishment, remanufacturing, and cannibalisation. These were then combined with the publicly available materials and various media (case studies, videos, seminars, presentations). All phrases were determined to have a strong relation with the core of this research, which is PR options.

The process began by collecting all the publications from the search engine. Some keywords were determined (Table 5.1). As a result, by using Google Scholar, Scopus, IEEE, and EBSCO, 931 journals, and 509 conference papers in total were identified. During the searching process, some books such as “A New Dynamic Effective Business in a Circular Economy” by Webster et al. (2013), technical reports, such as “Towards the circular economy” by EMF (2013), and briefing papers such as “A Global Redesign? Shaping the Circular Economy” by Preston (2012) were also identified as useful resources.

The resources that have been found were chosen by simple selection. Firstly, all of the files were tried to be opened, and classified based on year and type of paper. Within these processes, papers would be rejected if they were not in English, or the file could not be opened because of access limited. It was noted that less than 50% (especially from Google Scholar) could be collected. Furthermore, the structural selection process approach will be described in Table 10. As can be seen, the table is divided into three components (database, search string, and result). Each database searched some predetermined strings. The CE string itself was sought, and also other strings related to it, e.g. principle.

In addition, the string principle is important as it is the main purpose of this reformulation. This search strategy also engages the CE string with other strings such as RL, PR, repair, refurbishment, remanufacturing, and cannibalisation. The reasons to engage with those strings are because in the literature review chapter, it is described that they have a relationship with CE, and also because the implementation of this value will apply in RL. The PR and PR options, such as repair and refurbishment, are also used as they are the specific objects of this research. Furthermore, in Table 5.1, the result column shows the number of journals and conference papers found. The result has shown, the “circular economy” string provided the dominant result, whereas, the others are relatively small, even zero; for instance, “circular economy AND repair” in all of the databases.

Table 5.1 – Summary of literature search strategy for CE principles

No	Database	Search string	Result	
			Journal	Conference paper
1	Google Scholar	Circular economy	574	131
		Circular economy AND Principle	4	9
		(Circular economy AND Reverse logistics)	0	1
		(Circular economy AND Product Recovery)	2	0
		(Circular economy AND Repair)	0	0
		(Circular economy AND Refurbishment)	0	0
		(Circular economy AND Remanufacturing)	0	1
		(Circular economy AND Cannibalisation)	0	0
2	Scopus	Circular economy	139	250
		Circular economy AND Principle	2	3
		(Circular economy AND Reverse logistics)	0	8
		(Circular economy AND Product Recovery)	0	0
		(Circular economy AND Repair)	0	0
		(Circular economy AND Refurbishment)	0	0
		(Circular economy AND Remanufacturing)	0	0
		(Circular economy AND Cannibalisation)	0	0
3	IEEE Xplore	Circular economy	0	101
		Circular economy AND Principle	0	0
		(Circular economy AND Reverse logistics)	0	5
		(Circular economy AND Product Recovery)	0	0
		(Circular economy AND Repair)	0	0
		(Circular economy AND Refurbishment)	0	0
		(Circular economy AND Remanufacturing)	0	0
		(Circular economy AND Cannibalisation)	0	0
4	EBSCO	Circular economy	213	-
		Circular economy AND Principle	5	0
		(Circular economy AND Reverse logistics)	1	-
		(Circular economy AND Product Recovery)	0	-
		(Circular economy AND Repair)	0	-
		(Circular economy AND Refurbishment)	0	-
		(Circular economy AND Remanufacturing)	1	-
		(Circular economy AND Cannibalisation)	0	-
Total			931	509

5.2.1 Literature Filtering

As stated above, the data collection started by using the search engine and other resources. As each database contains files, journals, conference papers, etc., it needed to be filtered. All sources were filtered by analysing the titles, keywords, key ideas, graphics, and abstracts. Based on these processes, the number of files was then reduced. The articles with a strong link to this research purpose were reread in more detail. The definitions, characteristics, values, principles, case studies, and other information have become the focus of this process. The selected references were read in detail by using various approaches.

Firstly, the selected sources were reviewed by making small notes to obtain the understanding of each reference. The notes from all of the selected references were gathered to obtain the initial conclusion, especially to determine the next step. All of the literature review results have been provided in section 2.6. Based on these processes, 47 references from various resources that were filtered (Table 5.2) have been found. The 47 references were classified into journal, conference paper, book, etc., which included white papers, technical reports and online articles. In Table 5.2, the resources that will support the reformulation process of CE values are described. As can be seen, there are 19 journal references, 6 conference papers, 11 books, and 11 other selected resources.

Table 5.2 shows additional information. In general, the type of source found is dominated by journals. The sources were collected from 1966 until 2016. It can be seen, based on Table 5.2, that CE has been discussed in many sources since 2013. There are various different journals that have covered this issue, e.g. *Journal of Cleaner Production, Journal of Industrial Ecology*, and others.

Table 5.2 – Selected literature results for CE principles

No	Author	Reference
Journal		
J01	Ekins (1989)	Environmental Conservation
J02	Feng (2004) in Yuan et al. (2006)	Journal of Material Cycles and Waste Management
J03	Yuan et al. (2006)	Journal of Industrial Ecology
J04	Hongchun (2006)	Journal of Ecological Economy
J05	Huamao and Fengqi (2007)	Chinese Journal of Population Resources and Environment
J06	Yong (2007)	Journal of Material Cycles and Waste Management
J07	Geng and Doberstein (2008)	International Journal of Sustainable Development & World Ecology
J08	Dajian (2008)	Chinese Journal of Population Resources and Environment
J09	Chen (2009)	System Research and Behavioural Science

J10	Park et al. (2010)	Journal of Cleaner Production
J11	Mathews and Tan (2011)	Journal of Industrial Ecology
J12	Hu at al. (2011)	Journal of Cleaner Production
J13	Zhu et al. (2010)	Journal of Environmental Management
J14	Geng et al. (2012)	Journal of Cleaner Production
J15	Su et al. (2013)	Journal of Cleaner Production
J16	Ma et al. (2014)	Journal of Cleaner Production
J17	Ma et al. (2015)	Journal of Cleaner Production
J18	Li and Ma (2015)	Journal of Cleaner Production
J19	Pan et al. (2015)	Journal of Cleaner Production
Conference		
C01	Li et al. (2009)	Second Asia-Pacific Conference on Computational Intelligence and Industrial Applications.
C02	Yang (2011)	BMEI
C03	Xuan et al. (2011)	IACEED
C04	Ying and Li-jun (2012)	International Conference on Solid State Devices and Materials Science
C05	Zheng and Zheng (2013)	International Asia Conference on Industrial Engineering and Management Innovation
C06	Jawahir and Bradley (2016)	The Global Conference on Sustainable Manufacturing
Book		
B01	Boulding (1966)	The Economics of the Coming Spaceship Earth
B02	Kneese et al. (1970)	Economics and the Environment: A materials balance approach
B03	Pearce and Turner (1990)	Economics of Natural Resources and the Environment
B04	Lovins et al. (2013)	A New Dynamic Effective Business in a Circular Economy
B05	Stahel (2013)	A New Dynamic Effective Business in a Circular Economy
B06	Tuppen (2013)	A New Dynamic Effective Business in a Circular Economy
B07	Sempels (2013)	A New Dynamic Effective Business in a Circular Economy
B08	Mulhall and Braungart (2013)	Waste to wealth: the circular economy advantage
B09	Pinjing et al. (2013)	The Royal Society of Chemistry
B10	Webster (2015)	The circular economy: a wealth of flows
B11	Lacy and Rutqvist (2015)	Waste to Wealth: The Circular Economy Advantage
White paper, technical report, online article		
O01	Pintér (2006)	http://siteresources.worldbank.org
O02	Clift (2011)	http://www.ellenmacarthurfoundation.org
O03	Preston (2012)	Chathamhouse.org

O04	EMF (2012)	Ellen MacArthur Foundation
O05	Marion (2012)	Ecocitynotes.com
O06	EMF (2013)	Ellen MacArthur Foundation
O07	IMSA (2013)	Amsterdam: IMSA
O08	EMF (2014)	Ellen MacArthur Foundation
O09	EMF (2015)	Ellen MacArthur Foundation
O10	UNEP (2015)	United Nations Environment Programme
O11	ERN (2016)	European Remanufacturing Network

5.2.2 Literature Analysis

The 47 scientific sources need to be analysed more deeply to construct some themes that will be projected to become some CE principles. Firstly, identifying the themes can be more easily done based on the existing CE principles from the following nine *researchers*: Feng (2004) in Yuan et al. (2006), Pintér (2006), Yuan et al. (2006), Yong (2007), Geng et al. (2012), EMF (2013, 2015), Stahel (2013), Pan et al. (2015). Here, it was concluded that the existing principles related to the *economy*. Some researchers highlighted these points, for instance Pintér (2006) touched on accounting; Geng et al. (2012) were also concerned with an accounting system in an economy; Stahel (2013) retained the economics view in the CE through his principle that considered profit and cost efficiency. *Environment*, this point is mentioned by the above nine researchers as a direct explanation: Feng (2004) in Yuan et al. (2006) through the “3R” to keep the values of product, Pintér (2006) through “mass balances”, Yuan et al. (2006) through circulating in multi steps, Yong (2007) through implementation of “3R”, Geng et al. (2012) through the equal input process output, Stahel (2013) through circular flow, EMF (2013, 2015) through biological and technical flow, and Pan et al. (2015) illustrated the link between environment and energy to the business through “5R”.

According to the CE principles from these nine researchers, it can be concluded that almost all of them were describing the principles in the context of *circular understanding,* even though the exact term used could be different. Circularity, circular, or loop is used by Yuan et al. (2006), EMF (2013, 2015), Stahel (2013). *System thinking*, is described by EMF (2013, 2015). A *Cascade* was adopted in EMF (2013, 2015). *Reverse cycle* was illustrated by EMF (2013, 2015) through circulate product, Feng (2004) in Yuan et al. (2006) and Yong (2006) through reduce, reuse, and recycle. *Recovery* was adopted by Feng (2004) in Yuan et al. (2006), Yong

(2007), EMF (2013, 2015), and Pan et al. (2015). *Market* was described by Stahel (2013) through a functioning market. *Waste* was described by Geng et al. (2012) through equal output, i.e. one of the components is the amount of waste, and EMF (2013, 2015) through design out waste.

In addition, according to the analysis above, nine themes have been found by analysis based on the nine researchers. The analysing process now needs to be continued by looking at all of the selected references that have been collected. Based on Table 5.2, not all of the references have been analysed. Continuing analysis is needed to enrich the CE value formulation. As stated above, there are 47 references, nine of which have described the CE principles; those nine references have also been analysed. The rest, i.e. 33 references, still need to be analysed. It needs to be asserted that the 33 references were not formulating CE principles exactly. To support the analysing process of the 33 references, mapping keywords or themes are necessary (Figure 5.2). Figure 5.2 depicts the 33 references, each of which has several themes. The right side shows the references from even years, and the left side from the odd years.

Figure 5.2 shows various keywords, which were collected from the whole of the author's research. By comparing the existing themes mentioned earlier, some other keywords were found: *technology*, *innovation*, and *energy*. Technology was touched on by e.g. Chen, 2009; Preston, 2012; Lacy and Rutqvist, 2015; Jawahir and Bradley, 2016. Innovation was described by e.g. Preston, 2012; Lacy and Rutqvist, 2015. Energy was used by Ma et al. (2014); Dajian (2008); Lovins et al. (2013).

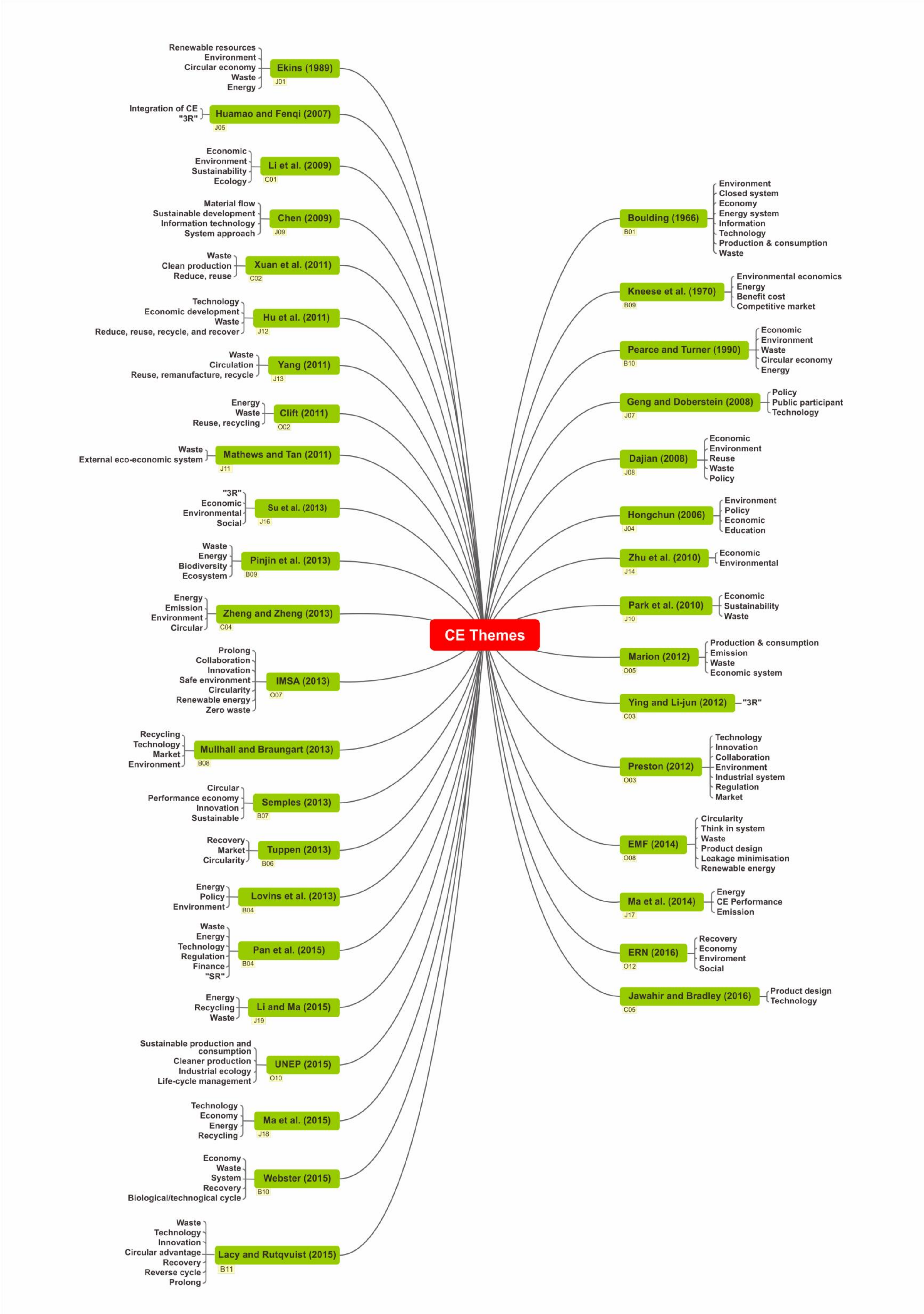

Figure 5.2 – Identification themes of circular economy

5.2.3 Thematic Analysis

The themes were produced based on the previous results such as CE principles. The themes are provided in Table 5.3. There are 11 themes have been found. Fundamentally creating a theme is intended to support the reformulation of CE principles. The words ‘theme’ and ‘principle’ are translated differently by dictionaries. The theme is defined by the Oxford Dictionary as “an idea that recurs in or pervades a work of art or literature”, while the principle is defined as in Chapter 2. In this stage, a deeper analysis is required, where each theme above will be defined to find the consistency of the theme. Throughout this stage, the CE principles will be reformulated.

In fact, one theme can produce one or more principles, and can possibly overlap with others as well. According to the 11 themes and analysis above, the CE principles will be reformulated. Firstly, economy is an important aspect in CE as, e.g. Stahel (2013) stated through some of his principles, that CE is about economics, and Geng et al. (2012) describe CE as an accounting system in economy. It is necessary to consider the economy aspect in the CE value. However, as one of the purposes of CE is to keep the value of a product in circulation longer, the focus is on the environment where the term “*optimising*” is chosen to represent the importance of economy but still considers other environmental aspects.

The second theme is environment; almost all of the CE references consider this theme (47 in total). One of the references is EMF (2013) which described biological material treatment as being to prolong the value of a biological product by following the proper process, which is returning it to the biosphere. This aspect is also important as a CE value, especially in terms of being conscious of the environmental regulations or policies, as some authors have stated, e.g. Marion (2012) and Hongchun (2006). Being *conscious of the environment* was chosen to represent this aspect. The circularity theme describes the continuing or sustainable process. By keeping this theme it becomes one of the CE values that is crucial, as Ekins (1989) underlined, to the life-processes of a living system.

Table 5.3 - Classification circular economy themes

No	Reference	Theme											Total
		Economy	Environment	Circularity	System thinking	Cascades	Reverse cycle	Recovery	Market	Technology	Waste	Energy	
1	Boulding (1966)	x	x	x	x					x	x	x	7
2	Kneese et al. (1970)	x	x	x					x			x	5
3	Ekins (1989)	x	x	x	x						x	x	6
4	Pearce and Turner (1990)	x	x	x	x		x	x			x	x	8
5	Feng (2004) in Yuan et al. (2006)							x					1
6	Yuan et al. (2006)		x					x					2
7	Hongchun (2006)	x	x										2
8	Pintér (2006)	x		x							x		3
9	Yong (2007)	x	x	x				x					4
10	Huamao and Fengqi (2007)				x			x					2
11	Geng and Doberstein (2008)									x			1
12	Dajian (2008)	x	x					x					3
13	Chen (2009)		x	x	x						x		4
14	Li et al. (2009)	x	x		x								3
15	Mathews and Tan (2011)	x	x	x				x			x		5
16	Park et al. (2010)	x	x							x			3
17	Zhu et al. (2010)	x	x										2
18	Hu et al. (2011)	x	x				x			x	x		5
19	Yang (2011)			x				x			x		3
20	Clift (2011)	x									x	x	3
21	Xuan et al. (2011)		x					x			x		3
22	Geng et al. (2012)										x		1
23	Preston (2012)		x		x				x	x			4

24	EMF (2012)	x	x	x	x	x	x	x	x	x	x		10
25	Ying and Li-jun (2012)							x					1
26	Marion (2012)	x											1
27	Zheng and Zheng (2013)			x			x				x		3
28	Lovins et al. (2013)		x									x	2
29	Tuppen (2013)			x				x	x				3
30	Sempels (2013)	x		x									2
31	Mulhall and Braungart (2013)		x	x					x	x			4
32	Stahel (2013)	x		x	x			x	x				5
33	Su et al. (2013)	x	x					x					3
34	IMSA (2013)		x	x	x	x	x	x		x	x	x	9
35	EMF (2013)	x	x							x			3
36	EMF (2014)	x	x	x	x	x	x	x	x	x	x		10
37	Ma et al. (2014)										x	x	2
38	EMF (2015)	x	x	x	x	x	x	x	x		x		9
39	Webster (2015)	x		x	x	x	x	x			x		7
40	Lacy and Rutqvist (2015)	x		x	x	x	x	x		x	x		8
41	Ma et al. (2015)	x						x		x		x	4
42	Pinjin et al. (2013)		x								x	x	3
43	Li and Ma (2015)							x			x	x	3
44	Pan et al. (2015)	x						x		x	x	x	5
45	Jawahir and Bradley (2016)									x			1
46	UNEP (2015)		x	x	x						x		4
47	ERN (2016)	x	x					x					3
Total		27	27	21	15	6	9	23	8	14	23	11	194

In addition, system thinking is building an integrated mind-set for the CE system; this theme also still needs to be kept as one of the CE values. This theme has been described by several authors, e.g. EMF (2013). A Cascade is aimed specifically at biological material that can be returned to nature safely. On another side, which is technical material, this can be handled in the reverse cycle and those two are possible to be combined for CE value. Those themes are important as they can cover the main activities of CE (Lacy and Rutqvist, 2015; Webster, 2015). Recovery covers several activities, for instance reduce, reuse, recycle, and recovery is an attempt to maximise the value of a product. By creating and following a procedure, the retained value of the product can be maximised. Here, the term *maximising retained value* will be used. Market is one of the successful CE implementations that can be adopted as a CE value, a more appropriate name might be *market availability*. It can accommodate reused, recovered, returned, and renewed product.

Technology: Chen (2009) described material flow as being associated with modern economy and information technology. Pan et al. (2015) stated that technology is one of the important aspects to reach a CE system. EMF (2014) described how advanced technology can boost the transition of information for industrial. Those reasons are considered for using the theme as one of the CE values. Energy is an aspect that is included in the circular process, and technically it cannot be recycled (Pearce and Turner, 1990). Pan et al. (2015) also described how renewable energy has an inevitable role in the circular industrial economy. Renewable energy, specifically in the process to *shift* from using conventional *to renewable*, facilitates the point that it is necessary for it to be adopted as a CE value. Waste is one of the key effects of industrial production, but it can still have value with proper treatment. In the CE implementation, Gent et al. (2009) stated that the minimum of waste will reflect the efficiency of the CE performance. Here the process of *eliminating waste* is one of main aspects in CE.

On the other hand, within the analysis of all the references, some values emerged that are fundamentally still related to the themes and also other descriptions in the literature. They are collaborative network, innovation, built-in resilience, minimising the leakage, and optimisation of change. The exact term *innovation* is not determined by references related to the CE; however, in some cases, innovation was described to achieve CE principles, such as by EMF (2013) through design out waste, where the implementation of design out waste can be done for innovation in the design of a product. Also other references that were describing technology indirectly stated the importance of innovation (Chen, 2009). Webster (2015) and Lacy and Rutqvist (2015) also described that designing for reuse needs innovation. Collaborative network value is needed to implement a successful CE. This is similar to a description from Hu et al. (2011) who state that a CE needs to have collaboration whether within the component system or outside of the internal system.

Built-in resilience, regarding system thinking is described by several references, e.g. Pearce and Turner (1990), EMF (2013); this point of view brings with it a new understanding that to implement CE is indeed necessary as it needs to build integrated positive values that can face challenging situations. With *optimisation of change*, CE can be implemented from zero implementation or in the middle situation; for example some companies might have implemented some environmental activities such as recycling. This activity can indeed still be kept, but for implementing CE, other CE principles still need to be followed. To cover this situation, optimisation of change principle is provided. Minimising the leakage, it identifies the uncontrolled situation that provides possibilities of loss in biological and technical aspect.

According to the themes and references analysed, there are 15 identified CE principles that can be stated: system thinking, circularity, innovation, built-in resilience, oriented to cascades/reverse cycle, eliminating waste, technology-driven, market availability, optimisation of change, optimising the economy, maximising retained value, minimising the leakage, collaborative network, shift to renewable energy, and being environmentally conscious. Each principle will be defined clearly in the next section. However, comparing those principles, it is realised that they do not have similar degrees of the principle meaning, i.e. “fundamental truth”. Some of the principles are natural elements of CE, and others are supporting, such as innovation and technology driven.

5.2.4 Circular Economy Principles’ Definition

The 15 principles need to be defined; the process has been completed by using all the information collected. The following CE principles can therefore be formulated:
(V1) **System thinking** is a value that encourages all of the elements/components in the CE to form a system that integrates and influences one with another. This view needs to be used in a holistic manner by using a framework, as the set of

components or objects interact with each other to achieve the goals in a real-world situation.

(V2) **Circularity** is building a circular process of product/component/material starts by reusing consumable and durable components of product. Circular processes are needed to preserve the original value of product/component/material that encompasses reuse, i.e. the perpetuation of its original purpose, keeping in it use for a longer process, e.g. repair, reuse, remanufacturing and recycling. This process emphasises circular product design, which considers the standardisation of components, design for easy EoL sorting, separation or reuse of product and materials, design for manufacturing, diversifying reuse across the value chains, namely cascades, and keeping the material stream uncontaminated.

(V3) **Innovation,** continuing the success of a company by using a new method, idea, product which are functions of innovation, encouraging us to stimulate redesign and rethink a system in the CE to reach the optimum result of its purpose. In the CE, the opportunities for innovation can be started from every process, such as in laptop design, where the product can be made with a modular design that can be easy to repair and reuse, even for designing out waste. The innovation can also continue during the business process, etc.

(V4) **Built-in resilience** is the capacity for recovering quickly from difficulties, in which there is a need to build system resilience that covers several aspects within CE, for instance economy, technology, etc. It is created through the positive values of being transparent, robust, reliable, and responsive. The requirement of the built-in resilience is acquired; it depends on the specific activity with which it will be concerned. The system can provide opportunities to work together that consider the number of nodes, connections and scales of systems that are necessary.

(V5) **Oriented to cascades/reverse cycle,** keeping materials longer in circulation is an opportunity for product, component or material in biological and technical nutrients to cross into different product categories to reach cost-effective, better quality collection and treatment systems. With this value, the reusability value of product is optimised as much as possible before going back to the biosphere, or continuing loops. Benefits will occur from the large quantities of material and components being returned from their point of use or point of manufacture and from a reduction in the amount of virgin material required.

(V6) **Eliminating waste,** this value must be applied to the origin of flow, i.e. from raw material to customer, and vice versa. The elimination of waste can be started by designing product that inhibits the possible amounts of waste, such as the material, design, etc., or the reverse process from customer to raw material which will provide a system that can eliminate a number of wastes.

(V7) **Technology-driven,** this value suggests that CE should adopt a suitable and economically viable technology to trace materials and products, or to recover materials. The main goal is to achieve both efficiency and effectiveness that support the optimisation of operations.

(V8) **Market availability**, this is the enabler of the CE that stresses the capability to create new market and media opportunities to resell used products, thus encouraging the reusability of products, components or materials. Reselling product/component/material should follow a standard quality for each product so that the product can be used safely. Second-hand products could be resold to existing or new markets.

(V9) **Optimisation of change,** it is the opportunities to transform in the different of adopting systems. The optimisation of change provide chance to modify, improve or design circular economy model. Changing to improve is needed in the implementation of system or business models that, according to the dynamics of the problem and the demands of the area, include the redesign of global production and consumption systems, which take into account the environmental, resources, technology, and consumer demand.

(V10) **Optimising the economy**, this principle emphasises the achievement of production and consumption, service and supply of money that the resilient economy can create, for instance, improving material productivity, enhancing innovation capabilities, and shifting from mass production employment to skilled labour. The optimisation cannot be undertaken without considering environmental aspects such as material and energy input, amount of carbon emission, balance of trade, cost saving, etc.

(V11**) Maximising retained value**, creating a system can keep/maintain a product with maximum value within the longer duration of the life of a product. A product basically faces a shrinking value through time that will make its value decline. However, through a suitable treatment, these situations can be avoided. The EoL product utilisation can be done through reusability activity. A comprehensive business model is needed which should consider profitability, environment, economy, collaboration, etc. This value will provide a technical protocol to maximise the retained value of the product.

(V12) **Minimising the leakage,** it is avoiding the loss of the biological or technical material value in the circulation that its value can still be maximised. Biological nutrients represent the loss of opportunities to maximise the cascaded usage period of the materials and the inability to incorporate the nutrient back into the biosphere due to contamination. For technical nutrients, leakage refers to the loss of materials, energy, and labour as products, components and materials are not, or cannot be, reused, refurbished/remanufactured, and recycled.

(V13) **Collaborative network**, this can support the creation of materials standards and information flow within the circularity, and allows stakeholders to work together within an industry sector or between different industries to achieve common goals. The implementation of a CE needs global participation within an industrial system such as industry, government and other stakeholders.

(V14) **Shift to renewable energy,** this principle stresses the reduction of the energy use per unit of output and accelerates the shift towards renewable energy by design, treating the economy as a valuable resource. The amount of non-renewable energy is not unlimited, thus dependency on it has to be reduced. The use of renewable energy not only positively influences the environmental and economic sides but also supports the system's resilience. The use of renewable energy will open up new opportunities within the CE activities, for instance the use of anaerobic digestion processes to produce renewable energy sources.

(V15) **Conscious of the environment,** preserving environmental resources through environmentally friendly activities and applying environmental regulation are the main focuses of this principle. For example, from a transportation aspect, it will consider the amount of energy used and CO_2 emissions.

5.2.5 Circular Economy Principles Mapping

The original intention of CE values reformulation was to reformulate the CE principles. This was done to obtain a holistic understanding of CE that could be implemented properly. However, within the reformulation process, another facet of that process was not only discovering the principle but several other terms were also found. According to the 15 CE principles defined above, the last stage, i.e. ***mapping/regrouping*** is operated; it is used to evaluate the 15 principles of CE previously formulated. The regrouping was done to find consistency within the definitions of CE principles formulation, the sequence between one item and another. The 15 items needed to be classified into appropriate terms within the various layers of the items of CE; the layers were classified into: *principle*, *intrinsic attribute*, and *an enabler*. **The first** layer describes the essential activities/values/rules that should be followed to implement CE. **The second** layer is the internal CE characteristics as natural elements. **The third** layer refers to the external aspects surrounding the CE that will support the practicality, possibility and continuity in CE implementation.

A principle concerns the essential characteristics that should exist in terms of developing, creating, designing, etc. of the system. It is also indicated as being impossible to be ignored, as a clear activity, a verb as an active action, as an absolute value (measurable). The intrinsic is defined as an essential natural element of a concept or system. Through this basic definition the *intrinsic attribute* is defined as the available attribute for use in the implementation of the CE concept. The attributes will emerge within the nature of the elements of the system itself. The attribute is indicated by a noun. *An enabler,* which is defined to make a system, operational, etc., is possible, practical or easy; it could be a culture, a technology, or an infrastructure, etc. It is also indicated by a noun.

After identifying the layer of CE principles, the next step classifies the principles into layers based on the CE definitions and characteristics described above. To make the process of classifying easy, some phrases that describe the characteristics of each layer will be used (Table 5.4):

1. First layer (a principle)

(A1) A verb that describes reusability activities
(A2) A verb that relates to the environment
(A3) A verb that relates to the economics
(A4) A verb that can be measured and controlled

2. Second layer (intrinsic attribute)

(A5) A noun that connects with the nature of CE
(A6) A noun that describes an internal genuine CE characteristic
(A7) A noun that describes advancement and achievement
(A8) A noun that can motivate the CE implementation

3. Third layer (an enabler)

(A9) A noun that has a role as assistant/facilitator
(A10) A noun as an element of the external environment
(A11) A noun that supports the operational level
(A12) A noun that can improve the system externally

Based on the phrases above, the classification result is shown in Table 5.3. The codes V1-V15, and A1-A12 describe the values and phrases, respectively. As illustrated in Table 5.4 in column V5, rows A1-A4, the category of the V5 value (oriented to cascades/reverse cycle) means it is categorised as a principle. Furthermore, the CE values finally can be categorised into three layers. In the first layer, there are six items: maximising retained value, cascades/reverse cycle orientation, economic optimisation, environment consciousness, leakage minimisation, and waste elimination. The second layer consists of circularity, built-in resilience, collaborative network, system thinking, and optimisation of change. The third layer engages three enablers: technology, innovation, and market availability (Figure 5.3).

Table 5.4 – Circular economy principles classification

Code	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15
A1					x	x				x	x	x			x
A2					x	x				x	x	x			x
A3					x	x				x	x	x			x
A4					x	x				x	x	x			x
A5	x	x		x					x				x	x	
A6	x	x		x					x				x	x	
A7	x	x		x					x				x	x	
A8	x	x		x					x				x	x	
A9			x				x	x							
A10			x				x	x							
A11			x				x	x							
A12			x				x	x							

(V1) system thinking; (V2) circularity; (V3) innovation; (V4) built-in resilience; (V5) oriented to cascades/reverse cycle, (V6) eliminating waste; (V7) technology-driven; (V8) market availability; (V9) optimisation of change; (V10) optimising the economy; (V11) maximising retained value; (V12) minimising the leakage; (V13) collaborative network; (V14) shift to renewable energy, (V15) conscious of the environment.

Based on the regrouping results above, it can be concluded that the term principle to cover all of the principles is no longer appropriate. The term value is used to overarch principles, intrinsic attribute, and enabler. Value is defined by Oxford dictionary as “the regard that something is held to deserve; the importance, worth, or usefulness of something”. The detailed CE values are illustrated in Figure 21. The first layer (green) indicates the principle; the second layer (yellow) mentions intrinsic attribute; and the third layer (blue) depicts the enabler.

Within the processes of the reformulation of CE values above, a conclusion from the specific diagram is needed about how the CE values that can be constructed are understood easily. The process is called a method for reformulating CE values (Figure 5.4). It has six stages. The first stage which is literature filtering, has 47 selected papers. The literature analysis then provides 11 themes. In the theme analysis there are 15 CE values. The CE values are then analysed, and mapped which produced three layers (principle, intrinsic attribute, and enabler).

