Contextualisation of Closed-Loop Supply Chains for Sustainable Development in the Chinese Metal Industry

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ABSTRACT

There are many factors influencing the sustainability of Closed-Loop Supply Chain (CLSC), in terms of industrial operation flows and environmental perspectives. This research aims to identify these factors in order to provide a better understanding of the process flows and interactions between the primary and secondary metal manufacturers and remanufacturers. In particular, it focuses on the influences of the Customer, Environment and Technology (CET) factors, with the intention of finding out “the specific approaches and techniques the Chinese metal manufacturers and remanufacturers adopt for sustainable development of the CLSC”. Qualitative case studies were performed in seven companies in the Pearl River Delta (PRD) region of South China. These companies are Small and Medium Enterprises (SMEs) of primary metal manufacturers, secondary metal remanufacturers, dismantlers, and third party reverse logistics providers. Data and information were collected through semi-structured interviews and observations on sites, in order to analyse the process flows in the supply chains. The key findings include the demonstration of the CLSC networks in the context of the Chinese metal industry, and the development of the process maps and Positioning Tool for case companies to identify themselves in the CLSC. These are theoretical and practical supports for academics and companies to understand the handling of various qualities and quantities of primary and secondary metals. Simultaneously, they assist companies in identifying and positioning themselves in the CLSC in order to define their direction for sustainable development in the long-term.

PUBLICATIONS

Conference Paper

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DEFINITION AND ABBREVIATION

Key terms and abbreviations in this thesis are defined as follow:

- **Closed-Loop Supply Chain – CLSC**

The Closed-Loop Supply Chain system, in which materials are returned and reused by the same originator, as the supplier or the manufacturer brings product back in, remanufactures it, refurbishes it then resells it (Kopicki, et al., 1993).

- **Context, Contextualising and Contextualisation**

The term 'context' comes from a Latin root meaning 'to knit together' or 'to make a connection'. Contextualising entails linking observations to a set of relevant facts, events, or points of view that make possible research and theory that form part of a larger whole. Contextualisation can occur in many stages of the research process, from question formulation, site selection, and measurement to data analysis, interpretation, and reporting. The need to contextualise is reinforced by the emergence of a worldwide community of scholars adding ever-greater diversity in settings as well as perspectives (Rousseau and Fried, 2001).

- **Corporate Social Responsibility – CSR**

A set of management practices that ensures the company maximise the positive impacts of its operations on society, and to operate in a manner that meets and even exceeds the legal, ethical, commercial and public expectations that society has of business (Jamali and Mirshak, 2007).

- **Customer, Environment, Technology – CET**

Throughout this PhD research, the factors of Customer, Environment and Technology and their interactive relationships were investigated, analysed and discussed. Research questions and frameworks were developed with regard to these issues.

- **Design for Dismantle – DFD**

Simpler manufacturing steps are applied to reduce the complexity in product manufacturing, fewer parts and materials are used, snap-fits are used instead of screws, which eventually help manufacturers to cut costs during manufacturing. It also reduces production time and costs at the dismantling stage, when parts and products are being recollected and taken apart (Sarkis, 2001).

- **Design for Environment – DFE**

Manufacturers taken into account the environmental affect of their productions, by minimising products' harmful effects on the environment throughout different stages of product life cycle, from the design and development to manufacturing, distribution, use and disposal (Hart, 1995; Dutton, 1998).

- **End-of-Life – EOL**

When products reach the end of their life cycle, they are either disposed by consumers, or collected and recycled for recovering any reusable parts.

- **End-of-Life Vehicle – ELV**

A vehicle which is waste – substance or object which the holder disposes of or is required to dispose of pursuant to the provisions of national law in force (The Council of the European Communities, 1975; ELV, 2000).

- **Open-Loop Supply Chain System**

In an open-loop system, products do not return to the original producers. These products will either be recovered by other parties willing and able to reuse the materials or products, or be disposed in landfills (Andel, 1997).

- **Pearl River Delta – PRD Region in South China**

The PRD was the first region in China benefited from the openness of market economy policy in the 1980s. With special policy in the region to stimulate economic activities, the PRD region has attracted a large amount of labour resources and capital investments from China and internationally for manufacturing activities. The PRD region takes up a third of non-ferrous metal production capacity in China, and there are vibrant activities in the recycling and remanufacturing of secondary metals.

- **Reverse Logistics**

The process of products, either purchased or used, returned by customers back to the point of origin, i.e. manufacturers or suppliers (Rogers and Tibben-Lembke, 1998).

- **Small and Medium Enterprises – SMEs**

SMEs are enterprises (firms / Corporations / Companies) with less than 250 people and have less than € 50 million (£ 30 million) total turnover (European Commission, 2003/361/EC). In countries such as the US, Canada, Mexico and China, the total employee number of the SMEs is up to 500 (APEC Profile of SMEs, 2003).

- **State-Owned Enterprise – SOE**

Centralised planning and state ownership enterprises (Pan and Parker, 1998).

- **Supply Chain Management**

Supply chain management manages the entire chain of raw material supply, manufacture, assembly and distribution to the end customer (Slack, 2004).

- **Sustainability**

Consuming products with recyclable resources instead of having a throw-away mentality (Cheremisinoff, 2003).

Economically, sustainability means avoiding major disruptions and collapses, hedging against instabilities and discontinuities (Costanza and Patten, 1995).

- **Sustainable Development**

Meet the needs of the present without compromising the ability of future generations to meet their own needs (the Bruntland Report, 1987).

- **Sustainable Supply Chain**

The management of raw materials and services from suppliers to manufacture or service provider to customer and back with improvement of the social and environmental impacts explicitly considered (NZBCSD, 2004; Jorgensen and Knudsen, 2006).

- **Town and Village Enterprises – TVEs**

Either collectively established by or initially based on and closely associated with rural communities such as townships and villages (Perotti, et al., 1999).

TVEs include all rural enterprises, whether collectively-owned, privately-owned, or self-employed (Hussain and Zhuang, 1998).

- **Waste**

Waste is the ‘unwanted things’ result in a deterioration of environmental quality because of air or water pollution or adverse effects on visual aesthetics (Havlicek Jr., et al., 1969). Waste is the unused human potential, and is the inappropriate system that add cost without adding value, such as waste energy and water, wasted materials, wasted customer time and the waste of defecting customers which eventually cause customer dissatisfaction and the loss of customer and sales (Bicheno, 2000).

CHAPTER 1

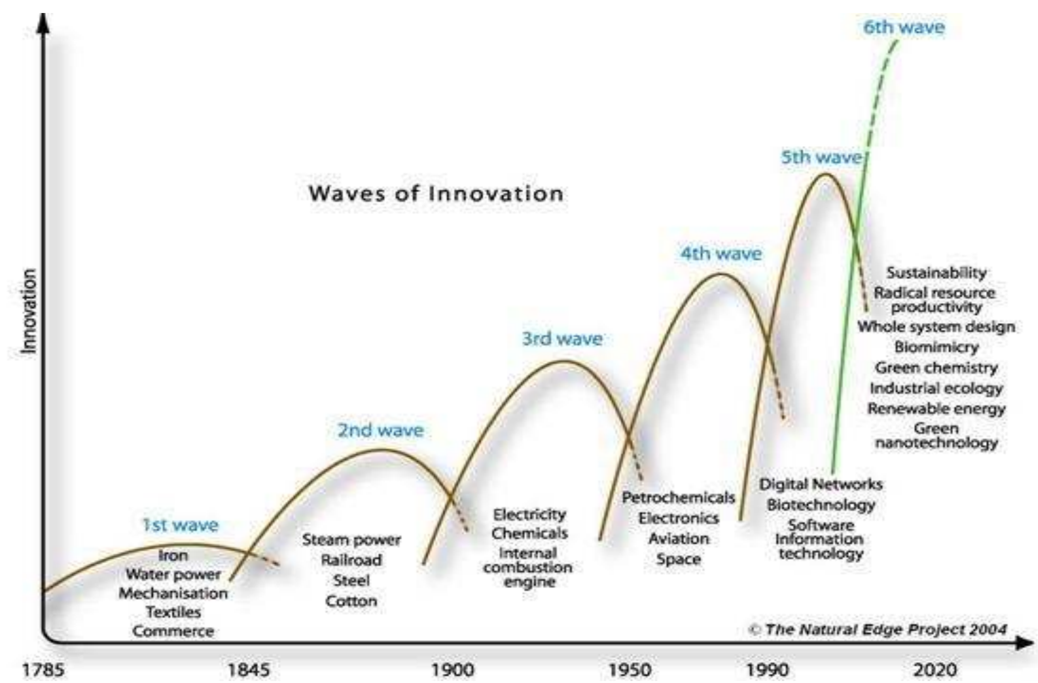
INTRODUCTION

1.1 Historical Development

Ever since the First Industrial Revolution in the 18th century, the industrialisation operations have been in the era of mass production and expanding growth in supply and demand. Starting with the development in the textile, steam power and iron industry in England, the increasing population and standard of living could be satisfied by the increased productivities. Manufacturing began to shift from manual labour operations to production using machinery, which largely reduced the limitation of manual power by applying power and energy from the environment for more efficient and effective manufacturing. In addition, the physical distribution network channels including railway, road and waterway infrastructure were also developed, which enabled better logistics and distribution flows of goods from manufacturing sites to the consumer market place.

About 200 years later, the Second Industrial Revolution took place in the late 19th century. There was the application of electrical engineering for manufacturing, which provided the necessary supports for creating more varieties of products in industrial manufacturing. For example, there were developments in chemical, electrical, petroleum and steel industries (Kranzberg, 1967), which provided basic production input materials for diverse industrial operation requirements in many different sectors, ranging from heavy industries to light industries. The large numbers of small scattered production sites were reformed into larger sized and better designed manufacturing factories for higher efficiency and utilisation of materials and energy resources. More importantly, the industrial revolution was not only a result of human knowledge from production experiences, but also largely directed by the development of science and technology implications.

The Third Technology Revolution began in the mid 20th century after the Second World War. It was an era of rapid technological progress associated with the development of information technology (Greenwood, 1999). Since then, there have been the applications of scientific operations management methods such as Material Requirement Planning (MRP), Manufacturing Resource Planning (MRP II), batch production, economies of scale production, Just-in-Time (JIT), as well as the industrial internal and external supply chain management. Consequently, the technology implementation in the production of goods and services increase the productivity of the workforce. There have been rapid growing numbers of high-technology and complex products and services produced to meet various customer requirements and needs with the rising living standards.



(Source: The National Edge Project, 2004)

Figure 1.1 Waves of Innovation

As illustrated in Figure 1.1, according to the National Edge Project (2004), the waves of innovation carried on since 1785, and had been developing in shorter time periods and at a faster pace since the Third Technology Revolution in the 20th century. From the development of the 3rd wave of innovation in electricity, chemicals and the internal combustion engine to the 4th wave of the petrochemicals, electronics, and aerospace; further onto the 5th wave of innovation of developing digital networks, biotechnology and software information technology. Currently, the industrial development is at the 6th wave of innovation which include development of higher level sustainability, radical resource productivity, whole system design, bio-mimicry, green chemistry and moreover, the progress of industrial ecology, renewable energy and green nanotechnology. This is the trend for industrial innovation from the beginning of the 21st century.

1.2 Development of Supply Chain Management

With reference to the historical development in industrial and technology revolutions, it should be noted that there are many factors that have impacts and influences on the innovation developments. These include the implications of economic, social, political, policies and also the understanding and acquisition of industrial skills, knowledge, science, and technology development. As a result, the expanding productivity for large quantity production of goods and services can be achieved, and products are bought and consumed by customers in the market place which bring in revenue for further industrial development. The value returned as capital reinvestment enables the maintenance of equipments and further process, and encourages further technical development of production operations. There had been a transformation in which suppliers and customers are inextricably linked throughout the entire sequence of events that bring raw material from its source of supply, through different value adding activities to the ultimate customer (Spekman, et al., 1998). Hence, Slack, et al., (2004) defined supply chain management as “managing the entire chain of raw material supply, manufacture, assembly and distribution to the end customer”.

Throughout the development of industrialisation in the recent 400 years, there are interactions between the supply chain operations management and the relationships of customers, environment and technology. This research focuses on the interactions of the Supply Chain Management and Customer-Environment-Technology (CET) relationships, as illustrated in Figure 1.2.

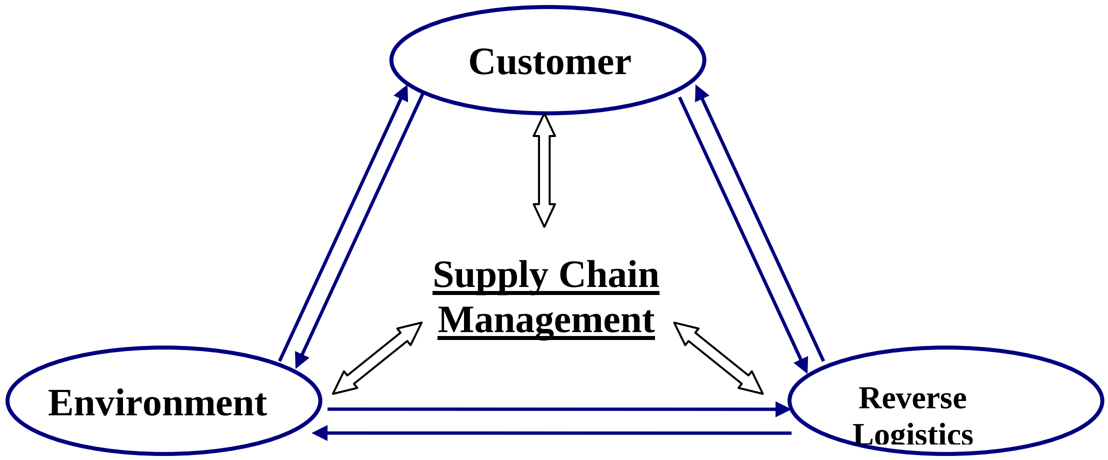


Figure 1.2 Supply Chain Management and the CET Relationships

Many different types of interactions exist between the CET factors within the context of supply chains and these 3 factors have their impacts on the performance of supply chains. The customers constantly demand improvements in customer service in terms of reliable delivery, flexibility, quality, responsiveness and at lowest possible costs (Sarmiento, et al., 2007). This in turn imposes considerable pressure on manufacturers and suppliers of goods and services. Hence the need is to design and operationalise efficient and effective supply chains so that there are maximum added values while minimising costs during the production and distribution processes. Increasing attention in the supply chain literature is shifting towards assessing the environmental impact of global supply chains. There are responsibilities for governments and companies on the impacts of their national and international economic development activities for sustainable development in the long term. In order to further discuss the supply chain management and the CET relationships, the major activity of supply chain management, which is the production of goods and services, is analysed and evaluated in more details in Figure 1.3.

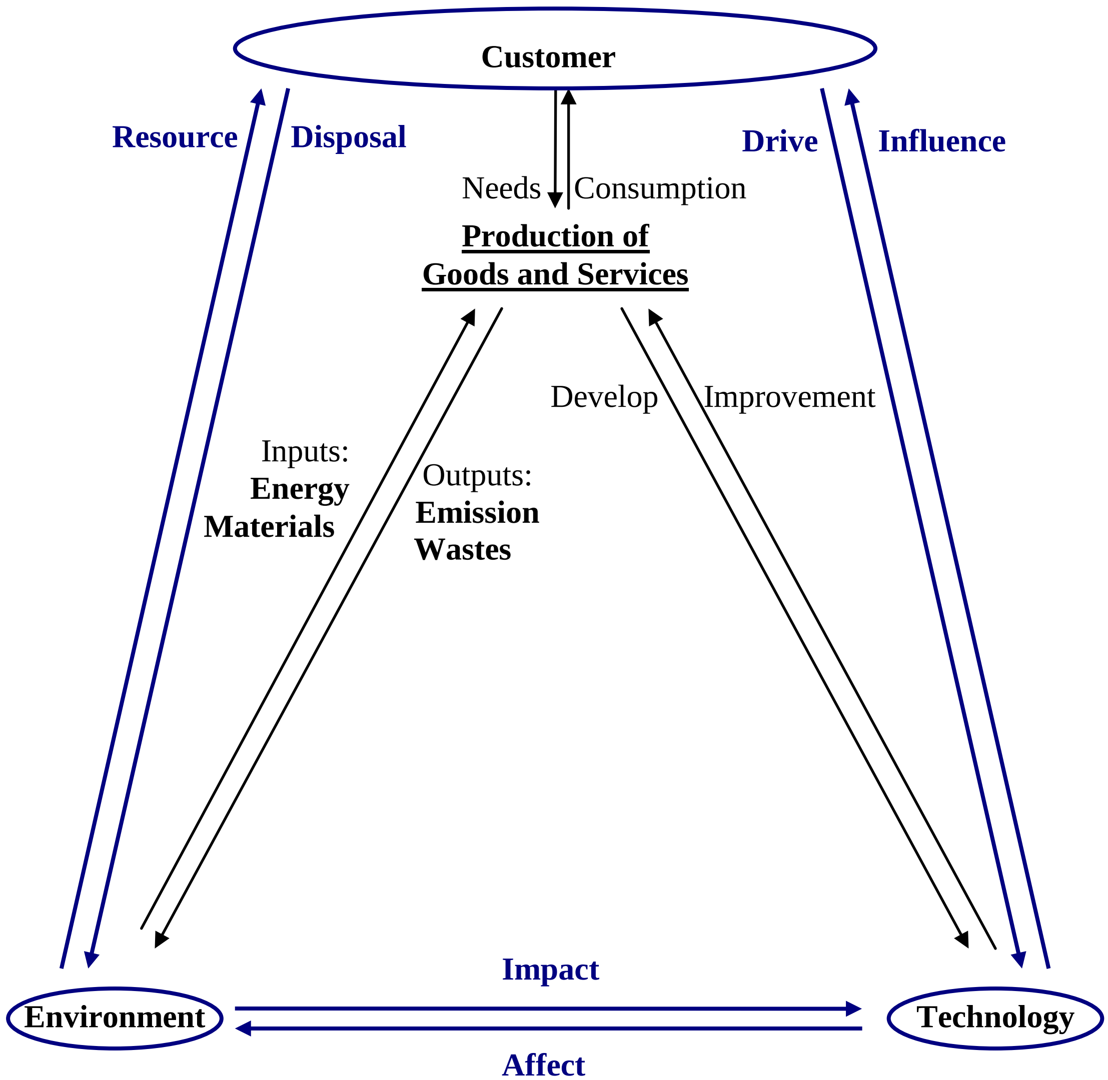


Figure 1.3 Production of Goods and Services and the CET Relationships

1.2.1 Customer – Environment Relationships

The element of Customer dominates in the CET relationships. This is because the aim of production is to meet the needs of customer in the market place. Hence, profit and additional value can be gained as revenue return from customers. According to Adam Smith's notion of 'the invisible hand' in the Wealth of Nations (Smith, 2000 [1776]), individuals, manufacturers and enterprises only intend for their own security; and by directing industry in such a manner as its produce may be of the greatest value. They intend only their own gain and as in many cases, led by an invisible hand to promote an end which was not part of their intentions. By pursuing their own interests they frequently promote that of the society more effectually than when they really intend to promote it. In other words, the invisible hand is an evolutionary process as market skills evolve over time. As a result, markets become more efficient, resources are used more productively, and income is spent more effectively. The activities and competitions between individuals and manufacturers, enterprises in the market promote the public interest (Grampp, 2000). The market itself is directed by customers whose choices are reflected in market prices that send signals to entrepreneurs who are directed by their self-interest to obtain profits and redirected by losses to ensure maximum production and customer sovereignty (Thornton, 2006). Therefore, customer is the major element that determines the production operations and also influences the environment and technology elements. The interactions between production of goods and services and the CET relationships can be analysed in details.

In order to produce goods and services that would finally reach the customer level, supply chain operations would need to obtain raw materials, energy and resources from the natural or industrial environment as the inputs for production processes. These inputs go through the processes of operations and would be transformed into outputs by acting on some aspects of their physical properties, information properties, possession, location, storage or accommodation, with physiological state or psychological state (Slack, et al., 2004). After the operation assembling activities, the mixture of tangible parts, components or products and less tangible services can be produced.

Efficient and effective supply chain management is about adding maximum value while minimising costs to these materials and resources during the production and distribution processes. Hence, value can be gained when goods and services are purchased and consumed by customers. Some studies have focused on technical aspects of dealing with pollution prevention (Chertow, 1998); whilst others have devoted attention to minimising production waste and achieving zero-defect production efficiency (Sarkis, 2001; Economy, 2004; Slack, et al., 2004). However, they all note that there are inevitable non-value added outputs such as emissions, scrap and wastes during production and transportation processes. Therefore, minimising wastes from production;

reducing transportation pollution by improving transport integration, for example, by increasing vehicle fill rates, lowering empty running, providing more back-haul opportunities and strengthening fleet utilisation rates are urgently sought (Mason and Lalwani, 2006).

As there are increasing demands for inputs of both renewable resources (such as soil and forests) and the non-renewable resources (such as oil, metals and other minerals), as well as the overwhelming amount of disposal of wastes and residues to the environment, the relationship between supply chain, customer and the environment becomes imbalanced (Hart, 1997). Resources are becoming scarce for production and consumption, the expanding landfill sites and increasing emissions to the air and water also bring negative impacts to the environment and human habitat on earth. Hence, the purpose of this research is to draw attention to the impacts of supply chain activities on the environment, with the aim to find out what approaches and techniques can be adopted by governments and industries in order to develop more effective and efficient supply chain operations processes for minimising the production damage and pollution to the environment.

1.2.2 Customer – Technology Relationships

The increasing customer needs and requirements drive the development of technology for the design, functions and usages of products and services. Advanced technology application in products would provide higher customer satisfaction and even more diverse functions to go beyond customer expectations. Furthermore, better designed products with higher level of technology would increase product durability and extend product life cycle. This is because better designed high-tech products have improved features and materials. They are with better alternatives of durable materials for longer product life and technologically advanced functionalities. Consequently, the implementation and improvement of higher technology in products also influence the buying behaviours of customers in the market, which are the motivation for further technology developments over time. As in the case of digital camera development, companies such as Canon, Sony and Kodak are constantly developing their products with more features and components in order to achieve greater customer satisfaction to win their shares in the market. As a result, there have been rapid improvements in the latest models of digital camera. With the help of technological development and application, the latest versions of digital cameras are developed with much higher resolution, more ergonomic design, and user friendly functions, with reduced weight and size. Similarly, the motivation and influences between customer and technology also happen in a large variety of consumer goods such as mobile phones, automobiles, computers, televisions, and so on. These represent the rapid developments of high-tech products especially in recent decades.

More importantly, from the manufacturing perspective, manufacturers are devoted to the development of higher level process technology and automation in their production. These include the hardware technology such as manufacturing machineries, equipments and facilities for automation with few labour requirement, as well as improved efficiency and accuracy for production operations. In addition, there are developments of software technology information system such as Flexible Manufacturing Systems (FMS), Computer Integrated Manufacturing (CIM), Enterprise Resource Planning (ERP) and Electronic Data Interchange (EDI). These are the integration of computer based systems which enable better flow of information between processes, better database and communication networks in the internal and external supply chain network. The application of barcodes and the recently developed Radio Frequency Identification (RFID) tag also provide higher speed of feedback which facilitates manufacturing planning, control and scheduling. As a result, the response speed to changes in the market and production requirement can be improved dramatically with the help of advanced technology development. More and more manufacturers are able to improve the efficiency and effectiveness in their operations management, as they apply higher value added processes in their design, planning and control operations. Further details of the implementation and impact of technology in supply chain management will be discussed in later chapters.

1.2.3 Environment – Technology Relationships

In addition to the relationships between Customer and Environment, Customer and Technology, there are also interactions between the Environment and Technology. Referring to the formula developed in the 1970s by Ehrlich and Holdren (1971) and Commoner (1971),

Environmental Impact = Population x Affluence x Technology

The developments of population, affluence and technology create impacts on the environment. As with the high speed of growth in population and affluence level in the consumer market, the production quantity increases the needs for materials, energy and resources from the environment. More significantly, the production of goods such as metals, chemicals, machinery, and automobiles cause considerable levels of pollution and damage to the environment. These include waste and residue disposal, waste water contamination and expansions in landfills. In addition, the huge quantity End-of-Life (EOL) and used products after customer consumption also create enormous negative impacts on the environment if they are not collected and disposed properly. According to this formula (ibid.), as the level of population and affluence are relatively controversial and much more difficult to constrain, technology seems to be the solution that is most acceptable to society (Hart, 1997). As identified by Sarkis (2001), the technological categorical issues facing the natural environment and manufacturing include process, product, and practice strategy issues.

1.2.4 Summary

The industrial innovation and the production of goods and services motivate the continuous development in industrial operations and supply chain management. In order to find the balance between the resources and players in the supply chain so that it would achieve sustainable development in the long term, factors such as customer, environment and technology need to be understood. There are interactions between these factors which have influences on the supply chain flow. Various operators along the supply chain need to cooperate with each other with regard to the CET factors and their influences. Hence, better supply chain management would generate sustainable benefits, creating additional values and achieving better utilisation of resources. Especially on the issues of pollution and damages caused by the production of goods and services, as well as customer consumption and post consumption activities. There have been changes in the supply chain operations and the CET relationships. The environmental issues of climate change and global warming due to rapid industrial expansion and human activities development have become one of the most important subjects for research and improvement in the 21st century. There are concerns and responsibilities for governments and industries with regards to the impacts of their national and international economic development activities on the environment. These are fundamental for their sustainable future development.

1.3 Thesis Structure

There are existing theoretical and practical research and studies on the production and operations management, especially in developed countries in Europe, Canada and the US. However, the number of existing research in supply chain for sustainable development in developing countries is very limited. Hence, the main purpose of this PhD research is to investigate the supply chain operation in the context of developing countries. In particular, it sets a research boundary by using the Chinese metal industry as an example, to find out the answers to the research question:

> **"What specific approaches and techniques do the Chinese metal manufacturers and remanufacturers adopt for sustainable development of the closed-loop supply chain?"**

Specifically, this research aims to find the balance between supply chain management and the interaction between the CET factors, in particular, focusing on the sustainable development of the CLSC operation. It performs both theoretical and empirical research in order to present the picture of the process flows among the supply chain operations, in the context of the Chinese metal industry. The objectives of this research are to develop process maps, frameworks and tools for companies to improve the efficiency of their value-added activities, as well as social, environmental and economic benefits. Hence, the research is proposed to assist governments, industries and companies; especially for SMEs in the developing countries, to identify their process flows and market positions, and to define their directions for sustainable development and improvement in the long term. The thesis structure is illustrated as in Figure 1.4.

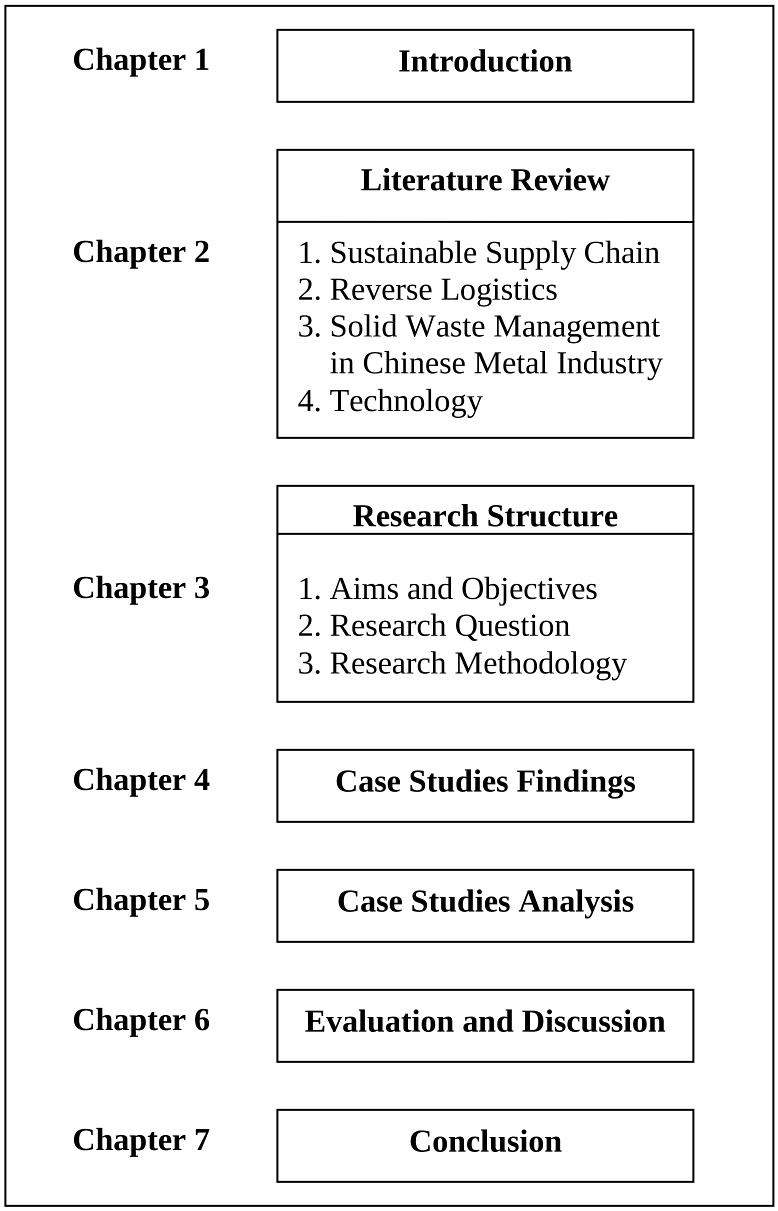


Figure 1.4 Thesis Structure

First of all, this Chapter is the introduction of historical development of supply chain management. In particular, it identifies the interactions between the factors, namely customer, environment and technology, as the main issues for investigation throughout this research.

Chapter 2 is the literature review on existing academic and empirical research and practices with regards to the issues of sustainable supply chain, reverse logistics, CLSC, the factors of the reverse logistics framework. In addition, there are reviews of solid waste management in the Chinese metal industry and the implication of technology in manufacturing and remanufacturing. By reviewing literature from the European and American contexts, as well as in the Chinese context, the literature review aims to provide solid background for the theoretical concepts of the research areas. These existing methods contribute to the sustainable development for the environmental and process operations in various countries and operation systems. By mapping the existing theoretical and empirical processes, this research provides better understanding of the CLSC and the CET relationships. The collections of literature were from books, journal papers and periodicals in the library and on the internet, and were referenced accordingly. The majority of the electronic journal articles and literature were searched through Athens EBSCO HOST Research Databases. The Chinese literature was assessed through the China Academic Journals Full-text Database (CAJ) on www.cnki.net. They are interpreted into English by the researcher for referencing.

Chapter 3 identifies the gaps in existing research and points out the areas that this research can contribute to both academic and practical knowledge. There are existing research studies that are mainly done in developed countries which are leading the CLSC operations and the recovery of wasted and used products. More studies in developing countries context are needed in order to provide guidance, and to compare and contrast the differences in the operations between countries in order to provide better understanding for both forward and reverse flows of the CLSC. In particular, attention should also be drawn to those SMEs which have large influences on the manufacturing and remanufacturing processes in countries such as China and India.

In addition to the theoretical background of reverse logistics, integrated solid waste management and process technology that contribute to the sustainable CLSC, case studies were performed in order to map the current processes in the context of the Chinese metal industry. The case study process and qualitative research findings from semi-structured interviews and observations are described in Chapter 4. The case studies were carried out with a local government official organisation and seven case companies, in order to find out the answers to the research question, and to map the CLSC process flows among case companies. There is particular focus on the issues of the CET factors and their influences on sustainable development. Company owners and employees from the managerial and operational levels were interviewed in order to provide better insight of issues involved in the operation among these companies.

The case study findings provide the essential background data and information for further analysis in Chapter 5. Models were drawn with regard to the case study findings so that the framework of sustainable CLSC can be presented in the Chinese context. These provide understanding of the flows and issues involve.

Chapter 6 is the evaluation and discussion based on the theoretical and empirical findings throughout this PhD research, with regard to sustainable CLSC in the context of the Chinese metal industry. The CLSC frameworks were contextualised to illustrate the internal and external operating processes in the case companies. Issues related to the CET factors were evaluated and examined in order to find out the answers to the research question. In addition, the CLSC Positioning Tool was developed for case companies to identify their processes and CET factors, evaluate themselves among the industrial environment, and plan for further sustainable development and improvement.

Finally, Chapter 7 concludes with the contribution of issues and findings discussed in this research, as well as the limitations. There are also suggestions for further research and investigations for both developed and developing countries, referring to the sustainable development of the CLSC.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This research starts with the literature review on existing studies in the areas of: Sustainable Supply Chain, Reverse Logistics, Chinese Secondary Metal Resource Recovery and Technology. The existing studies of sustainable supply chain and reverse logistics mainly look at the management of process flows between players along the supply chain. Specifically, literature in the secondary metal resource recovery in the Chinese context is also reviewed, in order to provide a generic picture and guidance from the existing literature perspectives. By comparing and contrasting the existing literature and research, there are more concrete understanding of issues which are related to operating flows in the CLSC. Case studies will then be performed based on the existing literature and frameworks, with the intention to contribute and fill in the gaps between existing academic knowledge and industrial practices.

2.2 Sustainable Supply Chains

2.2.1 Sustainable Development

As discussed in the previous chapter, there has been increasing attention of governments, organisations and individuals on tackling the environmental impacts of climate change and global warming which were caused by pollution, emission, and damages from production operations and consumption activities. As a result, the issue of sustainability has been raised. With reference to the Bruntland Report (1987), there are obligations for sustainable development to “meet the needs of the present without compromising the ability of future generations to meet their own needs". Since the development of industrialisation in the expanding global markets, there are concerns on the dramatically increasing consumption of natural resources in the global environment which leads to the reduction of resource reserves and even their extinction.

Typically, natural resources can be categorised as renewable resources and non-renewable resources. Renewable resources, such as air, water, wind, and sunlight, are those that can be replenished or reproduced over a period of time. Non-renewable resources, on the other hand, such as coal, petroleum, metals and other minerals which are finite resources on earth that cannot be reformed or regenerated after their consumption. Some researchers also introduced the classification of recyclable resources, which are resources for which fully-consumed units can be processed in some manner to obtain new units. For example, metallic minerals can be recycled and reused if appropriate processes are carried out (Shewchuk and Chang, 1995). In doing so, recycling non-renewable resources would increase the utilisation of resources, while reducing the need and consumption of the finite resources from the environment, and contribute to the sustainability of the environment.

Meadows, et al. (1972) investigated the major trends of global concern in the early 1970s, including accelerating industrialisation, rapid population growth, widespread malnutrition, depletion of non-renewable resources and the deteriorating environment. They warned that as there had been exponential growth in the world system, humanity consumption of resources would soon exceed the supply of resources on the earth. At the same time, the analysis of the causes of growth and the future behaviour of the system became very difficult. Hence, they tried to build models that represented a world system which could be sustainable and capable of satisfying the basic material requirements of all people. At the beginning of the 1990s, Meadows, et al, (1992) examined the world development and found that the development in the world system between 1970 and 1990 had been similar to what they predicted twenty years ago. The resource consumption reached a high level which had been pushing the natural resources supply closer to their limits. There were urgent needs to allocate resources seriously to the technologies of pollution control, land preservation, human health, material recycling and resource reuse efficiency (Ibid.). With the additional 30-year update of their research, Meadows, et al., (2004) used computer models based on population, food production, industrial output, pollution and non-renewable resources to demonstrate why the world is in a potentially dangerous overshoot situation. Once again, these models with various scenarios are the alarming signs indicating that people has been steadily using up more of the earth's resources without replenishing its supplies. The world might collapse one day as it greatly relies on diminishing global resources and produces excessive emissions.

On the other hand, Hart (1997) found that despite intense use of energy and materials, levels of pollution were relatively low in the developed economies. The reasons for that were due to the stringent environmental regulation, the greening of industry, as well as the relocation of the most polluting activities, such as commodity processing and heavy manufacturing to the emerging market economies in the developing countries. The demand for some virgin materials may actually reduce in the decades ahead because of reuse and recycling, as the developed economies recognise that obtaining natural resources for making products cannot be infinite. Hence, sustainability is created "by consuming products with recyclable resources instead of having a throw-away mentality" (Cheremisinoff, 2003).

2.2.2 Sustainable Supply Chains

Sarkis (2001) identified that the long-term sustainability of corporation depends on the sustainability of the social and natural environment. Organisations in the supply chain need to take on global perspectives when evaluating environmental concerns. Internally, for manufacturers, the manufacturing function efficiencies and the management of employees and facilities are central to their sustainability goals. This is because sustainable supply chain excellence requires efficient functions of business processes, human system and the enabling technology (Zaklad, et al., 2004). Externally, manufacturers are also expected to make sure the upstream (i.e. suppliers) and downstream (i.e. customers) of their supply chain are meeting social and environmental expectations for recycling EOL products and wastes. After all, the sustainable supply chain is defined as "management of raw materials and services from suppliers to manufacture or service provider to customer and back with improvement of the social and environmental impacts explicitly considered" (NZBCSD, 2004; Jorgensen and Knudsen, 2006).

In addition to the social and environmental perspectives, a number of researchers have defined sustainability in terms of economic dimensions (Pezzy, 1992; Sutton, 1998; Hargroves and Smith, 2005). Economically, sustainability means avoiding major disruptions and collapses, hedging against instabilities and discontinuities (Costanza and Patten, 1995). Table 2.1 highlights the distinction of sustainability across the environmental, social and economic dimensions with three different levels of priorities.

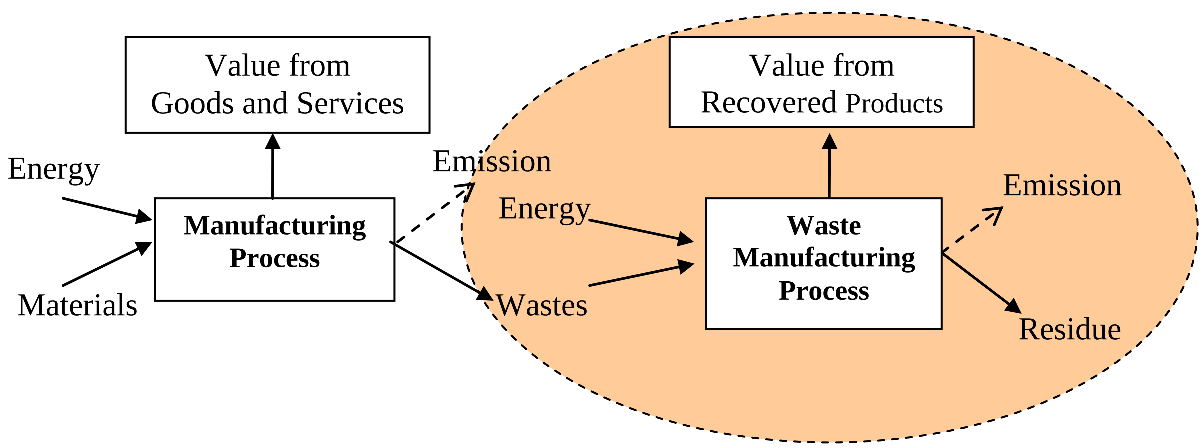
Table 2.1 Dimensions and Levels of Sustainability

	Environmental	**Social**	**Economic**
Sustainability	Level 1: Survival Sustainability		
	Protection of life support systems, Prevention of species extinction	Capacity to solve serious problems	Subsistence
	Level 2: Maintaining Quality of Life		
	Maintenance of decent environmental quality	Maintenance of decent social quality (e.g. vibrant community life)	Maintenance of decent standard of living
	Level 3: Improving Quality of Life		
	Improving environmental quality	Improving social quality	Improving standard of living

(Source: Sutton, 1998)

Sutton (1998) pointed out that the survival sustainability must be achieved for ensuring the long-term future stability. However, it is common in many developed and developing countries that effort to improve the standard of living in the short term has been diverting crucial resources and attention away from the long-term maintenance of basic survival capacity. Especially at the survival level, sustainability in any one of the environmental, social or economic dimensions cannot be achieved if sustainability is not achieved in the other two dimensions. Hence, this research is to develop supply chain sustainability with regards to the three dimensions, particularly applying the operations management aspects on minimising non-value added process activities in order to achieve operational efficiency. Consequently, these contribute to the environmental, social and economic benefits.

As discussed before in the CET relationships, there are inevitable emissions, wastes and returns during the production processes of goods and services. In addition, there are EOL or used products being returned after customer consumption, which can be collected and recycled for resource utilisation and regeneration of value. The material flows are illustrated in Figure 2.1.



(Adapted: White, et al., 1995)

Figure 2.1 Material Flows in Manufacturing and Waste Manufacturing Processes

The inputs of energy and materials through the manufacturing processes create value from goods and services produced. Subsequently, wastes from production processes can be collected and become the input materials for the waste manufacturing industry. Value can be generated from the remanufacturing processes when recovering secondary products. The purpose of waste manufacturing processes is to help reduce wastes created from the manufacturing industry and provide a material flow back to the point of material consumption, whilst leaving minimum amount of residue for further recollection and disposal. As highlighted in Figure 2.1, this research focuses on the impacts of reverse flow through the waste manufacturing processes, which is one of the important activities for developing efficient sustainable supply chain operations.

2.3 Reverse Logistics

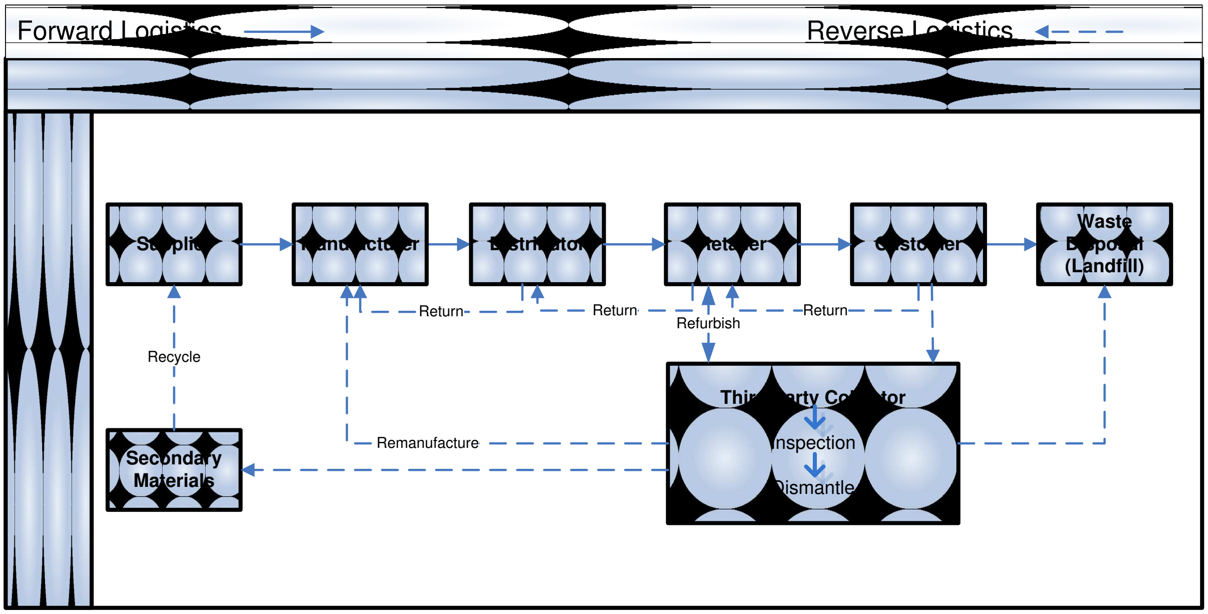
2.3.1 Reverse Logistics Overview

The waste manufacturing processes consist of remanufacturing, refurbishing, recycling and disposal activities which deal with the wastes and returns from industrial manufacturing processes and customer consumption (Thierry, 1995). These activities are described as reverse logistics, which is defined as “the process of products, either purchased or used, returned by customers back to the point of origin, i.e. manufacturers or suppliers” (Rogers and Tibben-Lembke, 1998). In other words, reverse logistics is the opposite direction of the traditional forward supply chain, which is the flow of products moving from supplier to manufacturers then onto distributors and finally reaching the customers. Reverse logistics processes involve the recovery and utilisation of inevitable wastes from supply chain operations, as well as collection and reuse of those EOL or used products which would otherwise be disposed in landfill. Hence, reverse logistics helps to reduce pollution and damages to the environment.

Since the 1970s, there have been a number of reverse logistics research and studies. The recovery and reuse of materials took place either in the factory in which the waste originated, or in specialised industries, or in separate small-scale plants, or even in home industries. Thus, the traditional division of labour and the lines of demarcation between industries are said to be changed (Zikmund, 1971; Kapp, 1974; Ginter, 1978). From the 1990s, there has been rising attention on researching the distribution infrastructure for reverse logistics, as more researchers are aware of the economic, social and environmental benefits from efficient reverse logistics process management (Tchobanoglous, et al., 1993; Curzio, et al., 1994; Cheremisinoff, 2003; Blumberg, 2005). Specifically, the objective behind reverse logistics processes is to either recapture the value of goods (or part of that value), or to dispose of those goods in a manner that recognises concerns relating to sustainability (Bernon, et al., 2004).

There are existing studies on developing the theory of reverse logistics (Thierry, 1995; Dowlatshahi, 2000; Ferguson 2001), focusing on the strategic issues in reverse logistics, which consist of strategic costs, overall quality, customer service, environmental concerns, and legislative concerns (Dowlateshahi, 2000). There are quantitative approaches on designing reverse logistics network, handling and warehousing issues, and product recovery management (Bloemhof-Ruwaard, et al., 1994; Spengler, et al., 1997; and Dekker, et al., 2003). Some explicit researches were conducted in various industries such as newspapers, magazines, and catalogues recycling (Kleineidam, et al., 2000; Daugherty, et al., 2001); glass or bottles recollection, refurbishing and reuse (Gupta and Chakraborty, 1994; Kroon and Vrijens, 1995; DelCastillo and Cochran, 1996); as well as packaging and reusing containers and pallets in the transportation and logistics sectors (Matthews, 2004).

Ginter and Starling (1978) identified that the recycling and the operation of reverse channels of distribution are appropriately receiving increased attention because of rampant solid waste pollution, frequent energy shortages and serious materials scarcity are recognised as realities of the modern age. The majority of researches tend to look at reverse logistics from a large-scale, by identifying the general flows within the distribution channel. Kopicki, et al., (1993) identified two basic types of reverse logistics systems as an open-loop and a closed-loop system. The open-loop system is that products do not return to the original producers. These products will either be recovered by other parties willing and able to reuse the materials or products, or be disposed in landfills (Andel, 1997). On the other hand, in the closed-loop system, materials are returned and reused by the same originator, as suppliers or manufacturers bring products back in, remanufacture or refurbish them before reselling them to the secondary market. This research focuses on the closed-loop system of supply chain, as illustrated in Figure 2.2.



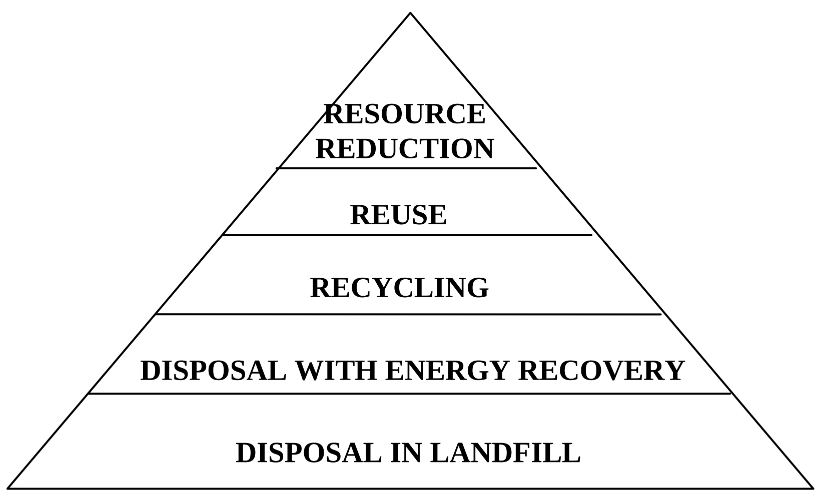
(Adapted: Rahman, 2004)

Figure 2.2 Closed-Loop Supply Chain

It should be clear that the Closed-Loop Supply Chain (CLSC) consists of two different directions of flow – the forward logistics flow and the opposite reverse logistics flow of materials, product and information. As pointed out by Zikmund and Stanton (1971), the ultimate customers who recycle their waste materials must undergo a role change. The customers become the first link in the channel of distribution rather than the last. Hence, the operating flow in the CLSC becomes very complex. Parties in the supply chain need to integrate their operations internally for the forward and reverse flow of materials and products. Externally, they have to understand and cooperate with their upstream and downstream partners along the supply chain to develop sustainable CLSC operations.

There are traditional Third Party Logistics (3PL) providers who are involved in the forward logistics flow of distributing raw materials, parts and finished products from suppliers to manufacturers to retailers, and eventually reaching the customers in the market. In addition, there are some 3PL or Third Party Reverse Logistics (3PRL) providers operating in the reverse logistics processes, in which they are responsible for collecting the returned products, parts and wastes from customers. The inspection and dismantling processes would be performed upon these collections, and the sorting processes and distribution would then be carried out for the refurbishing, remanufacturing and recycling operations. The recycling and reuse of EOL products or waste materials can bring economic benefits to product manufacturing, as reusing materials would reduce the consumption of primary raw materials for production.

It can be argued that for the regenerated materials and parts, they might be sent to other manufacturers or material collectors as secondary materials for their manufacturing purposes. Hence, products might not be returned to their point of origin, but may be returned to any point of recovery (De Brito, et al., 2002). On the other hand, waste materials and parts would be sent for disposal in landfills as they are going through the open loop system. The application of waste management is another approach regarding to the management of open loop system and the waste hierarchy is often suggested and used in waste policy making (Finnveden, et al., 2005). As in Figure 2.3, the waste hierarchy shows that the waste management strategy is to achieve energy recovery, recycling reuse, and the ultimate goal is resource reduction and prevention. The least favoured option in reverse logistics would be disposal into landfill.



(Source: Carter and Ellram, 1998)

Figure 2.3 The Waste Hierarchy

Rogers and Tibben-Lembke (1998) pointed out that there were no existing investigation on the disposition options between retailers and manufacturers, and there were still a large number of areas in reverse logistics waiting for exploration and investigation. More studies are needed for identifying the remanufacturing, recycling and reuse processes in more detail. With regard to the nature of operations, their survey research responses suggested that manufacturers were more likely to recycle or dispose returned materials than retailers. On the other hand, retailers were more frequently using centralised return facility to handle returns than manufacturers, or selling returns to a broker or similar entity, as shown in Table 2.2. This is partly because in the case of Business-to-Business (B2B), commercial returns come back in bulk; while in Business-to-Customer (B2C) relationship, there are more uncertainties in the quantity and time for products being sent back from customers. Hence, it would be easier for manufacturers to carry out recycling and remanufacturing processes with larger scale operations with the returned products and materials, and for the centralised return facility or 3PRLs to collect returns for reverse logistics processes for various retailers.

Table 2.2 Disposition Options between Manufacturers and Retailers

Disposition	Manufacturers	Retailers
Sent to Central Processing Facility	17.7%	29.2%
Resold as it is	23.5%	21.4%
Repackaged and sold as new	20.0%	20.5%
Remanufactured / Refurbished	26.7%	19.9%
Sold to Broker	10.1%	16.8%
Sold at Outlet Store	12.8%	14.5%
Recycled	22.3%	14.1%
Land fill	23.8%	13.6%
Donated	11.8%	10.6%

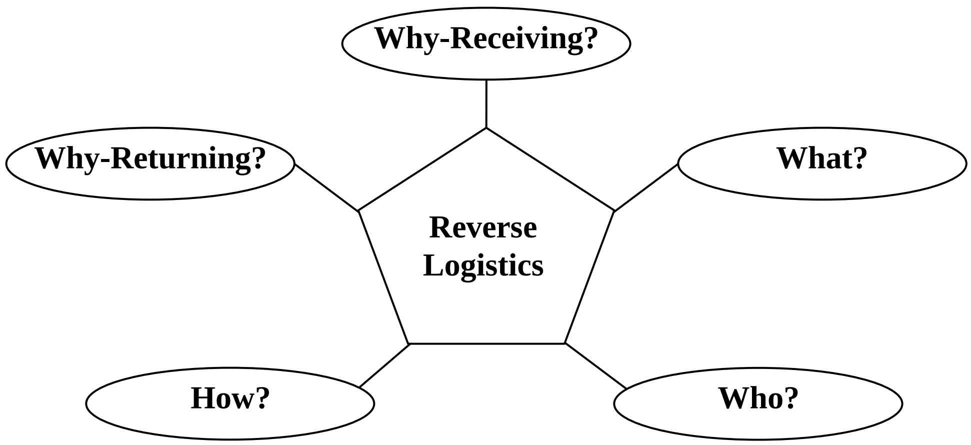
(Source: Rogers and Tibben-Lembke, 1998)

In order to investigate in detail for the similarities and differences of reverse logistics processes in manufacturing and retailing industries, and to explore the interrelationships between manufacturers and retailers through the forward and reverse supply chain operations, literature review is performed to evaluate the reverse logistics theories in existing theoretical researches and real industry findings. For manufacturing industries, manufacturers are those who manufacture products such as food and beverages, chemicals and chemical products, metal or fabricated metal products, non-metallic mineral products, as well as coke, petroleum products, and so on. And for retailing industries, retailers are those operating in sectors such as wholesale and retail trades, hotels and restaurants, and other services. Due to the nature of the parties and products involved in manufacturing and retailing industries, the reverse logistics processes within these industries have their unique characteristics. Hence, by clearly identifying the reverse logistics processes in these two areas, it would provide better understanding to develop state-of-the-art management in more diverse situations and environment.

There are a number of comprehensive reverse logistics case studies in the manufacturing and retailing industries. De Brito, et al. (2004) conducted a case study review with over sixty real cases involving reverse logistics in Europe and the US. According to the United Nations classifications for Industry, about 60% of these cases are in the manufacturing category, about 20% are within wholesale and retail trade and about 10% are in the construction industry. With respect to the product natures, they identified that the majority of the cases are on products with high value. As in their observation, almost 50% of the cases deal with metal products, machinery and equipment, about 30% are transportable goods like wood, paper and plastic; around 20% were food products, beverages, tobaccos, textiles and apparel, and the category ores and minerals accounted for less than 10%. The case studies were presented according to the decision-making focuses including: Network Structure, Relationships, Inventory Management, Planning and Control, as well as Information and Communication Technology implementation in the reverse logistics processes. Bernon, et al. (2004) carried out detailed literature reviews and case studies focusing on the UK retailing industries. In doing so, they clarified the scale of the problem and the huge potential opportunities available through improved management of reverse logistics process. The findings of these case studies are discussed in more detail in the following sections.

2.3.2 Framework for Reverse Logistics

In order to evaluate factors involved in reverse logistics, it would be feasible to discuss the relevant elements with some logical guidance. De Brito and Dekker (2002) developed a framework for reverse logistics, which identified five main dimensions of Drivers, Reasons, Processes, Product Characteristics and Actors in the field of reverse logistics, as shown in Figure 2.4. By applying these five dimensions into the cases of by-product returns, functional returns, reimbursement returns, service returns, EOL returns and end-of-use returns, De Brito and Dekker (2003) were able to illustrate and identify the problematic issues in these typical situations. Hence, this framework can be a platform for making further progress in the field and provide the roots for reverse logistics theory. With regard to the framework of reverse logistics, a number of literature were reviewed and summarised as follow.



1. Why – Receiving: Why companies get involved reverse logistics (Drivers);
2. Why – Returning: The reasons for products being returned (Return reasons);
3. What: What is being returned (Product characteristics and product types);
4. How: How is recovery carried out (Processes and recovery options);
5. Who: Who is doing the recovery (Actors and their roles).

(Source: De Brito, 2003)

Figure 2.4 The Five Basic Dimensions of Reverse Logistics

2.3.2.1 Drivers for Reverse Logistics

Melbin (1995) pointed out that “reverse logistics is not the natural ending to the supply chain, as for many products, it is just the new beginning”. As illustrated in Figure 2.2 in the previous section, parts, components, products and waste materials may be returned at any point from the customers to the retailers, or to the manufacturers in the reverse logistics flow. Blumberg (2005) found that “major consumer appliances experience a return rate of approximately 4.5%, parts and subassemblies of these units can have a much higher rate of returns (20-25%) over the product life cycle". Therefore, there is considerable amount of return products and materials that companies must deal with. As a result, reverse logistics should be part of the overall business strategy for any manufacturer and retailer (Gooley, 1998), because the focus of reverse logistics is on remanufactured products for manufacturing entities (Dowlatshahi, 2000). There are several factors that drive companies into reverse logistics operations in order to better utilise their resources, and to achieve sustainability in their supply chain development. In addition to the three driving forces of Economics, Legislation, and Corporate Social Responsibilities (CSR) (De Brito, 2003), the research also identifies Technology as another important driving force for reverse logistics.

2.3.2.1.1 Economics

Some companies recognise that new revenue streams can be achieved by developing products that are designed to be returned, refurbished and resold (Bernon, et al., 2004). In manufacturing industries, for example, materials such as metal, paper and plastic can be recycled and reused as secondary materials to produce new products. As long as the secondary materials are meeting the quality and production requirements, companies would generate savings by applying these lower costs secondary materials instead of virgin materials for their production. There are examples for product manufacturing such as Kodak disposable cameras (Toktay, et al., 2000), Xerox photocopiers (Maslennikova and Foley, 2000), and HP notebooks and desktop PCs (Guide, et al., 2005). These companies have developed comprehensive reverse logistics processes by collecting the after use products from their customers. By effective remanufacturing and reusing the qualified dismantled parts and components from their returned products into their new product manufacturing, manufacturers are able to reduce the need for manufacturing brand new components. Moreover, there are reductions for the consumption of input materials and the total production costs.

Similarly in retailing industries, there are cost saving economic benefits for collecting the customer's returned products for repackaging and reselling. For example, off season clothes would be sold in retail outlet for further profit contribution, rather than stocked as outdated inventory in the warehouse or returned to manufacturers. More importantly, for both manufacturers and retailers, these reverse logistics processes and reuse of the recyclable materials and components would reduce the costs for disposal to landfill. After all, the objective of reverse logistics processes is to minimise the costs of handling whilst maximising the value from the goods or correct disposal (Hughes, 2003), which leads to the goal of sustainable development.