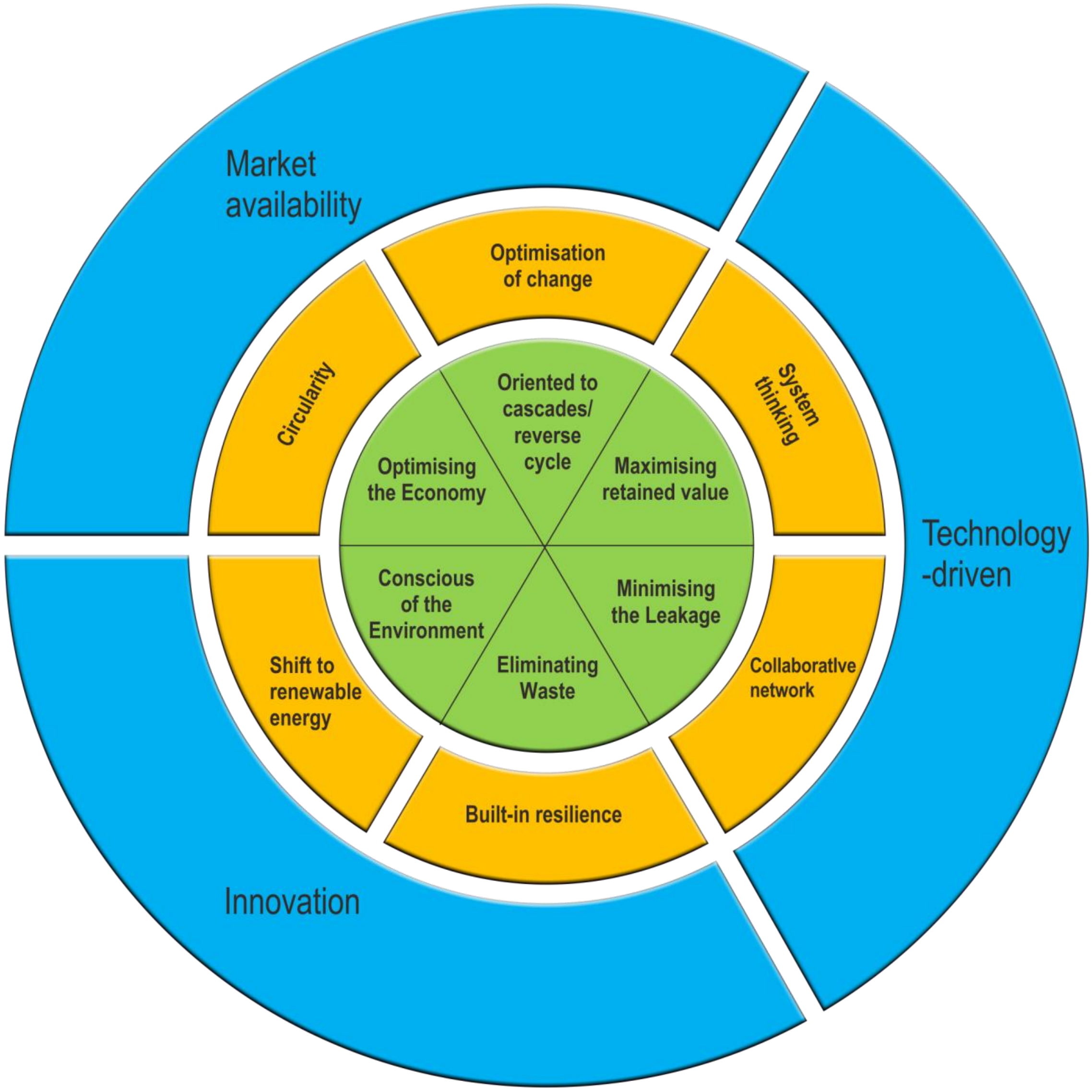

Figure 5.3 - Configuration of circular economy values

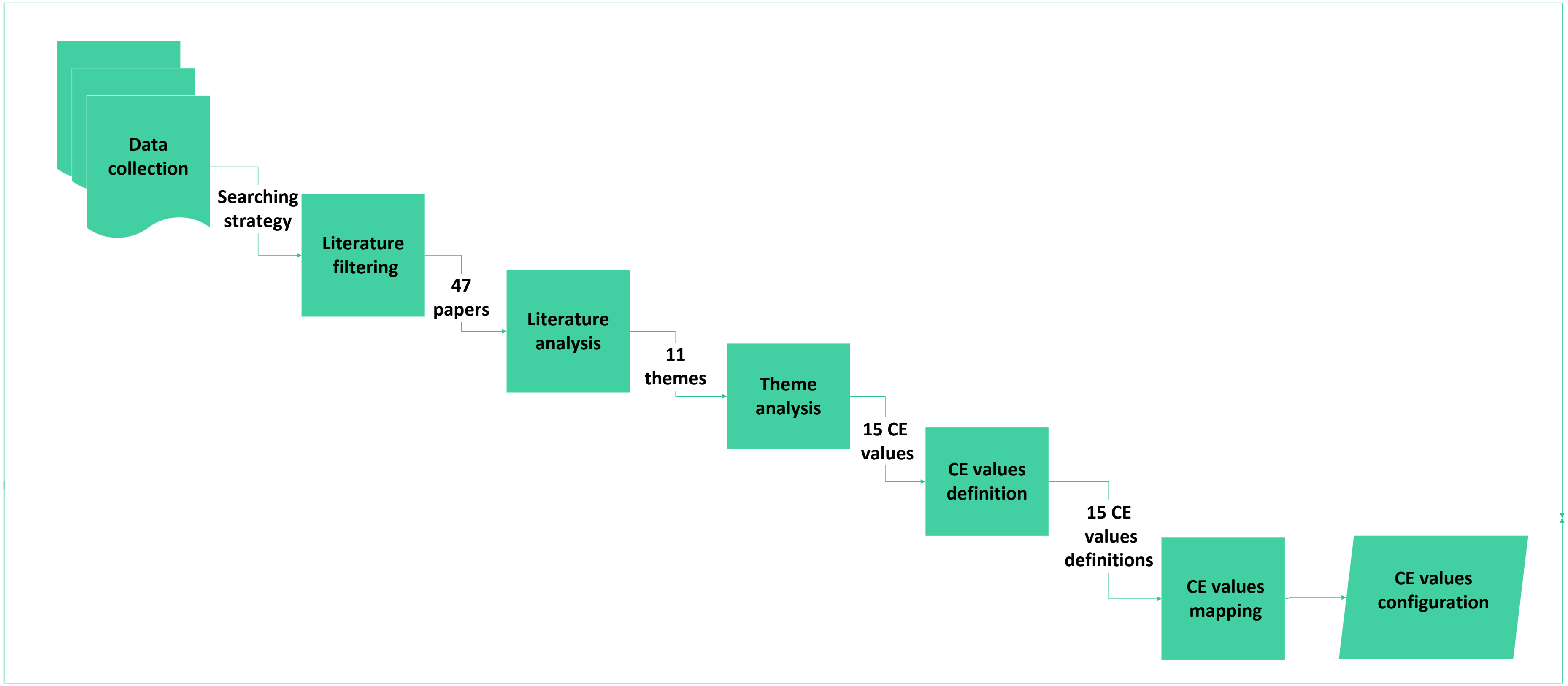

Figure 5.4 – Methodology for formulating circular economy values

5.3 Summary

The CE is a concept that has a wide coverage area, i.e. economy, ecology, social, technology aspects, etc., within which there are many activities in forward and reverse flow. Each flow distinguishes the type of material (biological/technical). The flow also consists of some processes such as collection, maintaining, redistributing, or cascading on the biological side. All of the processes were undertaken to support regenerative and restorative determinants that can systematically support the balanced life system. This concept also has a general purpose to contribute to the global economy. There are 15 CE values that have been found, even though it is proved that not all of them are defined as a fundamental truth (meaning of principle). Here, two other types have been identified – intrinsic attribute and enabler.

CHAPTER 6

EMBEDDING CIRCULAR ECONOMY IN REVERSE LOGISTICS OPERATIONS

The purpose of this chapter is to embed CE values into RL design through the formulation of a framework for designing RL based on CE values. The embedding process is an attempt to implement the CE values into RL operations cases. In Chapter 4, the RL design framework has been formalised, and CE values have been reformulated in Chapter 5. The embedding process is also an implementation process for CE values and RL design in real cases. In this research, RL operations, in order to PR operation options, have been chosen as a target for implementing CE values. The PR options are repair, refurbishment, remanufacturing, and cannibalisation. The process of embedding will be formulated step-by-step as that will make it easier to be understood and followed. In the last part of this chapter, a method will be proposed for designing RL based on CE values.

6.1 Identification of Embedding Process of Circular Economy Values into Reverse Logistics Operations

An RL design framework has been formulated which involves several steps. This research also found 15 CE values. Based on the literature, it is known that RL is more complex to manage than forward logistics (Rosen, 2001; Tibben-Lembke and Rogers, 2002; Amini et al., 2005); there is relationship between CE and RL (Xiangru and Wei, 2009; Chen and Chen, 2010; Ripanti et al., 2015, 2016); and the CE concept also offers the efficiency of resources use, and restorative and regenerative by design concepts (EMF, 2013). According to those facts, the embedding process is undertaken.

The formal RL design framework has five steps. Based on the above results, the embedding process of CE values will start to be arranged. Logically, the CE values will be embedded or inserted after knowing that the specific activities in the RL have been determined. The process after embedding will be analysed based on the literature, examples from existing literature, and logic flows. Furthermore, the step-by-step embedding process will be described further.

1. Deciding on reverse logistics operation options in order to have PR options

In this step, some PR options will be provided: repair, refurbishment, remanufacturing, and cannibalisation. By choosing these options, the next process will be clearer to be conducted, because in each option there are some specific considerations, such as requirements of PR options. Fundamentally, each option has a boundary that makes the activities more focused. Thierry et al. (1995) have identified PR through levels of disassembly, quality requirement, and resulting product (see Table 2.3 in Chapter 2). In this step, the user can choose more than one option, depending on the specific activities involved.

2. Identification of Reverse Logistics Activities

The general RL activities have been identified in Chapter 4, where there are nine activities: transport, collect, assess, classify, repair, disassemble, reassemble, store, and test. These activities need to be classified based on each option in PR. All of the activities per option of PR will therefore be analysed. The mapping results between PR activity and PR option are shown in Table 6.1. The mapping process is based on Figures 4.5, 4.6, 4.7, and 4.8 (in Chapter 4).

In Table 6.1, repair, refurbishment, and remanufacturing options cover the nine activities. Those options have same activities but their detailed activities could be different. For example, details assessing activity in product repair could be different from activities in the product refurbishment option. The cannibalisation covers seven activities excluding reassemble and test, because the cannibalisation will be part of other products where the testing and reassembling process will be taken over by another option.

Table 6.1 – Identification of general reverse logistics activities

PR activity	PR option			
	Repair	Refurbish	Remanufacture	Cannibalise
Transport	x	x	x	x
Collect	x	x	x	x
Assess	x	x	x	x
Classify	x	x	x	x
Repair	x	x	x	x
Disassemble	x	x	x	x
Reassemble	x	x	x	-
Store	x	x	x	x
Test	x	x	x	-

3. Considering and Reviewing Circular Economy Values

This step is the embedding process of CE values into the PR options after determining the activities. Considering and reviewing CE values is needed to provide the knowledge regarding those values. To support the considering and reviewing processes, the key points of CE values are provided (Table 6.2). The key points are expected to ensure understanding the process of CE values is conducted easily.

Table 6.2 – Circular economy key points

Code	CE value	Key point
V1	System thinking	Set up the **mind-set** for integrating the values
V2	Circularity	Process from forward to reverse flow, or vice versa
V3	Innovation	Using a **new method/idea** to redesign and rethink in order to optimise the results
		Implementing a **new method** for the business process
V4	Built-in resilience	**Recovering** from **difficulties** or problems
		Create positive values
		Work together by considering node, connection, and **scale of system**
		Building **an integrated system**
V5	Oriented to cascades/reverse cycle	Keeping material **longer in circulation**
		Maximising the circulation process
V6	Eliminating waste	**Reducing** a number of **wastes**
V7	Technology-driven	**Technology use**
		Efficiency and effectiveness of operations
V8	Market availability	**Reselling** the product
		Considering a number of demands
V9	Optimisation of change	Changing for **improvement**
		Dynamics of problems and demands

V10	Optimising the economy	Production, consumption, service, and supply of money
		Costing and budgeting
		Cost saving for **optimising cost and benefit**
V11	Maximising retained value	**Prolong the lifetime** of product
		Maximising the retained value functionally and economically
		Increasing the function of product recovery
		Increasing the number of recovered products
V12	Minimising the leakage	**Controlling** the loss of material, energy, and labour
		Identifying the inability to incorporate the nutrient back to the biosphere
V13	Collaborative network	**Working together** within different industries
		Stakeholder engagement
V14	Shift to renewable energy	**Reducing energy** used
		Moving to renewable energy sources
		Reducing energy output
V15	Conscious of the environment	**Preserving** the **environment**
		Environmentally friendly
		Environmental regulation
		Amount of carbon emissions
		Material and energy input

4. Mapping Reverse Logistics Options based on Circular Economy Values

This step explains how CE values are identified to be embedded in the specific PR options. The process is started by identifying the activities of PR options. Then, the analysing is done to correlate PR options activities with the 15 CE values. The detailed process of this stage is provided in Tables 6.3, 6.4, 6.5, and 6.6, which illustrate the mapping process for repair, refurbishment, remanufacturing, and cannibalisation, respectively.

Tables 6.3 and 6.4 have similar results in the mapping, because both have similar general PR activities, and similar main activities of options (this will be described further). Those tables show that the *repair activity* adopts 15 CE values. Repair activity here is the main activity for both options (repair and refurbishment). The repair option incidentally has same name as the activity “repair”, but here it needs to be clarified that it describes different items. Furthermore, value 10 (V10) *optimising the economy* is adopted in all activities for both options (repair and refurbishment), as the value is tangible and can be counted. Like V10, minimising the leakage (V12) is also applied in almost all the PR activities, except store and test. This is because V12 focuses on the activities within the main option. In Tables 6.5 and 6.6, the main activity of remanufacturing and cannibalisation are "*reassemble activity*" and "*disassemble activity*" respectively; both activities have 15 CE values. Similarly to Tables 6.3 and 6.4, V10 is also adopted in all of the PR activities.

By comparing all four tables, it can be stated here that V1, V2, V4, and V9 (system thinking, circularity, built-in resilience, and optimisation of change, respectively) are only applied in the main activity of each option. The reason those values are put in the main activity of each option is because they are an accumulation of other values, so those values can be measured when the other values are applied. In addition, those values are in the intrinsic attribute category (second layer) of CE values configuration. The rest of the values in this layer are collaborative network and shift renewable energy (V13 and V14). Different from other values in the second layer, V13 and V14 are still adopted in the "transport, collect and test" activities.

The PR activities illustrated above are the general activities of PR. Indeed, each option has specific activities that can be called a sub activity or process, depending on the type of products and industries. Nevertheless, the process of embedding CE values to the specific activities will be similar to the approach that has been applied in the general activities. Some adjustments are needed when applying the detailed process of the PR options. To prove this, some examples will be used. Two types of product, consumer goods and electronic, and aerospace product, will be applied and these are delivered in the next paragraph.

Table 6.3 – Mapping activities in repair operations with CE values

PR activity	**Circular economy value**														
	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15
Transport										x			x	x	x
Collect			x			x	x			x			x		
Assess						x	x			x	x				
Classify						x	x			x					x
Repair	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Store								x		x			x		
Test			x				x	x		x					

(v1) system thinking; (v2) circularity; (v3) innovation; (v4) built-in resilience; (v5) oriented to cascades/reverse cycle; (v6) eliminating waste; (v7) technology-driven; (v8) market availability; (v9) optimisation of change; (v10) optimising the economy; (v11) maximising retained value; (v12) minimising the leakage; (v13) collaborative network; (v14) shift to renewable energy; (v15) conscious of the environment.

Table 6.4 – Mapping activities in refurbishment operations with CE values

PR activity	**Circular economy value**														
	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15
Transport										x			x	x	x
Collect			x			x	x			x			x		
Assess						x	x			x	x				
Classify						x	x			x					x
Repair	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Store								x		x			x		
Test			x				x	x		x					

Table 6.5 – Mapping activities in remanufacturing operations with CE values

PR activity	Circular economy value														
	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15
Transport										x			x	x	x
Collect			x			x	x			x			x		
Assess						x	x			x	x				
Classify						x	x			x	x				x
Repair					x	x	x			x	x				
Disassemble						x	x			x	x				x
Reassemble	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Store								x		x			x		
Test			x				x	x		x					

Table 6.6 – Mapping activities in cannibalisation operations with CE values

PR activity	Circular economy value														
	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15
Transport										x			x	x	x
Collect			x			x	x			x			x		
Assess						x	x			x	x				
Classify						x	x			x	x				x
Repair					x	x	x			x	x				
Disassemble	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Store								x		x			x		

The PR options, which is chosen for proving that the types of CE value are the same as the mapping above, is the remanufacturing option, where the detail process for product consumer goods and electronics are: initial diagnosis, erasing data, disassembling, cleaning, inspection, replacement of worn parts with new ones, reassembling, software installation, consumable refill, and final check; incoming inspection, disassembly, cleaning, inspection, re-conditioning, reassembly, and final check & certification, respectively (ERN, 2016). Aerospace product processes are: incoming inspection, disassembly, cleaning, inspection, re-conditioning, reassembling, final check + certification (ERN, 2016). The mapping process for those products is depicted in Tables 6.7 and 6.8.

Based on Tables 6.7 and 6.8, it can be seen that the adoption of CE values is the same as the remanufacturing option (Table 6.5). The mapping process for the detailed PR activities can be started by classifying the detailed activities based on the general activities. This means that here the detailed process is readjusted into a general one, for example, in consumer goods and electronics, so the first activity is initial diagnosis. This activity needs to be analysed in more detail, such as asking what type of diagnosis will be done? Here, initial diagnosis is basically similar to assessment in the general PR in that it can be classified as assessment activity, where in Tables 6.7 and 6.8, the general and detailed activities are placed side by side. Those tables are intended to describe the classification and compare processes between the general and the detailed activity. Furthermore, in Tables 6.7 and 6.8 it can be seen that there are some detailed activities that have not been identified, such as transport, collect, classify, and store, which are highlighted in yellow. This situation is possible, as the detailed activities are dynamic.

Table 6.7 – An example of mapping process in remanufacturing with CE values in consumer goods & electronic products

PR activity	**Remanufacturing process**	**Circular economy value**														
		V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**	**V11**	**V12**	**V13**	**V14**	**V15**
Transport	-										x			x	x	x
Collect	-			x			x	x			x			x		
Assess	Initial diagnosis						x	x			x	x				
Classify	-						x	x			x	x				x
Repair	Erase data					x	x	x			x	x				
	Replacement of worn parts with new ones					x	x	x			x	x				
	Cleaning					x	x	x			x	x				
Disassemble	Disassembly						x	x			x	x				x
Assess	Inspection						x	x			x	x				
Reassembly	Reassembly	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Software installation	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Consumable refill	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Store	-								x		x			x		
Test	Final check			x				x	x		x					

Table 6.8 – An example of mapping process in remanufacturing with CE values in aerospace products

PR activity	Remanufacturing process	Circular economy value														
		V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**	**V11**	**V12**	**V13**	**V14**	**V15**
Transport	-										x			x	x	x
Collect	-			x			x	x			x			x		
Assess	Incoming inspection						x	x			x	x				
Classify	-						x	x			x	x				x
Disassemble	Disassembly						x	x			x	x				x
Assess	Inspection						x	x			x	x				x
Repair	Cleaning					x	x	x			x	x				
	Reconditioning					x	x	x			x	x				
Assemble	Reassembly	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Store	-								x		x			x		
Test	Final check + certification			x				x	x		x					

5. Identification Parameters of PR Activities based on Circular Economy Values

In stage 4, the involving of CE values for each PR option has been identified. The next task is identifying the parameters within the activities of PR. The parameters' identification is important to support the operational implementation of the framework. The process of identification can be started from taking one detailed activity/process (the examples are similar to Tables 6.9 and 6.10) that will be identified. The process taken is the disassembly process in the remanufacturing option (Table 6.5). Then, by looking at the CE values involved, in Table 6.9 five values are described (eliminating waste, technology-driven, optimising the economy, maximising retained value, and conscious of the environment). The next process is analysing both components involved previously (process and values). From the analysis results, several parameters can be produced, such as number of disassembled products, number of reused products/parts, number of unusable products/parts, number of parts per product, number of parts that can be reused, number of parts that cannot be reused, total number of reused parts, number of hazardous and non-hazardous products/parts, type of disassembly method, and type of disassembly technology. In addition, the parameters in Table 6.9 can be added, depending on the needs and analysis results. The type of decision that will be decided also determines the type of parameters involved.

Table 6.10 describes the identification parameters for aerospace product for the reconditioning process; as can be seen here, there are six CE values involved, they are oriented to the cascades/reverse cycle, eliminating waste, technology-driven, optimising the economy, maximising retained value, and conscious of the environment. Basically, the deriving of parameters from the process and CE values is similar to that described above. The process of reconditioning involves being oriented to cascades/reverse cycle values, where after the analysing process some parameters can be produced, such as number of reconditioned products/parts, and number of un-reconditioned products/parts. Those parameters can be used to maximise reconditioned products/parts.

Table 6.9 – An example of identification parameters and decisions in remanufacturing with CE values in consumer goods & electronic products

			Remanufacturing process	CE value	Parameter	Type of decision
Consumer goods & electronic	Remanufacturing	Disassembly	1. Disassembly	(1.a) Eliminating waste	Number of disassembled products; Number of reused products/parts; Number of unusable products/parts; Number of parts per product; Number of parts can be reused; Number of parts cannot be reused; Total number of reused parts; Number of hazardous and non-hazardous products/parts; Type of disassembly method; Type of disassembly technology	Minimising amount of waste; minimising hazardous products/parts
				(1.b) Technology-driven	Type of disassembly technology; Technology feature	Decision technology feature
				(1.c) Optimising the economy	Number of parts per product; Number of parts can be reused; Number of parts cannot be reused; Total number of reused parts; Cost of disassembly facilities, technologies, labour; Cost of disassembly process	Minimising disassembly cost
				(1.d) Maximising retained value	Number of parts per product; Number of parts can be reused; Number of parts cannot be reused; Total number of reused parts; Number of disassembled products	Maximising retained product in disassembly
				(1.e) Conscious of the environment	Rules/regulations for hazardous and non-hazardous product in disassembly	Decision on eco disassembly treatment

Table 6.10 – An example of identification parameters and decisions in remanufacturing with CE values in aerospace products

			Remanufacturing process	CE value	Parameter	Type of decision
Aerospace	Remanufacturing	Repair	1. Reconditioning	(1.a) Oriented to cascades/reverse cycle	Number of reconditioned products/parts; Number of un-reconditioned products/parts	Maximising reconditioned products/parts
				(1.b) Eliminating waste	Number of reconditioned products/parts; Number of un-reconditioned products/parts; Number of hazardous and non-hazardous products/parts	Minimising number of un-reconditioned parts; minimising hazardous products/parts
				(1.c) Technology-driven	Type of reconditioning technology; Technology feature	Decision technology feature
				(1.d) Optimising the economy	Cost of reconditioning facilities, technologies, labour; Cost of reconditioning process	Minimising reconditioning cost
				(1.e) Maximising retained value	Number of parts per product; Number of parts can be reused; Number of parts cannot be reused; Total number of reused parts; Number of reconditioned products	Maximising retained values in reconditioning
				(1.f) Conscious of the environment	Rules/regulations for hazardous and non-hazardous product in disassembly	Decision on eco reconditioning treatment

6. Analysing Parameters and Decisions in the Mathematical Formulation

After the identification process of the parameters and decisions in the fifth step, the parameters and decisions that have been provided need to be analysed. The analysing process is done with a quantitative approach. Through using the parameters and decisions, the operational level of the system will be exposed. The mathematical formulation is used to provide analysis for any type of "system". It could be a computer application, integrated system, or other formulation. The mathematical formula was chosen based on some considerations: firstly, due to the available information within the method; secondly, the quantification result can help the objective measurement of system performance. In this latter case, the mathematical formulation will be formulated by taking one example from minimising waste (taken from Table 6.9). Firstly, some variables involved need to be identified:

- Number of parts per product (N_{Part})
- Number of parts can be reused (N_{RP})
- Number of parts cannot be reused (N_{URP})

The first two parameters above can be formulated into equation (1).

$$N_{Part} = N_{RP} + N_{URP} \quad (1)$$

For number of parts cannot be reused, the formula is in equation 2.

$$N_{URP} = N_{Part} - N_{RP} \quad (2)$$

Some additional parameters are needed, such as:

- Disassembly method (M)
- Disassembly technology (T)

For covering those parameters above, a scenario is needed in which the optimum amount of waste (which is the minimum amount) will be affected by the quality of the disassembly method (MQ) and technology (TQ). This means M and T values will be multiplied by the amount of waste. The combined values of M and T will be called the quality of disassembly process or D_pQ. The formula is described in equation (3). It means that D_pQ, MQ, and TQ have a linear correlation; where better methods and technology can give better results in the disassembly process.

$$D_pQ = aMQ + bTQ \quad (3)$$

Where a and b are the coefficient values of method and technology quality respectively. The total amount of waste is represented in equation (4).

$$TN_{URP} = \sum_{i=1}^{n}(N_{Part} - N_{RP}) \quad (4)$$

For the minimal relative values formula (VTN_{URP}, see equation 5). The optimal standard of ($\sum_{i=1}^{n}(N_{Part} - N_{URP})$) means the company has to have a standard of minimal amount of waste. For example, one type of returned product has an optimal standard of amount of waste at 0.3 (only 30% waste of returned product), and based on the calculation results, TN_{URP} equals 0.5; thus VTN_{URP} is equal to 0.6 ($0.3/0.5$). Theoretically the value calculation is based on Ripanti et al. (2016).

$$VTN_{URP} = \frac{optimal\ standard\ (\sum_{i=1}^{n}(N_{Part} - N_{URP}))}{TN_{URP}} \quad (5)$$

Where n is number of product

The value of waste is portrayed in equation 6.

$$VP_{URP} = D_p Q \times VTN_{URP} \quad (6)$$

Or in the objective function form (equation 7):

$$\min f\left(D_p Q, VTN_{URP}\right) = D_p Q \times VTN_{URP} \quad (7)$$

Furthermore, the formulation of eliminating waste can be extended for the reconditioning process, as the number of hazardous parts per product (N_{HZ}) can reduce the number of reconditioned parts (N_{RcP}); where it depends on the following parameters: number of parts per product (N_{Part}), number of parts can be reused (N_{RP}), number of parts cannot be reused (N_{URP}), number of un-reconditioned parts of product (N_{URcP}), and number of non-hazardous parts of product (N_{NHZ}). Thus, equation (1) can be expanded to become equation (8) or (9); where N_{RP} can consist of $N_{RcP}$and N_{URcP}, and N_{RcP} probably consists of N_{NHZ} and N_{HZ}.

$$N_{Part} = N_{RcP} + N_{URcP} + N_{URP} \quad (8)$$

$$N_{Part} = N_{HZ} + N_{NHZ} + N_{URcP} + N_{URP} \quad (9)$$

To maximise the reconditioned parts of a product, the basic equation (10) can possibly be used, and to minimise the hazardous reconditioned parts, equation (11) is used. Or, for total product, equations (12) and (13) are respectively applied; where TN_{RcP} represents the total number of reconditioned parts of a product, TN_{HZ} is the total number of hazardous reconditioned parts of a product, and n is the number of products.

$$N_{RcP} = N_{Part} - N_{URcP} - N_{URP} \text{ (10)}$$

$$N_{HZ} = N_{Part} - N_{NHZ} - N_{URcP} - N_{URP} \text{ (11)}$$

$$TN_{RcP} = \sum_{i=1}^{n}\left(N_{iPart} - N_{iURcp} - N_{iURP}\right) \text{ (12)}$$

$$TN_{HZ} = \sum_{i=1}^{n}(N_{iPart} - N_{iNHZ} - N_{iURcP} - N_{iURP}) \text{ (13)}$$

Relative maximum value of reconditioned parts (VTN_{RcP}) and relative minimum value of hazardous reconditioned parts (VTN_{HZ}), for total product, can be measured by using equations (14) and (15) respectively.

$$VTN_{RcP} = \frac{TN_{RcP}}{Ideal\ Standard\ of\ (TN_{RcP})} \text{ (14)}$$

$$VTN_{HZ} = \frac{Ideal\ Standard\ of\ (TN_{HZ})}{TN_{HZ}} \text{ (15)}$$

As the process of reconditioning also strongly depends on the performance/quality of the reconditioning technology ($RecTQ$), the value of reconditioned parts (VP_{Rec}) and value of hazardous parts (VP_{HZ}) can be calculated by using equations (16) and (17); and the objective functions of maximum VP_{Rec} and minimum VP_{HZ} are respectively stated in equations (18) and (19); where $CRecTQ$ is a coefficient of reconditioning technology performance, ID_{RcP} is an ideal standard of the total number of reconditioned parts, and ID_{HZ} is an ideal standard of the total number of hazardous parts.

$$VP_{Rec} = CRecTQ \times VTN_{RcP} \text{ (16)}$$

$$VP_{HZ} = CRecTQ \times VTN_{HZ} \text{ (17)}$$

$$max\ f(CRecTQ, ID_{RcP}, TN_{RcP}) = CRecTQ \times \frac{TN_{RcP}}{ID_{RcP}} \text{ (18)}$$

$$min\ f(CrecTQ, ID_{HZ}, TN_{HZ}) = CRecTQ \times \frac{ID_{HZ}}{TN_{HZ}} \text{ (19)}$$

According to all of the results in this research, in order to embed the process of CE values into RL operations, the steps within the embedding process can be formulated to develop a framework for designing RL operations based on CE values. Fundamentally, the steps of the framework will be the same as the steps that have been explained above. However, presentation of the framework will be gathered into an integrated diagram. Even so, a narrative description is still needed. The framework is represented in Figure 6.1 which consists of six steps: (1) deciding RL operation options for PR options, (2) identification of RL activities, (3) considering and reviewing CE values, (4) mapping RL options based on CE values, (5) identification of parameters of PR activities based on CE values, (6) analysing parameters and decisions in the mathematical formulation.

Besides illustrating the framework, a detailed diagram is also provided in Figure 6.2 in which each step provides some sub steps that can support a user in easily adopting the framework. The first step provides the instruction to choose some options; the second step provides nine PR activities; the third has two sub processes: reading and understanding the CE values; in the fourth, the processes match the CE values to PR activities in detail, analysing the relationship of PR activities and CE values; the fifth consists of identifying parameters based on PR activities and CE values, and identifying the type of decision process; and finally the sixth step provides two processes: analysing the parameters and decisions, and formulating mathematical formulation.

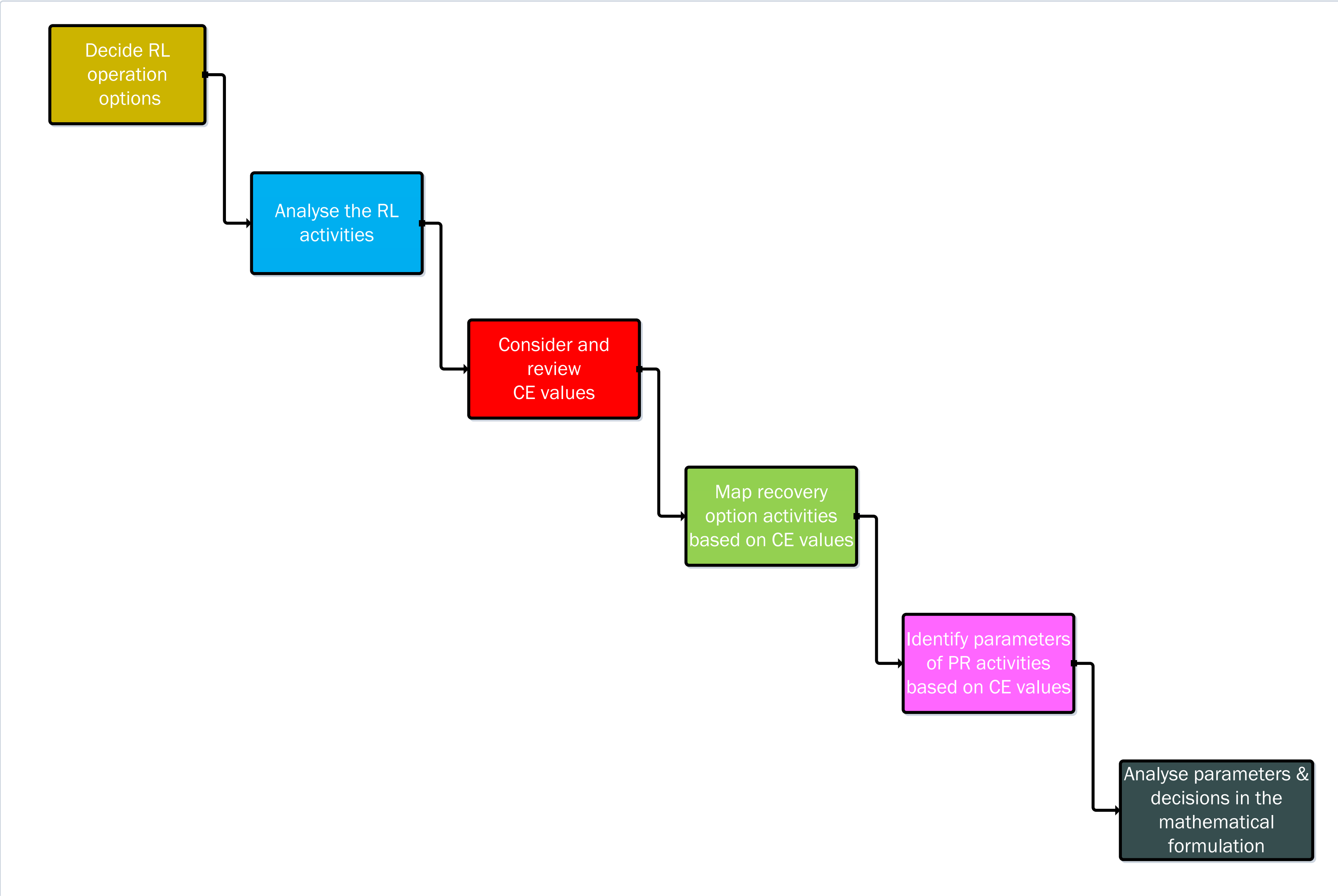

Figure 6.1 – A framework for designing RL based on circular economy values

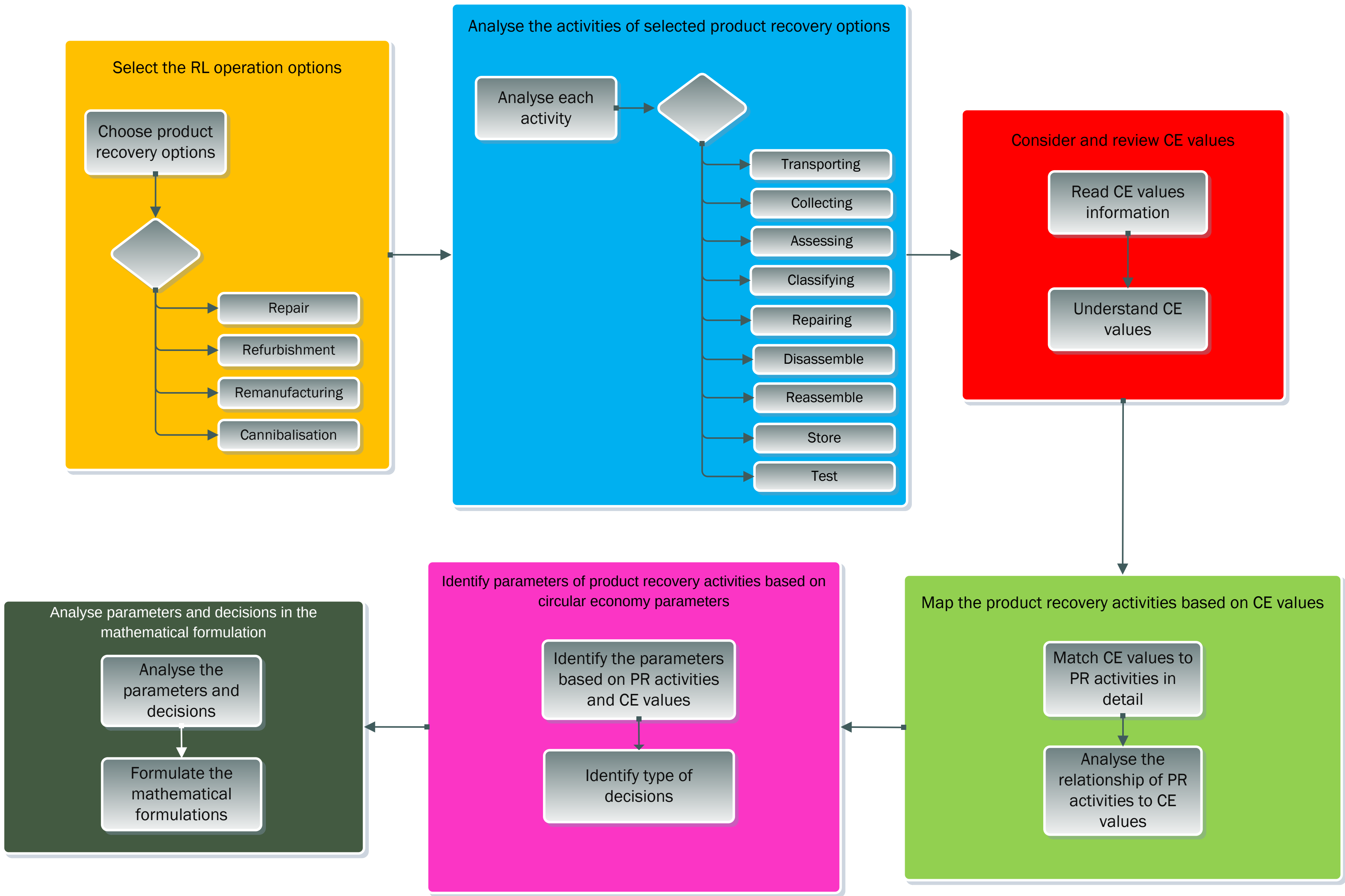

Figure 6.2 – A detailed of the reverse logistics design framework

6.2 Implementation of Framework in the Detailed Process of Product Recovery

According to the framework for designing RL based on CE values above, in this section, the framework in the more detailed process that can distinguish a PR activity with and without CE values will be tried to be implemented. This section will, however, not repeat the process explanation that has been described in the embedding process.