2.3.2.1.2 Legislation

With increasing disposal costs and environmental legislations, Doherty (1996) predicted that reverse logistics would play an important role in strategic business planning and sustainable development. In Europe, legislation for manufacturing industries such as the End-of-Life Vehicle (ELV) Directive (2000/53/EC) adopted by the European Commission pushes automobile manufacturers to collect their EOL products, and to manufacture new vehicles with a view to environmentally friendly dismantling and recycling. Automobile manufacturers must meet the clear quantified targets by the ELV Directive for reuse, recycling and recovery of vehicles and their components (ELV, 2000). For some manufacturers such as BMW, they have already invested in developing centres for ELVs collection and dismantling, in which reusable components and parts are dismantled and collected for reuse in the new vehicle's manufacturing, with respect to strict inspection and quality certification (Wu and Dunn, 1995). There are also other legislations that put pressure on the manufacturers for reverse logistics processes. For instance, the Waste Electrical and Electronic Equipment (WEEE) Directive (2002/96/EC) increases the responsibilities of producers, distributors and recyclers on electrical and electronic equipment for the after product cycle processes. Companies have to take back their products after consumer consumption, in order to reduce the quantity of wastes to landfill. And at the same time, it increases the reuse, recovery and recycling of electrical and electronic equipment (WEEE, 2002).

For retailers, there are relatively less legislations regarding to the collection and recycling of products. One example would be the AB 2449 (Levine) Plastic Bag Litter and Waste Reduction in the US, which required grocery stores to take back and recycle plastic grocery bags (AB 2449, 2006). However, in order to operate efficiently and effectively under all the strict legislations for manufacturing products and components, retailers were also engaged in working closely with manufacturers and distributors for used and returned products collection, sorting, and distributing back to manufacturers or suppliers in the upstream of the supply chain.

2.3.2.1.3 Corporate Social Responsibility

Thierry, et al., (1995) found that most products were designed in order to minimise the costs of materials, assembly and distribution. However, it did not take into account the repair, reuse and disposal requirement. That was because the traditional approach of many manufacturers had been ignoring the used products and did not feel responsible for their products after customer consumption. Many manufacturers generally believed that the costs of incorporating reverse logistics requirements would outweigh the benefits. However, there has been increasing attention from more consumers and organisations to the environmental and green issues, which positively encourages manufacturers and retailers to actively promote their corporate images by taking on more social responsibilities. CSR is a set of management practices that ensures the company maximises the positive impacts of its operations on society, and to operate in a manner that meets and even exceeds the legal, ethical, commercial and public expectations that society has of business (Jamali and Mirshak, 2007). In practice, these activities include the increasing concerns on environmentally friendly production, reducing production wastes and pollution to the environment, and promoting sustainable development.

2.3.2.1.4 Technology

Last but not least, technology can be considered as another driving force for reverse logistics operations. As discussed in the previous chapter in the CET relationships, technology development interacts with the production of goods and services as well as customer behaviours. Additionally, the development of process technology affects the waste manufacturing processes, as the activities of remanufacturing, regenerating and reuse of wastes, used products and parts would not be feasible without the appropriate technology application. For instance, because of technology availability and improvement in Design for Environment (DFE), it is possible for manufacturers to minimise products' harmful effects on the environment throughout different stages of the product life cycle, from the design and development to manufacturing, distribution, use and disposal (Hart, 1995; Dutton, 1998). Sarkis (2001) also found that the Design for Dismantle (DFD) had a variety of implications for manufacturing, as simpler manufacturing steps were applied to reduce the complexity in product manufacturing, which fit in with the efficiency programs such as concurrent engineering and total quality management. DFD is also proved to be necessary for sustainable products, as fewer parts and materials are used, snap-fits are used instead of screws, which eventually help manufacturers to cut costs during manufacturing. In addition, DFD helps to reduce production time and costs at the dismantling stage when parts and products are being recollected and taken apart.

The technological software development also motivates manufacturers to participate in the reverse logistics processes. For example, the DFE software which combines design concern with environmental issues can be used to analyse designs in terms of their cost and ease of disassembly along with environmental impacts. And the design freedom allow simplified EOL disassembly, thus reducing dismantling time and associated costs, with better information flows and feedbacks to parties and departments involved in the reverse logistics processes (Hopkinson, et al., 2006). Consequently, with the availability of applicable and affordable technology implications in manufacturing and remanufacturing processes, more enterprises are now participating in the reverse logistics processes. They are aiming to reduce the harmful effects to the environment and achieve long-term savings and benefits with sustainable development. Detailed analysis and evaluation of technology implications on reverse logistics will be discussed further in order to suggest better technology approaches, especially towards the issues of endorsing sustainable environment for the CLSC production and information flows.

2.3.2.2 Returns Reasons

Regarding to the nature of various types of products and components, there are a number of reasons for returns in the reverse logistics flow. In manufacturing operations, the return of products, components or materials occurs within and outside the company operations. Internally, there are leftover materials, scraps and defective products or components which might be collected and returned to the production processes for reuse or remanufacture. It would still be inevitable to apply reverse logistics processes before achieving the ideal zero production scrap or defects objective for production and operations management. In addition, catalogue, clothing or textile manufacturers might experience external returns from retailers on excess products (Autry, et al., 2001).

On the other hand, there are more uncertainties for product returns in retailing industries. Due to increasing market competition, retailers must increase customer satisfaction by offering warranty and return policies. Products might be returned by consumers for various reasons, including: defective, damaged or unwanted products, incorrect products, warranty returns or customer dissatisfaction (Bernon, et al., 2004). As a result, the returned products are in diverse status and need to be handled accordingly for repackaging or refurbishing, before they can be sold again in the same or secondary market. Retailers must be able to identify the product status and carry out appropriate reverse logistics processes against different situations. These activities demand a lot of time and labour resources which create costs for retailers.

2.3.2.3 Product Characteristics and Types

As discussed before, there are many products or components returns both in manufacturing and retailing industries for various reasons. According to De Brito and Dekker (2002), there are by-product returns, functional returns, reimbursement returns, service returns, end-of-use returns and EOL returns. They are either returned from customers to manufacturers and retailers, or being collected by third parties and central recovery facilities at the end of the product life cycle. These returns are with various characteristics, as some of the consumer returned products still remain in perfect conditions for selling, some of them might need repackaging; while some others might need repairing or refurbishing before resold. For those products that have reached the end of their life cycle, they might have to be scrapped or disposed in landfill. However, it should be pointed out that although these EOL wastes would normally end up in landfills, an increasing percentage of them are being recovered via various methods and techniques in order to regenerate value. In fact, “there is no waste in the world, only treasures being put in the wrong places”, as one party’s waste can be an essential raw material to another (Cheremisinoff, 2003). Therefore, the study of waste management is an important research approach for the collection, transportation, processing and recycling or disposal of waste materials. It aims to reduce the affect of waste material to the natural environment, and to increase the recoverable resources and values.

2.3.2.4 Processes and Network Design

More attention are paid to the implementation of reverse logistics processes and recovery options which would eventually improve the efficiency and sustainability of the entire supply chain system, including the forward and reverse logistics flow (De Brito, 2002). Although there are a number of existing research and processes maps and frameworks in the field of product design for manufacturing, they tend to focus on the efficiency of the forward supply chain manufacturing processes (Smith and Donald, 1991; Fine, 1998), and product development for meeting the end customer requirement (Smith, 1996; Ulrich and Eppinger, 2004). It is often assumed that reverse logistics is simply a matter of reversing the outbound distribution process. However, recycling and returns management have their own unique and complex issues that affect reverse logistics operations (Gooley, 1998). Returns in both manufacturing and retailing industries require special information systems, dedicated equipment, and personnel trained in non-standard processes (Langnau, 2001). Fleischmann (2004) identified “the main issue of logistics process and network design is the decision of integration or separation of the forward and reverse logistics”. In other words, companies have to decide whether to integrate their reverse logistics processes with their existing logistics structures. Otherwise they would subcontract to specialists and third party collectors to handle the returned product which means separating reverse processes from forward supply chain. After all, developing efficient and effective CLSC operations between the forward and reverse logistics will contribute to the sustainable CLSC management.

2.3.2.5 Participants and Their Roles

As discussed in previous dimensions from the reverse logistics framework, it should be obvious that parties in the CLSC play different roles in the reverse logistics processes. As illustrated in Table 2.3, products, materials and wastes might be returned by the consumers, retailers, wholesalers, manufacturers and suppliers to any point of origin. Retailers, wholesalers, manufacturers and suppliers must take the responsibilities of collecting, sorting and managing the process of recovering or disposing the returned merchandises. Blumberg (2005) analysed the internal participants in the manufacturing of retail consumer goods for reverse logistics and CLSC process. These include the departments of production, sales and marketing, distribution, finance, as well as customer service and product research and development (R&D). These departments have contributed in promoting the application of reverse logistics processes in some of the corporations, which increase their competitive advantages in terms of cost savings, profit maximisation and increase customer satisfactions.

Table 2.3 Participants in Reverse Logistics Processes

Returners	**Receivers**	**Internal**	**External**
Suppliers	Suppliers	Production	3PLs
Manufacturers	Manufacturers	Marketing and Sales	3PRLs
Wholesalers	Wholesalers	Distribution	Central Recovery Facilities
Retailers	Retailers	Finance	Public-Private Functions
Consumers		Customer Service	Government
		Product R&D	Organisations: Green Peace

(Adapted: Bernon, et al., 2004 and Blumberg, 2005)

In addition, there are external participants such as 3PLs, 3PRLs, central recovery facilities, public and private functions, which also play their roles in the integration of reverse logistics flows in the CLSC. The main difference between public and private networks is the concern of production waste or EOL products. As for public functions, materials are collected and recovered for environmental purposes; whereas private networks are mainly aiming for economic benefits. As a result, the private networks for reverse logistics are much more of a pull process than the public networks (De Brito, et al., 2004). Last but not least, government and organisations such as green peace, also participate in promoting reverse logistic operations. They establish regulations and awareness of reverse logistics activities for environmental sustainable development.

2.3.2.6 Summary

With regard to De Brito and Dekker's five basic dimensions of reverse logistics framework and literature review analysis above, Figure 2.5 is the summary of the expanded reverse logistics framework.

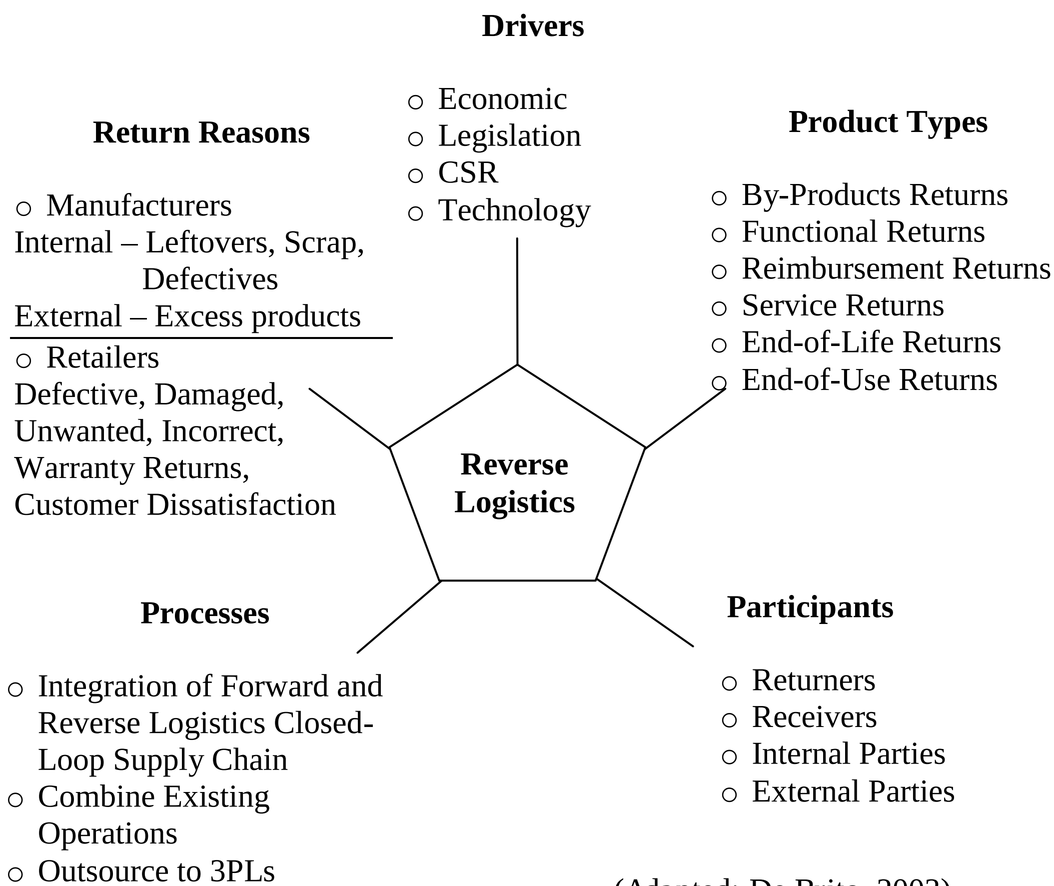


Figure 2.5 The Expanded Reverse Logistics Framework

Because of the driving forces from the economic, legislation, CSR and technology factors, waste, left-over, and scrap materials as well as EOL products, used products and parts are returned to manufacturers and retailers. Generally speaking, the differences between these five basic dimensions in manufacturing and retailing industries are not significant, although issues in retailing industries tend to be more diverse and returns are with smaller scale. In order to deal with these returns efficiently and effectively, parties in the supply chain need to integrate their operations internally for the forward and reverse flow of materials and products. In addition, they have to understand and cooperate with their upstream and downstream partners along the supply chain to develop sustainable CLSC operations.

Regarding to the CET relationships discussed in the previous section, since the CLSC is the integration of production of goods and services and reverse logistics, the CET relationship for the sustainable environment can be illustrated as in Figure 2.6.

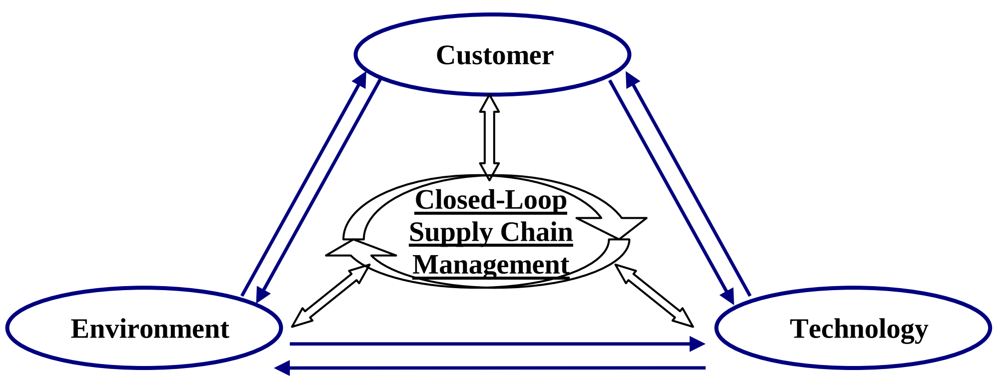


Figure 2.6 Closed-Loop Supply Chain Management and the CET Relationships

It is essential to find the balance between the CLSC management with the interaction between the CET factors, which contribute to the sustainable supply chain management. Similar to Figure 1.3 which illustrated the production of goods and services and the CET relationships, the detailed interaction between reverse logistics and the CET relationships are shown in Figure 2.7. Then the combination of the forward and reverse logistics activities for the sustainable CLSC management framework can be finalised in Figure 2.8 following.

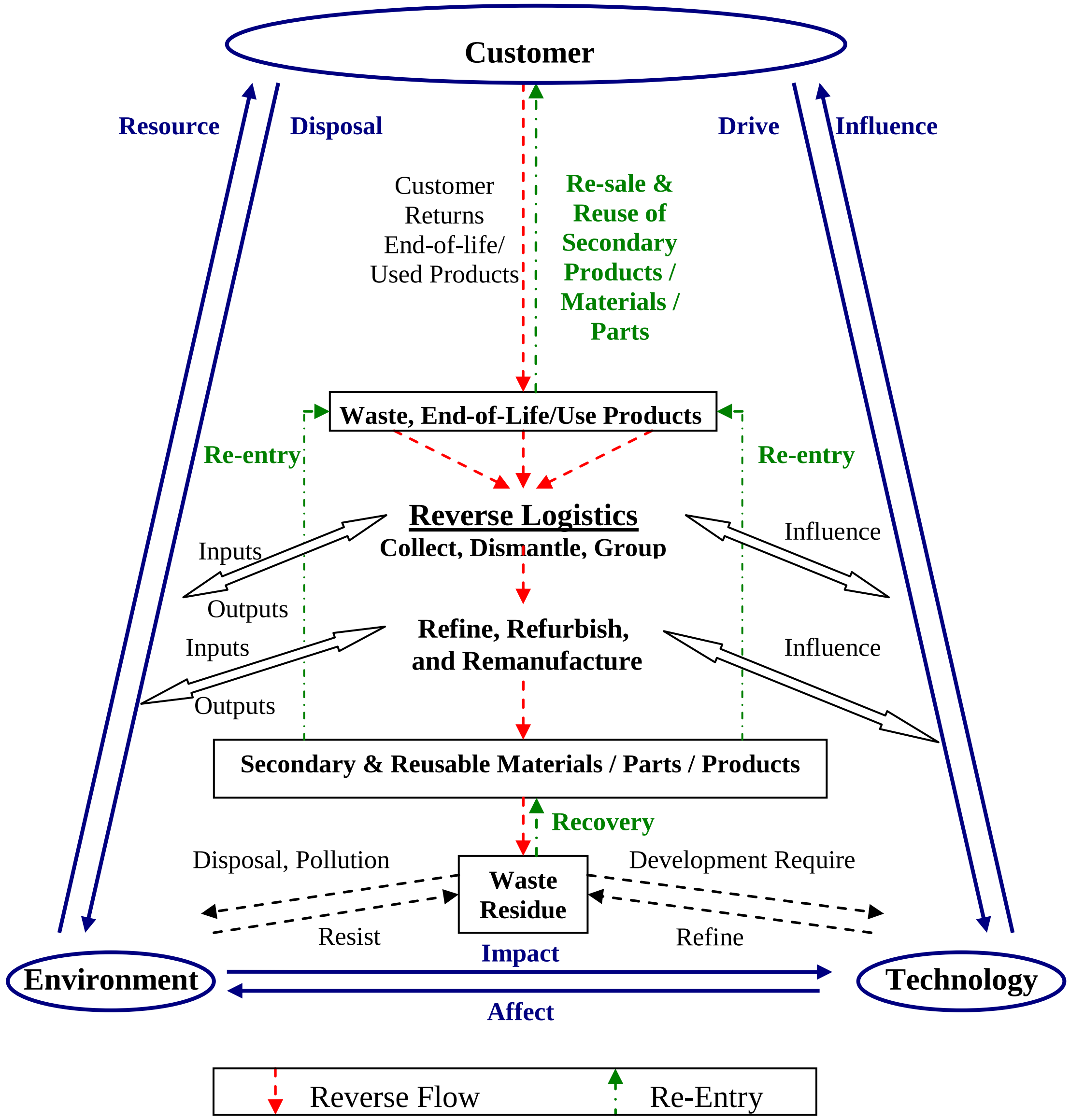


Figure 2.7 Reverse Logistics and The CET Relationships

The operation of reverse logistics is to collect, group and refine customer returns before the processes of dismantling, remanufacturing, refurbishing and regenerating. Similar to the production of goods and services, reverse logistics processes also need to consume inputs from the environment. They would need to obtain energy, space and other required materials for remanufacturing process operations. The end products from these processes are the so-called secondary and reusable materials, parts or products, which re-enter into the supply chain flow and would be bought and reused by customers. Some of these secondary materials and products have no quality differences compared to the primary materials or products, for example, in the case of aluminium cans. Other secondary materials and products might have lower quality compared to the primary ones, which reflect on their lower price value and might be sold in a secondary market to different groups of customers.

During the reverse logistics operations, there are inevitable outputs of emission, by-products and waste residues, which are harmful disposal and pollutions to the environment. Although it could be argued that the amount of final wastes and residues to the environment is much less than the previous waste disposal, as if they were not being collected and dealt with properly. There are still concerns on how to properly handle the final disposals and hazardous residues.

The development of technology also plays an important part regarding to the reverse logistics processes and dealing with residues and by-products from remanufacturing processes, as demonstrated in Figure 2.7. The technology elements influence the operations and flows in the reverse supply chain. There are various requirements for the remanufacture and re-entry of secondary materials and products into the CLSC, as well as the recovery and refinement of residues and by-products. For example, these include the development of solid waste manufacturing process systems such as bio-stabilisation, anaerobic digestion, bio-fractionation, wet oxidation and incineration-pyrolysis (Golueke and McCarhey, 1969).

Ultimately, according to all the discussion, analysis and evaluation above, Figure 2.8 presents a comprehensive framework model which shows the interactions between the Sustainable CLSC Management and the CET relationships. It illustrates the detailed interactive activities between the production of goods and services (Forward Supply Chain) and the reverse logistics (Reverse Supply Chain), which form a CLSC.

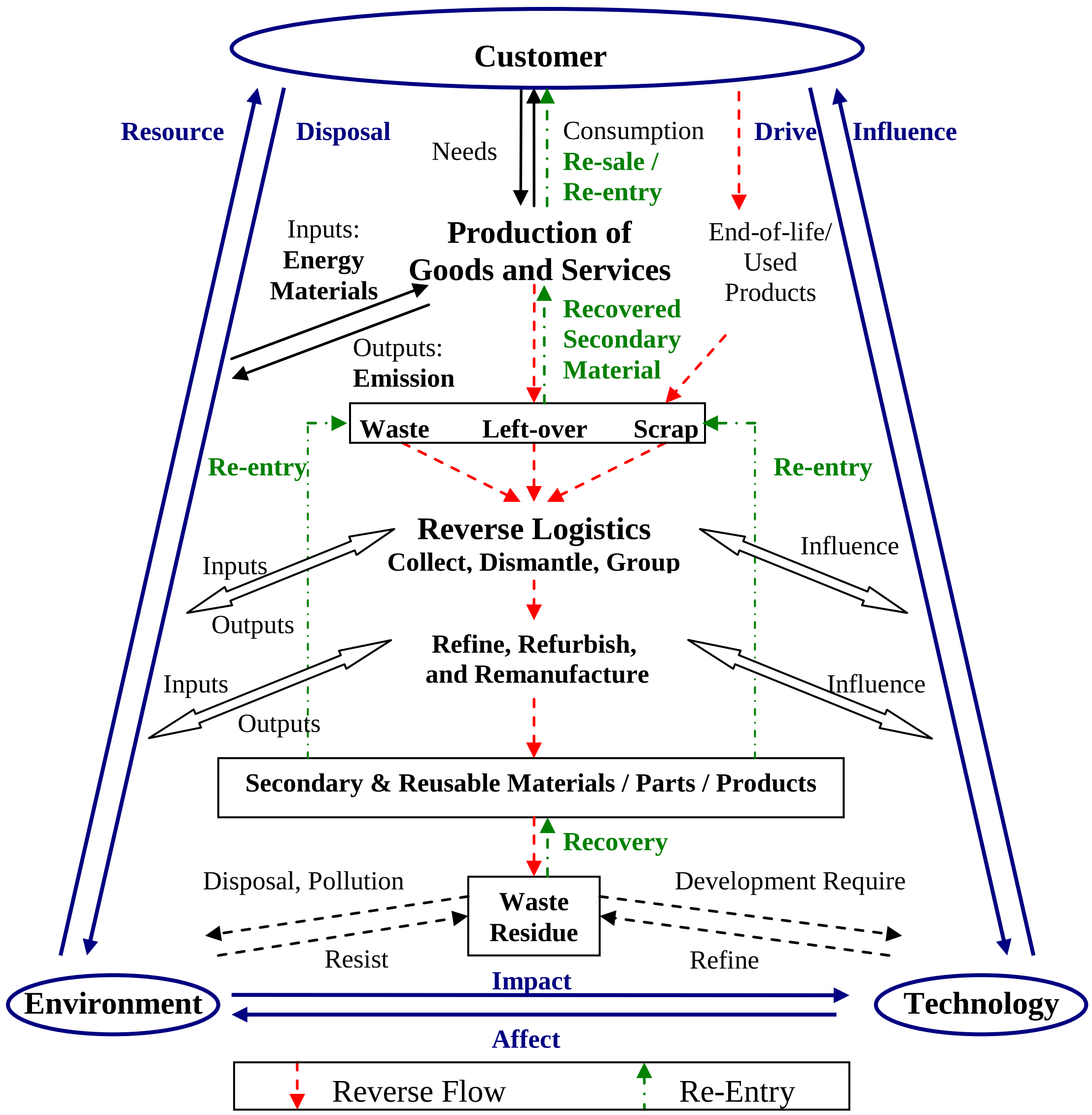


Figure 2.8 Sustainable Closed-Loop Supply Chain Management Framework

These activities are under the influences of the CET factors. In the mean time, the development of CLSC also creates impacts to the CET requirements, as the human economy development is a subsystem of the finite and non-growing earth, and sustainability is the ultimate challenge to the energy and creativity of the human race (Meadows, et al., 1992). The rationale of this research is to investigate the sustainable CLSC for solid waste identification, regeneration and remanufacturing processes, particularly in finding out how technology plays an important part in assisting efficient and effective remanufacturing processes of solid waste management and logistics flow.

2.4 Solid Waste Management in the Chinese Metal Industry

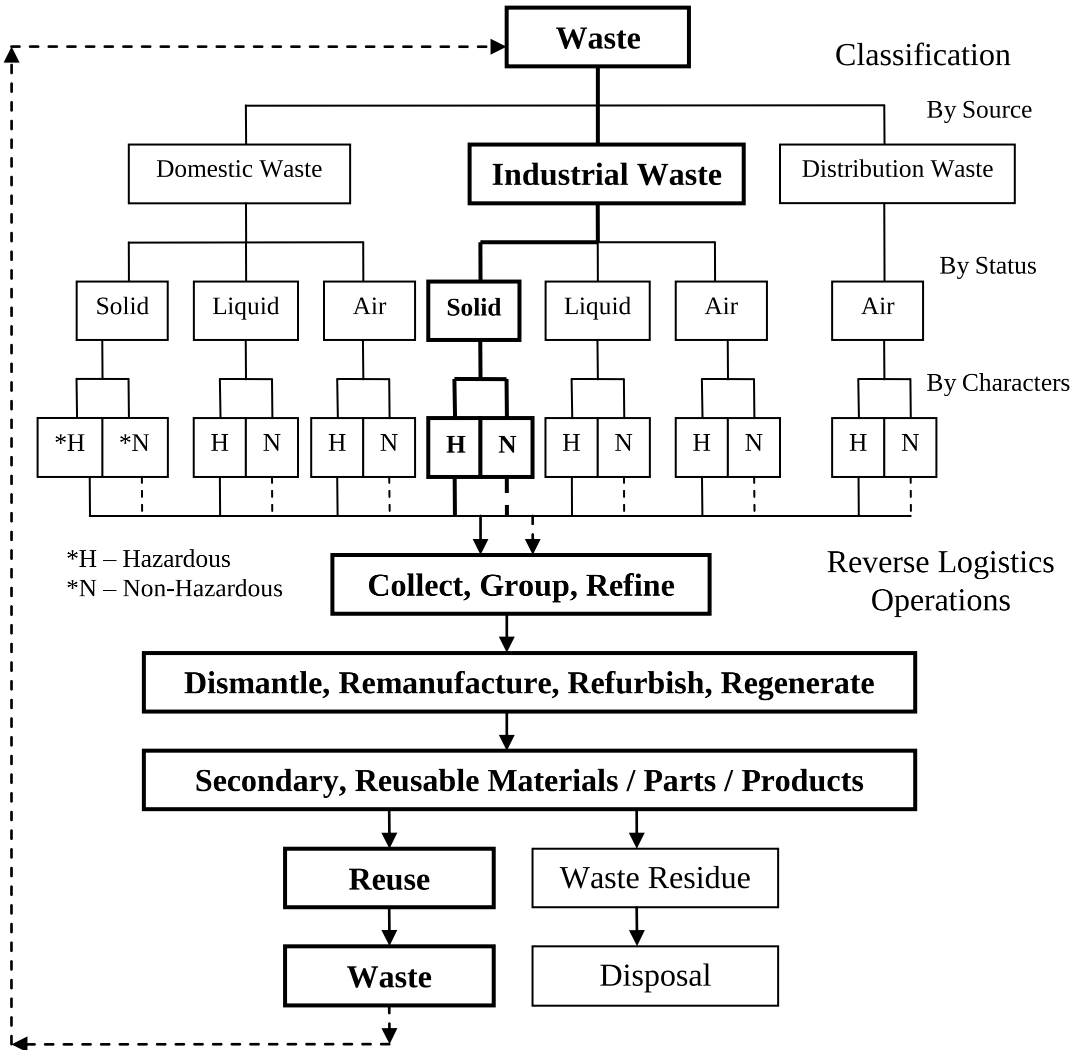
2.4.1 Definition of Waste

Prior to the evaluation of existing literature on solid waste management of the Chinese metal industry, the definition of waste needs to be clarified. There are two main approaches for categorising the definition of waste. Firstly, wastes are the 'unwanted things' which may result in a deterioration of environmental quality because of air or water pollution or adverse effects on visual aesthetics (Havlicek Jr., et al., 1969). According to the waste definition in legislations and directives such as UNEP, 1989 and OJ L78, 1991, waste is "any substance or object that the holder discards, or intends or is required to dispose of" (Hicks, et al., 2004). Secondly, many researchers describe wastes with regard to the loss of value of the substance or object, as in Bicheno's (2000) words, waste is "the unused human potential, and is the inappropriate system that add cost without adding value, such as waste energy and water, wasted materials, wasted customer time and the waste of defecting customers which eventually cause customer dissatisfaction and the loss of customer and sales."