Within the implementation process of using a framework, there are some procedures that need to be prepared. The first is providing the detailed process of PR options. The detail process will be adopted from Figures 4.4, 4.5, 4.6 and 4.7 in Chapter 4. Those figures will be classified as general PR activities (Figures 6.3, 6.4, 6.5 and 6.6). Each figure is classified by using different colours. Those figures represent the product repair, refurbishment, remanufacturing, and cannibalisation flow of processes for specific product, respectively.

Figure 6.3 has some detailed processes that describe the repair process of aircraft product with conditions as illustrated. The type of this industry is independent manufacturer. There are several colours in the flowchart that classify CE values based on the general activities of PR options. The red colour depicts the transportation activity where there some processes, starting from when the customer/aircraft operator sends the product to the remanufacturer. The process will be continued with another PR options process (in the different colours) until the manufacturer/OEM receives the requested part and sends the specific parts. The repair process is started from the customer/aircraft operator as an entity that receives a new product from the OEM. However, sending the new product from the OEM to the customer is not depicted in the diagram.

The repair is continued by an assessment process that is represented in black. The assessment handles the process after receiving the product in the remanufacturer entity, cleaning, and condition C2 (the detailed conditions have been described in Chapter 4). C2 means a non-destructive testing to diagnose the repairing points; the repair activity will be done after assessment. There is a purple diamond that depicts a condition of repairing needs. There are two options there, refer to other activities or replacement needs. Replacement is part of the disassembly process (represented in blue). The reassemble and test will be done after passing all of the processes.

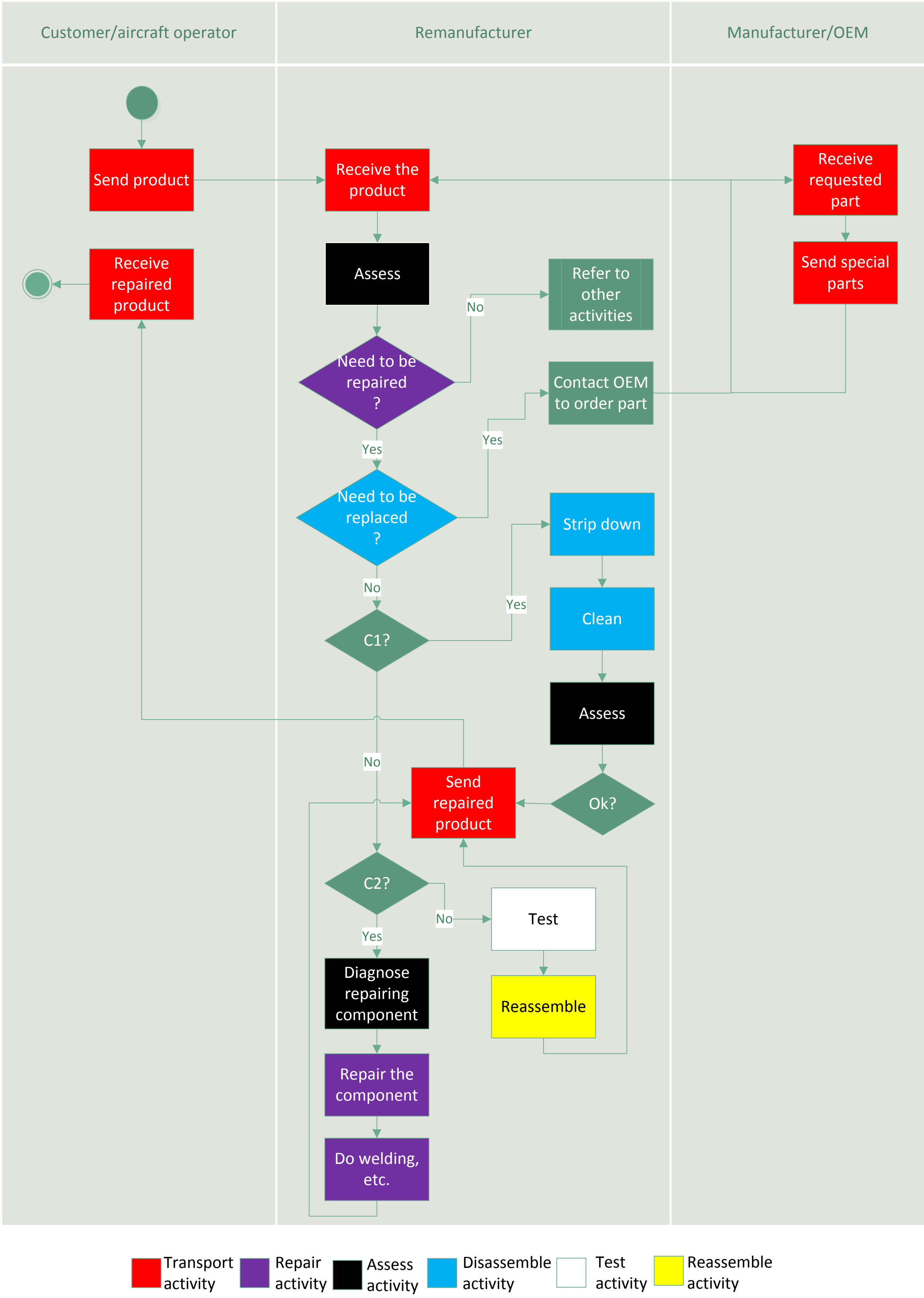

Figure 6.3 – An example of the detailed process for repair

The next step for the implementation of the detailed process of PR is identification of CE values in each activity of PR options. The identification will be similar to the previous embedding process, each activity, and detailed process of each PR option (Tables 6.1, 6.2, 6.3, and 6.4). It can be seen from those tables that the adopting of CE values is the same as the identification in Tables 6.3, 6.4, 6.5, and 6.6.

Table 6.1 illustrates PR and repair activities, which are shown in order to compare between the general and detailed activity of repair. The activity can be identified based on the identification result in the previous repair process. There are six activities (transport, assess, repair, disassemble, reassemble, and test) followed by the detailed activities in different colours. In Table 6.1 are also found the collect, classify, and store activities which were not identified in Figure 6.3. Collect activity is identified due to the function of the customer/aircraft operator as the collector of their old aircraft, while classify and store are put in the table but are not included in the process of the identification (those are coloured in soft green).

Similarly to the previous one, Figure 6.4 illustrates the classification of the refurbishment process that can identify the general PR activities of refurbishment. The refurbishment process for electronic product shown in the flowchart can be classified into three activities: transportation, repair, and assessment. First, in transportation, the process is started from when the supplier/customer sends or receives the collected product to the provider, customer, and recycling centre. Second, some repair processes are undertaken, such as erase data, upgrade, label with id, and repackage, including remarketing the reusable product. Third, the assessment process also identified covering some detailed processes, such as test functional hardware, and inspects cosmetic damage.

Table 6.12 depicts the identification of the mapping process of CE values in refurbishment. There are three main activities: transport, assess, and repair. Similarly to Table 6.11, the grey area is the impact activity of the function of the supplier/customer entity. The soft green coloured indicates that those activities will not be analysed as they were not described in the existing figure (Figure 6.4).

Table 6.11 – Mapping process in repair based on CE values

PR activity	Repair process	Circular economy value														
		V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**	**V11**	**V12**	**V13**	**V14**	**V15**
Transport	Send product										x			x	x	x
	Receive the product										x			x	x	x
	Receive requested part										x			x	x	x
	Send special parts										x			x	x	x
	Send repaired product										x			x	x	x
	Receive repaired product										x			x	x	x
Collect	Send product			x			x	x			x			x		
Assess	Assess						x	x			x	x				
	Assess (after cleaning)						x	x			x	x				
	Diagnose Repairing component						x	x			x	x				
Classify	-						x	x			x	x				x
Repair	Repair component					x	x	x			x	x				
	Weld					x	x	x			x	x				
Disassemble	Replace						x	x			x	x				x
	Strip down						x	x			x	x				x
	Clean						x	x			x	x				x
Reassembly	Reassemble	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Store	-								x		x			x		
Test	Test			x				x	x		x					

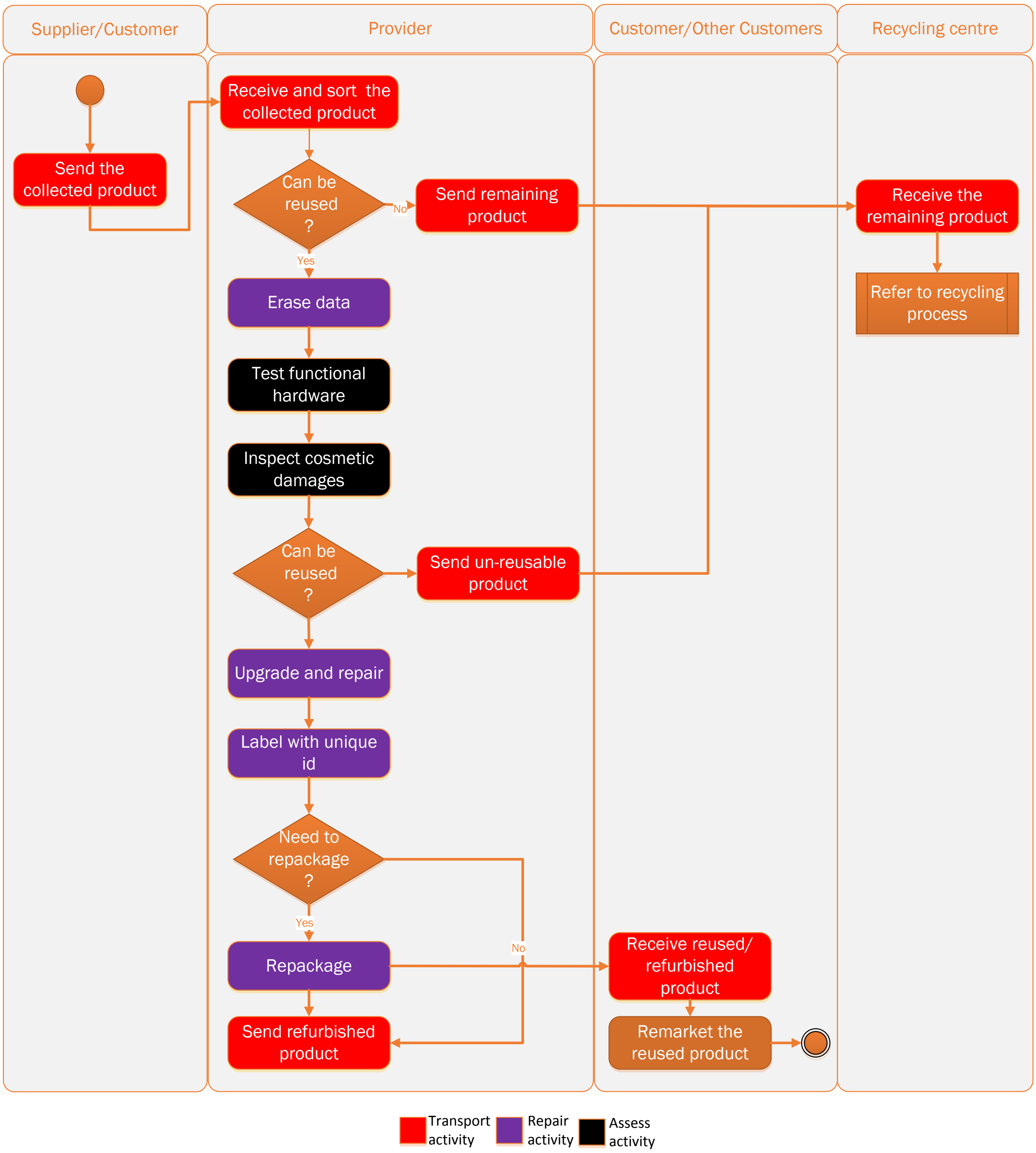

Figure 6.4 – An example of detailed process in refurbishment

Table 6.12 – Mapping process in refurbishment based on CE values

PR activity	Repair process	Circular economy value														
		V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**	**V11**	**V12**	**V13**	**V14**	**V15**
Transport	Send collected product										x			x	x	x
	Receive and sort collected product										x			x	x	x
	Send remaining product										x			x	x	x
	Receive the remaining product										x			x	x	x
	Send un-reusable product										x			x	x	x
	Send refurbished product										x			x	x	x
	Receive reused/refurbished product										x			x	x	x
Collect	Send collected product			x			x	x			x					x
Assess	Test functional hardware						x	x			x	x				
	Inspect cosmetic damages						x	x			x	x				
Classify	-						x	x			x					
Repair	Erase data					x	x	x			x	x				
	Upgrade and repair					x	x	x			x	x				
	Label					x	x	x			x	x				
	Repackage					x	x	x			x	x				
Store	-								x		x			x		
Test	-			x				x	x		x					

Figure 6.5 classifies six general activities in the remanufacturing process for forklift truck product, where the type of remanufacturer is an OER. The remanufacturing process is started from the market or rental, due to the forklift truck product predominantly coming from different kinds of rental model. The transport activity here relates to the sending and receiving processes of product from market/rental to OEM. Other activities, for instance repair covers, clean, and repair; disassembly encompasses change part, until repaint; and test, are needed when all of the other processes are finished.

Table 6.13 shows the remanufacturing identification of CE values' results where there are six main activities identified (transport, assess, classify, repair, disassembly, and test), plus collect.

Figure 6.6 classifies four general PR activities: transport, repair, disassembly, and test. The transportation here is the receiving process of cannibalised product and receiving the cannibalisation request; assess is the repair process; disassembly is removing component, and the test activity is install.

Table 6.14 illustrates that the cannibalisation process has four activities (transport, assess, disassemble, and test) and also collect. The detailed CE values adopted are provided in Table 6.6.

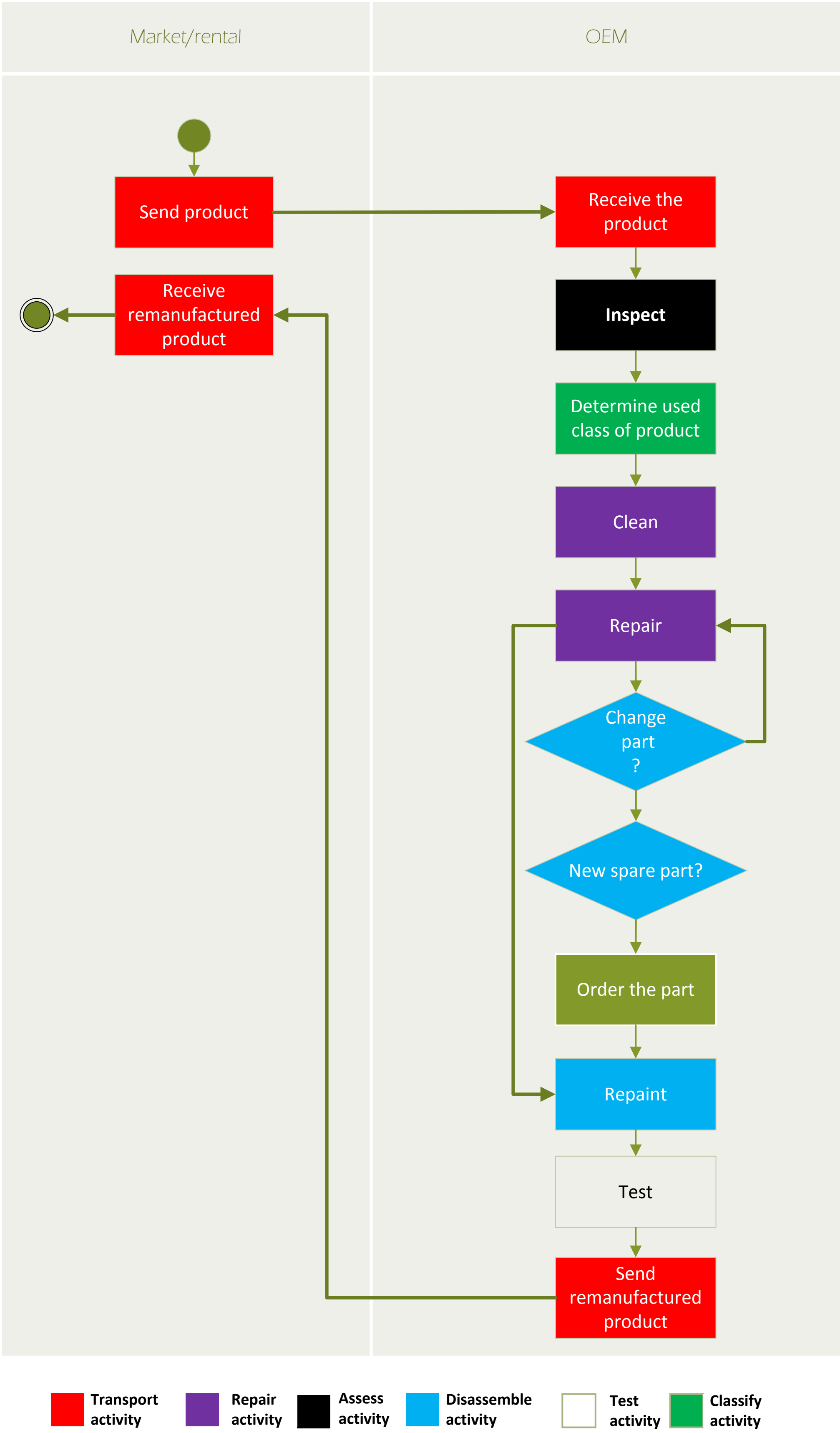

Figure 6.5 – An example of a detailed process in remanufacturing

Table 6.13 – Mapping process in remanufacturing based on CE values

PR activity	**Repair process**	**Circular economy value**														
		V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**	**V11**	**V12**	**V13**	**V14**	**V15**
Transport	Send product										x			x	x	x
	Receive the product										x			x	x	x
	Receive remanufactured product										x			x	x	x
	Send remanufactured product										x			x	x	x
Collect	Send product			x			x	x			x			x		
Assess	Inspect						x	x			x	x				
Classify	Determine used class of product						x	x			x	x				x
Repair	Clean					x	x	x			x	x				
	Repair					x	x	x			x	x				
Disassemble	Change part						x	x			x	x				x
	Use new spare part						x	x			x	x				x
	Repaint						x	x			x	x				x
Reassembly	-	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Store	-								x		x			x		
Test	Test			x			x	x			x					

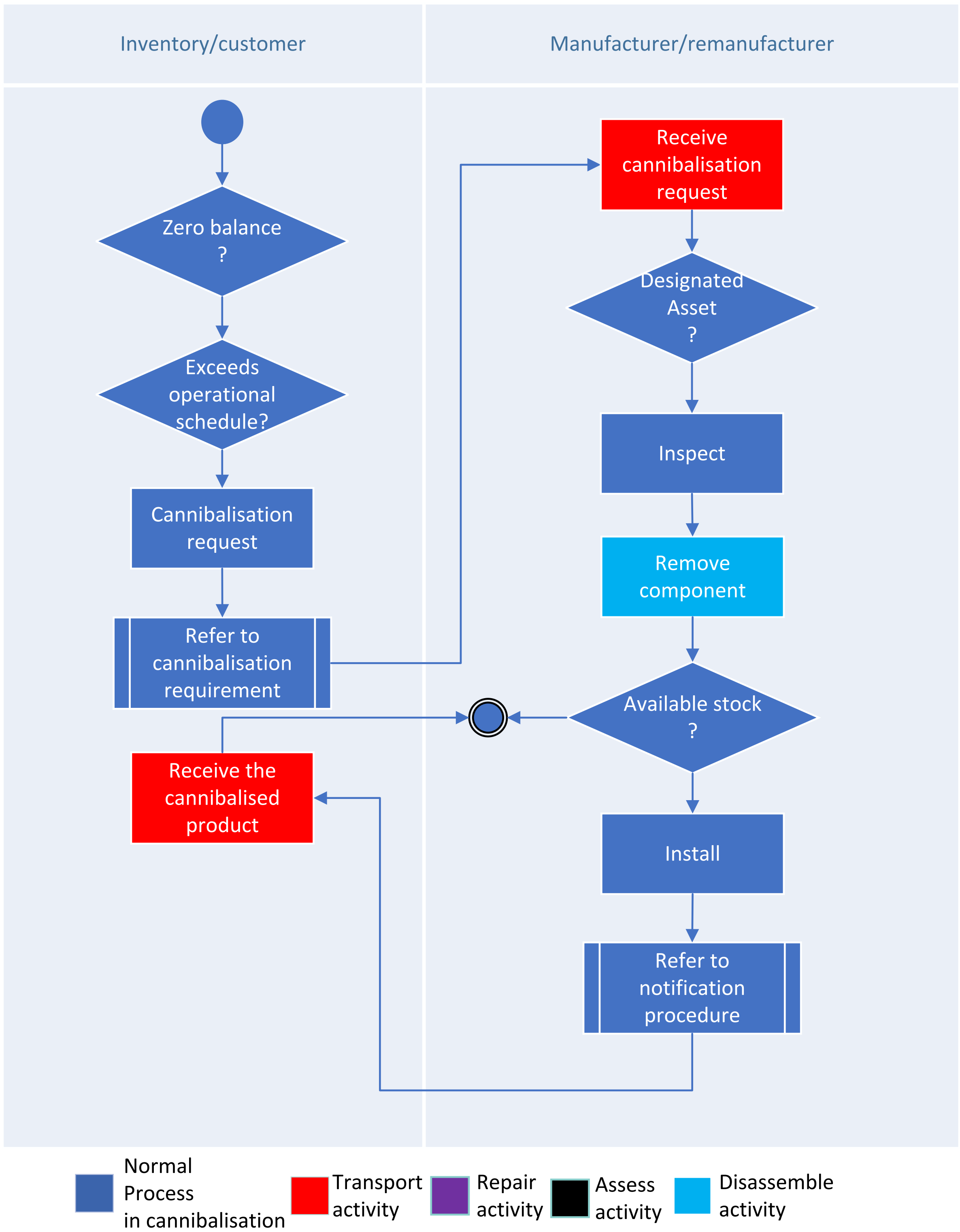

Figure 6.6 - An example of a detailed process in cannibalisation

Table 6.14 – Mapping process in cannibalisation based on CE values

PR activity	Repair process	Circular economy value														
		V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15
Transport	Receive cannibalisation request										x			x	x	x
	Receive the cannibalised product										x			x	x	x
Collect	Send product			x			x	x			x			x		
Assess	Inspect						x	x			x	x				
Classify	Determine used class of product						x	x			x	x				x
Disassemble	Remove component	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Store	-															
Test	Install								x		x			x		

In addition, through the implementation of the framework some processes of PR before and after adopting CE values are described, as depicted in Figures 6.7, 6.8, 6.9, and 6.10. Those figures are coloured in red and green where green is the process with CE and red without CE. Fundamentally those figures describe the approach to design PR based on CE values.

Figure 6.7 illustrates the repair process based on CE values through several new processes shown in green. As can be seen, after remanufacturing a received product there is a new process, such as counting the number of products and parts. There are some conditions involved such as selecting the type of method and technology to minimise the amount of waste, and determining the quality of the repaired product. Figure 6.8 basically has several similar processes to Figure 6.7, since the source of the parameters is similar. Figures 6.9 and 6.10 depict almost similar processes, as their parameters and decisions are similar.

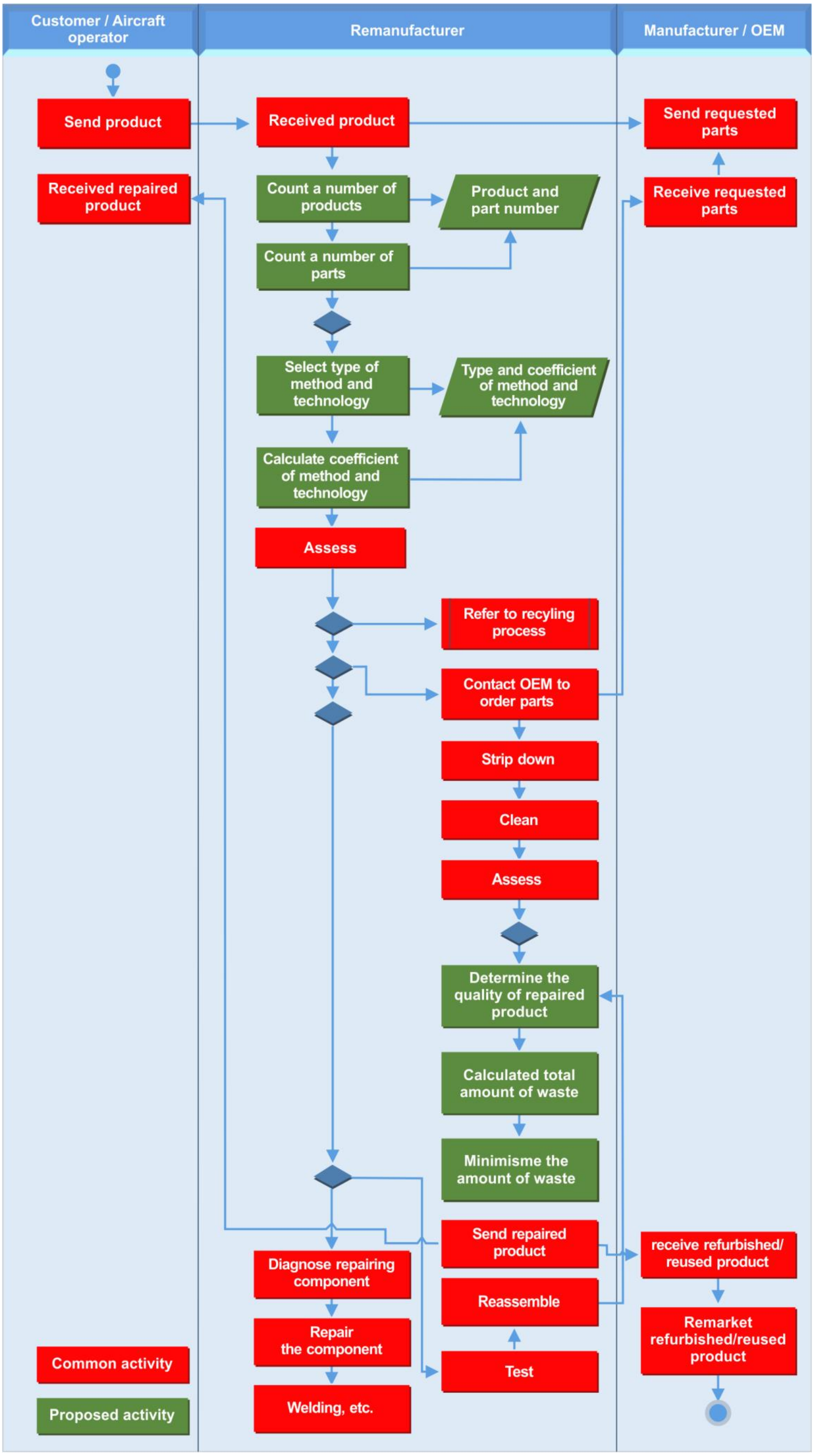

Figure 6.7 – An example of the repair process based on circular economy values

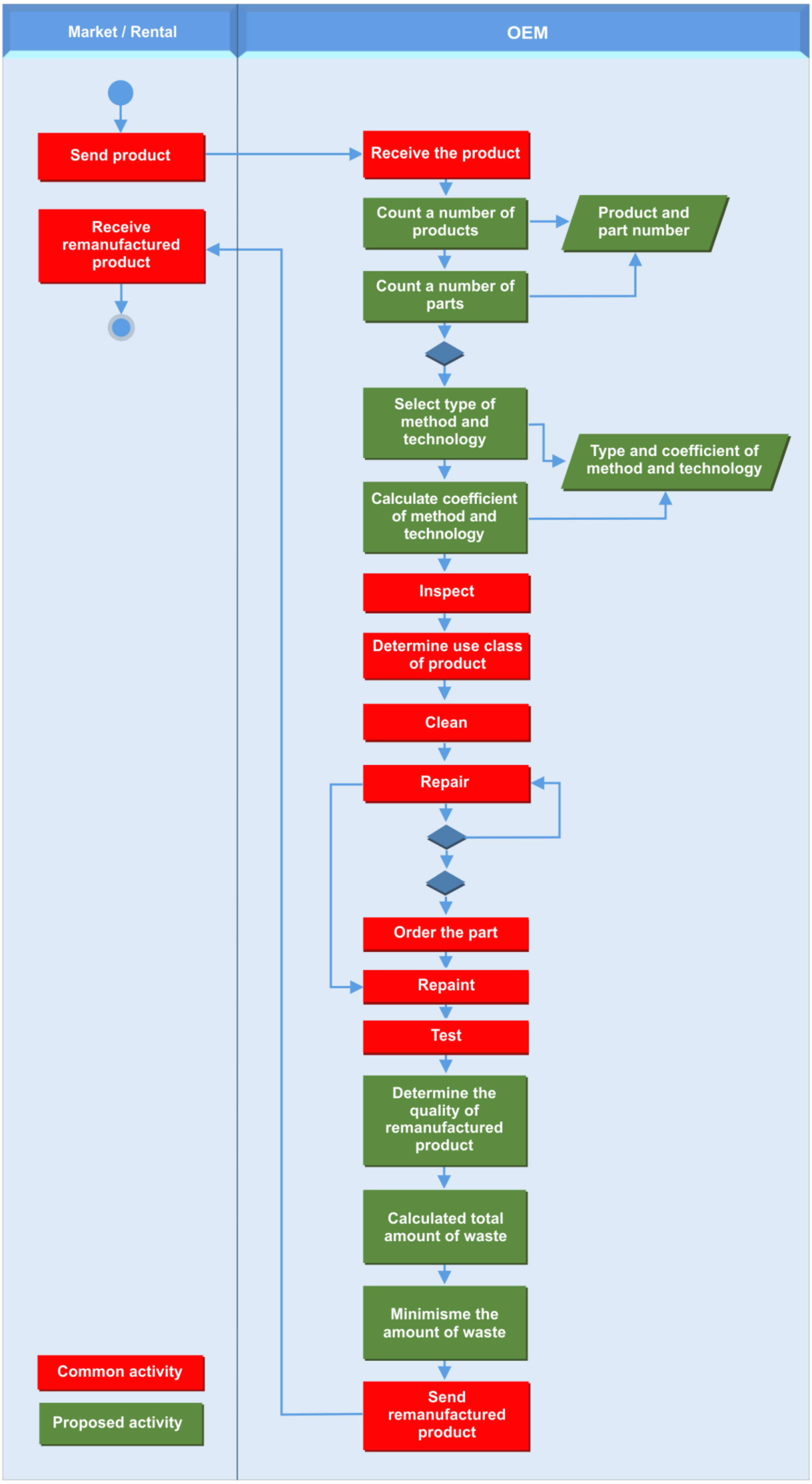

Figure 6.8 – An example of the refurbishment process based on circular economy values

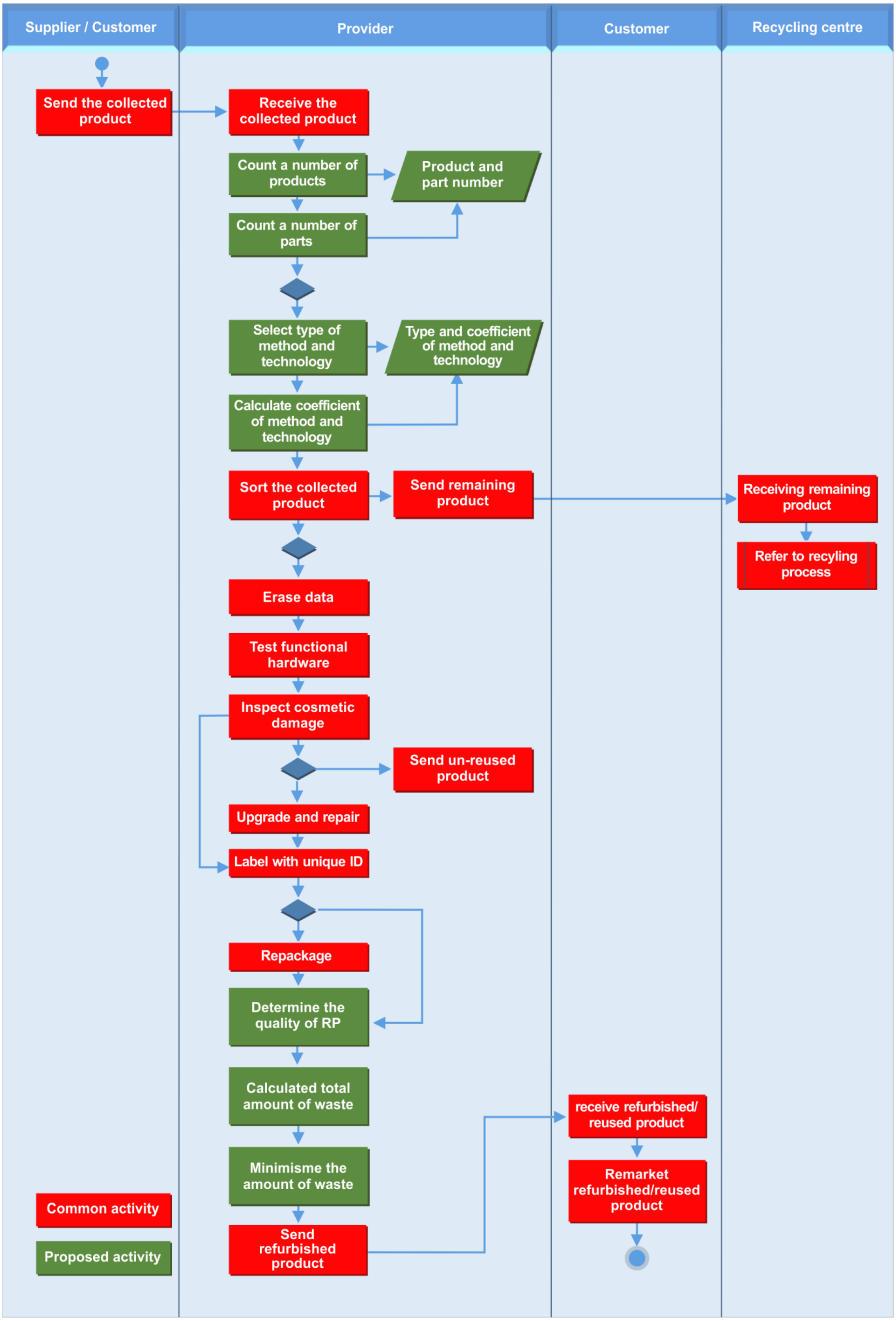

Figure 6.9 – An example remanufacturing process based on circular economy values

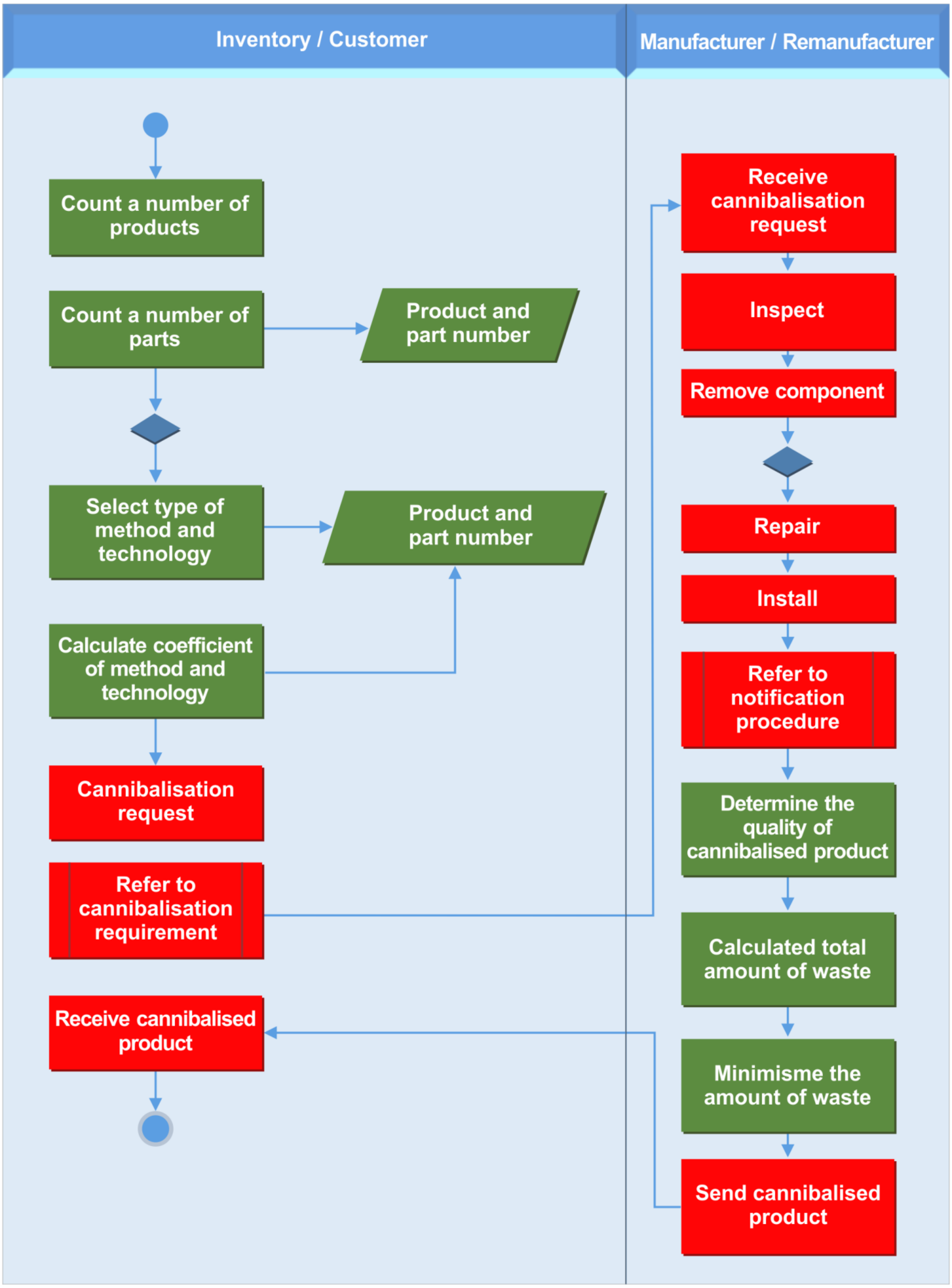

Figure 6.10 – An example of the cannibalisation process based on circular economy values

6.3 Summary

The embedding process of CE into RL is an implementation of both concepts. The process shows how to identify, analyse, and apply CE values and parameters in PR activities. The embedding process can be implanted to the specific product and specific PR options (repair, refurbishment, remanufacturing, and cannibalisation) even though, this research is not specifically implementing in the specific product. It is because the aim of this research is to produce a framework for designing RL based on CE values. Furthermore, the step-by-step of embedding process can be a guide to design an RL system. There are six steps proposed as a framework. Those steps can be provided based on synthesising results of formal RL design framework and CE values. Some examples were provided (e.g. electronic and consumer goods and aerospace product) to illustrate the clear embedding process. Those examples were chosen as they are considered suitable for PR options.

CHAPTER 7

TESTING THE FRAMEWORK FOR DESIGNING REVERSE LOGISTICS BASED ON CIRCULAR ECONOMY VALUES

7.1 Introduction

The framework for designing RL based on VE values is one of the main research results. Testing the framework also is the advanced process after embedding and implementing CE values to RL. This chapter will describe the testing process of the framework and also the validation process of the whole research results. The validation can be done after receiving the testing results. The logical process is represented in each section of this chapter. It shows structurally in Figure 7.1. The structure starts from section introduction (7.1), section 7.1 introduces briefly the testing and validation activities that will be conducted. Section 7.2 describes testing process of developed framework. It covers the development of testing instruments, testing strategy, testing results, and discussion. The testing purposes to confirm the quality of the developed framework through engaging respondents that provide the expert point of view.

The validation also will be done to validate the whole research results through evaluating the trustworthiness. Some strategies are prepared such as triangulation, peer debriefing and support, and member checking. Furthermore, the results from the testing of the framework and the validation of research result are concluded in the summary to provide the point of both activities.

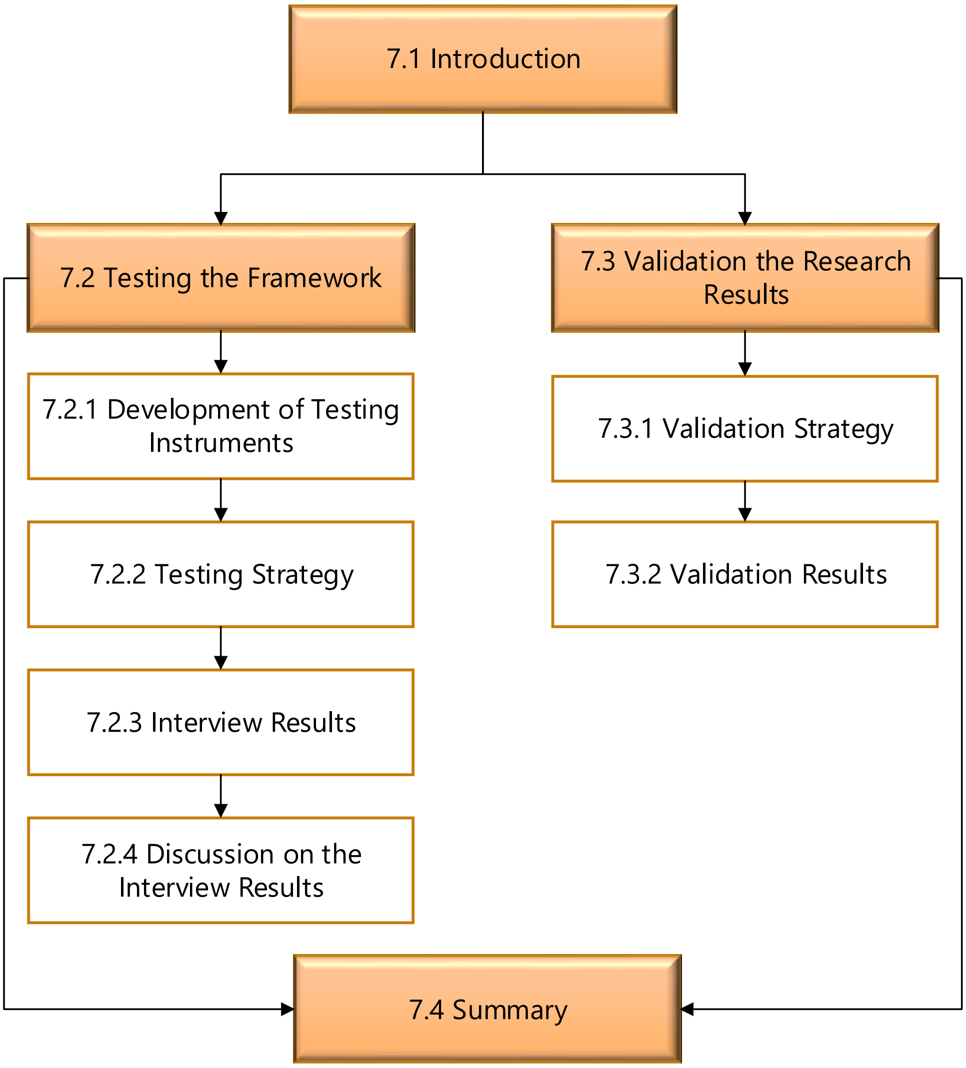

Figure 7.1 Structure of chapter 7

The framework is expected to be used by users (company, scientist, or government) for designing RL. Confirming the framework through testing is required to determine the quality of framework through key measurements. The testing process is needed in research. Hill (1987) asserts that accurate research needs to be tested by clear application. Accurate research needs to have a direct connection between researcher and first user in order to crystallise an event, contribute to the body of knowledge, suggest the relevant method, and develop new concepts from the research undertaken (Hill, 1987). In addition, Platts (1993) described a testing stage in the manufacturing strategy where the testing needs to provide practicality and procedural steps in the strategy formulation. He provided three criteria for the testing: *feasibility*, the process of the tested object can be followed; *usability*, the extent to which the process can be followed easily; and *utility*, the usefulness of the process.

In this research, the testing process is conducted to test the framework. Some criteria need to be arranged so that the framework is accurate. There five key measurements prepared to test the framework: fit for purpose/usability, feasibility, utility (Platts, 1993); consistency/repeatability, the consistency is achieved by using verified examination (Campbell, 1996); reliability/effectiveness, measuring the extent to which users can use products based on product characteristics (Rubin and Chisnel, 2008). Besides those criteria, to accommodate suggestions and relevant information, the strengths and weaknesses will be identified in the testing process.

The testing activities need to be planned so they can be done effectively. The testing was done by interviewing several participants. The testing needs to be planned, for instance by providing an interview guide. Within the testing, there are several initial activities such as discussions with the supervisor, and an expert. The initial activity's purpose is to obtain valuable input before conducting the testing. The discussion with an expert was undertaken jointly by the supervisor and researcher. The expert is from academia and has expertise in RL. The discussions were conducted to elicit another viewpoint.

Testing was done by interviewing some respondents from companies and also an expert. The interview procedure was started by conducting a pilot interview; this needs to be done before the main interviews so that any improvements can be made (Kvale, 2007). This research will adopt the semi-structured interview format, which provides the opportunity for the interviewer to ask some follow-up questions or explore the interviewees' answers.

An effective interview can be supported by different instruments, such as interview protocol and agenda; these instruments make it easier for both interviewer and interviewee. In addition, the interview results need to be analysed via several approaches, such as interpreting, coding and categorising data (Creswell, 2003; Kvale, 2007). The interpreting generally involves analysing the meaning of each answer to each question or statement. Coding and categorising are used to group the answers. Through those results the analysis will be conducted to provide the conclusions from the interview results.

7.2 Testing the Framework

7.2.1 Development of Testing Instruments

The first instrument to be constructed is the interview protocol which describes the technical procedure for the interview process. The protocol will help the interviewer to fulfil the objective of the interview, and for interviewees it will be easy to understand the interviewer views and the direction of the standard procedure used to conduct the interview. During the development cycle, the interview protocol was modified several times to improve its effectiveness. The first interview protocol was designed in Table 7.1. The protocol is divided into several parts: preliminary activities (explore company profile, business process, and send an interview guide). The protocol also consists of objective, target, and the strategy to achieve the target. The protocol is designed with two objectives: to confirm the interviewee procedure is understandable, and identify the strengths and weaknesses of the framework.

Table 7.1 – First interview protocol

<table>
<tr><th colspan="5">Interview Method</th></tr>
<tr><td colspan="4">Preliminary Activities</td><td>The Interviewer needs to:
• Explore the company profile
• Explore the business process
• Send an interview guide</td></tr>
<tr><th colspan="2">Objective</th><th colspan="2">Target</th><th>Strategy</th></tr>
<tr><td>1</td><td>To confirm the understandable of the framework</td><td>a</td><td>The participants can: grasp the logic flow of the framework</td><td>• Describing the research briefly
• Conveying the testing aim and objectives
• Introducing the framework
• Explaining the framework step-by-step
• Exploring the feedback and understanding the framework through questions about the understanding of this framework</td></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td>a</td><td>The participants can: explain the relevance of the framework</td><td>• Exploring examples of methods/activities that have been used in the company</td></tr>
<tr><td>b</td><td>see the importance of this framework for designing RL operations</td><td>• Figuring out and ensuring the framework is important for the company</td></tr>
</table>

2	Identify the strengths and weaknesses of the framework	c	describe several **activities** in the framework that have actually been done	• Identifying the similarities and differences between the current framework and the framework
		d	see the framework is providing an **easy/convenient** approach to implement the framework	• Exploring the possibility of adopting the framework
		e	explain the **strengths and weaknesses** of the framework	• Exploring the advantages and disadvantages/simplicity and difficulty of using the framework
		f	describe how the feasibility of designing the process of RL operations is to be **effectively** applied through the framework	• Exploring their evaluation of the framework and asking about their willingness to use the framework

Table 7.1 was analysed after conducting the pilot interview, it needs to improve regarding the efficiency of times, questions, and key measurements. The improvement interview protocol is illustrated Table 7.2. Table 7.2 illustrates the four main activities required to conduct an interview. Firstly, before interviewing, the interviewer needs to send an interview guide that explains the time duration, questions, and the interview agenda (Appendix 2). Within the interview, the interviewer will provide an introduction which will explain the research aim, CE concept, interview purpose, and also research ethics. In the latter, the interviewer describes that the interview results will only be used for research purposes. In the next step, the interviewer will describe the framework and explain the CE values. Questions will be asked in the interview and discussion section, where there are five criteria that have been arranged to achieve the interview purpose. Within the interview, the participant can interrupt, ask questions, and clarify some aspects. The last activity is a closing statement where the interviewer can ensure that the participant has finished giving feedback.

Semi-structured interviews still need a list of questions so the interview runs effectively (Table 7.3); some questions are constructed based on the objectives of the testing procedure. The questions are also intended to fulfil the five criteria in

Table 7.2. However, the questions can be expanded, based on the situation and needs.

Table 7.2 – Interview protocol

Preliminary Activities	• **Send an interview guide**
Introduction	• Research aim • CE definition • Interview purpose • Research ethics
Framework explanation	• Proposed framework • CE values
Interview and discussion	Criteria: • Fit for purpose/usability • Feasibility • Consistency/repeatability • Reliability/Effectiveness • Utility Strengths and weaknesses (input)
Closing	

Table 7.3 - Guide list of questions

Reference	Criteria	Questions
Platts (1993)	Fit for purpose/ usability	• Is the framework suitable to meet the objectives? • Is the overall concept understandable? Does it make sense? • Usability: can the framework be easily followed? • Does it have a logical flow and sequence of events? • Could managers adopt the approach suggested?
Platts (1993)	Feasibility	• Can the framework be applied: is it sufficiently understandable to use? • Would the framework provide managers with feasible options?
Harper (1994); Krishnan and Kellner (1999)	Consistency/ Repeatability	• Would using the framework provide consistent and repeatable results?
Rubin and Chisnel (2008)	Reliability/ Effectiveness	• Would using the framework lead to reliable and robust solutions? • Is the model considered to be a comprehensive approach?
Platts (1993)	Utility	• Would the framework provide a useful output? • Are the options likely to be implemented?

The interview will take an hour approximately. The detailed timeline is illustrated in Figure 7.2. The timeline depicts the detailed interview activities shown in minutes. There are three main parts: introduction, it will describe some activities such the research aim, CE definition, interview purpose; in the detailed explanation of framework will show the framework; interviewing process, it will ask some questions in the protocol or other related questions or suggestions; closing, it can be conclusion of the interview.

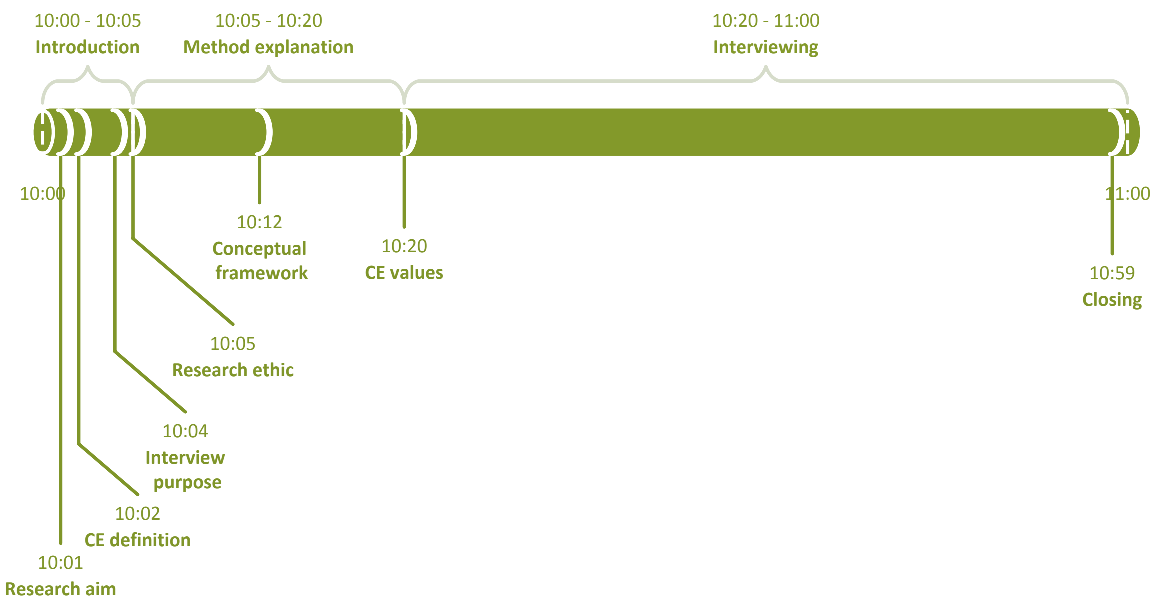

Figure 7.2 – Timeline of interview agenda

7.2.2 Testing Strategy

This section explains the testing approach through conducting interviews. The interview divides to two ways, pilot interview and interview.

A. Pilot Interview

The pilot interviews were conducted after having a structured interview instrument. The interview engaged two participants from aerospace companies. The participants were chosen for various reasons which will be described next. The respondents' profiles can be seen in Table 7.4.

Table 7.4 – *Profile of respondents in the pilot interviews*

Code	Role	Industry	Level
PR01	Flight dynamic engineer	Aerospace company - INA	Operational
PR02	Account manager	Aircraft maintenance company - INA	Tactical/Operational

The interviews were conducted in the UK; the first and second interviews lasted for 1 hour, 31 minutes and 1 hour 8 minutes, respectively. As mentioned in the introduction the pilot interviews aimed to provide opportunities to refine the interview design. Therefore, the analysing results of both respondents will be described briefly.

From the suggestions of both participants (PR01 and PR02) it can be concluded that there are some aspects that need to be improved. The first is related to the presentation of the framework. The step-by-step framework should be described at the beginning, and after that the diagram can be shown. Showing the diagram also shows all of steps that have been explained previously. The purpose of the interview, duration, research ethical practice, introduction related to the research, questions, and measurement criteria, are all important to rearrange so they can achieve the original interview purpose and provide a more convenient interview for both interviewee and interviewer.

The framework also needs to be revisited; this is related to the efficiency of the interview because participants do not need to know all of the information from the research. Selecting priority information is needed in terms of the understanding by the participant within an hour (the anticipated time for the interview). The appearance of the framework could also be slightly different from the original framework displayed in the research. Furthermore, sending the interview guide including the interview questions, framework, and key measurement/criteria out before interview is necessary so that the interviewee can know and underline what the interviewer expects in the interview.

B. Conducting Interviews

The detailed data of the participants are confidential; therefore, this research will only provide basic information on the participants (Table 7.5).

Table 7.5 – Profile of respondents

Code	Role	Industry	Level
E01	Principle lecturer	Education	Senior
R01	General manager	Logistics company	Strategic
R02	Senior Multi-Channel General Manager Operations & Returns	Multinational grocery and general merchandise retailer company	Strategic
R03	Director procurement and supply chain customer equipment	Mobile network operator, Internet service provider company	Strategic
R04	Director of quality & product development	Retailer of motoring and cycling products and independent operator in garage servicing and auto repair company	Strategic

The company profile of each respondent will be described. However, for the experts, their expertise only is described, as follows:

1. Expert (E01) has expertise in supply chain sustainability, RL, and carbon footprint measurement. The expert is engaged by many companies on research projects.
2. Respondent (R01)

   The company is engaged in logistics activities that cover direct logistics, RL, and innovation. The company covers various sectors such as automotive, textile, cosmetics, and telecommunication industries. It also has a wide network in several countries; has 19 years' experience in the logistics area; environmental certification that describes commitment to the environment from the company's services; and several relevant facilities, for instance a returnable packaging system, storage, registration of references, and handling customised orders. Furthermore, the respondent who represents the company also has experience in a Logistics Company for more than 10 years so is expected to provide an expert view and test the framework based on the five criteria that have been identified.
3. Respondent 2 (R02)

   As one of the largest retailers, this company has more than 400,000 employees, and serves customers in store and online. It has robust networks in more than 10 countries. The respondent who represents this company has significant experience specifically in returns management.

4. Respondent 3 (R03)

   The company has more than 500 retail stores, and is the largest and most advanced digital communication company in the UK. The respondent who represents this company also has expertise in supply chain and manufacturing.

5. Respondent 4 (R04)

   The company has more than 460 stores; it has retail centres and over 300 auto centres. The respondent who represents this company also has expertise in quality and product development.

7.2.3 Interview Results

The interview results will be reported in this section. The duration times are given in Table 7.6. All of the communication from the interviews has been recorded by using an electronic recorder. These interviews engaged four participants, and one RL expert. All of the interviews were conducted in the UK, and the type of communication for the interviews was direct interview and phone.

Table 7.6 – Time duration of interviews

Code	Date	Time duration		Type communication	Location
		Time start	Time end		
E01	16 August 2016	09.00 AM	10.00 AM	Face to face	UK
R01	10 August 2016	09.49 AM	10.52 AM	Face to face	UK
R02	2 September 2016	13.00 PM	13.57 PM	By phone	UK
R03	7 September 2016	11.00 AM	11.54 AM	By phone	UK
R04	7 September 2016	15.00 PM	15.55 PM	By phone	UK

As can be seen, the interviews with the four participants and one expert have taken approximately an hour each; this is related to the interview protocol (Table 7.2). In the analysing process of the interview results there are several stages. Firstly the interview recordings need to be *transcribed* to obtain clear information and interpretation. After reading the transcript, it is then categorised which is done by determining some key measurements (fit for purpose/usability, feasibility, consistency/repeatability, utility, reliability/effectiveness). Additionally, the interview also asked about the strengths and weaknesses of the framework; this part is essentially to accommodate input and suggestions from the respondent. According to the categorising results, a detailed analysis was undertaken. In the analysing process, other information from respondents will be documented, as that information will possibly be used to support the analysed statements. In addition, in the representation of interview results, a short amount of information regarding the company, and the reason for choosing the respondent will be provided.

The interview results for each respondent will be depicted in a mind map diagram. Each diagram was captured based on the respondents' general answers based on the key measurements. The diagram is used to ease the analysing process. Figures 7.3, 7.4, 7.5 and 7.6 consist of first layer, key measurement (blue), second layer (red) is questions, and the next layers are key answers from respondents. There are several yellow boxes that mention some additional information or notes. Figure 7.3 represents interview results from R01 who expressed the understandable of the framework by saying that the framework was similar to the daily activities of respondent's company. The respondent also mentioned the feasibility of the framework to be applied in the future.

Figure 7.4 depicts results from R02. In the fit for purpose/usability consists of the concepts of understandable, and logic flow. Some key information was described related to product return. In the logic flow the respondent focused on the commercial view and sustainability; for consistency/repeatability, the respondent described these as related to the cyclical process: feasibility, utility, and reliability. Those are only mentioned "yes". A clear description for will be described in the further sections.

In Figure 7.5, in the first key measurement, the logic flow related to strategic choice, organisational design, and commerciality. There are some little boxes that noted there are four times the respondent mentioned the same keyword. The respondent also touched on the organisational vision and cyclical process for feasibility and consistency/repeatability, respectively. Input was provided related to customer centric, corporate social responsibility, information technology, and human resources. Figure 7.6 describes the first key measurement is understandable with the focus on CE and return management, and in the logic flow R04 mentions organisational vision. Other answers are highlighted in the little boxes.

The expert focused on the framework that is proposed. Overall, the flow and content of the framework are logical. The first to fifth steps can be understood. The sixth step is still logical but needs to be adjusted as it was predicted that it might not be applicable. It was suggested that it be changed, for instance, to CE performance measurement, where mathematical formulation can still be used. In addition, other suggestions were highlighted, for instance the content of the guide needs to provide the CE values' keywords as the participant will be familiar with the CE values.