White, et al. (1995) classified waste by a multitude of schemes, including:

1. Source: Domestic, Industrial, Distribution Channel
2. Physical Status: Solid, Liquid, Air
3. Material: Glass, Paper, Metal
4. Physical Properties: Combustible, Recyclable
5. Safety Level: Hazardous, Non-hazardous

As illustrated in Figure 2.9 following, by classifying waste according to the multitude of schemes, different ways of reverse logistics operations would be performed according to the different wastes classifications.



(Adapted: Sun, 2005)

Figure 2.9 Waste Classification and Reverse Logistics Operations

As discussed earlier, the reverse logistics operations start with the collection, grouping and refining processes of waste, left-over and used products and materials. Then there will be the processes of dismantle, remanufacture, reuse and refurbish for producing secondary and reusable materials, parts and products. In the flow of CLSC, these secondary resources would be sent back to the supply chain and reused in manufacturing operations or by other customers. Eventually, the waste generated from these reuse activities would be going through the waste classification and reverse logistics operations processes again. On the other hand, for waste residues generated at the remanufacturing stage, the majority of them which are not suitable for reuse, would be disposed at the end stage of the operation. A small amount of them might go through the waste recovery stages for further regeneration if it is technically and economically possible. As highlighted in Figure 2.9, this research focuses on the process flow of handling industrial solid wastes, both hazardous and non-hazardous, through the reverse logistics operations in the context of the Chinese metal industry.

2.4.2 The Chinese Metal Industry

The majority of existing literature on the solid waste management of the Chinese metal industry tends to reveal the current situation from a macro level. For example, researchers present statistics and figures of the fast growing primary and secondary Chinese metal industry. They also highlight some of the problems and challenges within the existing industrial environment, and the metal manufacturing and remanufacturing processes. These include the dysfunctional environmental administrative system, the lack of policy coherence, legislation, control and reinforcement (Jiang, et al., 2001; Qiu, 2003; Wang, et al., 2005; Carter and Mol, 2006; Yap, 2006; Zhu, et al., 2008).

A number of researchers have evaluated the existing Chinese law and regulations especially on environmental issues (Chen, 2003; Yap, 2006; Peters, et al., 2007; McElwee II, 2008). For example, as listed in Figure 2.10, the Environmental Protection Law [1989] is formulated for the purpose of protecting and improving people's environment and the ecological environment, preventing and controlling pollution and other public hazards, safeguarding human health and facilitating the development of socialist modernisation. The Clean Production Law [2003] is enacted for the purpose of promoting cleaner production, increasing the utilisation ratio of resources, reducing and preventing pollutant-generating, protecting and improving the environment, protecting human health, and promoting the sustainable development of the economy and society (Law of PRC, 2007). It encourages and promotes higher technology application for cleaner production, especially motivating SMEs by providing guidelines and rewards for their improvement in cleaner production.

Law/Regulation	Effective Date
Environmental Protection Law	1989
Law on Prevention and Control of Environmental Pollution by Solid Waste	1995; amended 2005
Law on Prevention and Control of Atmospheric Pollution	1995; amended 2000
Law on Prevention and Control of Water Pollution	1996
Law on Prevention and Control of Pollution from Environmental Noise	1997
Energy Conservation Law	1998; amended 2008
Regulations on Labor Protection in Workplaces Where Toxic Substances Are Used	2002
Impact Assessment Law	2003
Clean Production Law	2003
Renewable Energy Law	2006
Administrative Measures on the Control of Pollution Caused by Electronic Information Products (also known as China's RoHS)	2007
Regulations on Waste Electrical and Electronic Equipment	Forthcoming
Circular Economy Law	Forthcoming

(Source: McElwee II, 2008)

Figure 2.10 China's Major Environmental Laws and Regulations

2.4.2.1 Waste in Forward Supply Chain Processes

In addition to the law and regulation reinforcement for environmental protection during industrial operations, manufacturers also take into account efficient operations for economic benefits. In the forward supply chain, there are different types of waste throughout manufacturing processes. These could be caused by individual workforce and participants within production during design stage or operations between processes. One of the leading researches in supply chain management for waste identification and control is the Toyota Production System. Ohno (1988) identified seven general sources in the production where wastes come from over-production, processing, inventory and correction such as rework and scrap.

The amount of wastes from these sources varies in different companies. First of all, the reason for over-production is because manufacturers in the production naturally feel more secure with a considerable amount of inventory, especially when demand in the market fluctuates over time. However, Ohno (ibid.) mentioned that “no waste in business is more terrible than over-production”. In the case of China, over-production remains a serious challenge in steel, iron, electrolytic aluminium, ferroalloy, coke, calcium carbide, automobiles, and copper smelting industries. There are increasing demand for production of various types of metals which generate increasing amount of wastes and side-products (Jiang, et al., 2001; Qiu, 2003). Serious oversupply had forced prices to fall and in some cases dropped below costs. The enterprise profitability decreases as more companies are losing money. In the steel and iron industry, increasing over-production and oversupply resulted in price markdowns for steel and iron since the second quarter of 2005 (NDRC News, 2006). Moreover, the storage and maintenance of overproduced inventory also take up warehousing space and resources. The quality and value of over-production inventory would depreciate over time, for example, the rusting of iron products if they are not handled and stored properly.

Secondly, the aim of manufacturing and production operation is adding value to materials and parts, in order to produce finished products that would gain profit for the enterprise. It is very important to minimise costs during production stages. Therefore, any materials or parts waiting at different stages of production process, or travelling inefficiently between processes in a production are all considered to be non-value added activities. These wastes at waiting or from transportation must be eliminated. The design of the processes is essential. For example, using appropriate machineries, production system, layout, transportation and communication between processes would increase productivity, production capacity and smooth flow of production (Hicks, et al., 2004).

Hence, Ohno developed the Just-In-Time (JIT) and Kanban system at Toyota to eliminate waste by reducing Work-in-Process (WIP) inventories and maximise productivity (Singh and Brar, 1992; Chakravorty and Atwater, 1996). JIT is the pull production system for internal production and external transportation of products between upstream and downstream in the supply chain. It aims to get the right parts and products to arrive at the right time with the right quantity. Last but not least, manufacturers must minimise the rework and scrap level throughout their production processes. In doing so, they are increasing the productivities and the utilisation of materials and parts for production, which reduce the production costs and costs for materials and wastes recovery activities.

2.4.2.2 Waste in Reverse Supply Chain Processes

In contrast to waste elimination in forward supply chain using JIT, Kanban methods, solid waste management can also apply as reverse logistics process methods for material recovery, waste control and management.

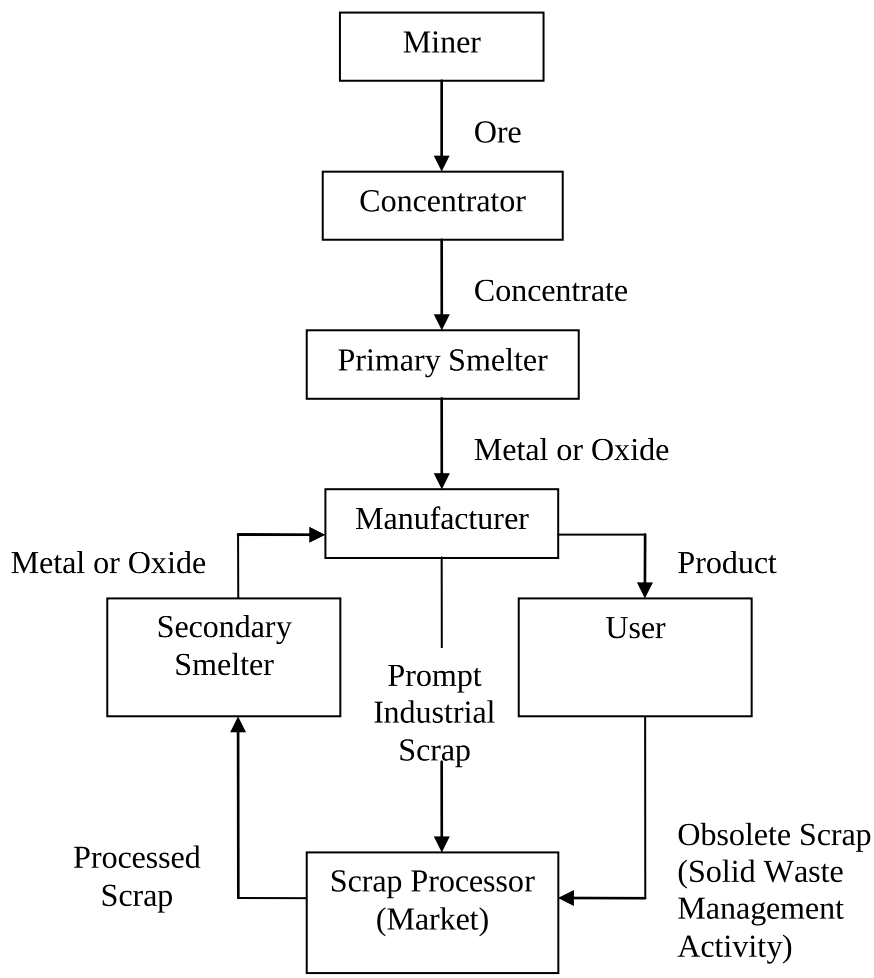
Similar to the drivers for reverse logistics, economics, legislation and technology are also the main factors that drive solid waste management operations. Especially for the economic factor, researches on solid waste management started from the late 1960s which tend to look at waste management activities from the economic perspectives. As in particular, according to Havlicek, et al., (1969), "the economic information for decision making in solid waste disposal presents important and critical problems by almost any criteria". Examples abound in various operations and industries. In the research of European automotive aftermarket, Harland (1996) found that operations managers were more likely to focus on minimising those waste streams that represent the greatest costs and value. However, this means that operations managers would pay less attention to those relatively low cost waste streams, and the opportunities for developing value added processes for those low cost waste streams would be neglected.

As already discussed in the CET relationships, Adam Smith's theory of the invisible hand expressed that the economic benefits influence the behaviour of individual and enterprise activities (Smith, 2000 [1776]). Hence, this leads to the development of market economy in capitalism societies. However, there is the unavoidable natural phenomenon of depression along with the development of capitalism market economy. As Chandler (1977) addressed, "the visible hand of management (should and have already) replaced the invisible hand of market forces where and when new technology and expanded markets permitted a historically unprecedented high volume and speed of materials through the processes of production and distribution". That is to say, a comprehensive integration of the invisible market force and the visible governed development strategies and legislations should cooperate with each other. The combined forces and enforcement can drive the modern integrated macro market economy to higher and sustainable level. And in the micro level of internal and external organisations and network structure, organisations should accomplish the responsibilities of the operations managers and waste managers in order to achieve higher level of efficiency and sustainability. This means devoting themselves to minimising as many waste streams as they can.

As a result, in multinational companies such as BMW, HP and Xerox, they have waste management departments in their organisations. Their waste managers concentrate on the environmental legislation and regulation, which include the physical waste, waste classification, transportation and disposal. Therefore, internal or external processes would be developed to recover raw materials at the early stage of the production system, or to produce a secondary product which would raise additional value even in the lower value waste streams within the supply chain (Wu and Dunn, 1995; Maslennikova and Foley, 2000). After all, both operations managers and waste managers should aim for the goal of sustainable development, by maximising potential value and minimising disposal costs, and consider the social and environmental impacts of their operations.

2.4.2.3 Integrated Solid Waste Management Processes

There are many existing methods, tools and techniques to support solid waste management. For the internal operations within the manufacturing process, as discussed before, there are JIT and Kanban system for controlling and eliminating the amount of waste generated through production processes. In addition, there are MRP and MRP II which are the production planning and inventory control system for managing manufacturing processes. These are software based systems to ensure that materials, parts and products are available for production and distribution to customers, with minimum inventory level. The primary metal processing cycle with the integrated solid waste management processes is shown in Figure 2.11. The processes involved in managing returns contain both strategic and operational perspectives. The strategic focus is on establishing a structure for implementation of processes within the firm and across key members of the supply chain. The operational focus is the realisation of processes that have been established at the strategic level. It is recognised that at an operational level, every reverse logistics system should have processing functions covering gate keeping, collection, sorting and disposition. Responsibility for each of these functions can vary depending on specified relationships between supply chain partners (Zhang, 2005; Li, et al., 2007).



(Source: Tchobanoglous, et al., 1993)

Figure 2.11 Primary Metals Processing Cycle and Solid Waste Management

In the study of Zhu, et al., (2008), they look into the insights for different industries in China focusing on a resource based capabilities through knowledge transfer and inter-organisational or inter-industry learning to improve the green supply chain management and CLSC practices adoption. Their research shows that Chinese manufacturers in the power generating industry, chemical/petroleum industries, automobile industry, electrical and electronic industry are still lacking the knowledge, experience and tools to effectively and efficiently improve their environmental performance. Their findings also provide policy implications for the Chinese government in supporting the green supply chain and CLSC practices, in terms of internal environmental management, supplier and customer relationships, investment recovery, and eco-design in different industries.

2.4.3 Chinese Secondary Metal Industry

In the case of metal industry, many countries and regions have large scrap metal piles at the local landfills or transfer stations. However, in many cases, the piles are unorganised and different metals are mixed together, making them unattractive to scrap metal buyers (Tchobanoglous, et al., 1993). The processes for dismantling and grouping these various mixed solid waste metal materials require investments on elements such as capital, technology, labour, equipment, facilities, energy and distribution channels.

The World Bank statistics for the production and consumption quantity of ferrous and non-ferrous metal clearly show the dramatic annual increase especially in the fast growing Chinese economy (**Appendix 1** and **Appendix 2**). There are significant growths in the Chinese metal production and consumption, especially for the four main metals of Steel, Iron, Aluminium and Copper. As China has raced ahead to become the world's fourth-biggest industrial producer, after the United States, Japan and Germany (Hennock, 2002), the metal consumption figures in China are remarkable. Even with the leading quantity of metal production, China still needs to import large quantity of metals and materials to meet its soaring industrial consumption. With regard to the concept of sustainability for future industrialisation development, there are urgent needs for solutions and supply for the expanding global metal production and consumption. These can be accomplished by recovering and remanufacturing solid waste materials, parts and products from the supply chain operation, and maximising waste recovery rate by advanced reverse logistics processes.

It can be argued that the majority of solid waste returns are collected and returned from manufacturers and firms at the industrial and manufacturing level. Some of the manufacturers also take part in reverse logistics flow of internal solid waste management. As in Blumberg's Research (2005), statistics showed that approximately 70% of reverse logistics services were still performed in-house. However, there is potential for third party waste management specialists to participate in supporting all or part of manufacturing waste management function, especially as more firms are expanding to multinational level of mass production in various regions and countries. In the mean time, as according to the UK Keynote market report (Graham, 2004), the metal recycling industry has also been expanding from operating on a national basis to an international platform. Nevertheless, the application of specialised separation and sorting equipment for recovering materials involve high levels of investment. Hence, companies may operate in a larger group, such as the European Metal Recycling Ltd and Sims Group Ltd, which have competitive advantages and capabilities of processing all key metals from industrial waste and EOL vehicles, as well as precious metals. The core competencies of these metal recycling companies are to provide specialised operation with economies of scales, facilities and systems, as well as their channels of product distribution and disposition for metal waste recycling and remanufacturing. Some researchers also identified the use of specialised recycling and third party providers could help to improve quality, efficiency, productivity of reverse logistics and waste management (Melbin, 1995; Krumwiede and Sheu, 2002; Meade and Sarkis, 2002).

2.4.3.1 SMEs in the Chinese Metal Industry

Although the mainstream of theoretical analysis and industrial benchmarking practices demonstrate the advantages of large scale supply chain networking for reverse logistics activities, the participation of Small and Medium Enterprises (SMEs) also take up a considerable part in the field. Especially in emerging economies of the developing countries, SMEs[1] have increasingly integrated into global value chains. They face social and environmental requirements from multinational buyers, and play an important role with regard to the sustainable supply chain management in the global value chains (Jorgensen and Knudsen, 2006).

In the case of China, much of China's success in spurring economic growth is usually attributed to the development of SMEs in the form of Township and Village Enterprises (TVEs) in rural areas and collectives in the cities. And TVEs respond much better to market conditions than the arthritic State-Owned Enterprises (SOEs) (MacBean, 2007). In 2002, there were more than 20 million TVEs with an estimated 150 million employees, responsible for over 30% of China's GDP and a third of China's rural income (Economy, 2004). On the other hand, TVEs create more industrial pollutions than SOEs, due to TVEs comparative disadvantages in low level of technology implication in production, lack of labour skills and education levels, relatively inefficient channels of information and key material distribution (Perotti, et al., 1999; MacBean, 2007). Zhao (2007) described the hidden defect behind the Chinese secondary metal industry for being mostly SMEs, as only 1-2% of the 5,000 remanufacturing companies are large size companies. Their operations tend to be in small size, with outdated equipment and tools. Works are mostly done by intensive labour operations with hazardous condition. It is extremely difficult for proper industrial and governmental management and control. What is worse is that they cause severe damages to the water, air, land and noise pollution to the local environment and residents.

On the other hand, Shang (2007) evaluated a number of existing techniques and technologies implemented in the Chinese metals remanufacturing operations to reveal the current situation in the Chinese metal industry. The research showed that the level of metal manufacturing and remanufacturing and the recovery rate of secondary metals could reach as high as 95%. Especially with the high value of secondary metals in the

[1] It should be noted that the definition of SMEs various in different countries in terms of employee numbers and turnovers. For example, according to the European Commission (2003) 2003/361/EC, SMEs are enterprises with less than 250 people and total turnover less than € 50 million (£ 30 million). However, in countries such as the US, Canada, Mexico and China, the total employee number of the SMEs is up to 500 (APEC Profile of SMEs, 2003).

global market, remanufacturing companies are motivated to develop better methods and techniques to recover and utilise metal resources as much as possible.

In addition to the identification of the economic influences of these SMEs, it is important to investigate the process operation characteristics of these SMEs in developing countries. A number of researchers have presented figures and information of the Chinese metals recycling, developed quantitative research models for reverse logistics network design and costs optimisation model (Zhang, 2005; Wang, et al., 2005; Dong, 2006; Li, et al., 2007; Song and Bai, 2007; Hua, et al., 2008). These researches develop guidance and benchmarking structure to direct Chinese metal remanufacturing SMEs towards sustainable development for themselves and society, and reduce the level of damage from their production to the environment.

2.4.4 Implications of Technology

In addition to the understanding of the CLSC and solid waste management, every company must understand the broad effects and implications of new technology and how they create substantial and sustainable competitive advantage. As discussed in the CET relationships, technology is changing the way companies operate internally, and altering the relationships among companies and their suppliers, customers and rivals. Porter and Millar (1985) identified "three specific ways that technology affects competition: it alters industry structures, it supports cost and differentiation strategies, and it spawns entirely new businesses". The benefits of manufacturing technologies include higher flexibility, better quality, higher capacity and safety, shorter lead time, cycle time, as well as less labour, inventory and space. Technological innovation and sophistication are based on the potential for altering a full range of strategic and industry structure variables, including cost positions, scale economies and power relations between buyers and suppliers. Firms pursue competitive goals by adopting what they deem to be appropriate technology initiatives (Powell and Dent-Micallef, 1997). Therefore, they must be able to capitalise on the new technology's benefits to provide a significant competitive advantage over others in its market (Meredith, 1987). In the study of the integrated UK steel supply chain between 1990 and 2001, Potter, et al.,

(2004) identified that the supply chain has undergone changes at a strategic, tactical and operational level. The tactical improvements include the integrated information control system and distinctive production processes for different product types. The main drivers behind these changes have been cost reduction and information technology.

However, firms only engage in profitable ventures which increase shareholder wealth, and the behaviour of the development and use of technology is a response to profit incentives to a certain extent (Guide and Van Wassenhove, 2001; Acemoglu, 2002; Guide, et al., 2003b; Suttmeier, 2005). From the study of Baldwin and Sabourin (2001) in the manufacturing sector, there is a considerable amount of market share transferred from declining firms to growing firms, which have been increasing their productivity through advanced technologies and performance of plants. Those technology users that were using communications technologies or combined technologies from several different technology classes increase their relative productivity the most. In turn, gains in relative productivity, research and development facilities and innovative activities were accompanied by gains in market share. However, their research does not show that by simply purchasing advanced technologies will lead to success. Implementation requires human resource strategy to develop the necessary worker skills. As in their words, "technology is just one part of the puzzle that creates a successful firm. Manufacturers must be aware that technologies performed poorly in the absence of proper alignments with structures and cultures, the supports of human relations and contingency" (ibid.).

Similarly, for remanufacturing processes, the implementation of technology in reuse activities must be value-creating (Guide and Van Wassenhove, 2001). Governments and industries must engage in finding the fine balance between financial profitability and key social and environmental goals (Lobel, 2006). Guide (2000) analysed that a number of remanufacturing firms in the US have adopted a market-driven product acquisition management approach. On the other hand, for European firms, they are not involved in product recovery for economic reasons, but because of environmental legislation. Hence, they are passively accepting all product returns and many firms that are operating under a waste stream approach, considering their product recovery system to be a cost centre rather than a profit centre (Guide, et al., 2003a). As a result, European companies are looking for ways to cut down their costs on processing those returned products. These encourage the development of high level technology and machinery systems for remanufacturing and recovery processes on returned products and parts. As according to Capes (2004), "any purchaser operating in a high wage economy needs a good excuse not to invest in this sort of minimally manned production capacity". However, there are needs for research in analysing and exploring the development and implementation of remanufacturing technology, as the existing research and practices are still very limited.

2.4.4.1 Environmental Technologies

As identified by Klassen and Whybark (1999b), the understanding of the relationship among environmental management, implementation of technologies and performance outcomes are limited. Their study on resource-based view of the firm, manufacturing strategy, and environmental management provided a basis for identifying and exploring the relationship between the selection of environmental technologies and performance outcomes. Environmental technologies were classified as either pollution prevention technologies, comprising remediation or end-of-pipe technologies. Allocation of investment in environmental technologies towards pollution prevention technologies offers the most promising path. In doing so, manufacturing firms must develop strategies and resources to enable the application and development of pollution prevention technologies at the plant level. Managers also need to ensure that workers are motivated to apply these technologies for their operations. As environmental management is not an isolated problem, manufacturing companies must make consistent progress in order to achieve sustainable development.

Klassen and Whybark (1999a) also suggested that research is needed to explore the relationship between the technology portfolio at the plant level and manufacturing performance outcomes. This would shed light on the continuing debate between the view that environmental performance is costly and potentially hurts firm and manufacturing performance, and the view that strong, proactive environmental management contributes to better performance.

On the other hand, Guide and Van Wassenhove (2001) identified that the acquisition of used products may be used as control lever for the management and profitability of reuse activities. As the world is operating under the notion of globalisation in which there are global transformation of networks, flows and interconnectedness (Held, et al., 1999). The transportation, distribution and logistics approach is concerned with value-added activities related to the flows supporting global production networks, from modes, terminals, and the vast array of activities linked with freight distribution (Hesse and Podrigue, 2006). These include the mobility of raw materials, parts and finished products, factors of production, capital, geographical and functional integration of production, distribution and consumption, as well as those wastes and used products and parts. As a result, there are growing interactions between manufacturers and remanufacturers in the forward and reverse process flows of the CLSC, which would increase the efficiency and effectiveness of sustainable supply chain operations. As manufacturers are applying higher level technology in their production to increase productivity and reduce wastes and scraps during their manufacturing processes, remanufacturers can also perform recovery and reuse activities with higher level technology and machineries to recover those reusable parts and materials.

2.4.4.2 Remanufacturing Technology in Different Contexts

However, technology adoption significantly amplifies differences in productivity between countries (Zeira, 1998). That is why manufacturers and remanufacturers in some countries may find it not profitable to adopt these new technologies as others. For example, Tu, et al., (2005) identified that it is critical for Chinese managers to understand the implication of high level of technology. Despite the potential benefits of using new technology and computer systems, Chinese employees often feel frustrated and distressed in their struggle to adapt to rapidly advancing and increasingly complex technology. Especially for those low-skilled workers, they would be put off by the complicated usage of technology and machineries. Hence, the productivity and job performance would deteriorate. However, according to Zhao (2007), the remanufacturing operations in China are operating with low levels of technology and equipment, and the recovery rate of the secondary metals is very low. Further scientific development is needed for industrialisation of secondary metal resources, in order to improve the development of secondary metals production in China (Li, et al., 2007).

As a result, companies must take practical measures to cope with the implementation of technology. For instance, companies need to build better communication mechanisms among employees, provide good technology training, and encourage employees to participate in the introduction of new technologies, provide timely technology support and set up rational reward systems. It should be pointed out that remanufacturing and recycling are the solution to the problem of solid waste pollution which relies on many factors, such as social responsibility, government enforcement, and legislation, as technology alone is not enough (Zikmund and Stanton, 1971).

Similarly, in industries such as in Southeast Asian countries, where new regional division of labour is emerging, the crucial task is to enhance its efficiency in investing in, and diffusing the institutional, infrastructural, technical and skills base appropriate to globally linked production. They must build upon their existing advantages to locate new niches with potential for dynamic localisation effects, in addition to maintaining political stability and investing in human resources (Felker, 2003). People are the key strategic resource, and strategy must be built on a human-resource foundation (Bartlett and Ghoshal, 2002). As the model of economic growth analysed in the research of Zeira (1998), technological innovation reduces labour requirements but raises capital requirements. Therefore, selecting the right production equipment is critical to survival and prosperity. The decision should be based on knowledge of the process, and a good grasp of machines available and how they will help competitiveness. After all, computer controlled machine tools are faster, more accurate and more flexible in manufacturing than the older, manually operated machines (Porter and Millar, 1985).

Furthermore, Meredith (1987) argued that not only large companies could benefit from these new manufacturing technologies, but small firms were just as well, or better, equipped to implement and benefit from technological advances, particularly in strategic areas. Smaller firms seem capable to capitalise on their benefits they are already used to competing with: Fast customer response, quick production, more customisation, greater variety, and so on. Yet these technologies are a major commitment for small firms, in terms of their managerial skill and capital requirements. The critical points may be in design, manufacturing, engineering and many other technologies. Selective investment at critical points in the production process will be the key factor for small firms. They must be able to capitalise on the new technology's benefits to provide a significant competitive advantage over others in its market (Dong, 2006; Zhao, 2007).

2.4.5 Summary

This section investigates the existing literature and researches on the CLSC operation, and in the context of the Chinese metal industry. There has been increasing number of legislation for environmental protection in China. However, there are needs for further research and guidance especially for the implementation of high level technology in the dominating SMEs operations. Although technology can help companies in achieving better quality and larger quantity production in shorter lead times with less labour, the implementation of technology in assisting manufacturing and remanufacturing processes require careful managerial decisions and commitment. Advanced technology system can be too expensive for implementation and maintenance for SMEs in developing countries such as China, especially as their processes mainly rely on large quantity of low costs labour force. Eventually, governments and industries must find the balance between profitability and the increase in productivity and efficiency, with regard to the costs of technologies, the complementing infrastructure and the availability of required human resource and skills, as well as the impact on the environment.

2.5 Research Gaps

2.5.1 Attention to Waste Management

First of all, referring to the existing case studies and research in the field of reverse logistics, the majority of the investigations focus on the product, components, packaging and parts returned to the point of origin in the CLSC. There are still areas for exploration for wastes and residue recovery particularly for sustainable development of manufacturing activities. Since there have been mass production of goods and services supplying to consumer markets all around the world, there are considerable amounts of waste, left-over and used products and materials flowing backward at different stages of the global supply chain. It is essential especially for manufacturers and governments to understand and manage these wastes with the aim to achieve sustainability, which would create long-term benefits to all parties of the global supply chain.

In order to develop comprehensive research for sustainable CLSC, solid waste management should be explored in both forward and reverse logistics flows. Gungor and Guppa (1999) claimed that further sufficient analytical research and work should be carried out to gain the attention of people in industry, government and academia. As pointed out by Dekker, et al., (2005), the fundamental issues are "how to use the existing theory in forward supply chain to address issues in reverse logistics", and "how can the theory of reverse logistics help to improve forward supply chain issues". Hence, this research is proposed to contribute qualitative data for reverse logistic processes and solid waste management techniques by exploring the links and cooperation between metal manufacturers and remanufacturers in industrial practices.

2.5.2 Attention to Developing Countries

As analysed in the literature review chapter, the majority of existing research are done mainly in developed countries in Europe and North America. These provide good resources for reverse logistics system operation and implementation, strategic decision making, legislation and processes guidance. On the other hand, a limited amount of research has been carried out for the reverse supply chain infrastructure in developing countries in Asia, Eastern Europe, and South America, where the implementation of the recycling and remanufacturing processes are falling behind. Especially for the emerging economies in countries such as Brazil, Russia, India and China, as these countries are experiencing fast growing manufacturing and economy development in recent decades. Not only their forward logistics and supply chain management, but also their reverse logistics development should be taken into account for better guidance for their current and future sustainable development progression.