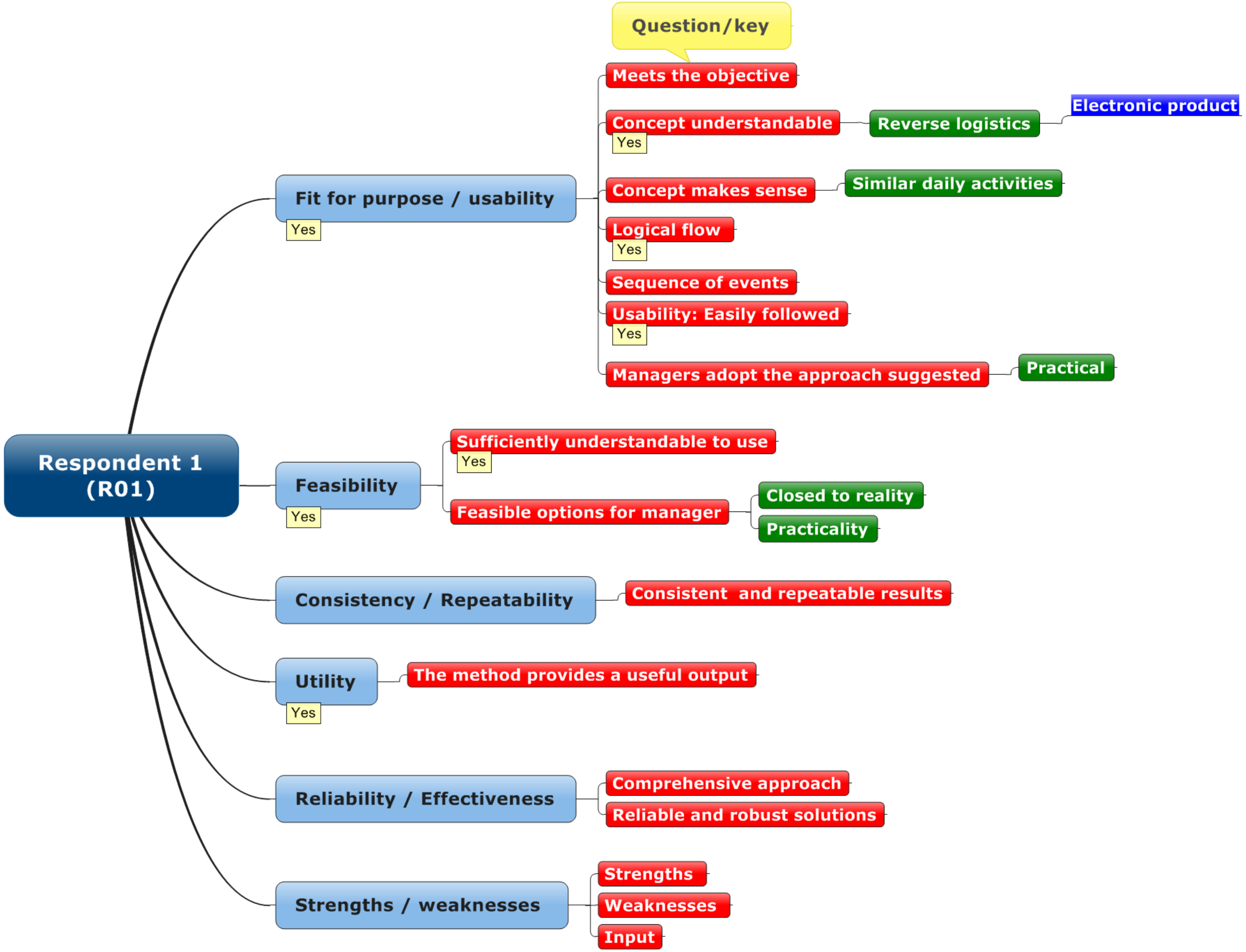

Figure 7.3 – An interview results map of respondent R01

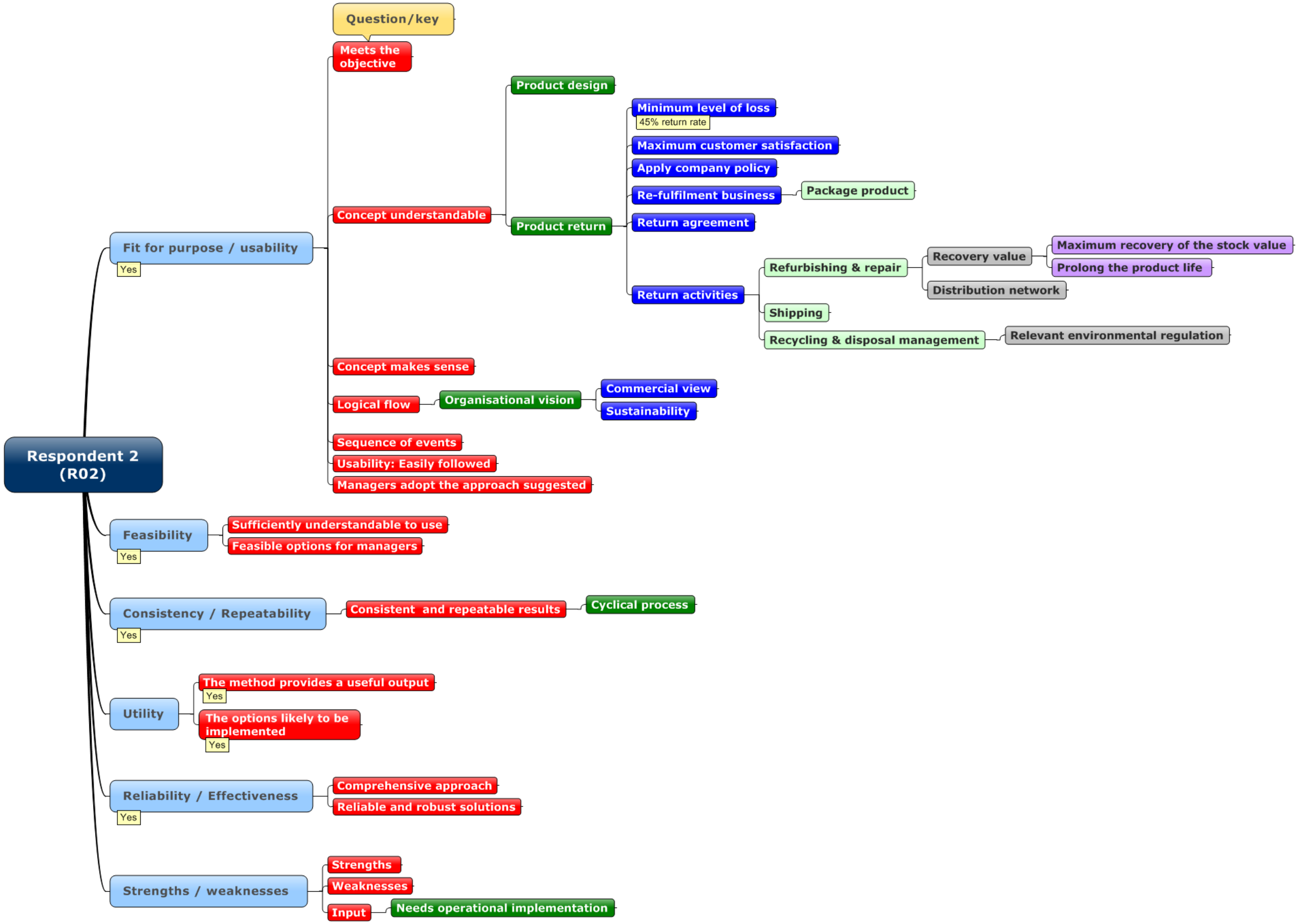

Figure 7.4 – An interview results map of respondent R02

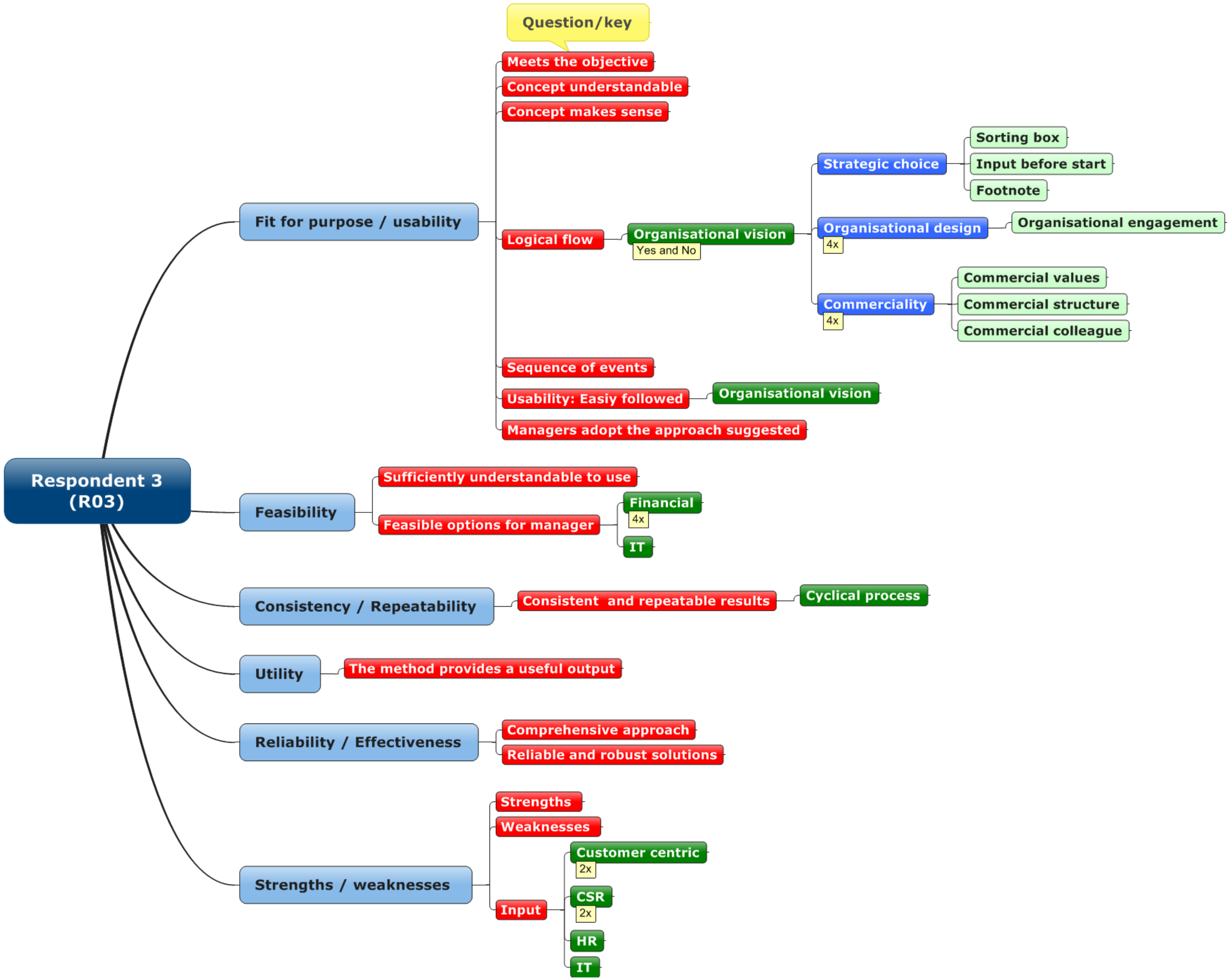

Figure 7.5 – An interview results map of respondent R03

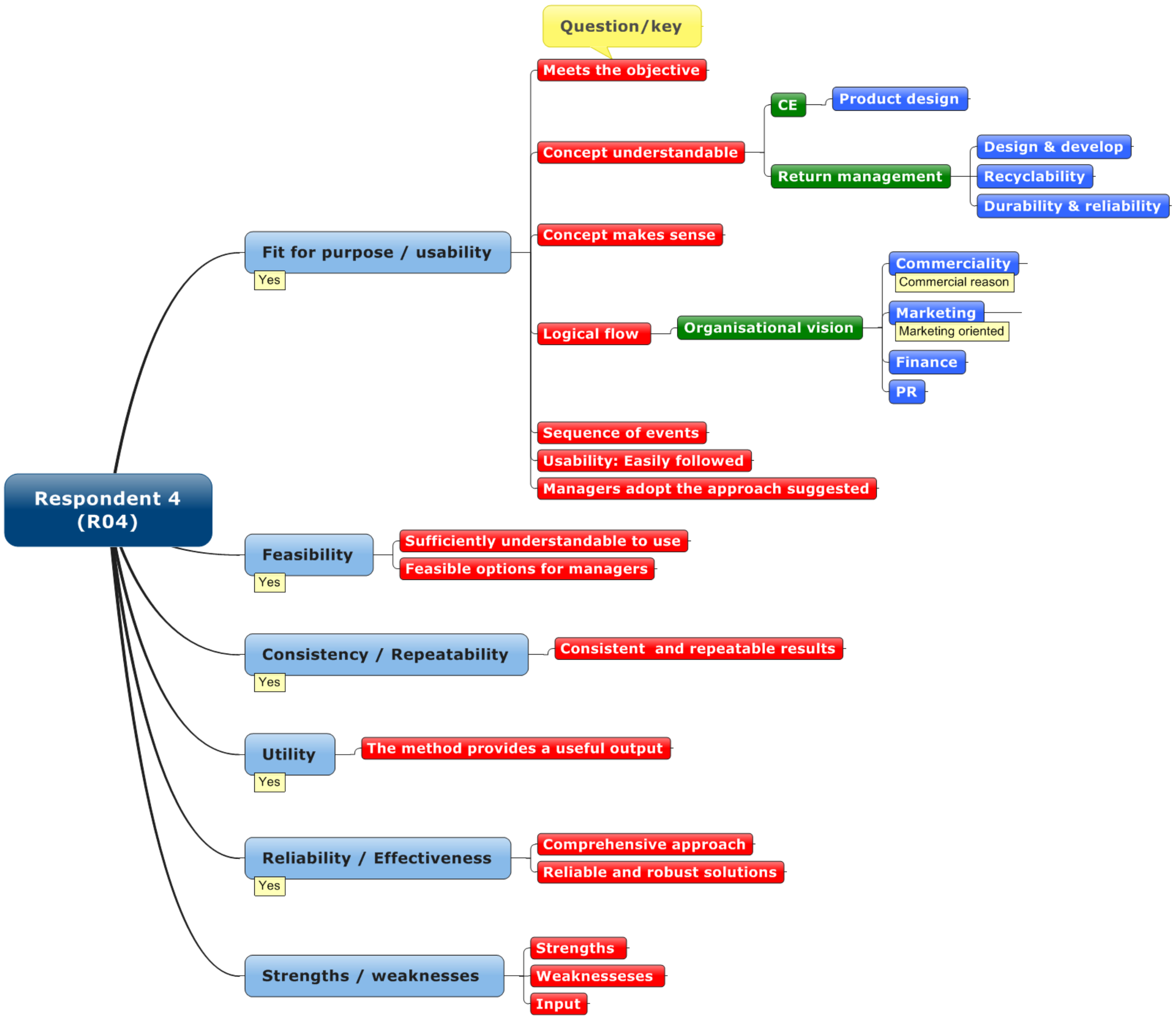

Figure 7.6 – An interview results map of respondent R04

7.2.3.1 Fit for Purpose/Usability

This key measurement will be used to measure the framework regarding whether it meets or does not meet the objectives. The purpose of the interviews is to obtain an expert view and test the framework. The key also measures the understanding of the framework, it will ask about the logic flow and also the ease of application.

The fit for purpose/usability key has been covered through some questions and discussion, where some respondents (R01, R02, and R04) confirmed that the method is clear and logical regarding this key measurement; however, there are some comments and notes to improve the flow of the framework, such as R02 suggesting enclosing a detailed document that can be understood easily.

> *"I can say quite clear….we've discussed this… In things we've been exchanging during conversation." (R01).*

> *"Yes, I think it does. I think as you talk through each box you obviously summarise them into fairly limited words.... there's probably a slightly more detailed document that explains exactly what it means but yes, definitely, it makes sense" (R02).*

> *"I would say yes at high level that gives you a structure you could work to that would take you through a review, would take you through every step, and should give you then a checklist approach to identifying opportunities. I've done a limited amount on this but it's understandable from that perspective yes" (R04).*

However, a slightly different answer was obtained from R03 who answered yes and no. From these answers it could be assumed that R03 confused the framework; however, the answer could describe that R03 also understood, therefore R03 provided input which is the positioning of RL/CE within the organisation.

> *"Yes and no. I think that because it's a crowded area, we talked about CSR, we talked about sustainability, we're taking about the circular economy. Some clearer positioning around where the boundaries are between those I think would be helpful and what the relationship is, because most people entering*

into this would go is this just another extension of the old... at the very crudest, is this just another extension of the green agenda" (R03).

This input is also correlated to one of the CE values which is collaborative network (Preston, 2012; IMSA, 2013). Collaboration or partnership is needed in CE implementation. Indeed, collaboration has a broad sense; it will cover the involvement of the organisation as the first user of the framework.

Based on the respondents' responses above, overall they can understand the framework flow, and the framework is logical, even though some improvements are required. The improvement is related to the additional information. The understandable is not only seen by the respondents' acknowledgement but also through their explanation during the interview. R01 and R02 correlated their own activities with the framework, stating:

"….because the methodology is very similar. Repair, refurbishment, often are confused when you speak often you say this is refurbishment, but refurbish tends to be a little repair…Where is the red line you know that same phrase that repair, from a refurbishment" (R01).

"…creating an exit route which drives the recovery of value on that product which, by definition, prolongs…. through a managed disposal process where it ticks all the relevant environmental regulations so that it's done in the correct way…" (R02).

7.2.3.2 Feasibility

This key measurement measures whether the framework can be followed or not. This question has been put to respondents and received several answers. Respondent (R01) answered directly that the framework can be implemented. R02 added some notes regarding the description of the framework, and provided comments that the method looks largely conceptual.

"I don't see why not…With this discuss in each... focus on what happen in... closed to reality... practical... so I don't see why not" (R01).

"Yes, and I think…. I probably need a little bit of help in more…but I'm sure that comes out in more detail in the other information that you've got there. So I broadly get the conceptual framework and I think the CE values, I'm trying to get my head round… so principles, attributes and enablers, I get all of that" (R02).

While respondents R03 and R04 provided some suggestions, they are in consideration of the size of business, and self-assessment, respectively for R03 and R04. These fit with the author's thoughts in the framework, i.e. that different types of industry, product, and function of the business have their own unique process; and self-assessment is needed at the beginning, within the implementation of the RL/CE framework. In addition, R03 touched on recovery options and organisational maturity which, recovery service as a part of learning process towards organisational maturity (Smith and Karwan, 2010).

"…. for true feasibility you need to be able to say that this is agnostic of the size of your business, the type of business and so on, and that it would be as challenging to a novice as it would be to someone who's been on this agenda for years. I think you could because the recovery options are a function of organisational maturity" (R03).

"…I think you could take every step, but knowing a bit about the whole process I would say yes you would apply it…the first one, you could take it and do a self-assessment you would have to involve all the functions, and as much as we know it would spark a start. So each function could actually take it and start tackling it. It would give you a new angle on things, and I think it would help you uncover opportunities that probably you hadn't identified through traditional challenges or ways of looking at things. That's the beauty of some of this stuff" (R04).

7.2.3.3 Consistency/Repeatability

The consistent and repeatable framework process can produce consistent/repeatable results as well. Two of the respondents (R02 and R04) confirmed that the framework is consistent, and can provide repeatable results as stated below.

"Yes, I think it does and it would do. You mentioned earlier about new products that come on the market and we would end up going through the same process of understanding that product based on its returns rates and its reasons and where it performed well and where it didn't, and then we'd find ways of optimising the recovery rates on those products. Yes, I mean we inadvertently go through the cyclical process with all of what we sell really" (R02).

"Yes, I think without knowing more detail it's difficult to say what you'd need to be more prescriptive about, or to define" (R04).

Nevertheless, this question was not answered specifically by respondents R01 and R03; it occurred as the focus of discussion tended to explore another point.

7.2.3.4 Utility

Regarding utility, the respondents were asked about the usefulness of the framework. Respondents R02 and R04 described that usefulness will be produced, but this depends on the organisation's commitment. These comments basically are related to some other inputs previously, where to apply an RL/CE framework needs to consider other aspects in the organisation.

"…I think it absolutely could provide a useful output. I think, as ever, the usefulness of the output depends on the input that's given up front really and whether a company is committed to investing in whether you'd call it a circular economical approach or a returns management approach. So I think it wholly depends on to what extent they can see the benefits at the end of the process and therefore what level of commitment they're going to invest up front" (R02).

"Again, you need at least a first level commitment to take the first step. So would it be useful? It would be useful as long as people understood what you were doing in the first place, and why you were doing it" (R04).

The framework literally described the structural step to design RL based on CE values without considering organisational engagement. In fact, to implement a framework, for instance RL/CE, it needs to consider management commitment. In fact, organisational commitment is the first consideration before starting to adopt the framework (R02).

7.2.3.5 Reliability/Effectiveness

This key measurement measures whether a method has a robust solution or not, and if the framework is considered to become a comprehensive approach or not, based on respondents R03 and R04 who were not answering explicitly. However, R03 suggested focusing on the operational process by highlighting secondary and tertiary markets, and also modular product. R04 provided possible information regarding some constraints that happen in industry which could make the values in the framework not applicable.

> *"I think the reasonable test would be to take two extremes, which is a company that makes all of its money and profit out of pristine sales, for which there is absolutely…...secondary market on anything. It speaks to that company as much as it speaks to a company which produces something that is hugely modular and can be reused with secondary and tertiary markets" (R03).*

> *"There may be actually key industry constraints impacting that. That was just the first thing that came to mind, that there may be some specific industry constraints that mean that you can't apply all of the values or the principles" (R04).*

In addition, regarding the function of secondary market and modular product, secondary, tertiary market or market availability (Stahel, 2013) are some of the CE values. Also modular product can be related to the aim of eliminating waste (Chen, 2009) and the cascade/reverse cycle (EMF, 2013).

7.2.3.6 Other Inputs

Generally, there is no formal RL design framework that can be followed; it could exist informally that has been created based on the experience of the company or manufacturer, as confirmed by R01:

> *"The reality, you run simulation model based on your experience, you have data, historical data, about different types of RL ….extend then you know...*

how we formulate this ... shadow, experience, productivity, and then... I know from learning every time and implementing based on documentation or database that I have..." (R01).

RL, return management, recycling, or disposal management are extremely close activities to the CE where sometimes there is ambiguity (R02). However, although those concepts and the CE concept are different, they can support each other through implementing CE values.

It's all practical things that all sit in and around something which inadvertently is the circular economy" (R02).

The engagement of organisational elements such as corporate social responsibility and finance are used in the process of RL/CE implementation.

"…if you want to make it a feel good project, lump it then with CSR. If you want to give it a bit of edge, put a finance overlay on it" (R03).

The organisational vision for CE should be determined before selecting the recovery options; where there is an integrated activity it should also be identified before selecting the recovery options. Another suggestion is creating options for commercial or sustainability objectives that can make clear the boundaries of the RL CE design. Other components can also be added in terms of strategy surrounding sustainability, for instance CSR and finance. In addition, respondent R03 added considering customer centricity in the alignment of RL/CE to the organisation.

''One is the customer experience. For this to work, it's got to be not only easy for the company, it's got to be easy and explicable to the consumer... I guess the point where they're moving on to now is customer centric…." (R03).

7.2.4 Discussion on the Interview Results

The testing was started by conducting a pilot interview. This was done for several reasons, e.g. to use it as an exercise, to obtain input before the interview, to improve the interview process, including the interview instrument itself. Through the pilot interview, the time duration can be improved. First, for PR01, it was conducted over one and half hours, but for PR02, it was improved to one hour. Improvement was also made to the interview flow, including representation of the interview guide. The duration of interview is important as it is related to the time availability of the selected interviewee, and an hour is regarded appropriate planning interviews.

Respondent R01 described modification to the RL process design is sometimes needed as fundamentally there is no formal framework that can be followed in the designing process. The framework has the potential to be implemented in the future, as designing RL for this company is dynamic. The company is also developing an RL operations system to which improvements are still being made. The framework is confirmed as being clearly understood, as commonly, the steps of the framework are conducted similarly at a practical level (i.e. they are close to reality). In addition, the framework is also justified in that it makes sense and is possible to be implemented and used. It is related to several companies' purpose when considering environmental parameters (i.e. regarding the CE value adoption).

Respondent R02 described some inputs that have been obtained specifically aligned to the process of CE to RL where the organisation's vision/strategy is one of the factors in the aligning process. The participant suggested embedding commercial views and sustainability in the alignment process. The suggestion fundamentally has been considered specifically for sustainability, where it is described in the CE values. Regarding the commercial view, it is also considered to be one of CE values in optimising the economy. However, both inputs will be considered in terms of the structure framework in order to place both factors so they can be seen more clearly.

Respondent R02 described the understanding of CE from a product design perspective. R02 also described that the main goal of *return management* is looking at minimising the levels of loss on returns across the business, and also maximising customer satisfaction. To conduct the return activities involves many partners, for example receiving depots, a centre to analyse damage, etc. Several other activities also have to be completed, e.g. asset recovery processing, delivery handling, damage analysing, replacing, etc. The company thinks that damaged product (for example a television) will become a bigger industry problem, a situation from which the company will benefit. The two main goals described above are evidence that the company considers the CE concept (at least from an economic aspect). Also, in implementation, the company realises several activities through having a large number of return options, having many partners and operating industry-wide, taking benefit from return activity, etc. Furthermore, the respondent also stated that *recycling* and *disposal management* are options that can be chosen as solutions.

According to the explanation above, some activities that have been undertaken by the respondent/company can be related to several CE values, such as cascading, through having a large number of return options, system thinking and collaboration via having many partners and operating industry-wide, circularity via taking benefit from return activity, etc., and also recycling and disposal management. Regarding the usability of the framework, the respondent answered that it is usable, and also gave further suggestions and comments, i.e. it will be really usable if it could provide a practical example. This is because the flow is quite theoretical and needs to be made more applicable.

Regarding utility, the interviewer ensured this by asking about the useful output and the possibility of implementing the framework. Respondent R02 stated that this will depend on how much time is needed to implement the framework; in fact, the company has many activities that it might be able to readjust. So, in general, R02 said, if the company commits to investing in the framework, then it can be implemented. Consistency/repeatability are where R02 rated the framework as having consistency, which had been observed through the cyclical process, from starting point to end. Regarding the feasibility of key measurement, Respondent R02 can see the feasibility specifically through the CE values which are divided into principle, attribute, and enabler.

The framework is confirmed as being feasible practically; it can work, managers will apply it, and it is sufficiently understandable. However, sometimes it was a little difficult to be understood where there was no generic form to explain its features more, because it needs a specific area in which to be implemented, where processes might be different from one to another. Thus, detailed information to explain each step of the framework is required which the interviewee could not see initially.

The framework is also consistent and repeatable. It undoubtedly will produce the same result when it is used and then used again at a different time, as long as it is treating the same product. Furthermore, regarding utility, the framework is predicted as being able to provide useful output; however, essentially this will depend on the company, and how much time the company will spend in following the step-by-step process of the framework. In addition, the usefulness of the output depends on the input that is given up front and whether a company is committed to investing in it. To achieve this, the database for guidance is provided based on the CE concept. Therefore, to measure the usefulness, a considerable amount of criteria that is necessary to think about has been found.

Respondent R03 described that there are several points that need to be considered, such as understanding the commerciality of return options. The organisational vision for CE should be determined before selecting the recovery option as well, where there is an integrated activity it should be identified before selecting the recovery options. Another suggestion is creating options for commercial or sustainability objectives that can make clear the boundaries of the RL CE design. Other components can also be added in terms of strategy surrounding sustainability, for instance CSR and finance.

In the specific key measurements, the respondent answered either yes or no. First, about the purpose/usability of the framework, regarding understandable, R03 rated it as understandable in one point, but could not be clear on another point; this might be because the framework covers many areas. It talks about CSR, about sustainability, and about CE. The position of the boundaries among them has to be defined more clearly. On the usability point, R03 agreed that the framework is usable; however, it needs to be readjusted based on organisational alignment. Indeed, the usability of the framework depends on the type of organisational alliance agreement, among others.

Regarding the feasibility of the framework to be implemented, R03 said that feasibility is strongly related to type, size, and characteristics of a business. It will be challenging and totally depends on the business agenda. The framework can be realised, because it is evidence of company maturity, and it is probably consistent and repeatable. Further, the framework is predicted as being able to produce the same result if it were executed in different times and by different people. This is justified through participant response. Concerning utility, the framework should be commercially, financially, organisationally, and IT viable; however, it is totally interrelated with the specific business and product. In addition, regarding the aspect of feasibility of framework, it is intensely correlated with finance, IT and HR. It also depends on the size of business, type of business, etc. Those elements can be used to drive managers to see the feasible options in using the framework, however, it will be challenging and depend totally on the business agenda of the future. The framework can be realised, because it is evidence of company maturity. A framework is rationalised that is not feasible, if to understand and be able to implement it takes a long time.

Based on the interview with the R03, it can be concluded that logical flow is a key issue to implement the framework. As it is one aspect of the whole organisational alignment, a framework for adopting logical flow depends on how much it makes sense for the company to use it – thus, the logical flow of the method needs to be specified.

To produce a similar result to framework implementation, the aspects of consistency and repeatability are necessary; those aspects probably mean that the framework used in different places and times, or by other users (e.g. managers), will generate a similar result (the framework is robust in output). These aspects are a little difficult to be justified without a detailed explanation of the framework. Here, the framework is doubtless consistent and repeatable, and possibly reliable and effective. The key aspects of reliability and effectiveness will construct a framework that can produce reliable and robust solutions. They can also make the framework comprehensive, which means it is commercially, financially, organisationally, and IT viable. Therefore, the framework is definitely also useful (it fulfils the aspect of utility). The framework provides a useful output with the options likely to be implemented.

Respondent R04 described how the framework is suitable to meet the objectives, where the objectives are to encourage or enable people who are in RL operations to assist them in designing CE values. The framework provides a structure that could be worked, that would take you through a review, take you through every step, and should then give you a checklist approach to identifying opportunities; it also gives directions that could be taken. It supports a step-by-step guide to do this properly, and also, it will open up opportunities that can be taken advantage of, are understandable and also make sense.

The framework is also feasible to be implemented. Its step-by-step acts are feasible to be done. R04 said, if he knew more detail regarding the framework, R04 believes it could be implemented. In addition, it is like a workbook on RL where the implementer can do self-assessment, etc. Moreover, the framework also achieves both the aspects of consistency and repeatability. The method can be used every time it is needed, and will still produce the same result; it would practically give a consistent and repeatable answer.

The framework will also produce a useful output as people would understand what was being done in the first place, and why it was being done. So, it fits back with the original vision. Finally, the framework is probably reliable and effective.

According to the interview results from respondents R01, R02, R03, and R04, and based on the five key elements (fit for purpose/usability, feasibility, consistency/repeatability, utility, and reliability/effectiveness), these were used to confirm the framework with industrial practitioners. Four practitioners were interviewed for one hour to obtain feedback regarding the confirmation. It can be concluded here that the framework can fulfil all of these five key elements.

Generally, the framework is fit for purpose (the first element). It is easily and clearly understood. The logical flow of the framework is a key attribute to ensure that the framework fulfils the key element usability. The framework gives a clear structure and direction to be followed and undertaken, respectively, and it is also appropriate to convene the objectives. Those reasons also cause the framework to be feasible for implementation (the second element). Its step-by-step acts are also feasible to be taken. The detailed information on framework can help practitioners to implement it easily. With the full information, it is like a workbook on RL (especially for designing RL) where practitioners can undertake self-assessment.

The framework is also consistent and repeatable (the third element). The framework is predicted to be able to give the same output (result), when it is used in a different time and place. It is also able to be used to produce a useful output/result (utility aspect, the fourth element). Finally, the framework is reliable and effective (the fifth element). The fifth element is able to make the framework comprehensive, which means it is commercially, financially, organisationally, and IT practicable and workable.

According to the interview, the strong input that has been acquired is the result of a detailed explanation. A detailed explanation of the framework is necessary to make it easy to use. On the other hand, the example case has to be used in implementation. It affects consideration of the parameters and other items in designing RL based on CE values rationally. The strengths and improvement areas can be concluded in some points below.

The strengths:

- The framework structure has been well organised that could be understood.
- The logic flow of framework is clear.
- The methodology is very similar to the real RL implementation.
- The consistent and repeatable framework can produce consistent/repeatable results as well.
- The identification of RL parameters.
- The identification CE values for each RL process.

The improvement areas:

- The representation of framework needs some explanations and instruments.
- The framework needs to consider the organisational vision.
- The element commerciality, finance, and CRS are an important consideration.
- The mathematical formulation could not appear as one of step in the framework. However, it can still use.
- The detail explanation of principles, attributes and enablers.
- The framework needs to provide the size of business and self-assessment.

7.3 Validation the Research Results

This research has produced some results that the results can be traced easily through the research objectives. The results need to be validated to evaluate the trustworthiness. Some strategies from Robson (2011) will be adopted for instance triangulation, peer debriefing and support, and member checking.

7.3.1 Validation Strategy

There are five evaluation trustworthiness strategies applied (triangulation, peer debriefing and support, and member checking, audit trail, and research dissemination). Each research objective will apply those strategies to evaluate the results. The strategy of validation will be described in Figure 7.7. Figure 7.7 illustrates the relationship between research objective and strategy of validity where each objective will be treated by each validity strategy. It means each objective has five results from triangulation, peer debriefing and support, member checking, audit trail, and research dissemination.

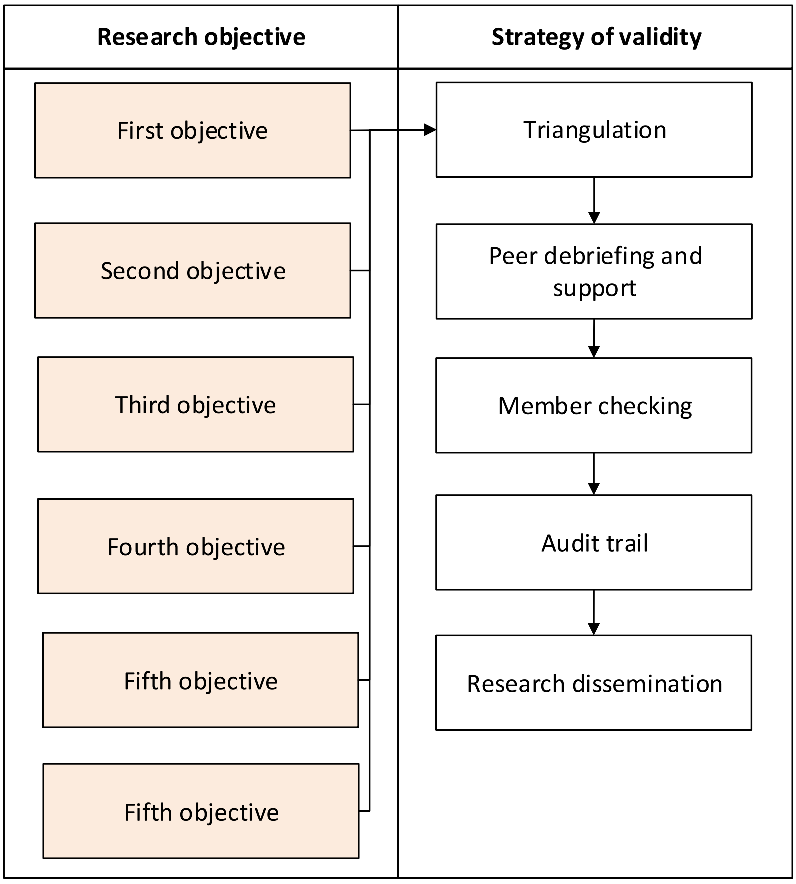

Figure 7.7 Validation strategy

7.3.2 Validation Results

The results are represented in each objective against validation strategy. Each objective will describe each validation strategy as follows:

1. Objective 1

- Triangulation

  The formalising an RL design framework has been done through some stages. First, conducting the literature review, it was done by preparing some relevant keywords. The selected literature (42 papers) also is reviewed. Second, implementing the framework into cases (examples), the cases were adopted from the literature that can be analysed the logic of the framework. Third, the framework will test through engaging some respondents from academic and companies.

- Peer debriefing and support

  The engaging the reverse logistics expert to obtain point view, suggestions, and advice that can enrich the understanding of RL design in general and measure the process of formalising of the framework. The experts allocated some meetings to provide inputs based on the research progress. Debriefing and support also got through attending and presenting conference and workshop.

- Member checking

  Member checking was done by some activities such as the conference and workshop that were attended to present this objective result. Besides, these activities, annually there is a review progress of research where this obtained the positive feedback, which means the research has been on track. Engaging RL expert in discussions was done to obtain the expert views and inputs.

- Audit trail

  The documentation was done since this research started. For this objective, it was begun with recording the literature review sources, notes to understand the RL and RL design, initial constructing results of the framework before producing the final version. The methodical documentation provides the opportunity to refine and trace easily.

- Research dissemination

  This objective result formally produces one conference paper that published in a logistics research network conference, and one unpublished paper in the doctoral logistics association workshop. In the doctoral workshop, the paper had been reviewed by the panel where the author needs to present to obtain the feedback.

2. Objective 2

- Triangulation

The reformulation CE principles have been conducted mainly through systematic literature review where, in the objective 2, there were 47 papers reviewed. The other processes to obtain the trustworthiness through triangulation is the implementing the CE principles into RL operations. The principles also will be confirmed by engaging some respondents to obtain the expert point of view.

- Peer debriefing and support

The support and peer debriefing also conducted through presentation and discussion with CE researchers. The positive feedback was obtained as in their point of view the CE principles can be a bridge to collaborate with another researcher from other areas. Furthermore, the analysing is needed to identify the extent to which the CE principles can be implemented. The support also obtained when this objective result was presented in the annually CE event (disruptive innovation festival).

- Member checking

Involving in the CE events provides opportunities to express the idea of research that can also obtain the relevant feedback. Other activities also were done such as submitting the journal that proposed the CE principles. In the process submitting some responses have been received that can refine the principles.

- Audit trail

As in the first objective, the recording documents surrounding CE principles has been placed systematically that can be easy to trace.

- Research dissemination

Reformulation CE formally will be published in a journal. The reviewing process also provides chance to obtain fruitful suggestions.

3. Objective 3

- Triangulation

The embedding CE in RL operations is the implementation of the first and second objective. Those objectives were conducted by literature review, which means the objective three is formulated based on the literature review as well. Implementation the objective three in the PR cases is an opportunity to analyse the logic process of embedding. Confirming the processes by comparing the real implementation is required; therefore the testing will be conducted structurally in this research.

- Peer debriefing and support

For this third objective, the peer debriefing involves the expert to discuss the important point of view that can enrich the logical embedding process. The support also got through attending and presenting a paper in a conference with special issue is circular economy. The sharing and discussion within the presenting or in the discussion during the conference was fruitful to encourage and enrich the research result.

- Member checking

Joining the conference (circular economy special issue) brings an opportunity to contribute more to a book project.

- Audit trail

The well-organised documentation provides the quality of research. The reformulation CE principles described clearly with a methodical explanation that it can be seen in chapter 5.

- Research dissemination

As stated above that this objective has been published in a conference and will be submitted a journal.

4. Objective 4

- Triangulation

The formulating mathematical formulation for quantitative analysing in the embedding process was done by conducting the literature review. The mathematical formulation constructed based on the available parameters of RL and RL based on CE principles. It also needs to implement in some cases or examples where the cases were adapted from the literature. Furthermore, the implementation formulation in the cases is analysed to produce the final equations.

- Peer debriefing and support

This objective is part of the embedding process where the mathematical formulation formally has been used in the implementation refurbishment, remanufacturing, and cannibalisation to find the maximising retained value. The formulation was presented in the conference where the positive feedback was obtained by the audience and panel.

- Member checking

The checking process of the logical-mathematical formulation has been conducted through some events attended and presented.

- Audit trail

The mathematical formulation can be easy to audit as it can be traced through the result implementation.

- Research dissemination

The opportunities to publish the paper whether in a journal or conference paper can give space to refine the research or obtain the useful input.

5. Objective 5

- Triangulation

Testing a framework to design RL based on CE has been conducted by doing some processes which are literature review and interview. The literature review is needed to construct the testing planning effectively that the testing can produce the measurable results. Testing the framework was done by interviewing some respondent to confirm the quality of the framework.

- Peer debriefing and support

The testing was conducted by interviewing respondents and an expert. Based on the interview results that in general the framework has some strengths such feasible to be implemented, the flow easy to understand, and the process is similar to the real situation.

- Member checking

Respondents and expert engaged in this activity to confirm the quality of the framework. There are five key measurements will be measured.

- Audit trail

The testing process has some documentations storage, first the testing instruments, audio interview recording, interview transcript, and translation interview results.

- Research dissemination

This objective result formally has been submitted in a journal (journal of production planning and control) with first revision.

6. Objective 6

This objective was conducted by following the trustworthiness strategies that can be reflected through each objective systematically. The strategies adopt five treatments (triangulation, peer debriefing and support, member check, audit trail, and research dissemination). The treatment has been described clearly in objective one until five.

7.4 Summary

This research adopted a testing method to confirm the quality of the framework for designing RL based on CE values. Semi-structured interviews have been conducted to obtain the points of view of participants and also an expert. The participants were chosen based on their knowledge, experience, and type of industry. All respondents were given a representation of PR options (repair, refurbishment, remanufacturing, and cannibalisation). In the implementation of the interview, several preparations were needed such as interview agenda, interview protocol, and list of questions. The overall results of the test indicated that the framework can be understood.

The interview results showed that respondent R01 highlighted the structure of the framework as being well organised, and could be understood. However, the weaknesses are not placed within the detailed description; for instance the PR activities need to be defined clearly based on the real activities. Furthermore, the sixth step, depicted as the mathematical formulation, that has been assessed, will not be applicable. At the end of the interview the respondent also added the importance of economic considerations in the process of designing PR operations. Respondent R02 understood the flow of the framework; however, it is regarded as a conceptual framework that needs an operational description so it can be implemented easily. The respondent also added the engagement of the organisation in applying the framework, as the feasibility depends on time allocation and the willingness of the company to apply. Furthermore, the respondent described other related points, such as sustainability and return management, within the interview.

Respondent R03 can also understand the framework; however, the framework can be more logical if it considers some organisational views, such as commerciality, organisational engagement, and being customer-centric. The framework also needs some supporting explanations and instruments. Furthermore, respondent R04 suggested aligning the framework with the organisational vision, such as marketing, commerciality, finance, and CSR. The respondent also provided some other terms in the return management, such as design and development, recyclability, durability and reliability.

The validation is to evaluate the trustworthiness by adopting five strategies (triangulation, peer debriefing and support, member checking, audit trail, and research dissemination). Based on those strategies, the result shows that this research is valid.

CHAPTER 8

DISCUSSION AND CONCLUSIONS

This chapter describes discussion and conclusions. The discussion aims to describe the author's interpretations and views against research findings, contribution to knowledge, implications for practice, and future work. In the research findings part, the findings and obstacles encountered during the finding process and the author's point of view regarding those findings are discussed. In the contribution to knowledge section is argued, and how the research can contribute to the body of knowledge is also described. The part regarding implications for practice discusses the technical aspects of research that can contribute to practice. The potential work that can be continued in the future, based on the opportunities that emerged during conducting the research, is finally delivered. The conclusions conclude the research results that properly correlate to the research outcomes and identify the research limitations and future work.

The structure of the chapter illustrates in Figure 8.1, the structure purposes to provide a systematic presentation that can be effective to understand the chapter. The chapter has four main sections, they are research findings (8.1), it correlates with some research objective; contribution to knowledge (8.2), it can be concluded based on the research findings, implication for practice (8.3), it also describes, the direct contribution in the practical area; conclusions (8.4), the conclusions are the main points of the research that can be conclusion based on the author experience or reflection during doing the research.

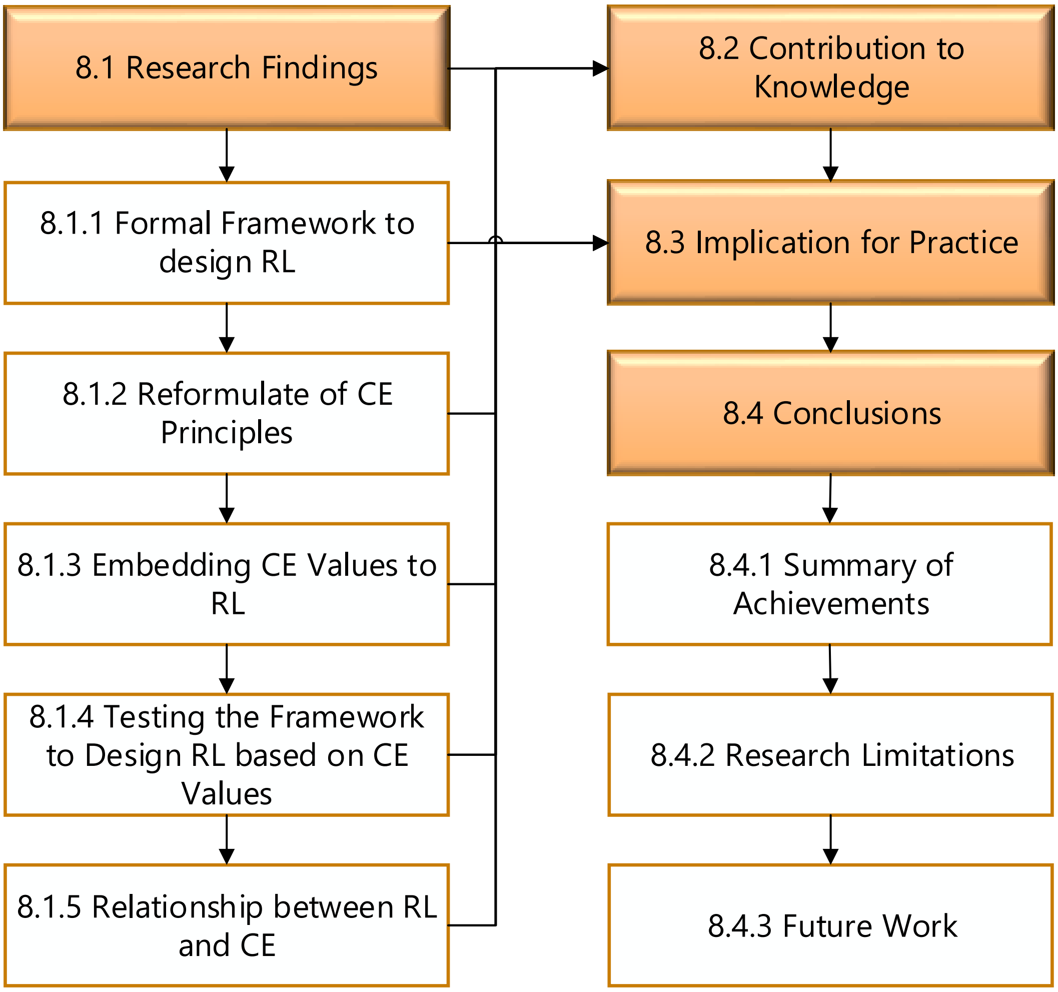

Figure 8.1 Structure of discussion and conclusions

8.1 Research Findings

The discussion focuses on five main facets: formal RL design framework, reformulation of CE values, embedding RL based on CE values, testing the framework to design RL based on CE values, and relationship between RL and CE. Those five aspects are described further.

8.1.1 Formal Framework to Design Reverse Logistics

The research revealed that an RL design framework is difficult to be found. It could indicate that implementation of RL does not use or have a formal framework; or it is possibly available, but was delivered informally. The formal framework of RL design can provide a systematic guidance that can be easily adopted. The systematic procedure to design RL offers the effectiveness of RL operations; because through the framework, the management process of RL will be controlled. The framework to design RL can also be related to some issues surrounding RL, such as effectiveness (Richey et al., 2005), uncertainty (Flapper, 1995; Guide et al., 2000), complex for management (Meyer, 1999; Tibben-Lembke and Rogers, 2002), and broad concept (Kopicki et al., 1993; Lembke and Rogers, 2002) which, through the formal RL design, some of the above problems potentially can be reduced and solved.

By formalising an RL design framework it was revealed that RL design is not similar to an RL network design, even though both of them can support each other, for example to design an RL network, first there needs to be a robust RL design. Comparing RL network design and RL design, it can be concluded that the latter is the first requirement in designing an RL operation, as a robust RL design will affect the quality of other RL implementations, such as RL network design, or an optimisation of distribution network. The limited amount of RL design researches indicate that the RL design has not been created formally, because the formal framework of RL design itself is methodically limited.

In the process of designing an RL formal framework, the RL network design was still considered. This is since the RL network also technically describes the design process of RL in general, a method to achieve an effective RL operation, the relationship of one entity to another, and some parameters involved in the network. Through RL network design, it can be learnt that RL characteristics are able to enrich the design of RL, although, the research regarding the formal framework to design an RL network is also limited. Furthermore, referring to the issue of RL network design, it can be concluded that RL network design focuses on the effectiveness of the network, such as distribution network, location of the production facilities, and transportation, while in the RL design, it focuses on the effective design of the whole RL system.

In this research, the formal framework for designing RL will specifically be implemented in PR options (repair, refurbishment, remanufacturing, and cannibalisation). The determination of PR options as an implementation object was done due to several considerations, such as the replacement product level and the retained value of product. Based on the considerations, the replacement level classification also was theoretically defined here. This classification can help to determine the priority level for doing RL activities. Furthermore, the implementation of the formal RL design framework in PR options was engaged based on some examples from the literature. Some facts were revealed, which are different types of industry, product, functions of the company (such as contract, independent remanufacturer, OEM/OER), and the availability of facilities (such as technology), where they have different detailed processes of activity. Through this research, a method to generalise the various processes of each product was discovered.

In the framework of RL design, the general RL activities based on the PR options (repair, refurbishment, remanufacturing, and cannibalisation) essentially needed to be identified. The identification of activities was used to inform how RL activities and PR options can correlate to each other. It was also based on the literature review, where the reasons to identify some RL activities and correlate them to PR options was defined through a rigorous approach, and further identified the detailed PR options process. The detailed process needs to be created by the author through a specific diagram that can be understood easily. In constructing the PR options, several parameters surrounding the PR options process were found.

The searching process to formalise the RL design framework was conducted by using various approaches. Firstly, reading logistics and RL books (e.g. *Strategic physical distribution management* by Lambert and Stock, 1987; *Strategic logistic management*, Lambert and Stock, 1993; *Contemporary logistics*, Johnson et al., 1999) and searching several sources using search engines, e.g. Google Scholar. Secondly, searching numerous scientific articles was conducted through search engines with keywords such as “reverse logistics design” and “framework design reverse logistics”. The search results predominantly referred to RL network design.

In the limited literature, the author needed to undertake a rigorous strategy that could provide accurate results. Some related literature on RL design was collected, for instance the RL design (Amini et al., 2005; Dowlatshahi, 2010a, b; Pochampally and Gupta, 2012), model of RL (Krumwiede and Sheu, 2002), RL network design (Fleischmann, 2001b; Bostel et al., 2005; Min and Ko, 2008; Lee and Dong, 2009), RL implementation (Kumar et al., 2001), and “design” in general (Beck, 2000; Ralph and Wand, 2009). Besides reviewing the literature, an investigation by collecting existing examples from the literature (ERN, 2016) was also done. Each key that related to RL design was analysed, synthesised and summarised.

The proposed formal framework of RL design was constructed to increase the effectiveness of the RL system, where the RL described has complex problems (compared to forward logistics) and uncertainty (quality and quantity of returned product). The framework is also able to be used to provide simplicity in developing the process of RL design that users can follow easily as a guide. Furthermore, by following the formal framework of RL design, clear processes are provided. Through the structural processes, it will be easy to trace back to the difficulties or problem.

8.1.2 Reformulation of Circular Economy Principles

The idea of CE principle reformulation in an available structure that can be implemented at an operational level, means achieving some findings regarding CE. Principles of CE have been academically described by several researchers (e.g. Yuan et al., 2006; Yong, 2007; Geng et al., 2012; Stahel, 2013; EMF, 2013; Pan et al., 2015). They all conveyed CE principles as, for instance, “3R”, “5R”, circulating multi steps, or others; however, they described the principles at the conceptual level, where a greater effort to understand and implement the principles is desirable. In this research, the CE principles were described at the operational level, specifically in RL, and especially PR cases; where none of those researchers has already implemented the CE principles in this area.

The reformulation process of CE principles was also provided comprehensively by using a systematic literature review method. This method provides the opportunities to other researchers to add another principle, as the 15 CE principles that have been found are not finally prescriptive. Other researchers can use the integrated approach that has been provided in this research, where it principally has five steps (literature filtering, literature analysis, theme analysis, CE principles definition, CE principles mapping). The integrated method has the potential to be used to reformulate or identify other concepts.

In the process of reformulation of CE principles, the author found 15 principles, but not all of them can be truly named as principles. This is because they fundamentally consist of three components: the essential activities (principle), natural element (intrinsic attribute), and supporting the practicality (enabler). In fact, through the reformulation process of CE principles, two other components (intrinsic attribute and enabler) were finally found. The term 'principle' is no longer appropriate to be used to cover the three components. Value is a term used to overarch principle, intrinsic attribute, and enabler. Moreover, the term 'value' in CE is rarely used. It was only found to be used by one author, Andersen (2007), when he described the environmental economic value in the CE. Value in items of CE here means the important aspects of CE. The 15 values discovered in this research form the main contribution in the CE area. Lastly, intrinsic attribute and enabler in the CE also potentially open a new debate in this area.

CE values have been reformulated based on conducting a systematic literature review in which several themes have been found and were processed as CE values. Within the formulation, several facts regarding values have been discovered too. First, there are several values that have been familiar to researchers, for instance, *system thinking* (Boulding, 1966; Ekins, 1989); *eliminating waste* (Pearce and Turner, 1990; Chen, 2009); *oriented to cascades/reverse cycle* (EMF, 2013; Lacy and Rutqvist, 2015),*shift to renewable energy* (Kneese et al. 1970), *built-in resilience* (EMF, 2013), and *optimising the economy* (Dajian, 2008; Mathew and Tan, 2011). However, other values have been indirectly touched upon by researchers, for instance *circularity,* and *innovation* (e.g. Preston, 2012; EMF, 2013; Sempels, 2013). Several other values were also identified; *technology-driven* (Preston, 2012), *market availability* (Stahel, 2013), *minimising the leakage* (EMF, 2013), *collaborative network* (EMF, 2013), and *conscious of the environment* (Yong, 2007; Li et al., 2009).

Furthermore, in this research, there are two new values that have been discovered as being the most prominent: *maximising retained value* and *optimisation of change*. Those values potentially have the most significant contribution to the reformulation of CE values. By comparing CE themes and values, it can be stated that those values have not yet been discussed explicitly by researchers.

The existence of CE values provides opportunities to implement them in specific cases in order to increase the efficiency of resources use. They might be used as a basis for RL for general purposes, even though in this research, the values were only implemented in PR options. Moreover, the reformulation of CE values in this research might be the first attempt to discover the CE value's methodical formulation through six comprehensive steps.

The reformulation process of CE values used a systematic literature review method which encountered many challenges while being conducted. Firstly, this research was started in 2013, where sources that were related to CE were limited. Although CE had started to be discussed in 1966 by Boulding, the number of researches on CE were still rare. By the end of 2015, the author was able to see an increasing amount of research in this area through using some search engine based databases (e.g. Google Scholar, Scopus, and EBSCO). In the middle of 2014, the CE reformulation was started by conducting a systematic literature review. As a result, some related CE journals (i.e. Yuan et al., 2006; Yong, 2007), a technical report from a foundation that is concerned with CE development, EMF, and a book entitled "*A new dynamic: effective business in a circular economy*"; were found. From the end of 2015 until October 2016, the reformulation was updated to adjust to the increasing number of scientific articles recently released.

In the process of searching the literature, it is necessary to point out that CE scientific articles were decidedly limited and were dominated by researchers from China. This is understandable as China is one of countries that has implemented CE. However, some of the articles were not in English, or several authors only used English for the title. This happened especially when the author used Google Scholar, while other search engine databases only showed limited results. Furthermore, in the limited sources, not all of them could be selected as references due to various considerations, such as the content needing to being relevant to the research focus.

The process of the reformulation of CE values has challenging aspects – firstly, arranging the systematic steps which was really confusing after having so many sources. Some approaches have been tried in order to summarise the sources, for instance making a review of each paper. This approach was ineffective because of the number of papers. The next attempt was gathering the sources through some themes in PowerPoint slides. As a result, it was producing many themes with too many slides. This approach was also rated ineffective; but through this method there were some themes that could be used for the next steps. The next attempt was classifying the themes from a previous attempt to mind map, where the relationship of one to another can be found. Through those approaches, the type of theme was improved. Improving the themes was also conducted by revisiting, analysing, and synthesising the literature.

8.1.3 Embedding Circular Economy Values in Reverse Logistics

In the embedding process, a systematic guide to embed CE values in RL has been discovered. It potentially can also be used for other implementations with a few adjustments. Here, the identification of CE values for each PR option (repair, refurbishment, remanufacturing, and cannibalisation) and each general PR activity (transport, collect, assess, classify, repair, store, and test) was also found. The identification can be a guide to know which CE values to engage for specific PR options and PR activities, and it can be used as an identification method if the user wishes to add or remove some PR activities.

Through the approach used for classification of the detailed PR options process to general PR activities, the number and type of CE values involved can be identified. The analysing approach to derive parameters in the specific PR option, activity, and process can identify the specific type of decision, and an approach can finally be used to analyse each parameter in each process to construct the mathematical formulation.

Through the embedding process, a framework to design RL based on CE values was constructed. Some processes are similar to designing an RL framework, with some insertion processes related to CE values. Through this framework, the PR options process before and after adopting CE values can be identified. The ultimate contribution of the framework provides an approach to handle the PR process, although the type of PR processes has many versions but any type of process can be used with the approach that is delivered in this research.

In developing a process of embedding CE values in PR options, many improvements have been conducted. The improvements are related to the content of the embedding process and order of activities. The iterative activities have been done to try the logic flow and content, for instance in creating some scenarios, comparing and analysing them, until obtaining the logical one. The attempt to embed CE values in PR options in this research might be the first one; this process was made really challenging because there was no model or framework that could be adapted.

In addition, in the process of finishing this part (embedding CE in RL), several other activities were conducted, for instance discussing with an expert who have expertise in the RL area. Discussions were conducted that related to the RL process and their opinions regarding each activity in the framework were given. The expert allocated time to more than one meeting to provide some inputs regarding the framework. Presenting findings in a conference on this specific topic was also conducted to obtain feedback from academia and practitioners regarding research in general, specifically the framework to design RL based on CE.

Based on the embedding process, some inputs concerning the representation of each title of each step, and also detailed activities for each step, were obtained. The most frequently used inputs and critiques were identified, particularly for the sixth stage. Previously, it had been described as a mathematical formulation model. It was predicted that this would not be applicable for the practical needs. After some analysis, stage six was changed for analysing parameters and decisions on the mathematical formulation. This stage is basically continued as part of the previous stage which is identification of parameters for PR based on CE.

8.1.4 Testing the Framework to Design Reverse Logistics based on Circular Economy Values

The testing was done by conducting interviews that have engaged four respondents and one expert. The testing process was operated through involving companies, in this case some RL, return management, and sustainability players. The interview is the testing approach used in an attempt to bring RL/CE issues to the users, introduce a body of knowledge to the implementation area, and obtain relevant suggestions; those are several suggestions from Hill (1987).

Through conducting interviews, it was found that some respondents can understand the framework clearly (R01 and R02), as confirmed through their statements. However, there are some notes from them regarding the flow of the framework: R01 stated that the framework is clear and makes sense. The framework is quite similar to what the company does. However, R01 underlined process six which is mathematical formulation, saying it is not really applicable. This statement was similar to one from the expert (E01) who said the mathematical formulation was not really suitable for the framework, even though it might be useful. The mathematical formulation in the process is required to revisit the urgency rate. If it is really needed, it means some adjustments also need to be described in the process (process number six). Respondent R02 suggested providing a detailed document to describe each process in the providing diagram (box).

The framework was rated feasible to be implemented, as confirmed by respondents R03 and R02 (see below). However, there are some improvement points, such as needing to adjust several aspects to make the framework able to be followed, such as size and type of business. Respondent R03 agreed through mentioning the function of organisational maturity, while Respondent R02 also agreed by concluding and defending the framework. The framework also confirms the consistency/repeatability; Respondent R02 said there is similarity between some processes that have been described in the framework (such as product and market flow), where those processes are also run within the company.

In terms of the useful output, this was defined through asking the utility. Some respondents (R02 and R04) replied that the framework has sufficient utility with some inputs. Respondent R02 underlined the commitment of management, so that the framework produces the targeted results. Respondent R04 also made a similar suggestion regarding commitment from the management, and added that the understanding of people who will implement it is necessary.

8.1.5 Relationship between Reverse Logistics and Circular Economy

Through this research, the activities of RL and CE have been identified, where they share similar activities, such as maintaining, collection, repair, refurbishment, remanufacturing, recycling, disposing management, etc. (Figure 8.2). Through Figure 8.1, it can be seen that there is a similar RL understanding in the figure, which can be compared to the RL activities illustrated in Figures 2.1 and 2.2 by Thierry et al. (1995) and Krumwiede and Sheu (2002), while CE in Figure 8.1 explains that the collection, reusing, repair/refurbishment until recycling are regarded as reverse cycle or cascade activities, where in the CE, those processes will be kept in circulation to achieve the highest value and utility.

The link between CE and RL can clearly be seen in the process for embedding CE in RL, where CE can be run in RL or conversely. In the embedding process, CE values in RL/PR can be identified and then the parameters between RL/CE can also be identified. The CE values that have been embedded in RL/PR options' processes in an integrated manner can be represented by one integrated process, even though the original process RL and can still be seen a separated manner.

Through this research, it can be stated that CE and RL can support each other because of their relationships; it also can mention that CE values can facilitate the gap between RL and CE, those concepts can implemented together. The author can conclude that CE overarches RL because CE shows broader area implementation than RL. Furthermore, RL focuses on the flow of product (focuses more on the operational sides), while CE focuses on optimising the use of resources (focuses more on the strategic sides).

In addition, there is limited number of scientific articles that describe the relationships between RL and CE clearly. It was challenging to justify looking for them at the beginning of research as the research started with a small amount of literature. However, in the middle of the research process the number of sources started to grow. Even so, the literature that describes the relationships of both concepts is still scarce (Ripanti, 2015; 2016). Nevertheless, sufficient knowledge can be found from each concept, RL (e.g. Meade and Sarkis, 2002; Tibben-Lembke and Rogers, 2002; Lambert et al., 2011) and CE (e.g. Hu et al., 2011; EMF, 2013; Stahel, 2013; Pan et al., 2015). Through each concept some understandings were found that strengthen the relationships between them.

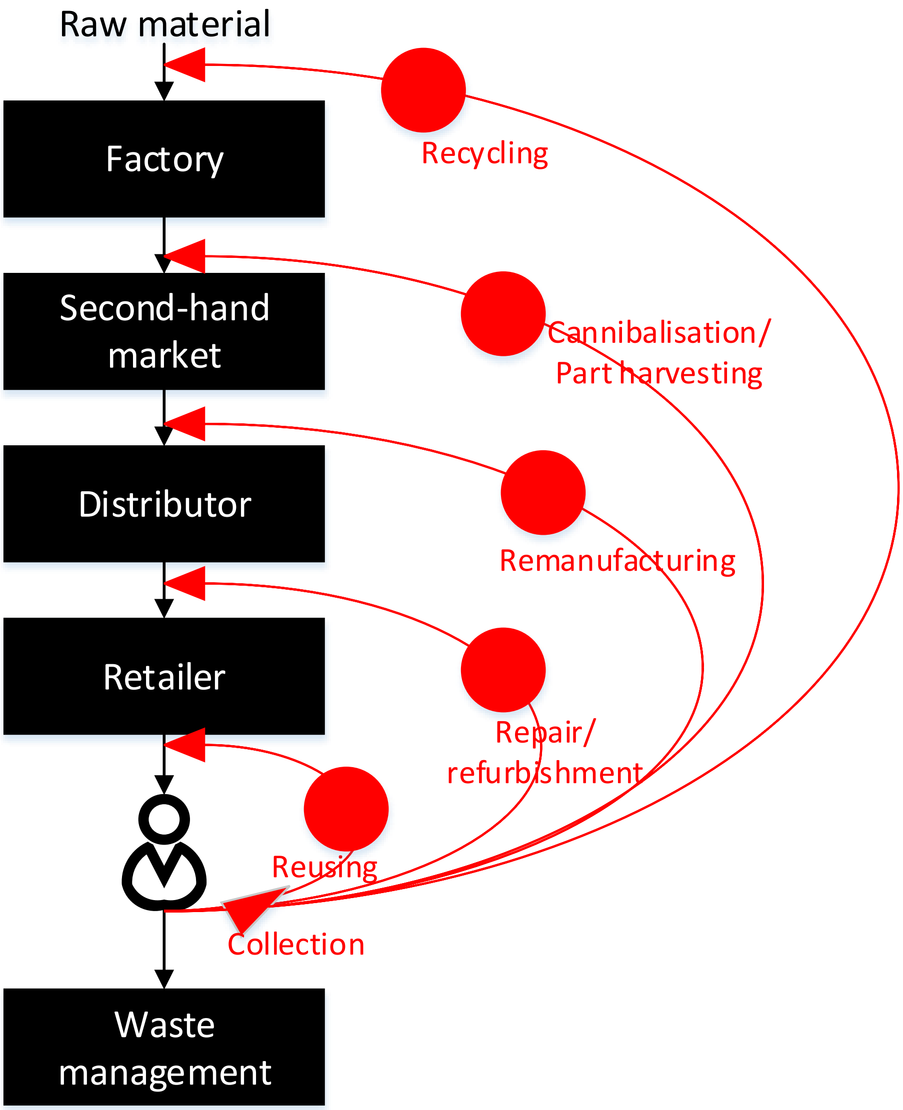

Figure 8.2 – Relationship between circular economy and reverse logistic

8.2 Contributions to Knowledge

This research contributes to the RL research area, in particular, formalising the framework for designing RL; a formal framework for this was rarely found academically. The common review regarding RL network design was found when the searching process for designing RL was completed. RL design and an RL design network are different, even though each can support the other. The differences are in the purpose: RL design focus is on how to make an RL operation effective systematically, while an RL network design focuses on how to make the network effective.

The formal RL design is important to provide a guide in order to produce effective RL operations comprehensively. The formal framework can be used to address some problems in RL, such as the complex management problem (comparing forward logistics), and uncertainty involved (quantity and quality of product return). Also it can be used as a first requirement before RL is implemented in another application, such as RL network design because to design an RL network, it first needs a robust RL design then an RL design network can be constructed properly. The formal RL design framework also has not been used by a company, where it is proven academically that there is a lack of formal RL design framework (as mentioned at the beginning, and later through an interview). The formal design RL framework is the first contribution to RL in this research.

In addition, within the RL design framework there are some stages that have contributions. Identification of the general RL activities was undertaken based on the literature, such as transport (Lambert and Stock, 1993; Dowlatshahi, 2000; Lummus et al., 2001); collect (Fleischmann et al., 1997; Meade and Sarkis, 2002); assess (Srivastava, 2008); classify (Pohlen and Farris, 1992); repair (Krumwiede and Sheu, 2002); disassemble (Srivastava, 2008); reassemble (Lambert et al., 2011); store (Krumwiede and Sheu, 2002); and test (Srivastava, 2008). Furthermore, the identification of the detailed process of PR options was undertaken by adapting various sources (e.g. ERN, 2016; IBM, 2016). Here, the detailed processes were provided in a systematic diagram; it can contribute as a guide for the operational process in PR options (repair, refurbishment, remanufacturing, and cannibalisation). Furthermore, the identification parameters for each PR option can support other needs, for instance the decision making process.

In the CE area, the contribution is the reformulation CE principles. Indeed, there are some researchers who have described CE principles (e.g. Pintér, 2006; Yuan et al., 2006; Yong, 2007; EMF, 2013; Stahel, 2013; Pan et al., 2015); however, they described CE principles in the conceptual level as principles that are not ready to be implemented in particular cases, specifically in the RL and PR options. The reformulation of CE principles in this research was done by systematic literature review, where the principles that have been formulated are not prescriptive or final.

The reformulation of CE principles is also provided in an available format that can be implemented for specific purposes, such as PR options.

Within the reformulation process of 15 CE principles, it was found that not all of them could be categorised as principles; some were termed as *intrinsic attribute*, which was identified as the natural characteristics of CE; and *enabler*, which was identified as the operational drive to make a system easy. To cover all of the terms have been found, another term such as value is needed. The word value was chosen to cover 15 CE values, including principle, intrinsic attribute, and enabler. The value in the CE has brought a new contribution. Value in the CE was limited to being described by researchers. One research has identified, Andersen (2007) who described environmental economic value.

In addition, in the three classifications (layers) of CE values, the layer principle has six values (for detailed values see Figure 5.2); the layer intrinsic attribute has six values and the layer enabler has three. Furthermore, as stated above, the reformulation of CE values was conducted by systematic literature review. A systematic method has been constructed to reformulate the values where the method has five stages. The method to reformulate the CE values is one of the contributions as it can be used for the general identification to other concepts; it could need some customising or it can also be used to continue the reformulation process of CE values.

The embedding of CE values in RL/PR options is the implementation part. The embedding process provides some contributions, such as the identification of CE values for each PR option per activity; classification of detailed PR options process to PR activity; identification of PR (repair, refurbishment, remanufacturing, and cannibalisation) parameters, and decisions; and an analysing method to convert parameters and decisions to become mathematical formulations. Those embedding processes besides providing the CE process itself, also deliver a method that can be used in different scenarios.

The ultimate contribution through those areas is a framework to design RL based on CE values. The framework is an implementation process for both RL and CE. The framework comes from the RL design framework from which it was constructed based on several researchers (Fleischmann, 2001; Amini et al., 2005; Bostel et al., 2005; Srivastava, 2008; Pishvaee et al., 2009), while inserting CE values in the framework was from the literature (e.g. Yuan et al., 2006; Yong, 2007; EMF, 2013; Stahel, 2013; Pan et al., 2015).

The contribution to knowledge of this research can be divided into primary and secondary contribution as follows:

- **Primary Contribution**
  - The development of a formal RL design framework based on CE values.
- **Secondary Contribution**
  - The general RL activities
  - The detailed process of PR options
  - A method to reformulate CE values.
  - 15 CE Values reformulated.
  - Configuration of CE values (principle, intrinsic attribute, and enabler).
  - Identifying CE values for each RL activity.
  - Embedding process CE values into RL cases.

8.3 Implications for Practice

The formal RL design framework can be used practically to develop the new RL system or modify the existing RL system. It was confirmed by R01 that the company has not used the formal RL design framework. The formal framework of RL design is useful as a necessary basis to implement another application purpose, such as RL network design, and constructing a model for RL, and other technical RL works (e.g. optimising the distribution network, transportation strategies, etc.). Those applications need to have a robust RL design so that they can run effectively. Furthermore, the identification of general RL/PR activities and process can be a direction for the practical implementation of RL or PR operations. The identification of parameters in each PR option process can be practically adopted to enrich the RL system as the parameters can represent the operational level of the RL system. The parameters can be applied to areas such as support in developing a model for optimising a distribution network, operational and scheduling. The RL design framework also provides a mathematical formulation that can be used as an initial input for other purposes in the RL operations (e.g. to calculate minimising the amount of waste, minimising disassembly costs, etc.).

The reformulation of CE values practically can be embedded into existing systems or concepts, such as RL or PR operations. The systematic embedding process has been provided in an available format by defining the definition for each CE value, and classifying the three layers of CE values, which are principle, intrinsic attribute, and enabler. With the clear systematic process of embedding CE values described above, the adoption process can be run directly specifically for RL or PR operations; however, for other concepts, the embedding process can be still used as a basis to increase the effectiveness of certain adopted concepts by making some adjustments.

A framework to design RL based on CE values practically can be implemented to achieve the effectiveness of RL operations through optimising the use of resources so that the resources can be kept in the highest utility and values within the flow. Furthermore, the identification of CE values for each PR activity can be used as a basis for the implementation of CE in PR operations so that the number and type of CE values will be easily known to produce a robust implementation. The providing PR (repair, refurbishment, remanufacturing, and cannibalisation) process can also be adopted practically to support the process itself so that through the process, any ineffectiveness can be identified easily and improvements undertaken. The provision for distinguishing PR (repair, refurbishment, remanufacturing, and cannibalisation) before and after adopting CE values practically, can support the implementation of a single RL operation and also RL-based CE.

The implication for practice can be concluded as follows:

- A formal framework of RL design can be used to guide the development of a new RL system or modify the existing RL system.
- The formal RL design framework can be adopted in the RL network design or other applications.
- General RL/PR activities and processes can be used for the implementation of RL operations.

- CE values can be embedded into existing systems or concepts.
- A framework to design RL based on CE values can support the implementation of a single RL operation and also RL-based CE.

8.4 Conclusions

8.4.1 Summary of Achievements

This research focuses on two main areas, RL and CE, and also a combination of them. Findings and contributions are given which academically and practically expose a new and important understanding of both areas. In the RL area, a formal RL design framework is formulated. This framework is necessary to increase the effectiveness of the RL system which, it is known, has some problems, for instance it is more complex to be managed than forward logistics, and uncertainty is involved, such as the quantity and quality of returned product. An RL design framework can, therefore, be a guide to develop or improve an RL system.

RL design might be used by researchers informally or implicitly; however, during the searching process, it was hard to find an RL design. Searching was done by reading logistics and RL books for instance *Strategic physical distribution management, Strategic logistic management,* and *Contemporary logistics*; and using search engines to find journals, conference papers, and other scientific articles. Within these limited sources, it can be seen that the formal RL design framework is rare. Additionally, in searching for an RL design by using search engines (e.g. Google Scholar), the result was frequently directed to RL network design.

RL design and RL network design, however, are different. RL design focuses on developing RL systems effectively, while, RL network design concerns building an effective network within the RL system, for instance optimising the distribution network, operational and scheduling, and transportation strategies. RL design and RL network design can support each other. To develop an RL network design first requires a robust RL design where the design of the network can be run effectively.

The formal RL design framework was constructed based on the literature review. Some keywords were used to search in the literature, for instance “reverse logistics design”, “model of reverse logistics design”, and also other related keywords that can support the construction process which are “reverse logistics network design” and “design”. To enrich the construction of an RL design framework, some existing examples taken from the literature were adapted. Analysis of the RL processes is required to know the operational level of the RL system.

In addition, this research focuses on PR options (repair, refurbishment, remanufacturing, and cannibalisation) which have been chosen for several reasons, based on the replacement of product level, where those options have minor and moderate retained values of returned product. In the implementation of a formal RL design framework, the PR options will be an object of research implementation. This research will not focus on a specific product, because it is concerned with providing a framework that can be applied to any type of product that is related to PR options (repair, refurbishment, remanufacturing, and cannibalisation). Nevertheless, some examples are needed to describe clearly the framework of implementation.

The systematic stages in the formal RL design framework were arranged based on the literature results given above. The first process was determined based on the research focus, which is PR option. By choosing one or more specific options, the identification of each option will be easier. The stage of identification of activities and entities accommodates the detailed activities of the RL options that have been chosen before. Through this stage, the general activities of RL/PR operations are identified. Then the activities related to the PR options were also used to identify the specific RL/PR activities for particular PR options (repair, refurbishment, remanufacturing, and cannibalisation). The next stage was to analyse the detailed process of PR options which identified some existing examples in the literature. Identifying the parameters stage was done according to the detailed process given before. The identification of parameters of PR options processes is important to depict the operational process of the PR system. Determination of the need for decisions can be determined to complete the specific requirements of the PR system.