A number of researchers identified that many of the returned products can be profitably sold at a lower price point in the growing 'Secondary Markets' such as outlet malls (Zinszer, 1996; Rogers and Tibben-Lembke, 2001). And reselling products overseas through international transfer is one of the possible ways to dispose returned goods and materials (Gooley, 1998). Blumberg (2005) also found that there had been increasing interests from the manufacturers, dealers and distributors in the CLSC and reverse logistics to recreate value from returns by reselling their returned products or materials to the third world countries. The key issues are not just to understand and meet the regulations and requirements of these developing countries, but also to consider the fact that to some extent, the greening of the developed world has been at the expense of the environments in emerging economies (Hart, 1997). One of the main reasons is because of the expensive capital and labour investments in developed countries for dealing with waste recovery activities. Therefore, there are increasing relocations of the polluting waste recovery activities moving to the developing countries where processes can be done with much lower costs. However, these reverse logistics processes in the developing market economies are largely done manually by low skilled labour with very limited amount of technology and low efficiency. These operations create hazardous problems to the health and safety of the workers and severe pollution and damages to the local environment. As a result, research is needed to investigate and explore the CLSC operations in the context of developing countries.

2.5.3 Reverse Logistics in the Chinese Metal Industry

As discussed previously, the annual metal production and consumption are growing significantly all around the world. Especially for the Chinese metal industry, there are growing demands for metal consumption to be accomplished by recovering and remanufacturing solid waste materials, parts and products through the reverse supply chain operation, and maximising waste recovery rate by advanced reverse logistics processes. The existing research on understanding the details of the process flow in the Chinese manufacturing industry is very limited at the moment. There is a need to understand current processes before further research and process improvement can be carried out. Hence, this research aims to contribute qualitative data information, analysis and evaluation, using the Chinese metal industry as an example. In particular, the research case study is carried out with SMEs operations, since the Chinese metal industry mostly consists of SME metal manufacturers and remanufacturers.

2.5.4 Summary

The discussion above analysed the existing literature and research gaps in the field of CLSC. As mentioned in Chapter 1, this research is proposed to investigate the current processes in China, with the aim to provide benchmarking methodologies and future research development and guidance for efficient and effective reverse logistics operations, particularly for SME metal manufacturers and remanufacturers in managing solid wastes. The aims and objectives of this research are to explore the current structure of the reverse logistics operations in China, as an example of a developing country, in order to contextualise and present comprehensive understanding of the CLSC operation for sustainable development. Particularly, as highlighted in Figure 2.12, this research is to fill in the gap in the CLSC sustainable development in the Chinese metal SMEs, among the interactions of the CET factors.

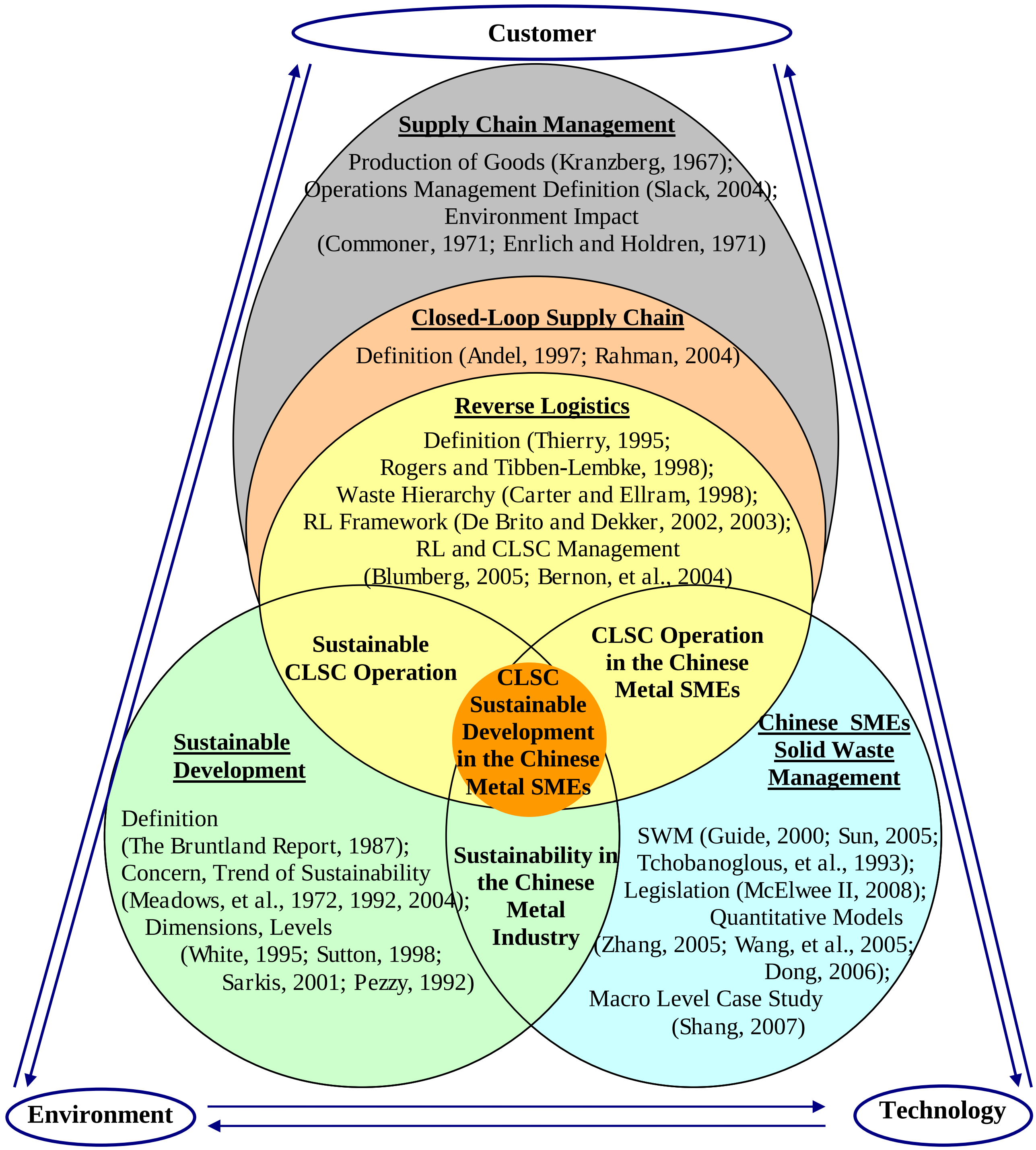


Figure 2.12 Research Gaps

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

Both theoretical and empirical researches were performed in this research in order to identify and understand the CLSC operations in the Chinese metal industry. The analysis and evaluation of literature in Chapter 2 provide a general outline of existing theoretical background on the issues of sustainable supply chain, reverse logistics, solid waste management and the technology available for manufacturing and remanufacturing processes. With regard to the literature review and findings, the empirical research was performed by investigating into a number of case companies in the operations of forward and reverse logistics flows in the Chinese metal industry. The aim was to find out how waste management and the implementation of technology are performed in the industrial context. In this part of the report, it describes the research aims and objectives as well as the research question, followed by the research methodology which was applied to complete the research project.

3.2 Aims and Objectives

In recent decades, there have been rising attentions in many countries for efficient supply chain operations while protecting the environment simultaneously. Although governments might be promoting and reinforcing the operations for proper collection, dismantle and regeneration of waste, used and scrap products and parts; some dismantling plants are still not operating efficiently or environmental friendly, especially in developing countries. The inefficient supply chain processes cause environmental pollution because of inappropriate control and disposal of products and waste materials. As a result, it is essential to develop appropriate guidance and framework models for efficient operations for both forward and reverse logistics flows, in order to increase the efficiency of value-added activities and social benefits.

Hence, the rationale of this research is to investigate CLSC management, focusing on the interactions amongst the forward and reverse logistics of waste identification, regeneration and remanufacturing processes. In particular, from the development of the Sustainable CLSC Framework (Figure 2.8), this research aims to explore the interactions between the CLSC management and the CET relationships. It investigates existing operation processes in the context of the Chinese metal industry, among the metal manufacturers and remanufacturers. Data and information were collected for developing frameworks and tools. These provide the necessary understanding and support for the Chinese SMEs to identify their processes for the CLSC flow and their positions in the industry. Hence, they can decide their direction for improvement in achieving sustainable development in the long term.

3.3 Research Question

The main purpose of this PhD research is to find out:

> **"What specific approaches and techniques do the Chinese metal manufacturers and remanufacturers adopt for sustainable development of the closed-loop supply chain?"**

This research is carried out in the context of the Chinese primary and secondary metal industry, in order to investigate and evaluate the operations from the perspectives of developing countries in terms of CLSC management for sustainable development. In particular, it focuses on the interactions and impacts of the CET factors among the Chinese metal manufacturing and remanufacturing SMEs. Hence, the sub-questions are referring to the customer, environment and technology factors as:

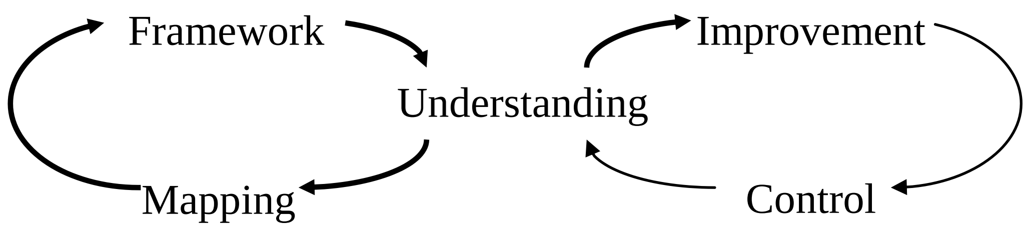
1) **Customer**: What reverse logistics and waste management approaches and techniques are integrated and adopted by the Chinese metal manufacturers / remanufacturers in order to meet customer requirements and achieve sustainability?
2) **Technology**: In what way should process technology be applied to increase efficiency and to reduce the non-value added processes during the forward and reverse logistics flow?
3) **Environment**: What is the impact of the metal manufacturing and remanufacturing processes on the environment?

3.4 Methodology

This research identifies and develops a holistic view of the forward and reverse logistics operation within the CLSC. According to Handfield and Melnyk (1998), the basic aim of operations management research is not to create theory, but to create scientific knowledge, which should provide one or more of the five objectives in the following:

- A method of organising and categorising typology
- Predictions of future events
- Explanations of past events
- A sense of understanding about what causes events
- The potential for control of events

As identified by Hudson and Ozanne (1988), with explanation or prediction, researchers are usually interested in similarities; whereas with understanding, researchers are equally, if not more, interested in differences. In addition, the research must pass the test of the real world, as an untested idea is simply one researcher's view of the phenomenon. It is for this reason that empirical research is the cornerstone for scientific progress. In order to improve the performance of any action or entity, there are needs to understand how and why the given situations and behaviours are generated (Christensen and Christensen, 1995). To understand behaviour there are needs to measure or analyse the behaviour over time, which requires some model representing current belief about the content and different elements of the entity or action. These give an insight and an understanding of the way processes work. Thus modelling with an analysis framework provides an understanding, which may be used, for improvement and control (Haque, et al., 2000), as illustrated in Figure 3.1.



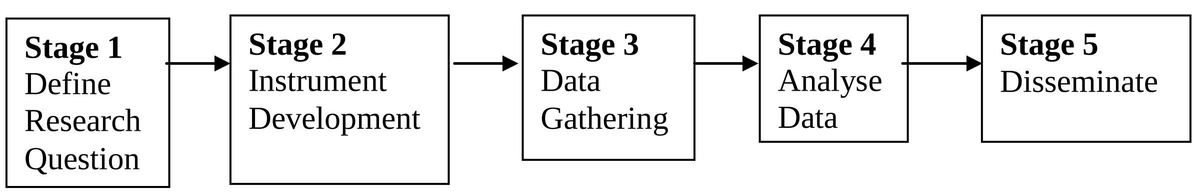
(Adapted: Haque, 1999)

Figure 3.1 Operations Management Requires Understanding

As discussed in the previous chapter, the existing research in the Chinese context of CLSC management is very limited. Hence, this research was carried out to explore the CLSC in the Chinese context. As highlighted in Figure 3.1, by mapping and constructing a framework to understand the current processes and supply chain operation in the Chinese metal industry, further research and study on improvement and control can be performed based on findings from this research. According to Yin (2003), the qualitative approach of a multiple-case study is considered to be the most appropriate method for this exploratory research purpose. This is because the in depth empirical qualitative studies were intended to enquire, experience and examine the contemporary operations, the views and opinions would be gathered from the interviewees and participants involved. As a result, a general picture of the CLSC was captured, as a framework for an understanding of the situation. Further improvement and control can be developed based on better understanding of the processes and operation management. Therefore, empirical research method of case study was applied, in order to investigate the related processes and to develop CLSC frameworks for the Chinese primary and secondary metal industry for sustainable development.

The research methodology includes three major modes of qualitative methods identified by Wolcott (1994): interviewing, participant observation and studying related materials. Data and information were collected and analysed with appropriate methodologies. For example, the pattern matching logic analytic technique (Yin, 2003) was applied in order to develop the CLSC framework from the case study companies with the potential managers and operators involved. In doing so, identifying and illustrating activities involved in the processes with regard to the CLSC operations and the interrelationships of the CET factors. In addition, the pattern matching logic also helped to clarify the constraining activities to the operations which reduce the efficient and effective CLSC for metal manufacturing and remanufacturing processes. Consequently, the CLSC frameworks were mapped and developed further with regards to the CET factors in the industrial context. Findings from the case studies provide better understanding of the forward and reverse logistics flow of the Chinese metal SMEs operations, and provide guidelines for improving supply chain management to achieve sustainable development.

There are five stages for research process as shown in Figure 3.2. After the first stage of defining the research question, there are the stages of instrument development and data gathering before data are analysed and finally disseminated. In this section, the second stage of instrument development is discussed in detail, before the process of data gathering and analysis.



(Source: Stuart, et al., 2002)

Figure 3.2 Five Stage Research Process Model

With reference to Perry (1998), the methodology chapter is divided into five sections. First of all, there will be a brief discussion of paradigms from which lead to the appropriateness of the realism paradigm. Secondly, the case study methodology will be justified, based on the existing comparison of several alternatives of the qualitative research methodology. The validity and reliability will also be addressed with regards to the case study methodology. Thirdly, there will be a discussion on selection and the number of cases for this research purpose, as well as the description of the basis of theoretical replication as discussed in the literature review chapter, and how it becomes the basis of the research design of case selection. Details of how interviews were conducted and how interviewees were approached will also be provided. Detail information of case companies and interview findings will be analysed in the next chapter of case studies findings. Furthermore, the design and application of qualitative research approach will be described, followed by the discussions of data analysis techniques and the brief discussion of the limitations in the case study. Last but not least, there will be discussion of ethical considerations such as the openness with interviewees and the appropriate treatment of confidential information.

3.4.1 Research Paradigms

There are two different approaches of scientific paradigms, which are the deductive approach representing the positivist paradigm and the inductive approach representing the phenomological paradigm including the critical theory, constructivism and realism (Guba and Lincoln, 1994). Deductive approach is to develop a theoretical or conceptual framework which researchers subsequently test using data (Saunders, et al., 2007), as positivists believe that there is a reality out there to be studied, captured and understood (Wilson and Vlosky, 1997). On the other hand, the inductive approach is to explore data and to develop theories from data that researchers subsequently relate to the literature (Saunders, et al., 2007). This is particularly applicable for building theory from case study research at the early stages of research on a topic, giving the strengths of this theory building approach and its independence from prior literature or past empirical observation (Eisenhardt, 1989).

However, a number of researchers identified that there is a close linkage of the deductive and inductive approach (Parkhe, 1993; Miles and Huberman, 1994; Perry, 1998). As pointed out by Perry (1998), pure induction might prevent the researcher from benefiting from existing theory, just as pure deduction might prevent the development of new and useful theory. In other words, it is impossible to develop any theory completely free from prior theory. Based on the data and findings from research activities, existing theories can provide guidelines to a certain extent for further research development in the subject. This research was carried out with a mixed application of both deductive and inductive approaches. As illustrated in the literature review chapter, the Sustainable Supply Chain Management Framework (Figure 2.8) was developed based on existing theory and knowledge with regards to the activities and processes in the forward and reverse logistics of the CLSC management. Hence, it would be used as a guideline for case study research in order to investigate further details in real industrial practices with reference to the CET factors. In addition, research findings will be analysed with reference to this framework. Further theory and framework would also be developed based on the research data and findings. In doing so, the mixed deductive and inductive approach would provide more detailed understanding of the sustainable CLSC management, particularly in the context of the Chinese metal manufacturing and remanufacturing industry. These would contribute in achieving the aims and objectives of the research, as well as answering the research questions.

3.4.2 Qualitative Research Method

Qualitative research involves analysing and interpreting texts and interviews in order to discover meaningful patterns descriptive of a particular phenomenon (Auerbach, 2003). There are a number of approaches and methodologies for qualitative research purposes, such as experiment, survey, archival analysis, history analysis and case study methodologies, as listed in Table 3.1. These strategies provide diverse information and focuses for different research purposes. They all have advantages and limitations in obtaining research information as well as limiting research biases and subjective influences from researchers.

Table 3.1 Relevant Situations for Different Research Strategies

Strategy	Form of Research Question	Requires Control of Behavioural Events?	Focuses on Contemporary Events?
Experiment	How? Why?	Yes	Yes
Survey	Who? What? Where? How many? How much?	No	Yes
Archival Analysis	Who? What? Where? How many? How much?	No	Yes / No
History	How? Why?	No	No
Case Study	How? Why?	No	Yes

(Source: Yin, 2003: COSMOS Corporation)

3.4.2.1 Comparison of Methods

The different qualitative research strategy can be applicable for various forms of research questions, the control of behavioural events and the time domain of the events. For example, well designed survey questionnaires would provide a large amount of data and participants' opinions in a relatively easy manageable way for researchers to analyse the responses, using both qualitative and quantitative analysis methods. The quantitative figures would provide clear information and comparison according to the responses regarding to the questions. However, according to Hatch and Wisniewski (1995), there are limitations and incongruity of using a survey questionnaire, as "no matter how open ended, survey questions still struggle to gather information about an important genre of quality inquiry". In addition, there are issues related to the response rate of the questionnaires and ensuring the validity and reliability of the responses and answers.

Some social scientific experiment research strategy would gather participants' actions and information by arranging certain research setting for research purposes. Yin (2003) argued that this would influence the behaviour of participants which might only provide information in the provided settings under certain criteria. It is essential for researchers to be independent from influencing or biasing participants' reactions and responses.

Furthermore, there are cultural differences that would affect data collection and the method applied for research. For example, Bell (1993) mentioned that many research projects begin with the statement of a hypothesis, which provides richness and boundaries, as well as an environment within which to interconnect data. Culture is used within qualitative research as an operational heuristic device, and researchers must be wary of reducing reality to the culture they themselves construct (Holiday, 2002).

3.4.2.2 Compiling Case Studies

Yin (2003) defined a case study as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident”. Meredith (1998) pointed out that there are three main advantages of case study methodology. First of all, the phenomenon can be studied in its natural setting and meaningful, relevant theory generated from the understanding gained through observing actual practice. Secondly, the case study method allows the much more meaningful question of why, rather than just what and how, to be answered with a relatively full understanding of the nature and complexity of the complete phenomenon. Last but not least, the case study method lends itself to easy, exploratory investigations where the variables are still unknown and the phenomenon not yet understood.

As discussed before, the aim of this research is to investigate and explore the metal manufacturing and remanufacturing processes, and to develop CLSC frameworks for sustainable development in the Chinese metal industry. According to Shavelson and Townes (2002), many social scientists still deeply believe that case studies are only appropriate for the exploratory phase of an investigation, as a holistic case study is shaped by a thoroughly qualitative approach that relies on narrative and phenomenological descriptions. Themes and hypotheses may be important but should remain subordinate to the understanding of the case (Stake, 1976, referenced: Scholz and Tietje, 2002). While survey methods may be very useful to compare results and attitudes within the same context, they may be much less suitable for comparisons across organisations that have different contexts. As long as complexity remains part of the operations management environment, methods that allow the knowledgeable researcher to observe and accurately assess the impacts of those contexts are likely to be needed. Case study remain one of the best ways to make sure that researchers are making valid observations and contributions to the body of operations management knowledge (Stuart, et al., 2002). Hence, this research was performed using the case study methodology, and applied the three major modes of qualitative methods of interviewing, participant observation and studying related materials (Wolcott, 1994; Patton, 2002).

A pilot interview with the local Innovation Centre officers was performed to gather brief information. A list of questions about the general information of the centre and the Chinese metal industry in the region was asked (**Appendix 3**). After that, the research could set off for the seven case companies based on the background information of the metal manufacturing and remanufacturing industry in the PRD region. During the empirical case study, semi-structured interviews were performed with employees of the seven case companies, both in the managerial and operating levels.

As case study methodology is one of the qualitative research approaches, the focus was on the interpretation, summary and integration from the respondents. The guidelines for case company interview questions (**Appendix 4**) were designed to generate data and information about the case companies, and also to answer the research question and sub-questions. In addition, there were specific questions focusing on the CET relationships within the case companies. These questions were designed and developed with reference to the literature review, in terms of the CET interactions, CLSC and solid waste management. They were modified from the pilot interviews with the contact persons from the case companies. Hence, data and information were then collected from managers and operators on the internal operations within their companies, and their external collaborating companies in the CLSC. In depth interview questions were also asked, subject to different interviewees, in order to gain more insight of their knowledge and experience. Although tables and statistical measurements are commonly used in quantitative research activities for data analysis and categorisation (Weiss, 1994), the findings of this qualitative study are supported by quotations and case descriptions. In doing so, the case study research is anticipated to generate better understanding from the experiences and opinions of the interviewees, and to present a better picture of the operations. In addition, there were on-site observations and studies of related documents and materials for data and information gathering.

3.4.2.3 Validity and Reliability

The issue of credibility of the research findings is essential for both quantitative and qualitative research, which includes validity, reliability and generalisability (Perry, 1998; Stuart, et al., 2002; Yin, 2003; Saunders, et al., 2007). Kirk and Miller (1986) defined validity as the extent to which inquiry yields the 'correct' answers; and reliability is the extent to which questioning yields the same answers whenever and wherever it is carried out. In other words, validity and reliability is about whether the findings are really what they appear to be, and whether the findings can be consistent in presenting different cases even if in different contents (Saunders, et al., 2007). Case studies are designed with exploratory, description or explanation purposes, and it must demonstrate that the measuring and findings are valid and reliable for its research purposes.

As these case studies were carried out by interviews and observations in the case companies, there were certain issues that should not be neglected in order to achieve data validity and reliability. For example, historical experience, background and mortality of participants might affect the results and data provided by interviewees. Moreover, there might be participant error or bias which might limit the reliability of the data provided during the interview process. Interviewees might have been saying what they thought their bosses wanted them to say (Robson, 2002). Therefore, the case studies were introduced to the interviewees that the research was carried out by a neutral research member, with the objective of trying to understand and to draw a general picture of the processes of their operation activities. The interviews and questions were structured without the intention to affect the process activities or organisational behaviour and culture. Interviewees were encouraged to provide related information freely regardless to bias and to minimise errors. In addition, actions were taken to reduce observer error or bias. For instance, by interviewing more members within the company at both managerial and operational levels, as well as researching in a number of companies in the same operating field. Data and information were generated and analysed with more thorough understanding from different perspectives.

Data analysis from interviews and observations, as well as the developed frameworks and the CLSC Positioning Tool were verified through contact persons within these case companies, and the Innovation Centre officers. These feedbacks and comments ensure the validity and reliability of the case studies findings. The researcher is also aware of the issue of generalisability. As pointed out by Saunders, et al., (2007), there are complexities and uniqueness with every business operation, especially as there are constant changing situations in every business organisations. Hence, the aim of achieving generalisability while identifying the individual uniqueness needs to be balanced when investigating and presenting the case studies. By selecting the case companies and observing different companies in both forward the reverse logistics process, it would provide a better generalisability for companies that are in similar positions and roles along the CLSC.

3.4.3 Selection of Cases

After defining the research questions and the aims and objectives of the research, companies were selected for the research investigation and observation. The qualitative approach of multiple-case study is considered to be the most appropriate method for this exploratory research purpose. This is because the in-depth empirical qualitative studies are with the intention to enquire, experience and examine the contemporary operations, the views and opinions would be gathered from the interviewees and participants involved (Yin, 2003). By applying the multiple-case study method, a general picture of the supply chain can be captured. It hopes to raise the attentions and find out concerns especially regarding to the dismantling and remanufacturing processes for metal manufacturers and remanufacturers, and problems encountered during their operation processes with regard to the CET factors.

A number of qualitative researchers have discussed the feasible number for multiple case studies. Generally speaking, a case number of around 4 to 8 would be sufficient in identifying the phenomenon with effective size, resource and time available (Eisenhardt, 1989; Meredith, 1998; Yin, 2003). Since this research is one of the piloting research studies investigating the Chinese metal manufacturing and remanufacturing SMEs' operations; it would be more appropriate to select a smaller number of case companies to generate pictures of the industrial operations before further investigations and research can be performed with a larger number of companies and their processes.

At the start of the case study research, a visit was paid to the Guangdong Non-Ferrous Metal Technology Innovation Centre, which is a local government organisation. Two officers from the centre participated in a semi-structured interview. During the interview, these officers provided general background information and data regarding to the remanufacturing of non-ferrous metals in the region. They also provided a list of twenty companies in the industry, which were members of the centre. After the visit, the researcher contacted these companies. Three dismantling and remanufacturing companies responded and were willing to participate in the research. Two of these companies also introduced their cooperating companies in the metal manufacturing industry for the research, which provided valuable information in the cooperating relationships between these companies in both forward and reverse logistics processes in the CLSC operations. With available resources and accessibility, the researcher also had accessed a 3rd party logistics provider and a 3rd party reverse logistics provider. Hence, the case study research took place in seven case companies in the PRD region. The researcher understands that some might argue the selection of case companies might be biased because of accessibility; however, the research would only be able to carry out with what is available. And these case companies are considered to represent companies in the context. Further details of these case studies are described in the following chapter of case study findings.

3.4.4 Data Analysis Techniques

According to Holiday (2002), there are many types of data, including the researcher's description of what they see and hear, and what participants say and write and what participants use and produce. Data is more meaningful when it is interconnected in systems or pathways, hence, decisions about what sort of data to collect and how to analyse the collected data is essential. And these would vary according to the research setting, as well as how information and data emerge during the research process.

Holiday (ibid.) also identified several important criterions for good data collection. First of all, good data shall provide the potential for detailed description by revealing different, deeper aspects of the phenomenon being studied. The detailed description can be achieved in both large and small studies. Even in the smaller scale case studies, it may be sufficient to describe instances of social action which highlight and add to a larger picture when set beside other studies. Another essential criterion is what the researchers do with the data, in terms of what they make of it, and how well they communicate this sense. Good data is that the researchers see the familiar as strange and do not see things for granted; they see things are artefacts of culture rather than the information about it.

In addition, the ultimate goal of case study analysis is to treat the data and evidence fairly, in order to produce compelling analytic conclusions, and to rule out alternative interpretations (Yin, 2003). Therefore, it is necessary to show the workings of the research for accountability of qualitative research. Different studies show their workings in different ways, in different orders and to different degrees of intensity (Holiday, 2002). Since the interviews in this research were performed with semi-structured questions with regard to their roles, experience and operating nature in the company, they were welcomed to provide their narrations freely as long as they were relating to the research area. As a case is ‘an integrated system with patterns of behaviour and that greater understanding about some phenomenon may be reached by studying across cases’ (Wilson and Vlosky, 1997). The analytic technique of pattern-matching (Yin, 2003) was applied, especially when a number of interviewees were describing similar operating processes and experiences. By merging these similarities and patterns, it helps to capture patterns and mappings of the operations.

A large amount of data and information was collected through the semi-structured interviews on site with managers and operators in these companies. Due to the fact that these interviews were completed using the Chinese language, the data noted during interviews were first sorted into categories and summarised using narrative analysis, before they were translated into English and referenced accordingly.

3.4.5 Ethical Considerations

Contrary to the European and American companies, employees in the Chinese companies are not used to filling in survey questionnaires for research purposes. It is acknowledged that employees in the case companies feel uncomfortable sharing information through survey questionnaires by post, as they found it difficult to build trust on how the data would be used. Hence, in depth interviews and observations were considered to more suitable for this type of research. The researcher had clear negotiated access to the participants at the respective industrial sites who were involved with this study. Data and information were collected based on the interviewees' experience and their daily operations, and would be kept confidential for research use only.

3.5 Summary

The research structure and methodology were carried out in order to achieve the aims and objectives of this research, and answer the research question with regard to the CLSC and the CET factors in the context of the Chinese metal industry. With reference to the existing literature and methods for research strategy and process, this research was performed using the qualitative case study method with seven companies in the Chinese metal industry. There were considerations over the paradigms, the case study methodology, the selection of cases and feedbacks to ensure validity and reliability of the research findings and development of frameworks and tools. The cultural, ethical and language factors were also encountered and taken into care, so that data and information collected could be interpreted, analysed and presented appropriately as in Chapter 4 and Chapter 5.