In CE area, reformulation of CE principles was conducted to provide an available format that can be implemented for specific purposes, particularly in RL. The CE principles have actually been described by some researchers (Yuan et al., 2006;

Yong, 2007; Geng et al., 2012; EMF, 2013, Stahel, 2013, Pan et al., 2015); however, they described the CE principles at the conceptual level, not implementing the CE principles in particular cases, specifically RL or PR operations. In the process of principles reformulation, other determinants, which are intrinsic attribute and enabler, have been found. Therefore, the process of principles reformulation needs to be changed by using value to cover the three determinants (i.e. including principle).

The 15 CE values were discovered by using a systematic literature review method which consisted of five stages. The process was started by collecting some sources through search engines, for instance Scopus, Google Scholar, and EBSCO. The searching process was done by using several strings (e.g. circular economy; circular economy AND principle). Through this process, 931 journals and 509 conference papers were found. Those sources were filtered by using specific steps to obtain the relevant sources. The 47 related sources were analysed until 11 CE themes were discovered. Indeed, theme is different from principle, where to produce a principle, a deeper analysis is needed. Through comparing existing themes and analysing the results, 15 CE principles were produced and each was then identified. During the identification process, different levels of the principles were discovered. A principle was defined as a fundamental truth of a concept. In the other levels, the natural characteristics of CE and external aspects that can make the implementation process easier were discovered. Those levels were named intrinsic attribute and enabler.

The other levels discovered, in the reformulation of CE principles, finds a new term to cover all levels in the CE. Value was chosen to overarch the three layers. The CE values term was rarely used, differently from principles that have been described by several researchers. Value in CE was used by Andersen (2007), when he described one value in CE which is environmental economic value. Furthermore, in this research the configuration of CE values into three layers was defined where in each layer, principles have six values, intrinsic attributes have six, and enablers have three. Each value can be added as stated above by following the systematic method that has been offered in this research.

In both RL and CE concepts, CE values in RL, specifically PR options through the embedding process, were implemented. The embedding process was constructed by adapting the formal RL design framework step by inserting CE values. The process is similar to the formal RL design framework in the first and second steps. In the third step, the CE values need to be considered and reviewed. This step will inform how the CE values can be correlated to the design process. The PR option activities mapping was done based on CE values, which means the PR activities have now been embedded. In this process, the identification type and number of CE values for PR options (repair, refurbishment, remanufacturing, and cannibalisation) were found. The embedding process was continued by identifying the parameters of PR options based on CE values. The parameters that have been identified can be used as a basis to implement RL/PR for another purposes, for instance as part of an integrated application system. In this research the parameters are used to complete the RL system by producing some mathematical formulations to support decision making process.

The systematic embedding processes above are used to construct a framework to design RL operations based on CE values. The framework needs a testing process to confirm its quality. The testing was conducted by interviewing and engaging some respondents from industries, and one RL expert. It was done to confirm the framework based on their expertise and experience. The semi-structured interview was chosen in which there were five key measurements arranged: fit for purpose/usability, feasibility, consistency/repeatability, reliability/effectiveness, and utility. The overall interview results confirmed that the framework flow can be understood; most of respondents also replied that the framework would be feasible to be implemented; the framework process was also rated as consistent; and the framework was also rated as providing a useful output. Some suggestions were also recorded to improve the framework for each key measurement, for instance before implementing the framework; one activity needs the practical commitment of management.

This research showed that there is a relationship between RL and CE, which can be seen through the activities of those concepts. The relationship is also asserted when the CE values are embedded in RL, specifically PR operations cases. The relationship of both concepts shows they support each other; for instance RL focuses on the efficiency of cost, product reuse and recovery flow, recapturing values of returned product, and the distribution channel, while CE focuses on keeping material longer in circulation. In this research it is stated clearly that CE values are described at the operational level and can be implemented easily for specific purposes. Through this research, both concepts are met that can be easy to be understood.

This research has fulfilled the objectives of the research which were stated at the beginning. The research was conducted by arranging a robust research programme that has led to achieving the research aim. Within the research process, there are findings that can contribute to academic knowledge; the research also contributes practically.

8.4.2 Research Limitations

First, the formal RL design framework was constructed by conducting a literature review. The amount of literature needs to be expanded to make the formal framework more established. The formal framework also needs to be tested separately by engaging a sufficient number of respondents in this area. Second, the research needs to be updated by including more recent publications. The CE principles testing then needs to be done separately by involving CE companies, experts, or other players.

The testing process for the framework to design RL based on CE values has been done by engaging several respondents. It was done by conducting pilot interviews and the main interviews. The number of respondents that have involved in this research to test the framework are limited. It is suggested that more respondents are interviewed, who can represent the real world. Furthermore, the engagement of companies that have implemented RL, CE, and RL and CE is necessary in the testing process for identifying the constraints of RL/CE implementation.

8.4.3 Future Work

There are several areas of work that can be recommended through this research. First, the formal RL design framework needs be tested to obtain the recommendation from the user. The testing result is necessary to produce a readily available design that can be applicable immediately by users. The test can be done by engaging the respondents from practitioner or academic. The engaging methods could be a workshop, focus group discussion, or survey. However, conducting a workshop is recommended as it is not only obtaining the input from the respondent but also it can stimulate the point of view during the workshop process. Second, CE values need to be tested before being implemented or embedded into other concepts. The test can be done by conducting some approaches such as workshop or focus group discussion. However, conducting a workshop is recommended as it is not only obtaining the input from the respondent but also it can stimulate the point of view during the workshop process. The testing of CE values purposes to measure how each value can be implemented practically by users that can analyse the potential implementation of each value. Third, the number of respondents should be increased to obtain more information regarding the framework of RL design based on CE values. The more respondents can provide the more information that can produce the comprehensive needs of the development framework of RL design. Fourth, the framework to design RL based on CE values can be aligned with organisational vision that can support the implementation of RL design framework easily. The organisational vision is related to such as the existing programme (e.g. CSR, human resources, and IT), financial support, and customer centric. In addition, users will find it easier to use the framework to design RL based on CE values by using an automatic computer application that has been constructed based on the information system model. The model could be used for different purposes. The complete design is attached in Appendix 1.

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Appendices

Appendix 1

A framework for designing RL based on CE values will be projected by using an integrated system/computer application which users can design an RL easily. It is envisaged, it can support the RL design process. The idea of the system is provided in a model. The model is called a hypothetical model of PR based on CE values. It aims to visualise the framework that has been formulated into a model. The model will be constructed based on information systems (IS) thinking. The idea of the model creation is to support the user in using the framework under integrated system such as computer application. It means the user only needs to input some data, and afterwards the result will be given directly. The model is illustrated by using a tool, which is a unified modelling language (UML), and will also be depicted by using some diagrams that describe the model in the logic of an integrated system.

a. Designed Model

A model was defined by Wilson (1990) as the obvious illustration of an object that can be depicted in mathematics, symbols, or words. It also describes entities, processes, and the links between them. This research will design a model using a conceptual model technique, which is UML. It describes a visualisation standard of a system in developmental and modelling language (Booch et al., 2005). There are two UML diagrams that will be used to illustrate the model of the system. They are use case diagrams that represent the typical interactions between users and the system; and the class diagram depicts the type of objects in the system and the relationship among them (Booch et al., 2004). This research will also provide a mock-up of the computer application.

The hypothetical model will be illustrated in the architecture model to describe some components or entities involved. It will also depict the link and logic between the components or entities. The architecture model is illustrated in Figure 1. It uses *class diagram* which is chosen to represent the relationship between each class in the model. The class describes the objects involved. The entities/objects and relations are arranged based on the framework activities. The class `ReverseLogisticsEntity` is at the centre of the architecture, where there are several classes that are derived, for instance `ProductRecoveryEntity`, `PartnershipEntity`, `CEValue`, and `UsedProduct`. In each class it can be seen that there are three layers, where the first layer indicates the name of the object or class, the second layer describes the parameters, and the third layer represents the operation that will be done in each class. In addition, each notation in the class diagram has a specific meaning; line means association, arrow means inheritance relationship, and diamond means aggregation. Figure 1 illustrates the general relation among the objects.

In more detail, the models for repair, refurbishment, remanufacturing, remanufacturing for disassembly, remanufacturing for reconditioning, and cannibalisation are respectively depicted in Figures 2, 3, 4, 5, and 6. Class diagrams for remanufacturing option in disassembly and reconditioning process are used to describe in detail explanations based on specific cases which is consumer goods and electronic product, and aerospace product. The class diagram can describe clearly all interacting entities, the attributes of each entity (class), and also the operations of each class. By using this approach, all parameters and decisions we have already discussed are precisely defined in the class diagram.

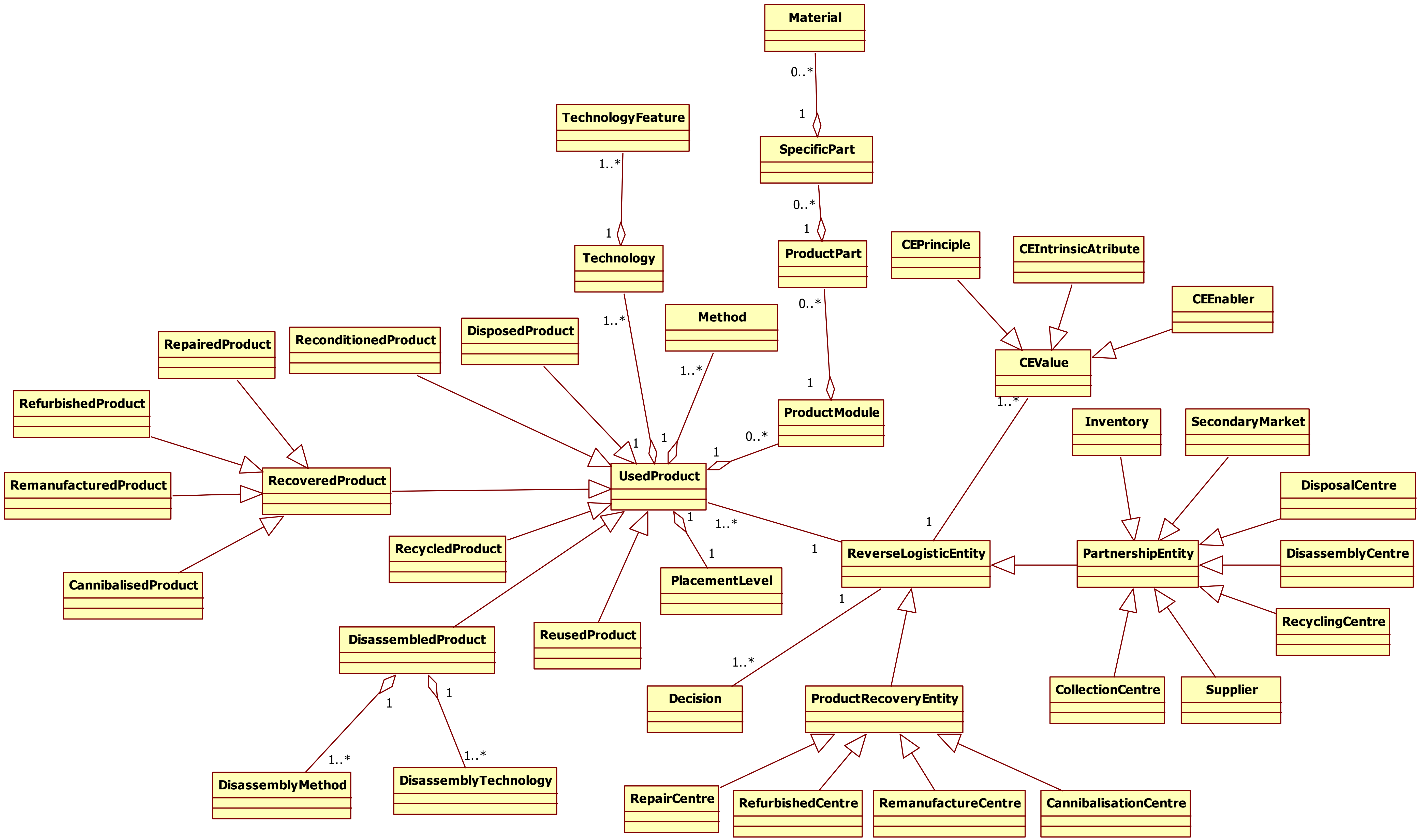


Figure 1 – Architecture of Product Recovery Model in Class Diagram

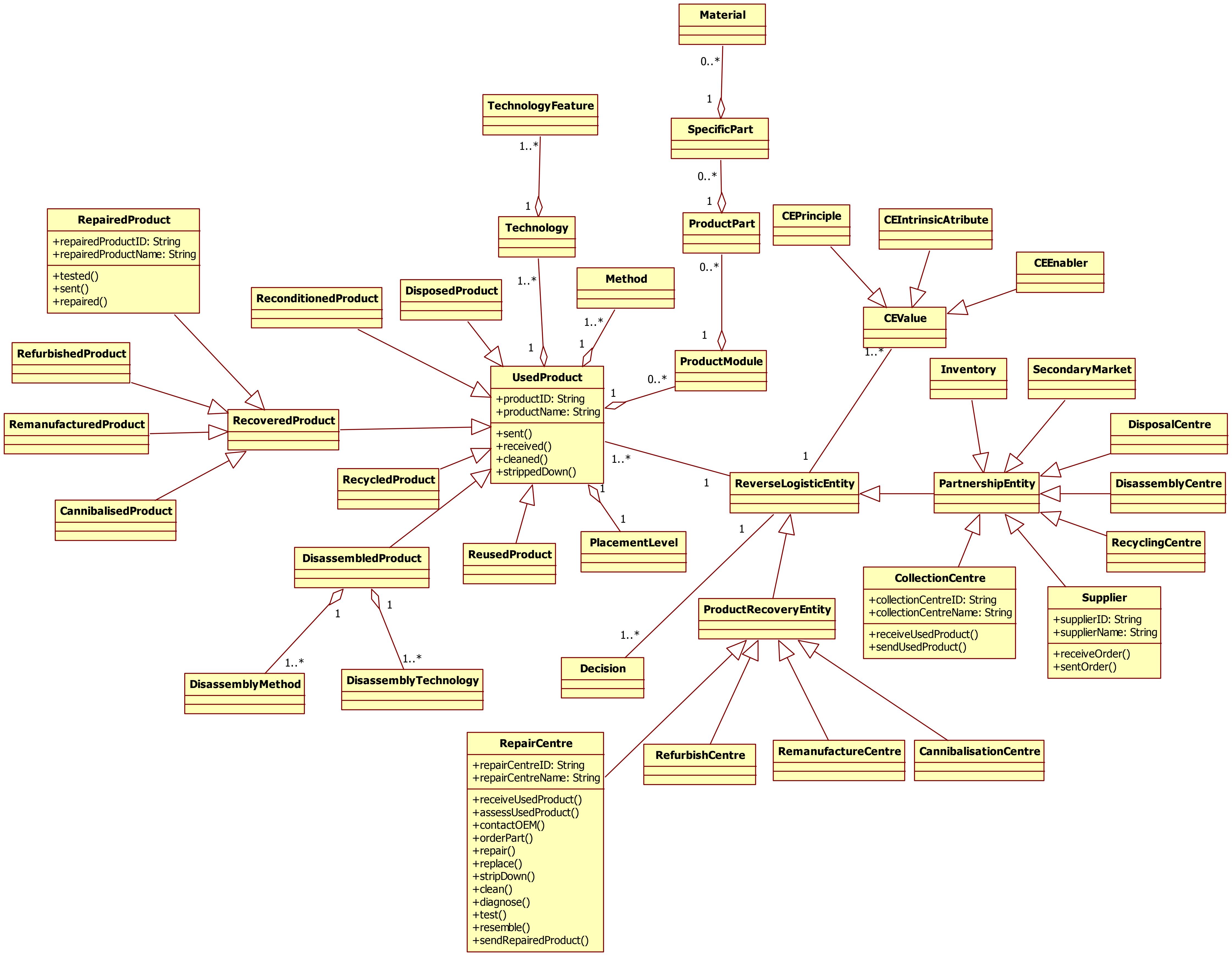


Figure 2 - Class diagram for product repair model

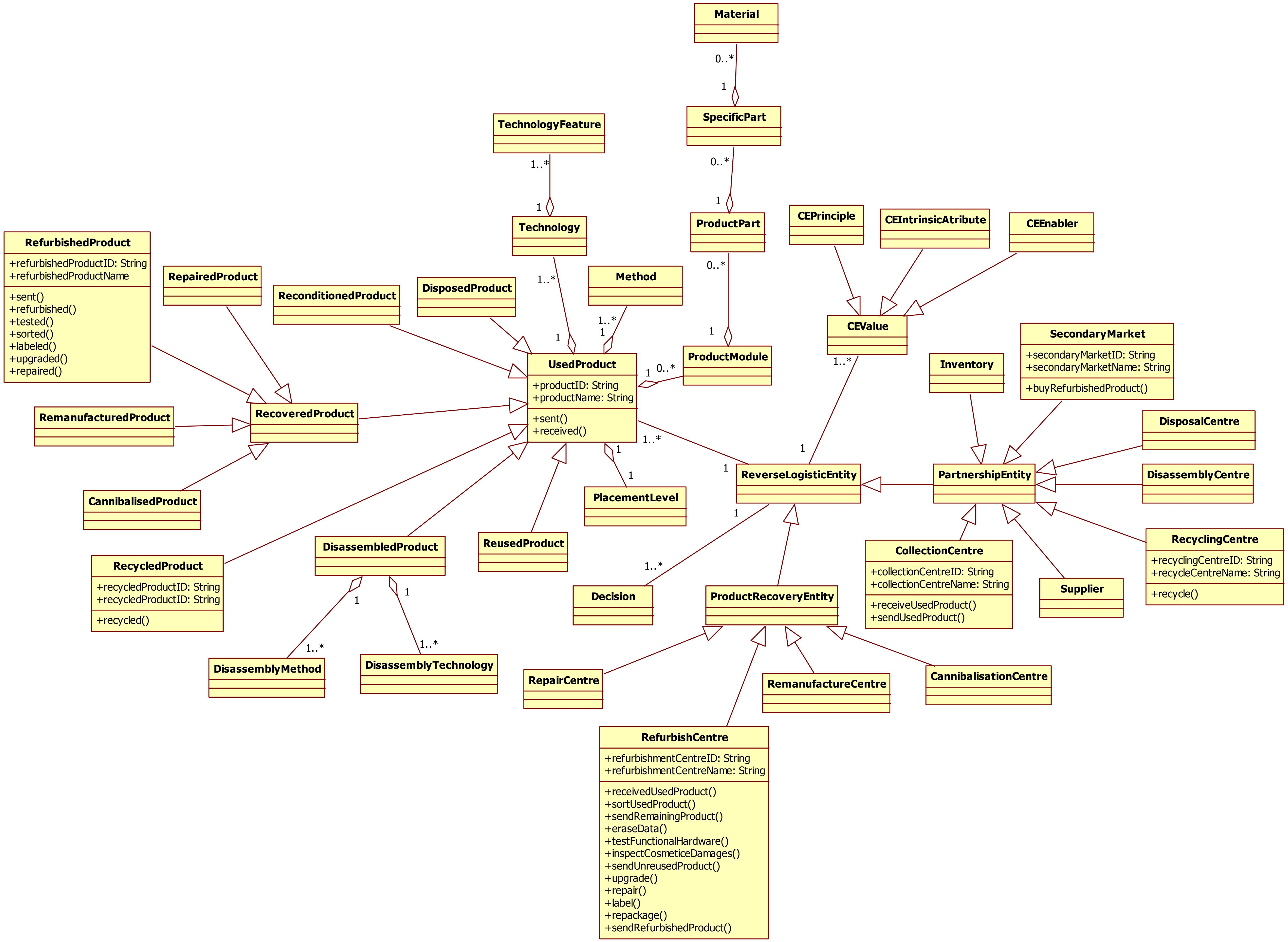


Figure 3 - Class diagram for product refurbishment model

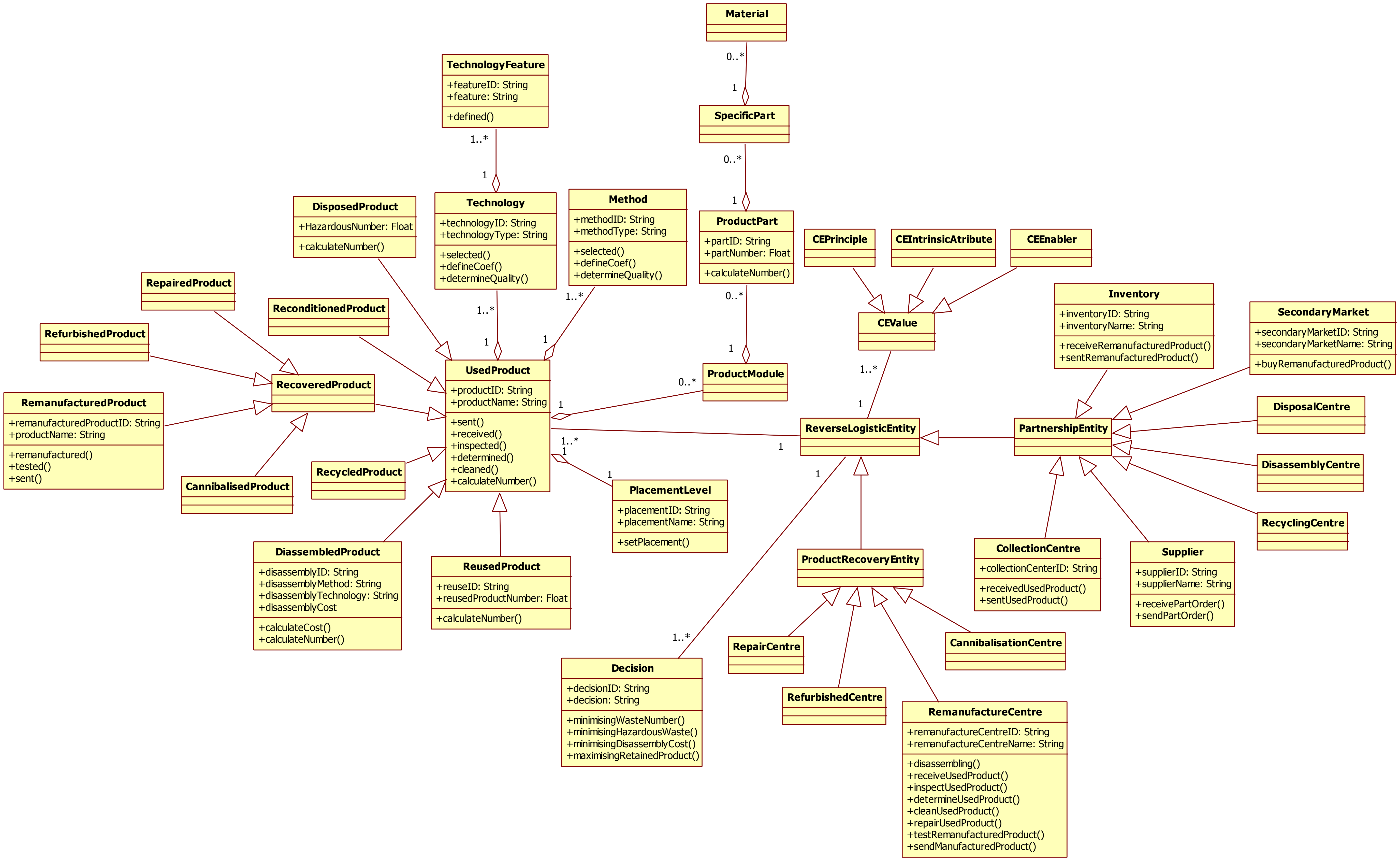


Figure 4 - Class diagram for proposed product remanufacturing model

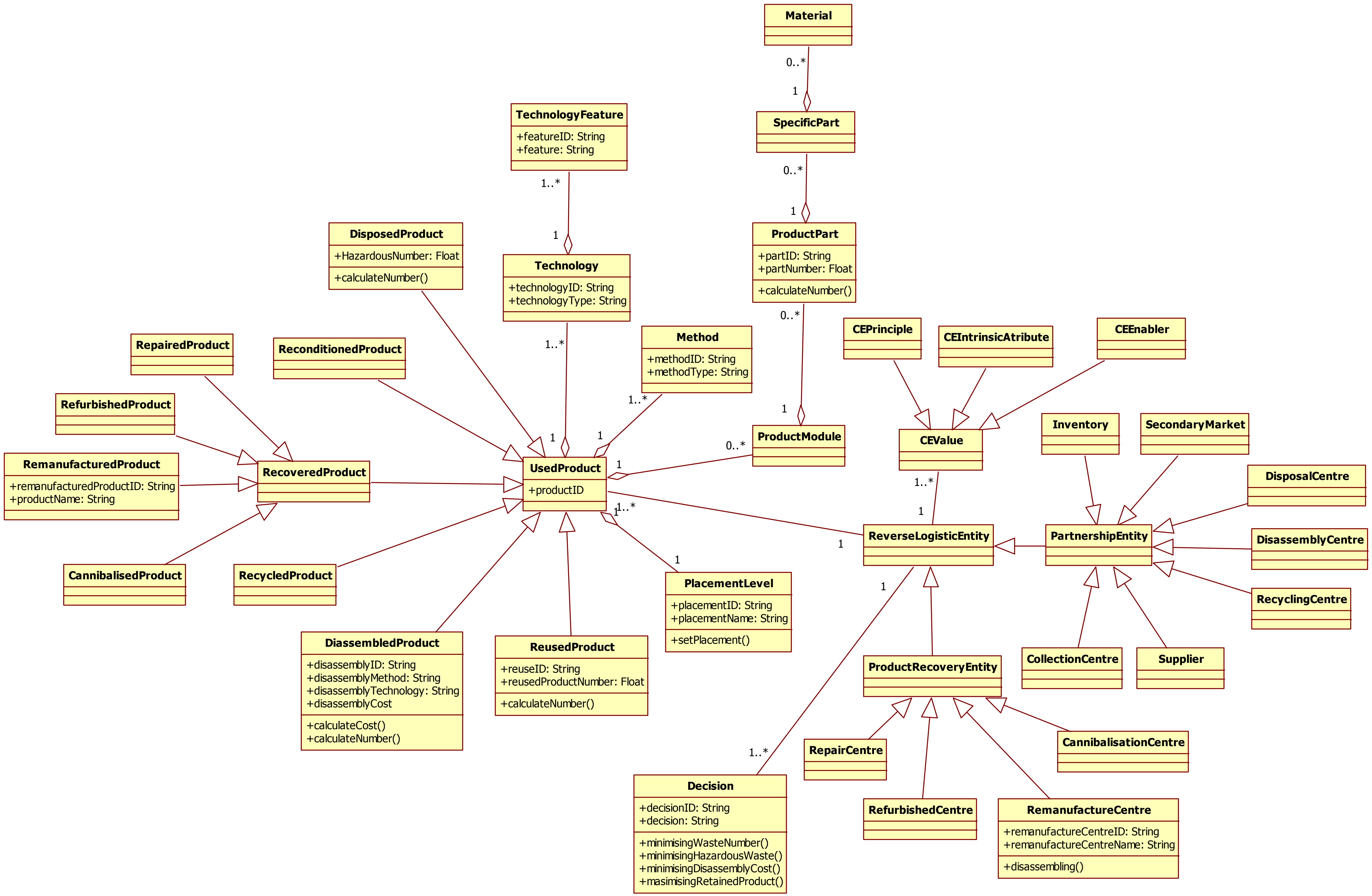


Figure 5 - Class diagram for proposed product remanufacturing model in disassembly process

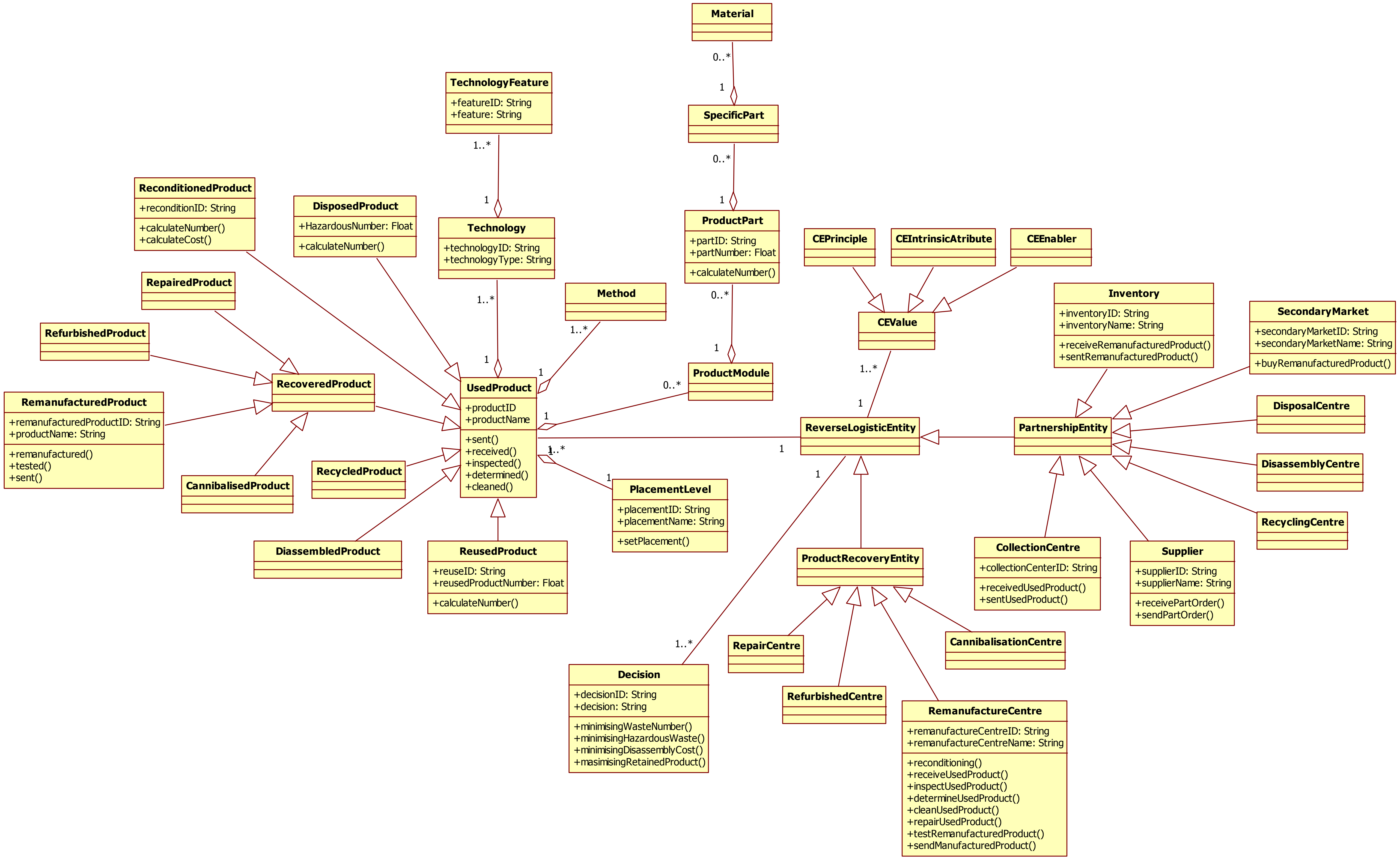


Figure 6 - Class diagram for proposed product remanufacturing model in reconditioning process (aerospace product)

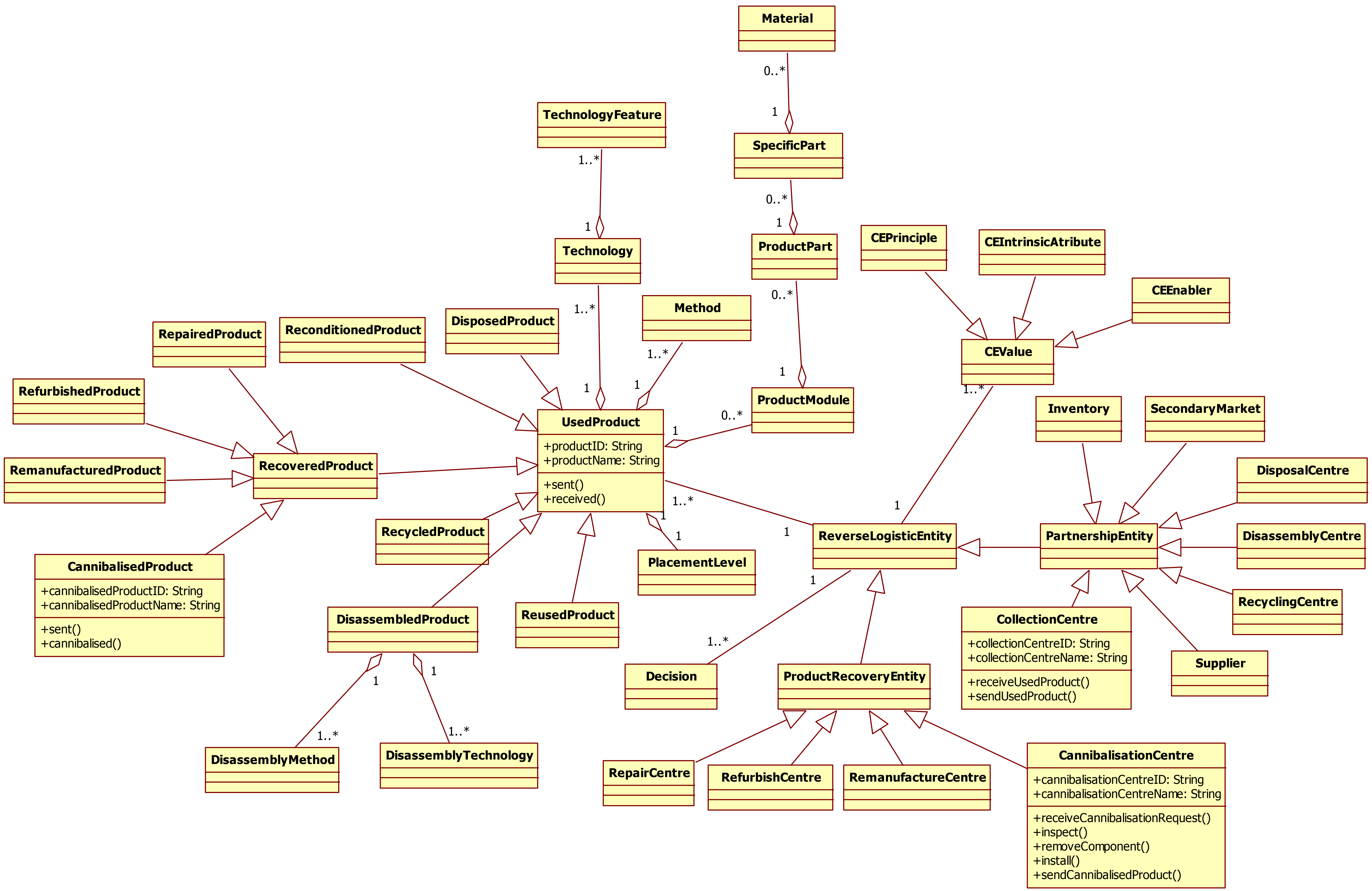


Figure 7A - Class diagram for proposed Product Cannibalisation Model

For illustration purposes, a detailed description of class `RemanufactureCentre` for the case of remanufacturing option for goods and electronic products is depicted in Figure 7A. Specifically, class `RemanufactureCentre` has eight main operations that have an exclusive purpose. Four ultimate partners of the remanufacture centre in undertaking the remanufacturing option are secondary market, inventory, collection centre, and supplier. Each operation that relates to the activities in the remanufacturing option (especially for goods and electronics) can be presented in part of the class diagram in Figure 7B. For example, the secondary market is who will buy/receive the remanufactured product, supplier is who will receive and send a part order coming from the remanufacture centre, and collection centre is who receives the used product.

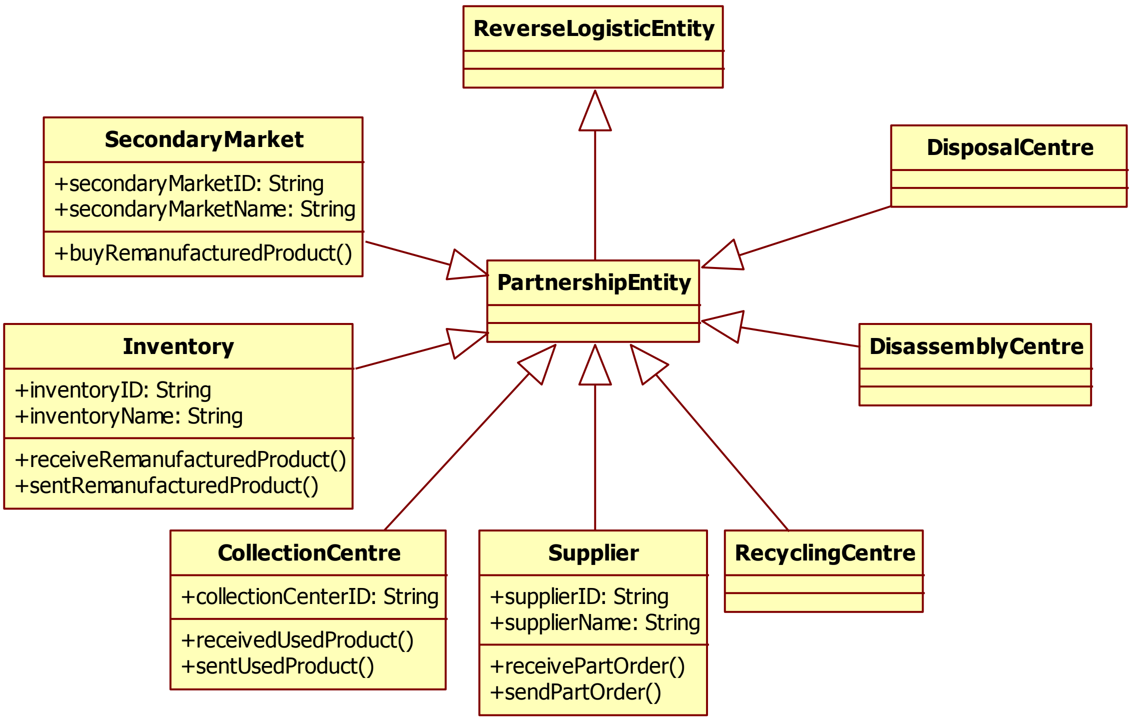


Figure 7B - The composition of class PartnershipEntity

Practically, the implementation of a development framework of CE value-based RL will affect the reverse logistic entity decision (Figure 7C). Several operations of decisions can be determined which depend on parameters' objective function being defined. Based on the objective function, some decisions can be decided; such as selecting the proper method and technology (see Figure 7D in classes `Method` and `Technology`), deciding the technology feature (see Figure 7D in class

TechnologyFeature), setting the product number (see Figure 7D in class usedProduct), etc.

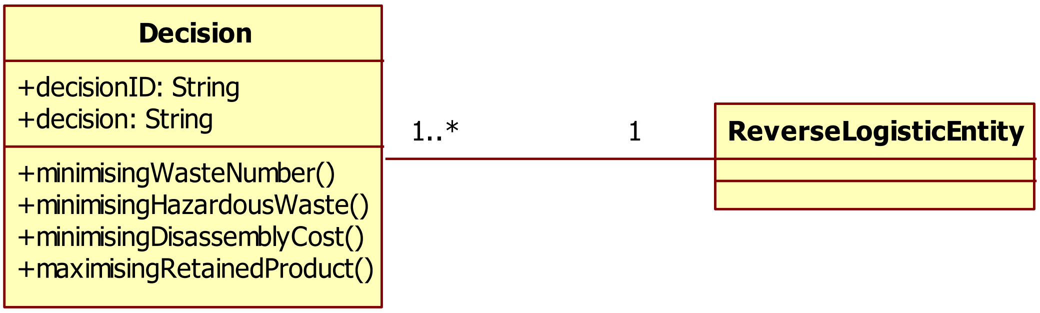


Figure 7C. The composition of class Decision

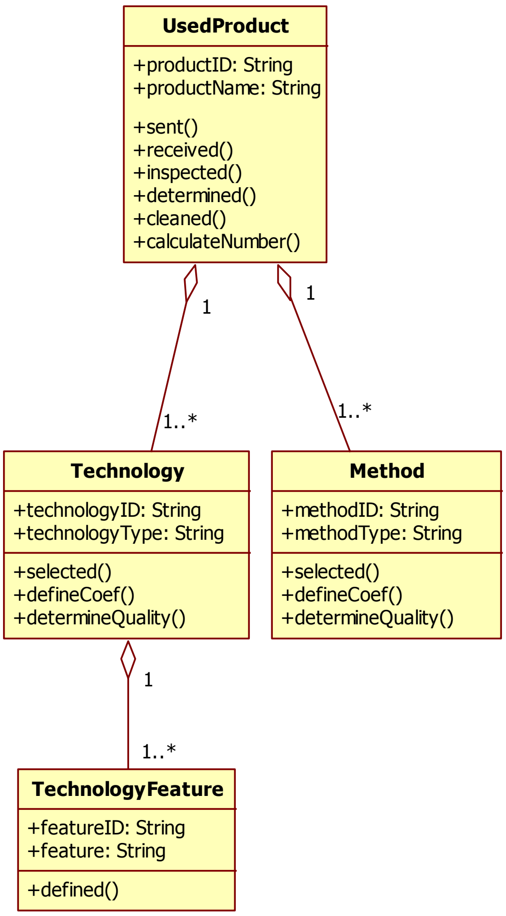


Figure 7D - The composition of class UsedProduct

b. User – System Interaction of Model

The representation of a model needs a tool. A computer-based application thinking can be used to provide the clear deliverables of the model. As stated above, this research is using a UML tool to analyse and visualise the model. To design the model it is necessary to prepare the user interface that can be used for designing a computer application in the future. In this research the case diagram will be used to illustrate the interaction between user and system (Figure 8). There are three types of user (actors): industry, scientist, and other stakeholders; which can be generalised as RL players.

The user interface is created to describe the human/computer interaction of the model. Figure 8 illustrates how actors (industries, scientists, other stakeholders) interact with the model, where they can use the model that adopted CE values through the database. The picture consists of three components: database, model, and interface. Each component interacts with each other. In addition, the model is completed by arranging a menu that consists of five main menus: home, RL operation, RL activities, data input, and result (Figure 9). Each menu is described as follows: (1) Home. (2) RL operation. This menu provides the possibility to choose the operations that it will focus on; it can choose more than one option. (3) RL activities consist of several activities that involve some RL operations, the logic will be arranged, based on the information in the framework, where certain operations could have certain activities. (4) Data input, this tab provides the opportunity to input some customised requirements that are needed, such as type of industry, type of product, parameter, and decision. Those data inputs will be readjusted by the database. For example, consumer goods and electronic product could have specific requirements that need to be saved in the database. (5) Result: this tab will produce or execute all of the information that has been inputted previously.

In addition, in terms of the user interface diagram (Figure 8) there are three domains: database, model, and interface domain. These three components interact with each other. Each component has a specific function, and also covers specific tasks, for instance model domain represents the whole model. This means it covers all of the activities that have been described above in the class diagram.

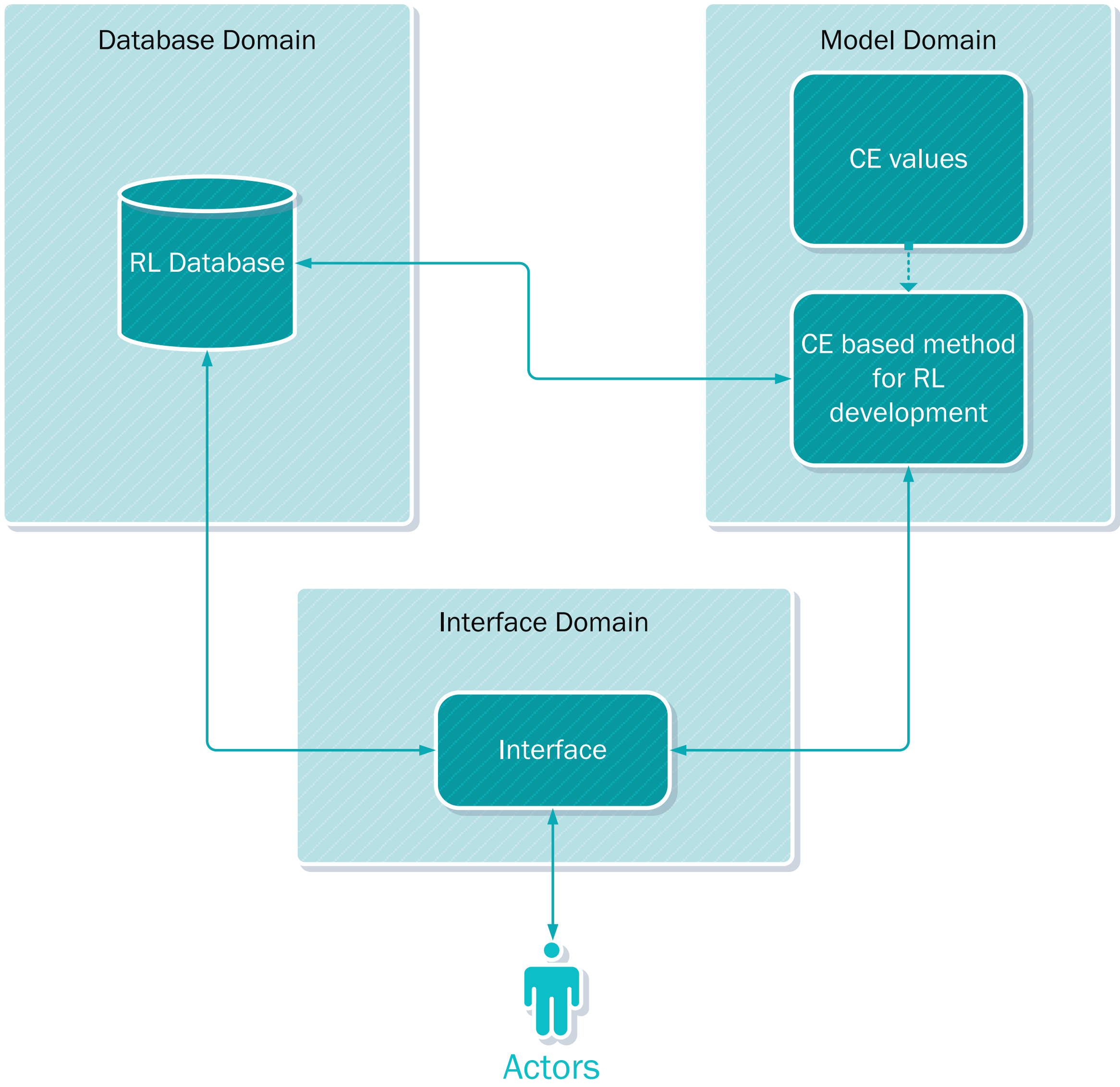


Figure 8 – User interface design

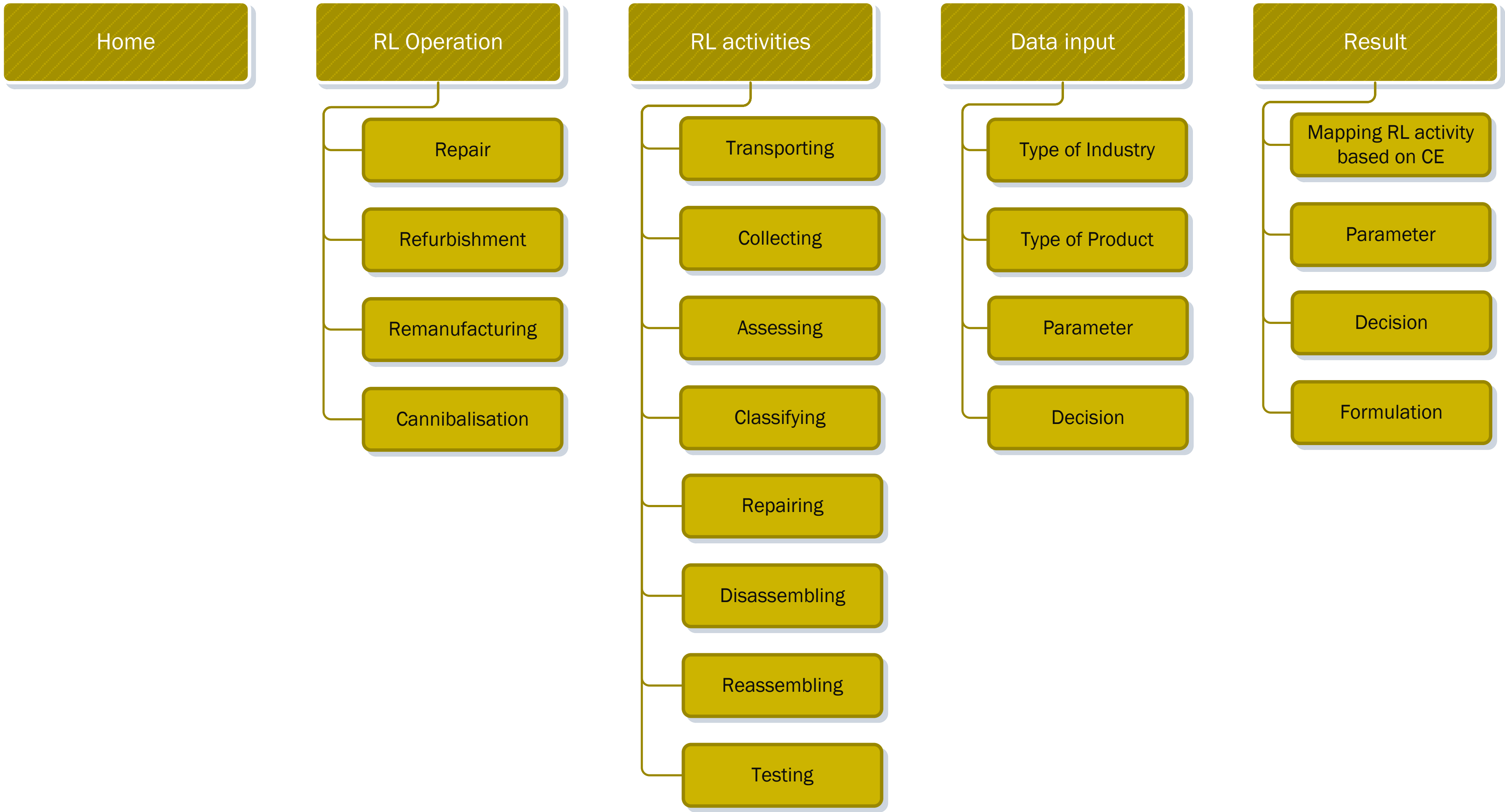
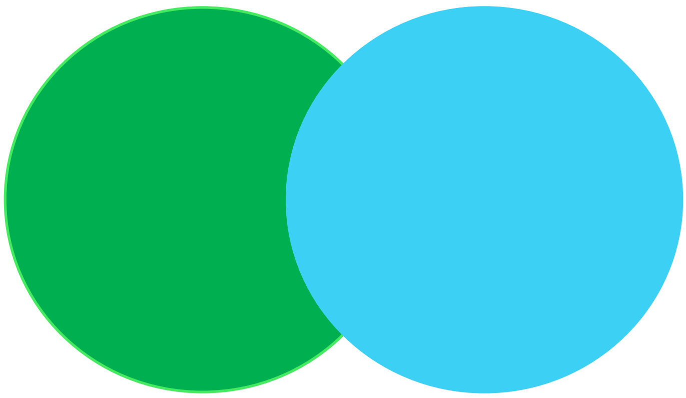


Figure 9 – Application menu

Appendix 2

Interview Guide

TESTING A FRAMEWORK FOR DESIGNING REVERSE LOGISTICS BASED ON CIRCULAR ECONOMY



Cranfield University
September 2016

A Framework to Design Reverse Logistics Operations based on Circular Economy Values

Background

The research is combining reverse logistics and circular economy. Both concepts share the similar activities such as repair, refurbishment, remanufacturing, and cannibalisation. This research aims to propose a framework to design reverse logistics operations based on circular economy values. There are some tasks that have been done in this research, for instance formulating fifteen circular economy values, formalising reverse logistics design framework, and a framework for designing reverse logistics based on circular economy values.

The framework has been formulated based on such as literature review, synthesising the literature, and discussion. The test process is needed to confirm the quality of the framework. The test will engage practitioners and experts through an interview. The point of view will be used as the considerations in providing an expert view and test the framework on the following criteria.

The interview protocol will be prepared to support the interview process. There are several activities will be arranged in the interview which is describing the research briefly, describing framework, and asking some questions. The type of industries will be chosen based on some considerations for instance industry sectors, the reverse logistics activities involved. The respondent are chosen based on the role and experience in reverse logistics professionals.

Purpose

The testing purposes to confirm the quality of a framework to design reverse logistics operations based on circular economy values. It will confirm the understandable and identify the strengths and weaknesses of the framework.

Interview Agenda

The interview will be done in an hour approximately. Before conducting the interview, there are several preliminary activities will be done by interviewer for instance exploring company profile, business process, and also sending an interview guide.

Within interview, the interviewer will describe the research and the framework. Some questions will be asked to explore the point of view. The interview results ultimately will be used as a consideration to recommend the design of reverse logistics based on circular economy values. The detail interview activities and the timeline illustrate in Figure 1 and 2. While, the interview protocol and list of interview questions depict in Table 1 and 2. Table 1 depicts the interview criteria and structural activities during the interview. Table 2 illustrates some interview questions that are derived based on the interview criteria. The list of questions will be given to the respondent before interview that can highlight some important points. By giving the interview guide is expected, the respondent can be easier to pay attention in order to describing research and framework.

In addition, the interview is a semi-structured interview where it could provide an opportunity to the interviewer to explore some questions based on the feedback from the respondent. Regarding research ethic, the data has been obtained from respondents will be used for the research only.

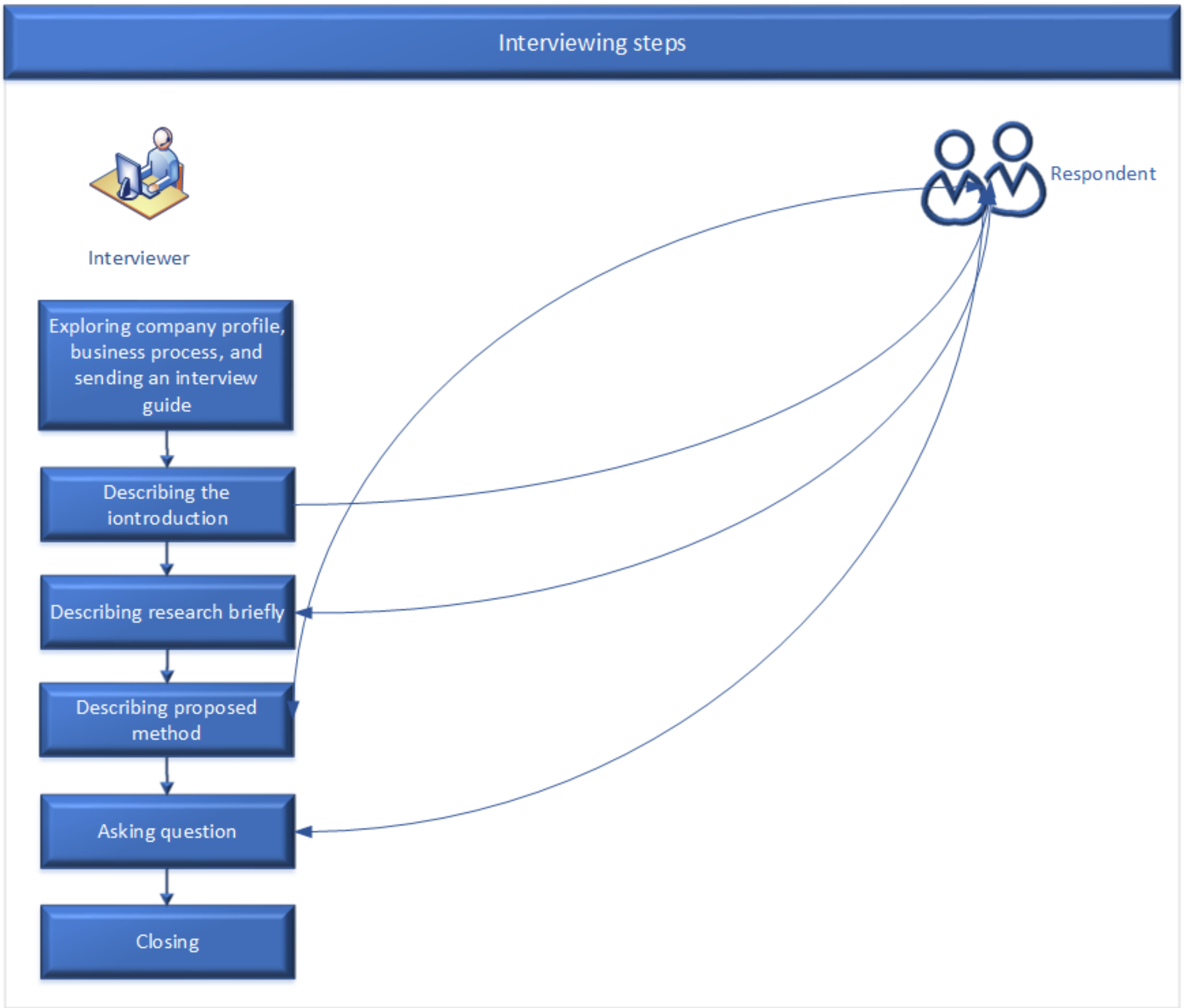


Figure 1 – Interview activities

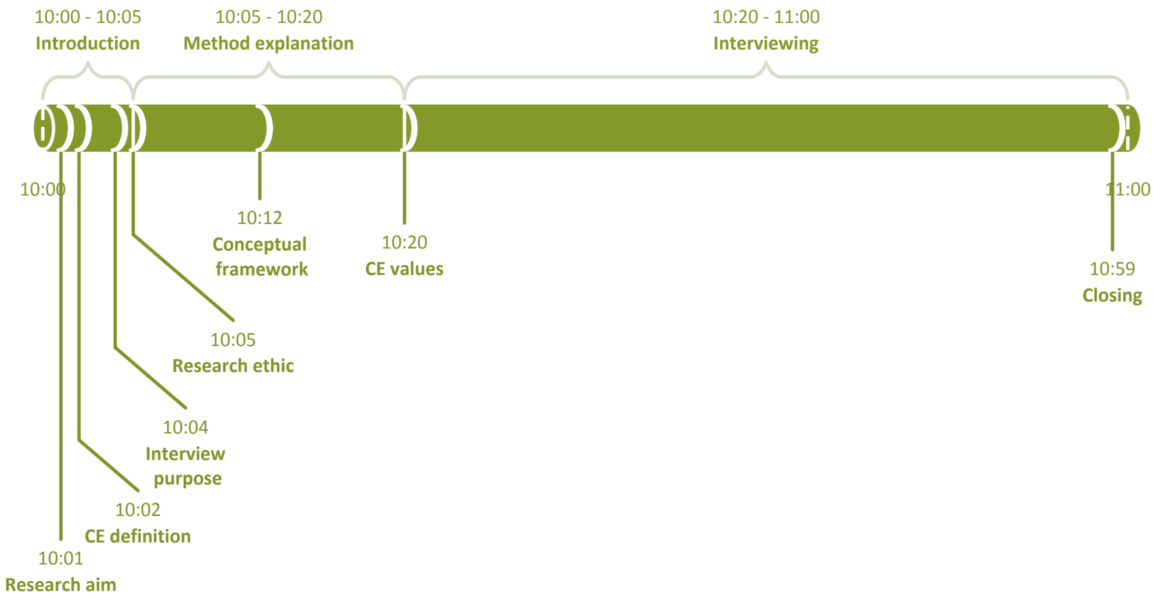


Figure 2 – Timeline of interview agenda

Table 1 – Interview protocol

Preliminary Activities	• **Send an interview guide**
Introduction	• Research aim • CE definition • Interview purpose • Research ethics
Framework explanation	• Proposed framework • CE values
Interview and discussion	Criteria: • Fit for purpose/usability • Feasibility • Consistency/repeatability • Reliability/Effectiveness • Utility Strengths and weaknesses (input)
Closing	

Table 2 - Guide list of questions

Reference	Criteria	Questions
Platts (1993)	Fit for purpose/ usability	• Is the framework suitable to meet the objectives? • Is the overall concept understandable? Does it make sense? • Usability: can the framework be easily followed? • Does it have a logical flow and sequence of events? • Could managers adopt the approach suggested?
Platts (1993)	Feasibility	• Can the framework be applied: is it sufficiently understandable to use? • Would the framework provide managers with feasible options?
Harper (1994); Krishnan and Kellner (1999)	Consistency/ Repeatability	• Would using the framework provide consistent and repeatable results?
Rubin and Chisnel (2008)	Reliability/ Effectiveness	• Would using the framework lead to reliable and robust solutions? • Is the model considered to be a comprehensive approach?
Platts (1993)	Utility	• Would the framework provide a useful output? • Are the options likely to be implemented?

Research Context

The detail framework will be illustrated in the step-by-step below:

1. Deciding on reverse logistics operation/reverse logistics options in order to have PR options
2. Identification of Reverse Logistics Activities
3. Considering and Reviewing Circular Economy Values
4. Mapping Reverse Logistics Options based on Circular Economy Values
5. Identification Parameters of PR Activities based on Circular Economy Values
6. Analysing Parameters and Decisions in the Mathematical Formulation

Those steps are illustrated in Figure 3 and 4 in a proposed and detailed framework flow for designing RL based on circular economy values.

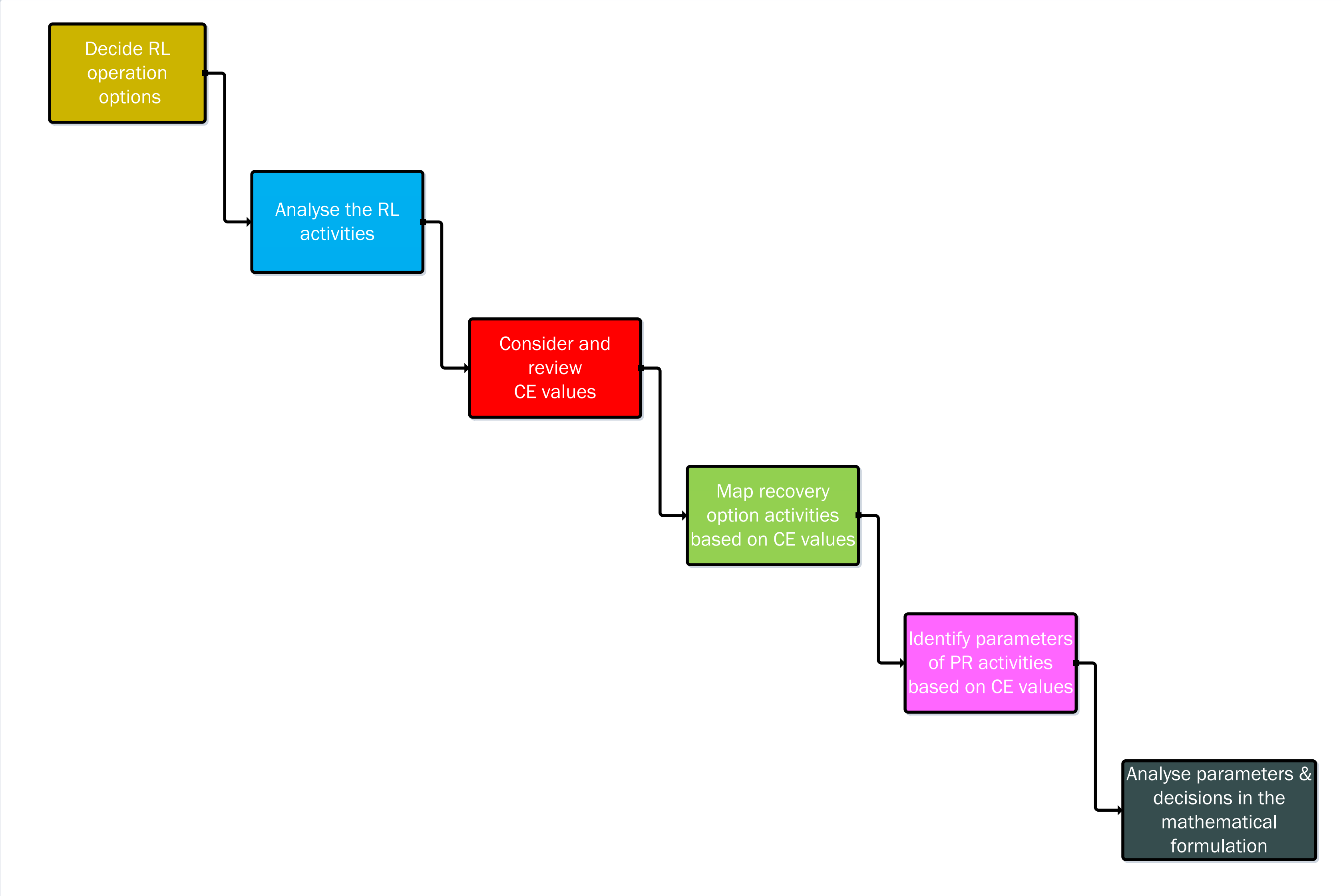


Figure 3 – A framework for designing RL based on circular economy values

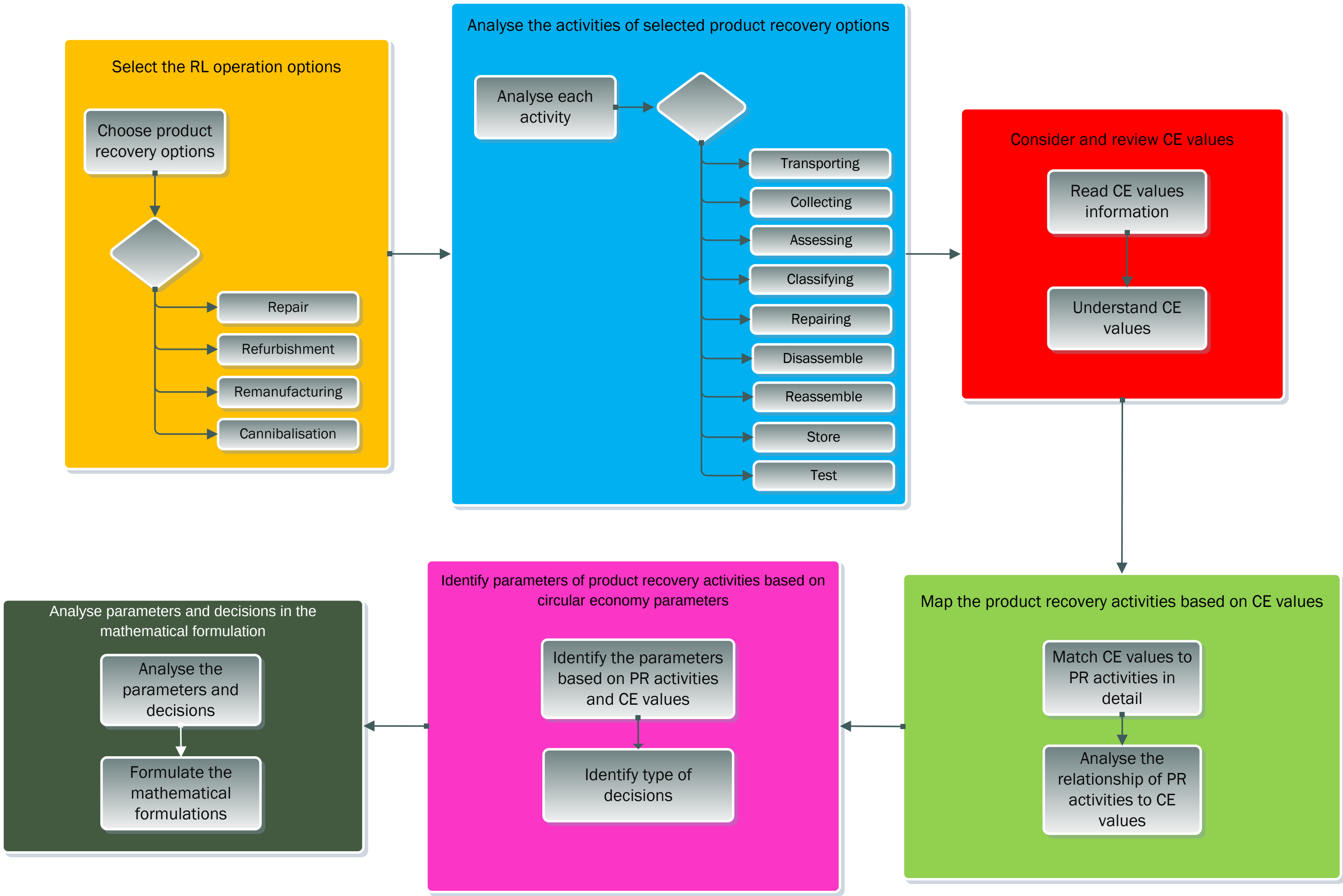


Figure 4 – A detailed of the proposed reverse logistics design framework

Conclusion

The interview results are expected, they can be as an input that can be used as the recommendation in designing reverse logistic framework based on circular economy values.