CHAPTER 4

CASE STUDIES IN THE PRD REGION

4.1 Introduction

With regard to the aims and objectives of this research, field work and case studies were performed in the Pearl River Delta (PRD) region in the south of China between October 2005 and February 2007. This region is a concentrated area for metal production. It takes up a third of non-ferrous metal production capacity in China, and there are vibrant activities in the recycling and remanufacturing of waste, used and scraps metals and other materials. Hence, this region is a fertile area for undertaking research in this type of sector.

4.2 Industrial Fieldwork and Case Study Processes

Qualitative empirical research was carried out with semi-structured interviews and observations with local Innovation Centre and seven case companies in the primary and secondary metal manufacturing and remanufacturing sectors, as well as the distributing and logistics companies.

4.2.1 Local Government Visit

At the beginning of the field study in early October 2005, a visit was paid to the Guangdong Non-Ferrous Metal Technology Innovation Centre. It is a local government organisation for non-ferrous metal manufacturing companies mainly in Dali town, Foshan city, in the PRD region of Guangdong Province, in the south of China. Two officers were interviewed. They were briefly introduced with this research purpose and the semi-structured interview lasted around two hours. They were asked to provide general information and data about the past and current operations of the metal industry in the region (**Appendix 3**). They also expressed the local government's concerns on some of the current issues and problems faced by the industry, and some of the plans for improvement in the future. The information provided general background information and a better understanding of the metal operations in the industry. This may encourage more research to explore the forward and reverse flow of the metal industry in the region. The research findings were also sent back to these officers for their feedbacks and comments towards the completion of this PhD research.

4.2.2 Case Study: Company Visits

After the visit at the local government organisation, with the resource and accessibilities available, industrial visits were carefully planned and performed under certain time series. According to Philliber, et al, (as referenced by Yin, 2003), a list of questions is prepared, as the research is designed to deal with the four major issues:

1. Find out the questions to study;
2. Look for the relevant data;
3. Collect the data;
4. Analyse the results.

The research focus is on Small and Medium size Enterprises (SMEs) and their approaches and techniques in dealing with the forward and reverse flow of supply chain management in metal manufacturing and remanufacturing, with regard to the CET factors. A total of seven SMEs were studied in this research. The guidelines for interview questions (**Appendix 4**) in the case study companies were designed in order to find out relevant information for the research purpose. These interviews and questions were structured to acquire general information of these companies, their operating activities, market position and competitiveness, as well as the changes that companies and employees can apply for their development for managerial and operating roles. From these interviews and observations on site, the processes of these companies were mapped, with particular focus on the external interactions between the metal manufacturers and remanufacturers. The case study information are presented in Table 4.1 and 4.2.

Table 4.1 Case Study Company Background

	Company Type	**Code**	**Field of Operations**	**Turnover (RMB Approx.)**	**Turnover (GBP Approx.)**	**No. of Employees (Approx.)**
1	Logistics Provider	L_{3PL}	Distribute cargos of secondary metal and plastic materials	100m	8m	150
2	Remanufacturer (Metal)	R_{M1}	Recycle and remanufacture metal and plastic materials	60m	4m	80
3	Manufacturer (Metal)	M_M	Manufacturer of various metal hardware	50m	3.5m	100
4	Remanufacturer (Aluminium)	R_{AL}	Manufacture of aluminium bars and Remanufacture of aluminium residue materials	90m	8m	150
5	Remanufacturer (Metal)	R_{M2}	Recycle and recover secondary metals and plastic materials	60m	4m	50
6	Manufacturer (Stainless Steel)	Mss	Manufacture stainless steel products	60m	4m	150
7	Reverse Logistics Provider	L_{3PRL}	Third party reverse logistics provider	150m	10m	500

For confidential reasons, the names of these seven companies remain anonymous. And they are coded according to the nature of their operation. As listed in Table 4.1, Company L_{3PL} is a 3rd Party Logistics (3PL) company which provides freight forwarding services for import and export cargo containers. Company R_{M1} and R_{M2} operate in the waste and used metal and plastic materials recycling and reproduction operations. Company M_M is a metal manufacturer who produces metal hardware products, and Company Mss is a manufacturer who produces stainless steels products from bought in raw materials to finish products. Company R_{AL} is specialised in manufacturing aluminium bars and recently developed the remanufacturing processes of recycling and remanufacturing aluminium residues, which was focused for this research. Last but not least, Company L_{3PRL} is a 3rd Party Reverse Logistics (3PRL) which deals with the distributing, recycling and remanufacturing secondary metals and waste materials. In terms of company visits for case studies, these companies were visited between October 2005 and February 2007, as shown in Table 4.2. Research findings, process map illustrations, frameworks and tools developed from the case study research were analysed and returned to the contact persons in these case companies for feedbacks at the data analysis and writing up stage of this PhD. There were adjustments based on those feedbacks and they were refined before presenting in this thesis.

Table 4.2 Case Study Performance in Research Companies

	Date Visited	**Code**	**Revisits**	**Number of Managers interviewed**	**Number of Operators interviewed**	**Total Research Hours Spent in Companies**
1	October 2005	L_{3PL}	YES	8	7	50
2	December 2005	R_{M1}	No	2	2	6
3	January 2006	M_M	No	1	2	6
4	May 2006	R_{AL}	YES	9	6	60
5	August 2006	R_{M2}	YES	6	7	30
6	September 2006	Mss	No	3	1	8
7	February 2007	L_{3PRL}	No	3	3	8
	Total	**7**	**/**	**32**	**28**	**168**

As listed in Table 4.2, due to resource availability and accessibility, and the information required for this research, there were detailed investigations and observations in Company L_{3PL}, R_{AL} and R_{M2}. In addition to the observation in the production and operation processes, at least 50, 60 and 30 hours were spent at these companies respectively. The semi-structured interviews took place with a number of managerial personnel and staff from the operation level. The detailed list of interviewees and their information are presented in **Appendix 5**. These include the name and code of the case companies, name and position of the interviewees and their interview duration. There are also reference codes and numbers for each of the interviewees, which will be applied in the case study findings description especially when quoting their words from the interviews. For example, officer Mr. J. W. Zhou from the Guangdong Non-Ferrous Metal Technology Innovation Centre will be referenced as "(GD.01, Appendix 5)", and the managing director of Company L_{3PL} Mr. C. H. Pang will be referenced as "(L_{3PL}.01, Appendix 5)", and alike.

There are liaison between the forward metal manufacturers, i.e. Company M_M, Mss and R_{AL}, and the reverse metal dismantlers or remanufacturers, i.e. Company R_{M1}, R_{M2}, R_{AL} and L_{3PRL}. The waste, left-over, scraps, and residues are distributed and transported from the forward manufacturers to their reverse counterparts, with the help of distributors, such as Company L_{3PL}. There are also supplies of secondary metals and other materials imported from overseas, and entering the dismantling and remanufacturing processes in Company R_{M1}, R_{M2} and L_{3PRL}. Further details of these external interactions between the seven case companies will be described in the next section. It is useful for the exploration and mapping of the forward and reverse logistics processes in the related primary and secondary metal industry in the region. It also provides better understanding of the internal and external flows and operations between players in the forward and reverse supply chain. Eventually, it will help to develop frameworks and tools that would illustrate the industrial processes for both academic and practical interests, in order to achieve the aims and objectives of this research.

4.3 Fieldwork Findings

This section presents the data and information gathered and summarised from the empirical fieldwork study. It is divided into two parts, including the general background information of the primary and secondary metal industry in the region, according to the semi-structured interviews with the local government organisation officers. In addition, there is also background information of the seven case companies. With reference to Kvale (1996), a combination of approaches for data analysis is applied, including condensation, narrative and interpretation (translations from Chinese into English).

4.3.1 Background Information

Dali town (as indicated in the map in Figure 4.1) is located in the PRD Region of Guangdong province, in the south of China. It has been a famous town for primary and secondary metal manufacturing industry. Due to its great concentration on aluminium production, it is named "The Biggest Aluminium Town in China".

Figure 4.1 Location Map of Dali, China

The Guangdong Non-Ferrous Metal Technology Innovation Centre is a non-profit government organisation who serves non-ferrous metal production in the region. It works closely with industrial organisations such as the Nanhai Aluminium Profile Association and Guangdong Quality Supervision and Test Centre. From the official data provided by the officer (GD.01, Appendix 5) from the centre, there are more than 2,000 companies (either government or privately owned) in the town that are engaged in the production of aluminium products, particularly for the aluminium profiles for the construction sector. In addition, there are large scales of production of copper, stainless steel, zinc alloys, cast aluminium alloys and ironware materials. The total output of these productions is more than 2 million tons per year, which makes up 50% of the supply in Guangdong province, and 35% of the total supply in China. In particular, the output of aluminium profiles for the construction sector is more than 1 million tons per year.

In 2004, the output of non-ferrous secondary metal in China reached 3.1 million tons, which created a total industrial value of 68 billion RMB (approximately 5 billion GBP). There are large numbers of organisations in the Chinese secondary metal industry, including over 5,000 secondary aluminium, 2,000 secondary copper, 400 secondary lead and 200 zinc companies (GD.02, Appendix 5). The large amounts of secondary resources come from the collection and recycling activities from China and abroad, and the number has been increasing gradually each year. China has become the second largest country of secondary metal production in the world, following the USA. In 2003, the secondary aluminium output was 1.45 million tons; and by 2004, the output quantity was 1.7 million tons, which was a 17% annual increase. And for secondary copper output, it was 0.93 million tons in 2003, which also had a 14% increase and reached 1.06 million tons by the end of 2004 (The World Bank Group, 2006).

In recent years, there has been increasing development of secondary metal industry in China, in order to compensate the resource shortages of raw materials. As a result, there are more and more applications of secondary metals in production, providing that they meet the quality criteria for manufacturing standards. It is estimated that there will be rapid growth in recycling and dismantling of EOL vehicles and household products in order to recycle and reuse the valuable and reusable materials. The secondary metal industry processes is relatively efficient. There are processes from the collection of waste, used and scrap metals to the separation of different materials, then onto fusion and melting which eventually form the secondary metals. The reverse logistics supply chain has also been developed on the basis of large scale aluminium production in Dali (GD.01, Appendix 5).

Specifically, there are different channels of collecting waste, used and scrap metals from various places and industries within China and also from overseas to Dali town. The estimation of reverse waste, used and scrap metal collections from within China had reached 1 million tons per year. And the imported amount from overseas is also more than 1 million tons per year, which is a third of the total import of junk metals in China. There are around 300 registered companies and organisations and more than 30,000 practitioners in the secondary metal industry. 100 of these organisations had been appointed by the Chinese Department of Environment as the qualified specialists in importing junk waste metals such as copper and aluminium (GD.02, Appendix 5). Subsequently, the collected junk metals from production wastes, as well as from the EOL machineries or daily products would be sorted and dismantled according to their characteristics and usages. Then they would be distributed and sold to the next level of operations in the reverse supply chain, for recycling, regeneration and reuse. Dali has become one of the biggest markets for bulk remanufacturing of waste, used and scrap metals. It has attracted a large amount of junk metals from all over China and worldwide. As a result, local government need to develop a sustainable market for managing and controlling the CLSC activities (GD.01, Appendix 5).

4.3.2 The Industrial Environment

The reasons for the active development secondary metal industry in Dali are strongly linked to the economic development in the PRD region and mainland China, as well as development in the international environment.

4.3.2.1 Government Concerns

Since the reformation process in the late 1970s, there have been rapid improvements in the Chinese economy and social living standards. Resources such as non-ferrous metals that are largely used in the modern society development have growing demands in manufacturing and construction sectors. The fast growing economy in China has led to dramatically increasing consumption of resources and increasing pollution to the environment. On the other hand, there are resource scarcities, especially for non-ferrous metals. As a result, managing and utilising non-ferrous metals is essential for maintaining the development of the economy and society. The Chinese government had established a list of regulations and legislations such as the Long Term Development Programme for the Non-Ferrous Metal Industry in China, and the Control of Solid Waste Pollution to the Environment (GD.01, Appendix 5). Details are to be developed in order to present better procedures to plan for the long term development for the metal industry. These include utilisation of primary and secondary metals, other resources and raw materials. In addition, from the environmental protection point of view, these would minimise the pollution of waste and used metals to the environment and also the pollution during the recycling and remanufacturing processes.

The Chinese government has been more aware of the development of the CLSC. It aims to facilitate better circulation and utilisation of resources, which ultimately lead to cost and resource savings, and reduction of pollution. The local government in Dali has been supporting the secondary metal industry, providing better encouragement and vantage for its development.

4.3.2.2 Trends of Market Development

The fast growing economy in the PRD region has provided great support for the development of the secondary metal industry. It meets the need of the existing market environment and helps to upgrade the level of manufacturing operation. The PRD region is largely influenced by international trading activities. Back in the early 1980s, the PRD was the first region in China which benefited from the openness of market economy policy. Businesses and operations in the region have experienced great improvement and flexibility in reacting to changes in the market place. The PRD region has drawn large amount of investments from Chinese and multinational organisations to manufacture their products in the region, and then transport and sell their products globally. Consequently, the PRD region has attracted the resources and finance both from China and overseas. In addition, millions of low cost workers from remote towns and villages all over China have gathered into the region, which play an important role for the labour supply in manufacturing activities. These are the indispensable external factors which help to create better-developed infrastructure for manufacturing. With the effective management of these external factors and the internal basic features such as land and building facilities, the PRD region has been integrating these factors for higher-level industrial expansion. This includes the forward and reverse logistics system developments which eventually lead to a CLSC. Especially as the secondary metal industry provides foreseeable benefits and resources to the environment, it can also be developed further based on the congregation of finance capital and labour intense factors. Hence, there are strategic advantages for improving secondary metal industry in order to achieve the objective of resource utilisation and regeneration for reproduction, and long term sustainable development.

Statistics show that since the 1980s, there have been rapid increases of scrap metals for import, dismantling, trading and remanufacturing. Currently, there are around 30,000 workforces in the secondary metal industry dealing with the trading, dismantling and remanufacturing activities, which recycle and reproduce at least 500,000 tons (per month) of scrap metals, including secondary iron, steel and aluminium. Dali has been appointed as the core area for non-ferrous metal production in the government's development plan; along with few other areas in the PRD region, as the centres for scrap metal collection and remanufacturing processes (GD.02, Appendix 5).

On the other hand, there are several other places in China which have their own specialities in secondary material remanufacturing. Some of them are involved in waste or used engine collection for reuse and remanufacture, others are mainly dealing with recycling and dismantling used household electronics such as personal computers, televisions and refrigerators. For example, in Taizhou near Shanghai, there are 40,000 workforces dealing with the collection and dismantling old television sets. They dismantle 2 million tons of televisions annually, from which around 200,000 tons of copper, 120,000 tons of aluminium and 1.4 million tons of steels are collected for reuse (GD.01, Appendix 5). The re-usage of secondary metals for production greatly increases the utilisation of resources, especially for those scarce non-ferrous metal resources.

4.3.2.3 A Leading Operating Industry in China

In recent years, increasing amounts of large size companies are aware of the importance of quality in production, they are actively integrating quality management in their manufacturing processes to achieve high standards in operation such as ISO9000, ISO9001, and QA9000 qualification. Some companies even reached the ISO14000 environmental quality approval (GD.02, Appendix 5). Corporations are aiming for "mainly high automation with additional human assistance when necessary" (GD.01, Appendix 5). These applications should also apply to the reverse logistic processes for highly automation in manufacturing operations to achieve better quality management. However, in some of the case study companies, managers did express their opinions upon the implementation of automation in their remanufacturing process as not being applicable in the near future. There are a number of reasons. For example, due to the size of their operation, the complexity of products and parts they receive for dismantling, as well as the availability and capability of machineries for dismantling and remanufacturing processes. Therefore, some of the companies are still relying on lower cost manual operations rather than investing in expensive machinery systems.

4.3.3.4 The Logistics Service Industry Development in Dali

From the information collected during this research, there has been development in the supply chain operations. Firstly, there are developments of logistics and supply chain infrastructure. It is about "location, location, location". Dali has a supreme location advantage, as it is only 10 kilometres from the Class One port in China – Nanhai Pingzhou. There are 3 container yards and customs nearby, making the import and export business activities very convenient (GD.01, Appendix 5). Dali is also the south china centre for the Shanghai Futures Market. All trading activities are operating in the area of Dali and its suburbs. Hence, Dali is one of the most important logistical information platforms for the Chinese non-ferrous network (GD.02, Appendix 5).

Secondly, Dali is also the research and development centre for non-ferrous metals in Guangdong province. The R&D centre provides channels for cooperation between academic and industrial organisations, which helps to improve the technology development and tackle key problems in production operations and techniques (GD.01, Appendix 5). It also provides an information and communication channel for the industry, with the latest news and development updates of knowledge and technique development in production, quality management and patent issues.

Thirdly, through the industrial network association, the network for waste and used metal industry had been formed. There have been importing and exporting operations in the industry guided by the association, which assists companies to start market exploration and develop managerial strategies. For instance, there is cooperation between the central control centre and its members in developing techniques and managing processes for solid waste material dismantling, remanufacturing and disposal. The centre also helps to build joint cooperative relationships between metal manufacturers and remanufacturers, in order to assist them in dealing with their production wastes and returns for recycling and proper disposal.

4.4 Case Company Information

In this section, the findings of the seven case companies are described in details. These include the general background information of the case companies, their operating size and areas, as well as their manufacturing and remanufacturing processes. In particular, the focus will be on the CET factors and the relationships of these companies in the CLSC. According to the operating natures and similarities of these case companies as illustrated in Table 4.1, these case companies are grouped and their information will be summarised and presented accordingly:

Group 1. Metal Product Manufacturers – Company M_M and Mss

Group 2. Metal Product Remanufacturers – Company R_{M1}, R_{M2} and R_{AL}

Group 3. 3rd Party Reverse Logistics Providers / Distributors – Company L_{3PRL} and L_{3PL}

The information, quotes and references from interviewees, both from the managerial level and operational shop floor level, have been interpreted from Chinese into English. They are presented in Italic type and referenced according to their codes in **Appendix 5**.

4.4.1 Metal (Hardware) Manufacturer – Company M_M

Company M_M was set up in the mid 1980s. It started up as a small family business and had grown into bigger size production with one plant located in Dali. It has just under 100 employees. It plans to set up another new production plant in the central coastal region of China near Shanghai, which is another large market base for metal manufacturing industry. It specialises in producing small-size metal hardware for various purposes, using different sorts of metals such as copper, aluminium, iron, stainless steel and tin. These various types of metal hardware are supplied as components for its customers to produce different items such as lighting products and cooking equipments. Company M_M performs its operations on bought in metal and materials, and carries out forging, rolling and casting operations. The finished products are made from various metals and are cut and finished according to different customer requirements. Each year, it produces a large range of more than 1,000 types of metal hardware which are around 110,000 tons in weight.

4.4.1.1 Technology

During the interviews with the production manager and shop floor staff on site, they described a clear picture of the development of the company. At the start up stage of the business, the majority of the operations were done by manual operations. Very limited level of machinery operations were performed using second-hand aged machineries imported from developed countries such as the US and some other European countries. As the business grew bigger with more workers on the shop floor, better ways of manufacturing operation were developed. Since the beginning of the 1990s, the company has been experiencing increasing demand and sales for their products, more varieties of products and components were required by their customers from the region and other parts of China, as well as overseas companies. Hence, it invests more on improving the machinery equipments for production, which assist higher complexity of casting and cutting on more diverse metals and metal alloy products. According to the production manager,

> "With the higher level integration of machinery and computer systems, our production equipments can provide better design and more accurate cuttings for our products. The productivity has been increased dramatically compared to the manual production. As a result, we are now able to produce various products within a short lead time. However, to a certain extent, for some of the operations we still prefer to use our skilled labours which are with higher flexibilities, especially when changing to new production operations, cutting and surface finishing some complex

> products. Some of the automated equipments are too expensive.” (M_M.01, Appendix 5)

4.4.1.2 Environment

Since the operations involve casting and cutting of metals, the utilisation of metal materials are essential for Company M_M to try and keep down the costs. Therefore, it investigates for better design and utilising the cutting of metals to minimise left-over and waste. The production manager said that he was pleased with the cooperating operations developed in the region:

> “From time to time, we would have people from the dismantling and remanufacturing plants knocking at our factory doors to give us a deal on collecting our left-over parts, with a genuine good price on those wastes. That was how we started to develop a long term cooperative relationship with Company R_{M1} and some other companies for collecting our left-over materials weekly or monthly. Although we have been working so hard to reduce our left-over materials during our casting and cutting processes, there are still at least 10% of wastes and scraps from out production. However, we can recover some of the costs by selling those left-over or waste materials to the recyclers. They provide the workforce coming to our plant to take away the left-over materials, so that our workers can concentrate on our own production. We only need to provide one small size corner of our factory plant to store up the waste materials and they would be collected from time to time. It also saves our time and costs on handling and transporting those wastes to landfills for industrial wastes.” (M_M.01, Appendix 5)

4.4.1.3 Customer

In terms of the input metal materials, the requirement and the quality standards of the finished product would need to be taken into consideration. In order to maintain the quality of the casting and cutting of components, the production manager responded that as long as the bought in metals meet the metallic requirement, it does not matter if they are primary or secondary.

> "Some people tend to think that secondary metals are much cheaper than the primary ones. However, from our experience, it might not always be the case. We do sometimes purchase regenerated secondary metals or materials when they are not used as the essential components for certain products. Some of the good quality secondary materials are only a little cheaper (than the primary ones). It might be true that we can still save costs on those materials, but in the case of producing metallic bearings for example, we would definitely use the primary metals which provide better and more stable metallic requirements. Hence, we can ensure the quality of finished products reaching high quality standard." (M_M.01, Appendix 5)

4.4.2 Metal (Stainless Steel) Manufacturer – Company Mss

Company Mss was founded in 1992 as a small family owned business. It has been expanding towards a medium size company. It is located in an industrial park and has factory facilities of over 80,000 square meters. The main operation of Company Mss is to produce stainless steel plates and pipes. It has over 2,000 tons of plates and pipes in stock and nearly 100 pieces of state-of-the-art plate processing equipment on site. It produces a large range of stainless steel products from different shape and length of stainless steel pipes and parts for furniture manufacturing, decoration and construction purposes. Its production capability has reached 300,000 tons per year and has been growing at an annual rate of 10%.

4.4.2.1 Technology

The price of metals fluctuates both in China and overseas. There are many influencing factors such as market demand, supply of primary and secondary metals, various industrial regulations and activities. Therefore, maintaining good relationships with suppliers for the purchase of required input stainless steel for production is one of the essential issues for Company Mss. In addition, because of the competition in the market, it is vital for companies to develop efficient production system and advanced production operations for their manufacturing activities. Hence, Company Mss has been investing in developing its equipments and machineries for producing high quality products. It has a team of engineering experts who concentrate on the R&D and the improvement of manufacturing machineries. For example, the team has developed one of the best surface finishing machineries in the industry which is able to provide the 'mirror' finishing for their stainless steel products. In their words,

> "We must improve every day. Not only in improving our machinery for higher efficiency and reduce scrap and wastes during production, but also in producing innovative products that meets our customers need." (Mss.03, Appendix 5)

> "*... as the world's changing so quickly and* we are proud to see the progresses in our productions. Look at all those new products we manage to produce, it is exciting!" (Mss.01, Appendix 5)

4.4.2.2 Customer

Different from Company M_M where it focuses on relatively small component cutting process and with a more concentrated plant layout, Company Mss has larger production area and is separated into three parts including the input stainless steel storage area, production area and finished product storage area (**Appendix 6**). The bought in stainless steel materials are stored in large rolls or separate sheets, and are transferred to the production area where the stainless steel sheets goes through machineries. They would be pulled and shaped into long pipes with different dimensions for further cutting according to customer requirement. After that, the finished products will be transported and stored at the warehouse before they are packaged and dispatched. According to the general manager (Mss.01, Appendix 5) of the company, they have a large network of suppliers of materials and customers within China. However, since they have high demand for good quality finished products, they purchase good quality stainless steel sheets mainly from the north of China, which are transported by train or ship to the local station or port, and then distributed to their factory door. He said, "The recycling and recovery of stainless steel is very common in the industry. In order to provide good quality products, we only accept the high quality stainless steel for our production, regardless to primary or secondary forms. As we are now expanding our market to overseas in countries such as the US, Europe and Middle East countries, our customers would certainly appreciate our high quality products base on good quality materials. We will do all we can to make sure that the raw materials we purchase is up to standard, so that we can produce high quality products based on them." (ibid.)

4.4.2.3 Environment

Since the production of Company Mss is about shimming and shaping on bought in stainless steel sheets into pipes or cubics, the left-over materials from production are easier to be collected and managed than those produced in Company M_M. In addition, since Company Mss only deals with stainless steels, although there are different kinds of stainless steels in terms of hardness, the varieties of stainless steels are far less complicated than waste metals from the production of Company M_M. Hence, the separation of the left-over metals is much easier. Company Mss has established cooperative relationship with Company R_{M2} in dealing with the left-over stainless steel. They would transport their collected left-over or scrap stainless steel to Company R_{M2} on a weekly basis. Company R_{M2} would pay for those secondary materials according to the specifications and the weight of the stainless steel.

During the interview on site with the production manager, he mentioned that,

"Since we have established stable long term production processes within our production system, the rate of scrap and waste through our machinery production is monitored and being kept low at under 3% (an average of 25 tons per day). The input quality and quantity of stainless steels are carefully managed and controlled which enable us to keep our production costs low with better utilisation of materials and production efficiency **…** Most of our scraps are usually produced at the beginning of changing production line between different sizes and dimensions of products. However, since we are expanding our customer bases and producing larger range of products, quite a significant amount of scraps and wastes are produced at the early testing stage. These are inevitable wastes. However, as long as we could ensure accuracy right at the start of the production, and adjust our machinery for the manufacturing processes, the majority of products produced would be meeting our high quality standard and our customer satisfaction. *In the case of our newly developed 'mirror' finishing stainless* steel cubic, we did have to carry out a lot of testing before producing those perfect finished products which are highly appreciated by our Italian customers for their furniture production." (Mss.02, Appendix 5)

Because of the cooperative relationships between Company Mss and R_{M2}, the information of scraps and wastes specification are shared between the two companies, which enables Company R_{M2} to have much better knowledge and understanding of the scraps it deals with. As a result, it can plan better for the remanufacturing processes or further sales to its customers according to the wastes it receive from Company Mss.

4.4.3 Metal Remanufacturer – Company R_{M1}

Company R_{M1} was founded in the early 1990s and collects scrap and waste metals and other materials from industrial and daily activities. It has an operation site of 60,000 square meters. Its main business operations include dismantling metal, as well as plastics products and parts. 90% of the dismantling and sorting processes are done by manual operations by hand or with tools. The separated components and parts would be grouped and resized through basic machineries and then sold to other remanufacturers for further physical or chemical recovery and regeneration operations. Some others are sold to manufacturers and to be used as raw materials for their production. For this research purpose, the processes of metal dismantling, separation and recovery were observed.

4.4.3.1 Customer

Company R_{M1} has close relationships with it suppliers and customers. 80% of the used or waste metals and plastics are imported from overseas countries such as the US, UK and Canada. It also established local collections for manufacturers such as Company M_M in the region. By maintaining close relationships with it suppliers, Company R_{M1} can benefit from a relatively stable supply of secondary materials and wastes for its dismantling and recovery operations. As mentioned by the production manager,

> "It is very important that we have a stable supply of materials from our suppliers, from local and overseas, so we can schedule our workers and operations more efficiently. We want to get good quality used or waste materials so we can sell them for higher prices after the dismantling and resizing processes. That is why most of our materials are imported from developed countries, from which the used materials or products are with better reusable quality ... However, as you know that the prices of metals fluctuate a lot, and the demand from our customers change all the time. Therefore, we have to face the risks when buying in our materials, the transportation time and costs, as well as our production lead time and do our best to react quickly in respond to the market." (R_{M1}.02, Appendix 5)

From the observation on site, the collected secondary metal products and parts are with different sources and characteristics. Some of the imported materials arrived in containers from overseas were sorted at the source and were packaged in batches. Some of the metals are in mixed status and require sortation before further dismantling and grouping. Some of the pictures taken on site are shown in **Appendix 7**.

4.4.3.2 Technology

The production processes in Company R_{M1} are mainly the sortation of imported or collected metals from its suppliers. These operations are largely done manually. The managing director described that although they understand there would be a trend for the application of technology in the industry, it would not be feasible for implementation in the near future, as he mentioned that:

> "We did visit our suppliers in the Western countries and see their production lines for sortation. However, for most of the supplied materials we collected, almost all of them are with different kinds of metals and plastics or other materials, it would be impossible to sort them by total automation. It would just be too expensive especially as we are only a small size company. We can easily use our manual labour for the operations which can be so much more flexible and cheaper. At the moment, we only need the magnetic machine for sorting, and cutting machine for chopping metals into smaller pieces during the resizing stage. Personally, I do not think that we would implement more mechanical production system in the near future." (R_{M1}.01, Appendix 5)

4.4.3.3 Environment

Due to the nature of Company R_{M1}, its operation is sorting and dismantling bought in secondary materials and products, certain amounts of pollution had occurred during the operation. However, since it is a small size operations and it does try to reduce the wastes from its operations in order to maximise the percentage of material recovery, the pollution is fairly limited. On average, there are around 160 containers of materials coming in every month. The lead time and turnaround time of sorting products is very short. The workers are working in shifts depend on the quantity of incoming materials. They can dismantle and sort out all the metals or plastic materials from one 40 feet container (Maximum 26 tons) within two or three days to a maximum of one week. As the company helps manufacturers such as Company M_M deal with their left-over or waste materials, it increases the reusability of those metals which would otherwise be wasted in landfills. The sorted metals would be sold to the next level of remanufactures for physical or chemical regeneration and produce secondary metals. Some of them would be bought by Company M_M again, as raw materials for their production inputs. For example, to produce metal keys or other products which do not require high quality metals. Company R_{M1} is motivated by the profit it gains from buying in low-cost used and waste materials while selling them with higher price after remanufacture processes. It contributes positive impacts on the reverse supply chain operation of metal remanufacturing. It is one of the many business operation examples in the region.

4.4.4 Metal Remanufacturer – Company R_{M2}

The size and operating nature of Company R_{M2} is very similar to Company R_{M1}. It is also a dismantler and remanufacturer for secondary metal products. Company R_{M2} also deals with other used and scrap products and materials which contain plastics, wood and paper. For this research purpose, the operation of metal dismantling and separation were observed, in addition to the data and information generated from the semi-structured interviews with employees from both the managerial and operation level. The operating site of Company R_{M2} is 70,000 square meters and it employs just under 100 workers working with a two-shift system daily. It deals with around 150,000 tons of waste and used products and materials annually, which are around 180 containers per month. 85% of its dismantling, sorting and grouping operations are done manually.

When a container of mixed metals comes into the factory, workers would firstly unload the cargo container at the sorting area. Similar to the description in Company R_{M1}, the waste and used metal products and parts can be in sorted packs tied up or in loose status. Therefore, they need to be put together according to their nature in order to ease the dismantling operations. The operation managers would then identify the groups of incoming products and parts, and allocate the areas for the operations to carry out. Then the operators will be working in teams under a team leader in dealing with their dismantling tasks. The process map of Company R_{M2} is illustrated in Figure 4.2.

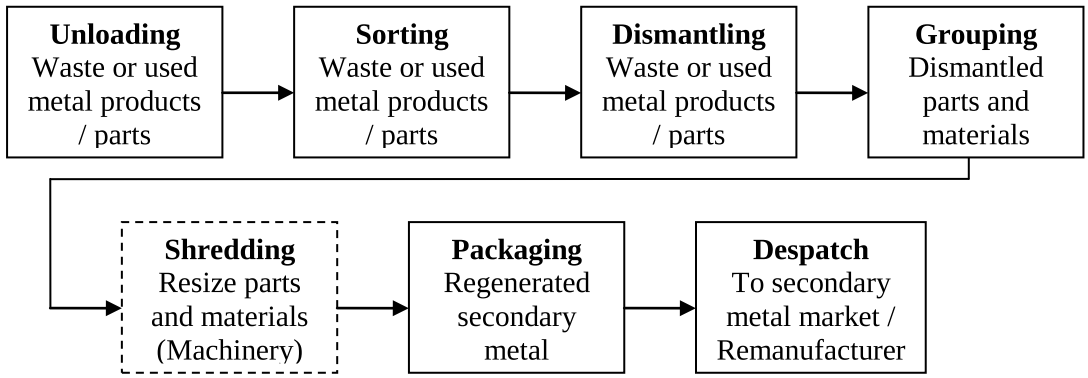


Figure 4.2 Process Flow of Metal Remanufacturer - Company R_{M2}

There are mainly two types of incoming products and parts that operators have to deal with. For those products of different types coming in batch, workers have to dismantle them with tools, separating each parts and components and grouping those screws, nails, parts and materials accordingly. For those complicated products or parts which cannot be dismantled by hand, they would be put in the shredding machine for cutting. The resized materials would be first separated by hand with the help of magnetic tools and then grouped together. These are the main operations for separating and sorting ferrous and non-ferrous metals. After all the products and parts are dismantled and grouped, they would be put through the shredding machine for resizing if a smaller size is required. Or for those screws, nails and parts that can be reused without remanufacturing, they would be grouped and packed for reselling.

On the other hand, for those incoming materials which are already grouped and packed, workers only need to double check and remove the impurity materials. These materials would then be sold straight away as a pack to the next level remanufacturers unless further dismantling and sorting is required. For instance, for the stainless steels scrap coming from Company Mss, since Company Mss would provide information of the types of the stainless steels, they would be pressed into solid blocks or shredded into smaller sizes then sold to other stainless steel remanufacturers for re-melting and regenerating of secondary stainless steels.

4.4.4.1 Customer

Similar to Company R_{M1}, a large percentage (>70%) of the incoming waste and used products and parts for the remanufacturing operation at Company R_{M2} are imported from overseas. Hence, maintaining a stable supply chain network is essential for the company to operate its remanufacturing processes, as well as dedicating and scheduling the operating teams. By working with individual manufacturers such as Company Mss which provide detailed information for the types and characteristics of the scrap and used metals, Company R_{M2} would increase the efficiency for sorting and grouping those metals. As according to the operation manager,

> "It is so much easier when dealing with those incoming scraps and materials which we have more information about what they are. Then we can simply group them together, resize them and sell them to our customers and passing on the information we receive from our suppliers ... That is why, for example, we are working well with Company Mss in dealing with its stainless steel scraps. We are acting as its collecting agent and those scraps can be quickly sorted and sold onto the remanufacturers for re-melting, or to other stainless steel manufacturers for their operations." (R_{M2}.03, Appendix 5)

With regard to the customer network for selling the dismantled and sorted metals and materials, the general manager mentioned that:

> "As there are high demands for secondary metal in the (Chinese) market, all of our recovered metals are sold in the secondary markets. Around 80% of those secondary metals are sold locally in the PRD region, and 20% of them are sold to customers in other parts of China ... We do come across variances between those imported metals. For example, different countries use different type of glue or paints on their metal products. The cleaning and removing of these impurities are essential for maintaining the high quality secondary metals after the remanufacturing processes. However, the identifying and separating of those impurities take up a lot of time and

> effort. Since the costs of labour and machinery for the separation in those developed countries are very high, that is why those wastes are travelling all the way as mixed metals and be sent back again in remanufactured pieces after the processes here on our site." (R_{M2}.06, Appendix 5)

4.4.4.2 Environment

From the observation on site, Company R_{M2} has designed its plant into different areas for dismantling and remanufacturing different kinds of metals and materials. There are workshop areas for sorting different metals, plastics, wood and paper products or parts. Each workshop is operating in a small work flow so that the incoming wastes and materials can be sorted at one corner; separated and grouped and then pass onto the conveyors or machines for shredding and resizing. The optimisation of production flows minimises the wastes and scraps produced especially during the dismantling and transporting processes. It also minimises the need for manpower and energy required for those processes.

In addition, from the information provided from the interviewees (R_{M2}.05, R_{M2}.06 and R_{M2}.08, Appendix 5) and the observations on site, Company R_{M2} tends to have strict requirements on the types and quality of the incoming wastes and used products from its suppliers. The containers it receives normally contain single types of materials and parts. According to the General Manager,

> "We normally buy in less mixtures of materials in the containers, and require our suppliers to provide as much information as possible, so that we can sort out those wastes and scraps within a very short lead time, or some of them can be sold straight onto our customers. Hence, the waste and scrap through our operation is minimised." (R_{M2}.06, Appendix 5)

With regard to the environmental issues, the owner of Company R_{M2} said:

> "To some extent, you are right that we are operating to gain profit from our operations, as all of the business would do. However, at the same time, by recovering those scrap metals and plastics, we are helping to save the environment. Otherwise those wastes would be dumped into landfills or even into rivers or countryside. As you can see, all the recovered materials can be reused for manufacturing metal and plastic products, which is the contribution we do for the society, right?" (R_{M2}.01, Appendix 5)

4.4.4.3 Technology

Although the majority of production is done by manual operation which requires low level of skills, Company R_{M2} does consider investing in higher level machinery which would increase its competitiveness in the market for its regenerated products. According to the owner of the company,

> "We do invest in machineries which enable us to produce better quality regenerated metals and plastics, so that we can compete better in the market with other companies. Our products are even exported back to those developed countries, which is not possible for most of other companies in the area. They (secondary metals) would need to meet the high standard requirements for those overseas buyers. Although it can be very expensive to purchase those machineries for our production, we do see the return on investment for the implementation of technology and machinery systems for our processes. Especially as we are expanding our supplier network and trying to stabilise the quantity of our incoming wastes and materials, those systems will increase our productivities while handling larger quantity in the long term." (R_{M2}.01, Appendix 5)

The process map for company M_M, Mss, R_{M1} and R_{M2} is illustrated in Figure 4.3.

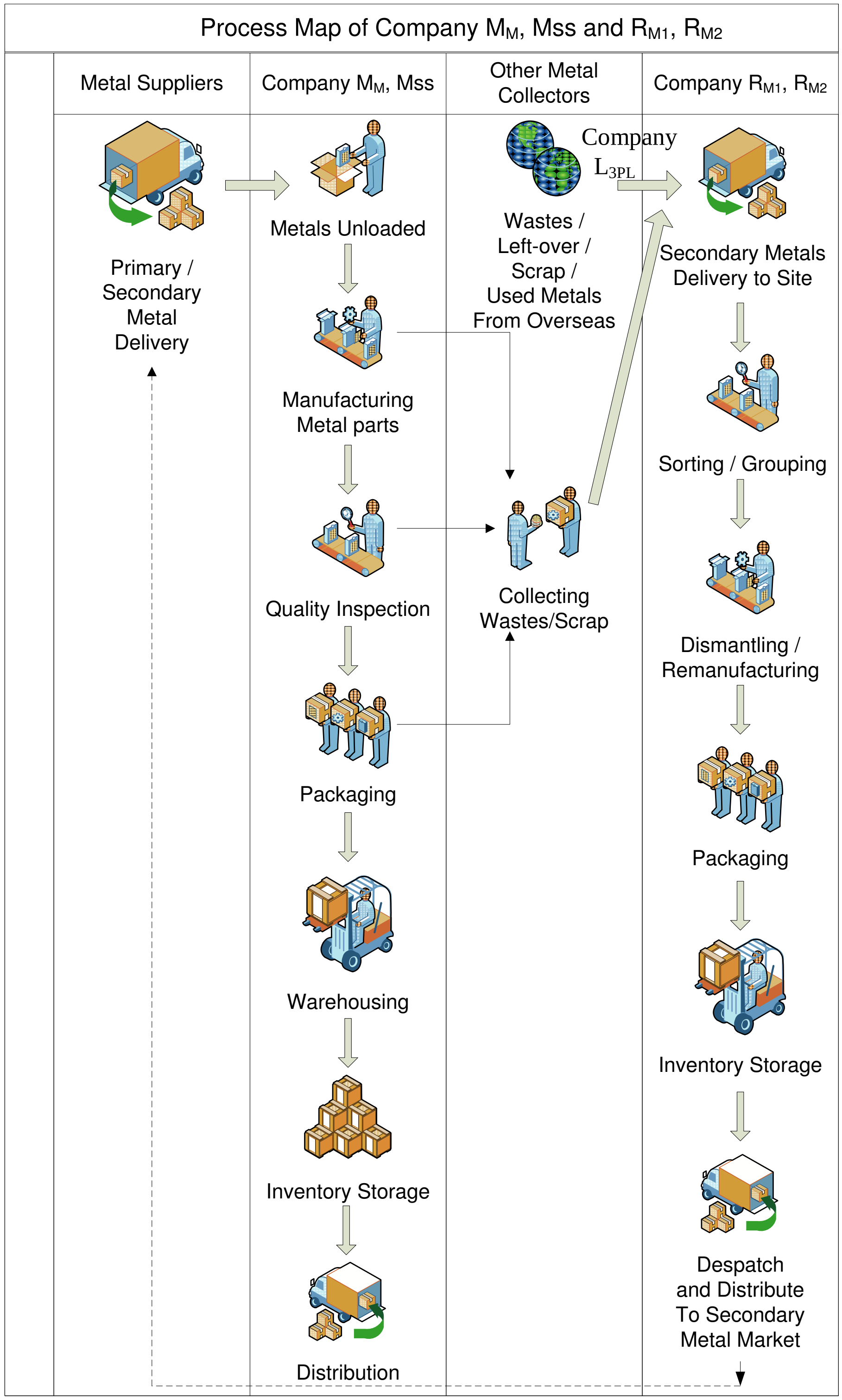


Figure 4.3 Process Map for Company M_M, Mss and R_{M1}, R_{M2}

4.4.5 Aluminium Manufacturer and Residue Remanufacturer – Company R_{AL}

Company R_{AL} was set up in the late 1980s as an aluminium manufacturing company in Dali. It is a family business operation founded and managed by three brothers. At the beginning of their business, they brought in second-hand machinery from European countries for aluminium bar production. It is through the very basic and traditional processes where aluminium ingots are extruded through a die and then being cut into individual aluminium bars or pipes. The operation technology, process and capacity have been improving dramatically since the 1990s. Similar to other businesses in the aluminium manufacturing industry in Dali, better methods of production are developed. Company R_{AL} also invested in its production machineries and systems, which enable higher level of extrusion, forging, casting and surface finishing quality for its products.

However, according to the general manager from the manufacturing of aluminium department of Company R_{AL},

> "We are aware that during the aluminium production, there are at least 30% production wastes and residues occurring together with the emission, especially during the extrusion process. 20% of those production wastes are reusable and are collected; however, at least 10% of the residues are mixed with other materials and water which is very difficult to recover." (R_{AL}.04, Appendix 5)

As there have been increasing demands for aluminium products, it would create severe problems if those tons of hazardous sewage and wastes were not dealt with properly but being poured into landfills. The three owners of Company R_{AL} believe that there must be ways for further recovering aluminium from these sewage and wastes. In doing so, it will not only help to reduce the damage to the environment, but to increase the utilisation of raw aluminium materials for production. Therefore, they carried out R&D in the company, as well as established research relationships with a local university in order to develop feasible methods for recovering those aluminium sewage and residues from production.

Although the cooperation between industrial practitioners and academics are reasonably good in the Western developed countries, this was one of the pioneering projects in China. During the three years research period, Company R_{AL} has been collecting and storing wastes and residues from its production, as the research source for its patented remanufacturing method development. As the company finally set up a subsidiary department for aluminium residue remanufacturing in 2006, these large quantity of wastes and residue collections went through the system for testing and remanufacturing. They were then being converted into by-product – aluminium hydroxide [$Al(OH)_3$] and the non-hazardous finished products – aluminium oxide [Al_2O_3]. $Al(OH)_3$ can be reused in Company R_{AL} for its aluminium production, while the final crystallised powder Al_2O_3 can be sold to other productions such as ceramic manufacturing as input material. The technology of converting hazardous aluminium residues into non-hazardous reusable materials has been a huge success for the company. As a result, it receives hazardous wastes and residues from many other local aluminium manufacturers. The remanufacturing process does not only provide a free solution for those manufacturers to dispose their hazardous wastes, but also generate profits for the company as it receives those free raw materials for aluminium residue remanufacturing processes. There is pure profit for Company R_{AL} selling the finished products to other manufacturers.

4.4.5.1 Customer

At the research interview, one of the owners of the company talked through the history of Company R_{AL} and its operations. At the time when they started up the business, their customers were only the local aluminium product manufacturers with low levels of production capability and minimum requirements for their aluminium products. Therefore, the bars and pipes produced in Company R_{AL} were not of high industrial quality, and the machinery system for production was lacking behind. In order to improve the production capability and quality, it was a necessary adventure for the company to import second-hand machineries from European countries which provided much better extrusion, forging, and casting functions (R_{AL}.01, Appendix 5). With further investment and development in production system and automation, Company R_{AL} has become one of the leading SMEs in the area which produces more varieties of aluminium products to meet higher customer requirements. The customer network of Company R_{AL} expanded to the greater PRD region, as well as other parts in China and even overseas. The manufacturing capacity has reached 800,000 tons per year, which is a large figure for a SME company operation (R_{AL}.04, Appendix 5).

Customer satisfaction is one of the most important motivation and incentives for the company. Higher levels of machinery systems and technology have been implemented with the aim to improve production lead-time and product quality. Hence, Company R_{AL} has been actively developing ways for improving its production standard, efficiency and quality, in order to maintain good relationships with its long term customers and to establish new networks with more customers from different region. By establishing close relationships with customers, it also enables it to react quickly to the change in the market, to produce-to-order and to minimise the inventory of finished products on site. As a result, Company R_{AL} has been one of the most competitive SMEs in the aluminium manufacturers in Dali, and has been expanding its production to meet increasing customer demands.

4.4.5.2 Environment

As mentioned in the interviews by the owners of Company R_{AL} and also the production managers, environmental concern is one of the most important issues throughout the development of the company. Another owner of the company mentioned:

> "We clearly understand that the production of aluminium alloys create hazardous wastes and residues which can be very dangerous to the environment, in addition to the health and safety of our workers and the local air condition and water quality. Dali has become one of the most polluted towns in the PRD region because of the large amount of aluminium production and inappropriate disposal of manufacturing wastes and sewages. We certainly recognise our responsibilities to the social health and environmental protection. Therefore, we always try to reduce the amount of wastes during production and be very careful in disposing

> our production wastes and residues. Since the fast growth in our production quantity, there are considerable large amount of wastes and residues created during our production. We were looking for ways to control the hazardous damages from our production to the environment. We felt that the government could only provide very limited solutions and there is an urge to solve the pollutions from our production. That is why we invest in our own R&D. It is also a way for us to control and reduce our production costs, as well as environmental disposal costs." (R_{AL}.02, Appendix 5)

The third owner of the company, the youngest brother of the family, is in charge with the subsidiary department for the aluminium residue remanufacturing process. He leads a team of engineers of the company, together with professors and researchers from a local university that are researching on the project of developing remanufacturing processes for aluminium residues. At the start of the project, they took the wastes and residue samples for lab research and apply chemical theories in order to purify the residues into non-hazardous materials. Then the group finalised the process and results and started planning the actual industrial operation processes. The aims and objectives of the industrial operation are to recover as much aluminium alloy in the residue and sewage as possible, and eliminate pollution and hazardous objects during the remanufacturing process. Most importantly, the operation must be feasible in practice and can be carried out in batch and large capacity production. As described by the third owner of the remanufacturing plant,

> "The fact that we are a company specialised in aluminium alloy production allows us to apply our expertises and knowledge in the manufacturing of aluminium products. Therefore, we can provide better insight and knowledge in developing ways to recover residues and wastes created from our manufacture processes. Together with the academic knowledge and lab research provided by the university, we can develop better solutions for the remanufacturing processes. We really value the cooperation with the

> academia and we would certainly be in close relationships for further development in the coming future." (R_{AL}.03, Appendix 5)

4.4.5.3 Technology

The investigation of this research focuses on the techniques of the remanufacturing processes developed by Company R_{AL}. The company invested in a new plant (70,000 square meters) in a newly structured industrial park at the suburb of Dali. It developed machineries, operating system, the containers and storage facilities for the project to be put into practice. Almost every process was started from scratched and the whole process system was tested for six months before the flourishing flow was taken into action. As the first invention of remanufacturing processes in the industry, it applied for a patent on the invention. The plant is divided into different areas for each process stages, including the storage section of the hazardous residues and waste, separation section, chemical reaction section, sintering section, filter and refinement section, the final separation, calcinations and storage of finished product area.

As illustrated in **Appendix 8**, the main flow of the processes transform the hazardous aluminium residue into the final non-hazardous finished product Al_2O_3. Inevitably, certain side products and objects would occur during the remanufacturing processes. For example, there is emission of CO_2 during the sintering process. However, these emissions would be collected and be used for the process of crystallisation. After the refinement stage, the separated wastes and residues would re-enter the production system for further recovery. The whole production performs in a loop operation. Hence, it maximises the regeneration of those aluminium residues through a list of operations and eliminates pollution and emissions during the remanufacturing process.

In line with the remanufacturing operation, Company R_{AL} pays additional attention to the collection of residues and wastes created from its aluminium manufacturing processes. Better techniques are developed at its manufacturing site and almost all of the production residues and waste would be collected and transferred to the new remanufacturing plant for regeneration operations. It also receives residues and wastes from other manufacturers delivered to the factory door. Those companies only need to pay for the transportation of the wastes materials and Company R_{AL} would help them deal with the disposal and transformation of the hazardous materials into non-hazardous materials. Since those companies are all operating in the nearby industrial areas in Dali, the transportation costs and pollution are very limited.

Figure 4.4 illustrates the process map for Company R_{AL}. To the research date for the interviews, Company R_{AL} already established cooperating relationships with at least one fifths of the aluminium manufacturers in Dali and responsible for their residue and waste disposal. The productivity for residue recovery reached 100 tons per day through the remanufacturing system at the subsidiary plant. That means more than 36,000 tons of residues would be recovered by the plant per year (R_{AL}.05, Appendix 5). Obviously, the recovery activities would radically reduce the level of pollution from the aluminium manufacturing in Dali, and bring advantages for further development of the industry and environmental protection rewards.

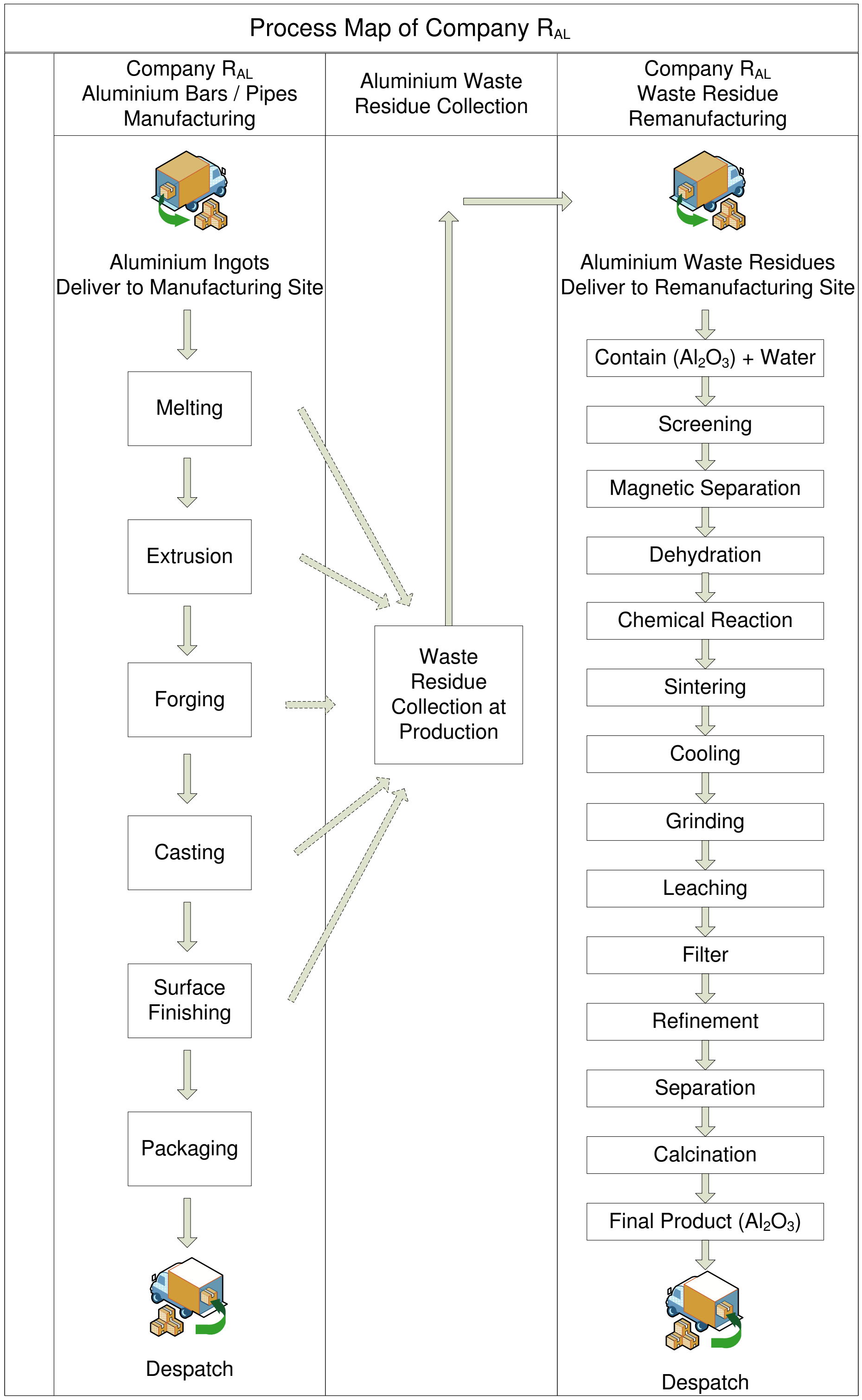


Figure 4.4 Process Map for Company R_{AL}

4.4.6 Third Party Reverse Logistics Provider – Company L_{3PRL}

Company L_{3RPL} is a medium size material recycling company which was founded in the mid 1990s. It specialises in the collection, processing and recycling of various wastes, including metals such as Gold, Silver, Copper, Aluminium, Iron, Stainless Steel, Tin and so on. It also deals with different kinds of plastics and other recyclable materials such as paper, wood and waste computer, electrical appliances and machineries. The collections are mainly from the production of large-sized foreign-invested enterprises, joint ventures and other enterprises in the region. The company site visited for this research is the headquarter plant which has an operation area covering more than 100,000 square meters and about 500 employees. Its production capacity reaches 500,000 tons per year. It also set up branches in few other locations in the PRD region. During the visit to Company L_{3RPL}, there were interviews with the general manager, vice general manager and operations manager, as well as staff at the recycling and processing workshops.

Company L_{3RPL} has established its practical organisation structure in order to improve the core competitiveness of its operations. It has introduced advanced human resources, equipments, technology and through multi-purpose channels such as cooperation, purchase and win-win integrated resources operations. It has strict management from the top to the bottom level, systematic work arrangement, partnership and dedicated teams. It aims to achieve scientific decision making and high efficiency for its operations. All staff working in the company must pass the technical trainings and examinations of resource recycling, which ensure the competitiveness of the company (L_{3RPL}.02, Appendix 5).

4.4.6.1 Customer

Company L_{3RPL} mainly serves various large-sized enterprises from the PRD region and abroad. These are the Fortune 500 companies which are located in the PRD region, including manufacturers in the metal, automotive, food and beverage industry. The general manager emphasised the core values of the company is of faithfulness and win-win situation with its customers. In his words,

> "We will adhere to the values of scientific development, listen to the market and customers and dedicate to the core business so as to make our

> enterprise more powerful, and create more fortune and value for our employees, customers, enterprises and the society." (L_{3RPL}.01, Appendix 5)

The company has established close cooperative relationships with some of their main customers. As mentioned by the vice general manager,

> "We have at least *170 employees working on our customers' sites. Th*ere is higher efficiency by sorting wastes and scrap materials at source. We certainly benefit from our good cooperative relationships with those automotive manufacturers. Especially, their wastes, left-over materials and scraps are of very good quality **…** By sorting at source, materials are separated before they were transported which would reduce the amount of labour work on our own production site. We own about 100 vehicles for the transportation and collections operation. Further dismantling and sorting would then be carried out by our remanufacturing process teams on site ... The speed of our processes is essential to our success, as we need to maintain efficient operating lead time in order to manage good cash flow for our production and sales." (L_{3RPL}.02, Appendix 5)

4.4.6.2 Environment

Company L_{3RPL} has accumulated and built up precious techniques and experiences in dealing with wastes and used materials. It contributes in building up harmonic and economical social environment by its reverse logistics processes. As a third party reverse logistics company, it provides services for collecting, sorting, dismantling, remanufacturing and recycling processes for various wastes, industrial left-over and scrap materials. It serves the Fortune 500 companies in heavy and light metal manufacturing, engineering, electrical and electronic productions, as well as food and beverage, health care and so on. These services are largely welcomed and cooperated by those companies in the region, as environmental issues have become one of the essential topics in their global operations and market competitions. By outsourcing the reverse logistics systems to a professional third party reverse logistics providers such as Company L_{3RPL}, it would facilitate those Fortune 500 companies in handling waste materials; so that they can focus more on their forward manufacturing processes for further development and success.

4.4.6.3 Technology

In addition to the technical and managerial talents in Company L_{3RPL}, the company also devote itself to scientific management and advanced technology implementation. Although at the moment, 70% of the production operations are done manually, plans for implementation of higher level of operating machinery systems are undergoing. With more capital investment, Company L_{3RPL} is aiming to achieve the goal of 80% automation in operation within the next five years. Based on the process equipment requirement, Company L_{3RPL} has introduced advanced equipment systems from European countries such as Germany and Sweden, for its processes in iron processing, foam graining, aluminium separation, plastics processing, PET bottle disposal, daily chemical liquid disposal and waste wood material disposal (L_{3RPL}.02, Appendix 5).

The process map for Company L_{3PRL} and its customers (mainly Fortune 500 companies) is illustrated as in Figure 4.5.

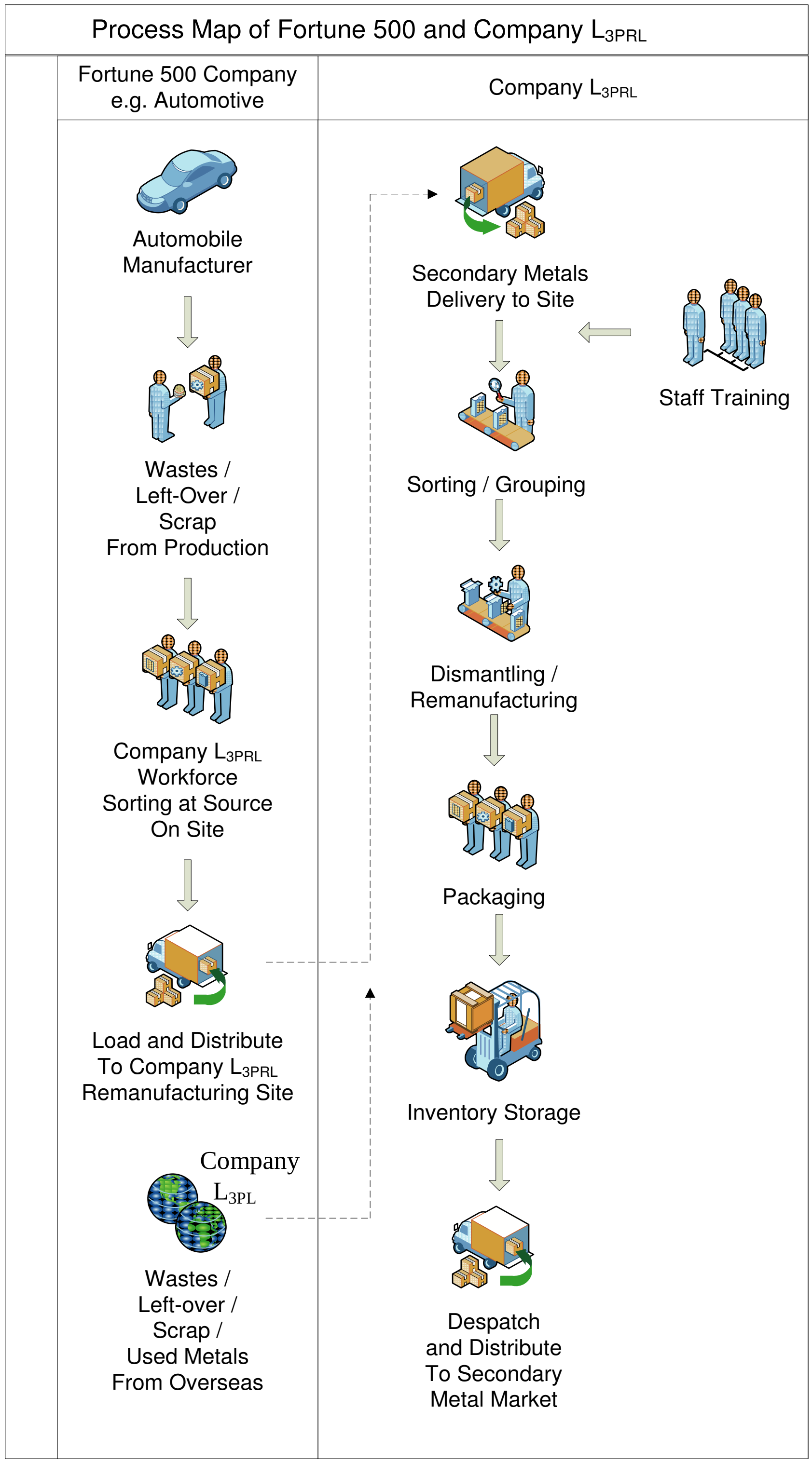
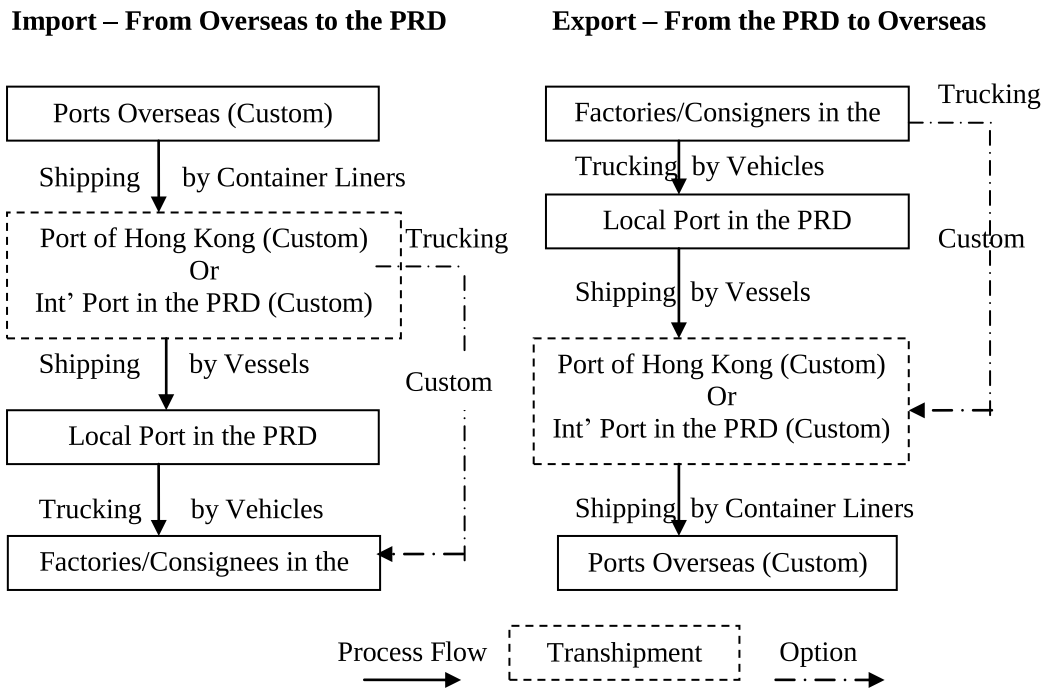


Figure 4.5 Process Map for Company L_{3PRL} and Customers

4.4.7 Distributor – Company L_{3PL}

Company L_{3PL} was founded in 1997 as a logistics and international freight forwarding company. It is a family owned SME which has been expanding its operations rapidly during the 10 years of its operations. Company L_{3PL} was approved by the Department of Foreign Trade and Economic Cooperation of Guangdong Province as a self-support import and export enterprise. It was also appointed by the Ministry of Communications of the PRC as a shipping company specialising in waterway cargo transportation in the PRD region connecting with Hong Kong and Macao. It is one of the biggest SME logistics and distributors in the region dealing with import and export transportation of cargo containers. It owns a fleet of vessels and trucks, which operate between the PRD region and Hong Kong. Due to geographic characteristics of the PRD region, as it is the convergence of the Pearl River, with the West River, the North River and the East River, large container ships cannot enter the waterway of the region. They can only load and unload containers at international ports in Hong Kong or Shenzhen. Therefore, logistics companies such as Company L_{3PL} who owns river cargo vessels act as the agents transferring cargo containers to cities and towns along the PRD region. Company L_{3PL} also provides further service distributing containers to their customers' door by their own trucking team. It has offices in Hong Kong and in different cities and ports in the PRD region in order to facilitate its logistics services in the area.

In 2005, Company L_{3PL} had a total volume of freight traffic of 555,000 tons. It owns a fleet of nine multi-purpose cargo vessels (six of them are of 1,600 tons carrying capacity, which equals 150 TEU [Twenty-foot Equivalent Unit]), and more than thirty trucks. The turnover volume of freight traffic was more than 86 million tons-kilometres and the total number of containers handled was more than 65,000 TEU. About a third of these cargo containers were imported waste and used metal and plastic materials from overseas such as the US, Canada and European countries. The containers were transported from these countries and unloaded in Hong Kong International Terminals – the second busiest port in the world (L_{3PL}.03, Appendix 5). Company L_{3PL} provides documentation services for the containers going through the customs, and then the containers would be picked up by trucks and delivered to the local port for loading onto Company L_{3PL}'s vessels. Then the cargo containers would be shipped to ports near Dali, such as Nanhai Pingzhou port. Further trucking services would be provided by Company L_{3PL}, and individual containers would be distributed to various companies in the region, such as Company R_{M1} and R_{M2}. Figure 4.6 illustrates the operation flow of Company L_{3PL}.



(Source: Huang, 2006)

Figure 4.6 Import and Export Operations of Company L_{3PL} in the PRD

4.4.7.1 Customer

As a logistics and international freight forwarding company, Company L_{3PL} provides services to large varieties of customers. It transports all sorts of cargo containers from import and export goods, products, waste and scrap materials, to beverages and frozen food. It provides comprehensive freight services to its new and long-term customers, including consigning, shipment bookings, storage, transhipment, bill settlement, customs declaration, inspection and so on. It aims to offer customer orientation, multi-level operations, high levels of quality and efficiency to its customers (L_{3PL}.04, Appendix 5).

It should be pointed out that according to the local regulations and requirements, logistics and freight forwarding companies must obtain associated certifications in order to provide services to their customers for clearance at customs and customs declaration documentations. Therefore, these companies tend to be specialised in shipping and transporting certain kinds of cargo, especially for those hazardous cargos such as waste and used metals or plastic materials, chemical and fireworks. Throughout the years, Company L_{3PL} has become a well-experienced agency in import operations for wastes, scarp, used metals and other kinds of materials, and it has built up cooperate relationships with a number of long term customers, including Company R_{M1} and R_{M2}. As described in previous case information, due to sensitive prices and demand elasticity of secondary metals and wastes materials, it is essential for the shipments and cargo deliveries to be punctual. For Company R_{M1} and R_{M2}, it is very important that they receive their overseas imported containers of waste and scrap materials to their doors at the time they are expected. These would require a very efficient operation of the whole logistics and distribution system. According to the operations manager in Company L_{3PL},

> "*Our aim is to 'provide customer oriented supreme ser*vices with qualified *and cost effective benefits'. Therefore, we are doing our best to* provide high quality logistics and transportation to our customers. We understand the importance for our customers to receive their cargo in the shortest time possible ... We are proud of ourselves for managing our own vessel and trucking team so that we can provide services 24 hours a day, 7 days a week and 365 days a year. We schedule our vessels for shipping operations between Hong Kong and the PRD region everyday. Our operation and *trucking teams are allocated at the ports so that our customers' cargos* would go through custom clearance and be picked up and delivered to our *customers' door promptly. That is how we have gained our credits and* reputation among our clients for offering efficient and reliable freight forwarding services." (L_{3PL}.08, Appendix 5)

Company L_{3PL} has a number of experienced staff working in the operation teams at various offices at ports in the PRD region and Hong Kong. They are the ones who schedule the vessel shipments and trucking operations. One of the general managers mentioned that,

> "Good time management is one of the most important issues in our operations. We have to cooperate efficiently between each department within the company, as well as with external cargo container liner companies and our clients. We would receive large amounts of data and information regarding to shipments and cargos every day, and it is very important for us to analysis our information efficiently and respond in shortest time possible ... It takes about 10 hours for our vessels to travel between Hong Kong and the ports in the PRD region. Then after the custom clearance, it takes few hours for road transportation of the cargo containers that finally reaching our custo*mers' door. Although you might* argue that these operations take longer time than transporting containers by trucks on the road, we do benefit from high capacity vessels, which can transport 150 TEU cargos per shipment. These would provide cost efficiency both for our customers and our operations, especially as we are dealing with large amount of cargo containers every day." (L_{3PL}.04, Appendix 5)

4.4.7.2 Environment

It can be argued that because there are emissions from vessels and vehicles in the distribution operations, the logistics and transportation industry generate direct pollution to the environment. As a result, the control and management of emission and fuel efficiency are essential for the industry. In the case of Company L_{3PL}, it pays attention and takes records of its vessels and trucks for better management and control. It recognises that with appalling fuel efficiency of its vessels and vehicles not only damage and pollute the environment as a whole, in terms of the waterway and road way transportation, it also creates high costs in the fuel consumption. Therefore, the company devotes itself to investing in better designed vessels and vehicles for its operations. According to the manager of the vessel team,

> "We participated in our vessel design and manufacture. For the latest 6 vessels adding to our vessel team, we have been working closely with the vessel manufacturer and developed high quality vessels with high capacity and low fuel consumption. And we will certainly apply the techniques with t*he other 3 older vessels we have in order to improve our vessels' overall* rate of fuel consumption and reduce the pollution level of the emission during operations. These would help to drive down our costs on fuel and bring costs savings to the company." (L_{3PL}.05, Appendix 5)

There are other ways for improving fuel consumption and efficiency. For example, the captains and control crews of the vessels are trained and have good skills in operating their vessels and route according to the weather, wind and water conditions. One of the captains of the vessels mentioned in the interview,

> "We pay attention to our operating route and weather conditions, and we would record and analyse our operations and fuel consumptions during each shipment. These would enable us to gain better knowledge in terms of operating the vessels with highest efficiency as possible. We know that this would help to lower our operating costs, especially when the cost of fuel is so high these days. Even the very small operations still help for the savings on fuel during the shipping operations. And we get rewards for being the most efficient fuel consumption vessels in the team. In addition, the maintenance of vessels, such as general checks with the engine, and other parts of the vessels would help us to identify any initial problems and prevent major breakdowns **…** We also work closely with our operation teams for the containers loading arrangement. The effective way of allocating laden and empty containers, according to their weight and size, is also an important way to maximise our vessel carrying capacity and enabling better fuel consumption and control." (L_{3PL}.12, Appendix 5)

The trucking vehicles engaged in the road transportation is another major area for Company L_{3PL} to control and manage its logistics and freight forwarding operations from the perspective of the environment. Route scheduling is essential so that the trucks will operate with the most sufficient routes in between the company's trucking site, to the ports and reaching customers in various locations. The company has its own maintenance team and warehouse for vehicles and vessel parts, and provide in-house maintenance and operations for its vehicles and vessels. These facilitate quick and reliable services to its trucking and vessel teams whenever there are breakdowns. The maintenance team also gain high levels of experience and superior understanding by maintaining and tracking records for each of the vehicles and vessels, so that they can deal with general maintenance regularly and sort out problems more rapidly. There are cost savings by operating the in-house maintenance rather than outsourcing to other companies. As described by the manager of the trucking team,

> "We must be very careful and need to make sure that our vehicles are with the best conditions so that they are ready to handle the large amount of work load of container transport every day. Our maintenance team have very good knowledge with each of the vehicles and would keep tracks of the records for each truck, so that when we come across problems, we can react quickly and replace parts or reschedule for alternative options. As we have high levels of demand from our customers, we do have to work very hard throughout the year and do our best to manage and control our vehicles and hardware equipments. This is the nature of logistics industry and we must keep up with our speed in order to win over the competitions in the industry. On the other hand, we would maintain good cooperative relationships with other logistics companies, as from time to time we do need to help out each other when there is unexpected vehicle break down situations." (L_{3PL}.06, Appendix 5)

4.4.7.3 Technology

The logistics and distribution industry in the PRD region have been through a dramatic development period since the mid 1990s. Due to fast changes and increasing competitions in the industry, Company L_{3PL} has been investing and implementing high levels of technology and equipments for its operations, as well as better designed and fuel consumption vessels and vehicles as described in the previous sections. The enhancement of the hardware equipments provides strong bases for the rapid development in the company.

In addition to the hardware facilities, modern logistics companies are also developing themselves with high level of technology and software operations. Company L_{3PL} has implemented scientific management and information system throughout its teams and departments. These include the implementation of Enterprise Resource Planning (ERP), which enable efficient data sharing between the operation team, the trucking team, the finance and sales team within the company. There are also external data sharing and updates with its customers and the customs at different ports in the region, as well as with the container liner companies.

For example, in the case when a container is unloaded from the container ship at the port in Hong Kong. The cargo container information is received and entered into the system and staff from each team would be able to achieve the data information. The trucking team would be the first ones to schedule the pick up time according to the location of that container. At the same time, the operation team would be able to schedule the next shipment for transporting the container, along with the batch of containers from the same customer or customers nearby. Then they can produce the required documentation and forms for custom declaration, and send them through Electronic Data Interchange (EDI) to the landing ports and customs. They would also contact their customers and notify them the time for expected delivery to their doors. In some cases, they can also pick up the unloaded containers from their customers from the previous delivery, which makes an efficient laden-empty trip for the trucks and returning the empty container to the ports. The sharing of information greatly improves the efficiency of the communication and logistics operations in between these different parties, which enables higher speed of turn-around time for the shipping companies and their customers.

4.5 Summary

This chapter has described and illustrated the findings from the local government visit and the seven case studies in the metal manufacturing, remanufacturing and 3rd party (reverse) logistics companies in the PRD region in the south of China. The data and information are provided by employees of the case companies from interviews, as well as observations on site. These are based on the knowledge and experiences from interviewees from managerial and operational levels in case companies. It provided relevant data and information for the forward and reverse logistics flows between these companies, especially on the issues of influencing the CET factors. The process maps for the group of metal manufacturing Company M_M, Mss and remanufacturing Company R_{M1}, R_{M2}; Company R_{AL}; the Fortune 500 Companies and Company L_{3PRL} are developed from data and information gathering during these studies.

It should be obvious that companies are all devoting themselves to producing products and services that would meet their customers' demand in the market place. It is essential for both metal manufacturers and remanufacturers to have control over the quality and quantity of incoming input materials for their productions, so that they can reduce production costs and produce good quality finished products. Remanufacturing of waste metals not only helps to utilise the diminishing metal resources, it also cooperates and urges metal manufacturers to take into account the production efficiency, waste collection and recovery from their production. These would lead to savings on production costs and reduce damages to the environment. Although the Chinese metal SMEs are strongly based on the cheap labour manual operations especially in the remanufacturing operations, companies have started to invest more on higher level technology to facilitate their processes. The R&D in industry and the cooperation between industry and academic would encourage positive incentives for the industry to reach higher development and initiate sustainability in the long term. Further analysis is carried out in the next chapter in order to evaluate the similarities and differences between companies, so that it can provide a better understanding of the process operation to achieve sustainable development for the CLSC.

CHAPTER 5

CASE STUDIES ANALYSIS

5.1 Introduction

With regard to the process maps, data and information presented in Chapter 4, further analysis can be performed in order to generate better understanding of the CLSC in the industrial operations in the PRD region, particularly among the case companies of metal manufacturers, remanufacturers, as well as third party logistics providers for both forward and reverse supply chain.

In this chapter, first of all, it will analyse the internal operations of the case companies, particularly focusing on issues regarding to the CET factors. The external cooperation processes between the case companies will also be analysed. Comparison and contrast of these case companies will also be carried out, in order to show the general situation in the industrial context. This will be followed by examination of the industrial environment and the metal industry in Dali, using the aluminium industry as an example. The process maps and frameworks for the CLSC in the Chinese metal industry are developed based on these case findings and analysis.

5.2 Analysis of Research Findings

5.2.1 Case Studies Analysis – Metal Manufacturers

Table 5.1 analyses the information collected from the three metal manufacturers: Company M_M, Mss and R_{AL}. Their general background information, production activities, and capacities are compared. In addition, information regarding to the CET factors is analysed to find out answers to the research question and sub-questions.

Table 5.1 Case Studies Analysis – Company M_M, Mss and R_{AL}

Attributes	Company M_M	Company Mss	Company R_{AL}
Company Type	Metal Manufacturer	Metal Manufacturer	Metal Manufacturer
Products	Various kinds of metal hardware	Stainless steel plates and pipes	Aluminium bars and pipes
No. of Employees	Up to 100	Up to 150	Up to 150
Factory Size	60,000 m^2	80,000 m^2	100,000 m^2
Production Capacity	110,000 tons / year: 1,000 various kinds of metal hardware	300,000 tons / year	800,000 tons / year
Customer Factors			
Suppliers	Primary, Secondary Metal Materials Suppliers 40% Contracted	Primary Stainless Steel Sheets and Plates Suppliers 50% Contracted	Primary, Secondary Aluminium Ingots Suppliers 60% Contracted
Supplies	100% from China	100% from China	100% from China
Customers	Lighting Products, Cooking Equipments 100% in China	Construction Industry, Furniture Producers 80% in China 20% overseas	Construction, Light Industry Producers 75% in China 25% overseas
Customers Requirement for inputs Metals for Production	No Around 30% of input metals are secondary regenerated materials	Yes Customers require high quality products which sometimes cannot be produced with secondary generated material	No 40% of input aluminium are secondary regenerated material
Reasons for Using Secondary Materials	Secondary metals are around 30% to 50% cheaper than primary metals	Apply both primary and secondary stainless steel for production as long as the quality of the input stainless steel is meeting the quality standard.	Using secondary materials for production would increase the utilisation of aluminium; the saving on input material costs can be as high as 50%

Attributes	Company M_M	Company Mss	Company R_{AL}
Logistics Flow of Recycling or Disposal	Co-operating with Company R_{M1} and other dismantlers for collecting and recycling production left-over and scraps (5%)	Co-operating with only Company R_{M2} for collecting and recycling production left-over and scraps (3%)	All residues (10%) from production are sent to the Aluminium Residue Department for recycling and remanufacturing
Customer Influence on Production Capacity	Growing customer demand encourages further expansion for the company to open new factories in other locations in China	Better designed machineries are developed by the in-house engineering team in order to meet high quality standard from customers	Higher level of machinery system is applied in order to meet the fast changing customer requirement in the market
Production Lead Time	For most of their products, it takes around 2 weeks from order to final product dispatched to customers	It takes 10 to 15 days for producing stainless steel plates and pipes in batch	Normally it takes 7 days from order to dispatch. 4 more days are needed for those require special mould for production
Technology Factors			
Production Process	Can be complicated when handling various types of metals such as: - Copper - Aluminium - Iron - Stainless Steel - Tin Process Operations: 1. Forging 2. Rolling 3. Casting 4. Surface Finishing 5. Packaging 6. Despatch	Plant design layout for - Input material storage - Production area - Finish product storage Buy-in stainless steel plate and sheet are put through machines for: 1. Forging 2. Rolling 3. Casting 4. Surface Finishing 5. Packaging 6. Despatch	Aluminium bars and pipes are produced according to customer requirement and types of aluminium required Production processes for its products, including: 1. Melting 2. Extrusion 3. Forging 4. Casting 5. Surface Finishing 6. Packaging 7. Despatch

Attributes	Company M_M	Company Mss	Company R_{AL}
Means of Process	30% Manual 70% Machinery	20% Manual 80% Machinery	30% Manual 70% Machinery
Technology Applications	It takes time to change production line and moulds for cutting. Therefore, efficient production scheduling is essential for the process flow; Higher level machinery systems provide better design and accurate cuttings	State-of-the-art process equipment increase the competitive advantages, reduce wastes and scrap from production, and fulfilling higher customer satisfaction	Higher level of machinery enables higher quality products and shortens production lead-time: Normally takes 7 days from the customer placing the order to the products despatch
Reverse Logistics Operations	The rate of left-over and scraps during production is about 5%; Around 80% of those wastes are stored at one corner on-site and are collected by Company R_{M1} on a weekly basis; Some other metals (20%) that R_{M1} does not deal with would be sold to some other dismantlers and remanufacturers	Left-over and scraps are monitored and minimised (3%), which would be stored at one corner on-site and are transported to Company R_{M2} on a weekly basis; Wastes information are recorded and provided to R_{M2} which would ease the remanufacturing process	Different types of aluminium and aluminium alloy need to be selected as input materials; secondary regenerated aluminium is also applied; Residue during production are collected for further recovery in the remanufacturing department; Left-over and scraps are collected and put back straight into the process flow for re-melting

Environment Factors			
Attributes	**Company M_M**	**Company Mss**	**Company R_{AL}**
Health and Safety	Basic training and protection are provided Higher level of safety protection is needed especially for those operators who are operating the cutting machineries	Intense training and protection are provided There are health and safety signs and constant monitoring of operators to ensure higher safety at workstation	Basic training and protection are provided Higher level of safety protection is needed especially for those operators who are dealing with the hazardous materials
Production Materials Utilisations	Higher level of computerised cutting machinery would reduce the level of left-over and scrap metals during the forging and cutting process	The scrap rate during production is kept under 3% (25 tons per day); The concern is on controlling and reducing the inevitable scrap rate during R&D and changing production line	Aluminium wastes can re-enter the production flow and increase the utilisation of input materials; The quality of secondary input materials affect the rate of residue occurred during production
Control of Wastes and Emissions	Inevitable metal wastes during production, and hard to collect those metals and waste water especially during the cutting stage. Some of the residues and scraps would end up in landfill disposal	Inevitable stainless steel during production, and is hard to collect those metals and waste water especially during the cutting stage. Some of the residues and scraps would end up in landfill disposal	Inevitable wastes and emission during production. The hazardous residues and scraps ended up in landfill disposal; but they are now collected and recovered by the remanufacturing system

By comparing the data and information in Table 5.1, there are certain issues regarding to the similarities and differences between operations in these three metal manufacturers. First of all, their suppliers of metal input materials are all from the local area or other places in China. 40%, 50% and 60% of these suppliers have established contracts and regular supplies for these three companies respectively. These enable material supply stability and cooperative relationships between players along the supply chain in the metal manufacturing industry. As a result, the inventory levels are kept low (as from the observations on-site at these companies), the production-to-order can respond quicker to customer requirements, and the lead-time for production is kept within a week.

Secondly, there are certain quality requirements for the application of secondary metals in metal manufacturing. For example, since it is very common to regenerate stainless steels for reuse in industry, Company Mss would only apply higher quality stainless steel for its production to ensure high quality productions to meet customer requirements. Similarly, Company M_M and R_{AL} benefit from applying secondary metals for their productions which are with lower price compared to primary metals. As long as these metals meet the production requirement, by applying secondary metals, it would increase the utilisation of input metal materials while reducing the whole production costs. The supply chain is completed in a closed-loop cycle as secondary metals are re-entering the production system. Eventually, the total amount of reusable resources being disposed in landfills can be reduced. However, it should be pointed out that these three case companies are examples of metal manufacturers who are actively participating in dealing with their wastes with remanufacturers and dismantlers in the region. Some companies in China or some other developing countries are still lacking behind in handling their waste and left-over metals, which are causing damages to the environment and the supply chain operations.

Furthermore, because of the implementation of technology system and machinery into the operating system in these metal manufacturing companies, more varieties and larger quantity of products can be manufactured with higher quality standards. These lead to higher sales for the increasing demand in the Chinese and the expanding global market. On the other hand, the complexity of collecting and sorting waste metals are increasing due to the development of manufacturing. Especially for Company M_M which deals with large varieties of metals in its production processes. Therefore, being able to maintain a low level of scrap during production, and efficiently collecting the wastes and left-over metals are critical for the operation management. More efforts are needed for Company R_{M1} when dealing with left-over and scrap metals from Company M_M, as there are more varieties and complexity. On the contrary, for Company Mss and R_{AL}, the cooperation with their recycler is less complex, especially with better information sharing of the metal characteristics. The sorting and regenerating processes lead-time for the secondary metals coming from these companies can be minimised.

Last but not least, from the environmental aspects, there are still improvements for these companies to achieve in order to increase the health and safety for their workers and production stability, while reducing the emission, waste and damage to the environment. Among these three metal manufacturers, Company Mss had designed its factory floor layout and production process to be operationally and environmentally friendly. Particularly on the health and safety protections for the operators, training and information provided are sufficient to enable the company to maintain a high quality and safe production environment. In the case of Company R_{AL}, for those operators who are handling the hazardous materials and waste residues, it is essential for them to have high level of protection, as well as controlling and minimising the damage of those materials to the water and air environment.

These are brief analysis and summaries of issues with regard to metal manufacturers from the case study research. They are the typical representatives of SMEs operations in the region which are operating in relatively low scale production. However, it is crucial for the industry and government to understand their operations and to manage the whole supply chain flow with the aim to protect the environment. In particular, with regard to the issue of developing sustainable CLSC, by mapping the process flows and identifying the CET factors would provide better understanding for more efficient and effective management and control.

5.2.2 Case Studies Analysis – Metal Remanufacturers

Table 5.2 summarises the similarities and differences between the three dismantlers and remanufacturers: Company R_{M1}, R_{M2}, and R_{AL}, as well as Company L_{3PRL} – the Third Party Reverse Logistics Provider. The operating activities and processes flow in these four companies are investigated in detail in order to map the reverse logistics process flow in the secondary metal industry in the region. The issues regarding to the CET factors are also presented for further analysis and discussion.

Table 5.2 Case Studies Analysis – Company R_{M1}, R_{M2}, R_{AL} and L_{3PRL}

Attributes	Company R_{M1}	Company R_{M2}	Company R_{AL}	Company L_{3PRL}
Company Type	Dismantler Remanufacturer	Dismantler Remanufacturer	Aluminium Residue Remanufacturer	3rd Party Reverse Logistics Provider
Operating Activities	Collecting and sorting various waste, left-over, scrap metals, plastics and other materials; Reselling the recycled, recovered materials to secondary metals /material markets	Collecting and sorting various waste, left-over, scrap metals, plastics and other materials; Reselling the recycled, recovered materials to secondary metals /material markets	Collecting hazardous aluminium residue from manufacturing and regenerate into $Al(OH)_3$ and Al_2O_3 which would be used for producing aluminium or other products	Collecting and sorting various used, waste, left-over, scrap metals, plastics and other materials; Reselling the recycled, recovered materials to secondary metals /material markets
No. of Employees	Up to 80	Up to 100	Up to 150	Up to 500
Factory Size	60,000 m^2	70,000 m^2	70,000 m^2	100,000 m^2
Production Capacity	50,000 tons / year	100,000 tons / year	36,000 tons / year	500,000 tons / year
Customer Factors				
Suppliers	1. Metal collectors (90%) for used, waste and scrap metal products / parts / machineries 2. Metal Manufacturers (10%), such as Company M_M 25% Contracted	1. Metal collectors (80%) for used, waste and scrap metal products / parts / machineries 2. Metal Manufacturers (20%), such as Company Mss 30% Contracted	Aluminium Manufacturers in the region 100% Contracted	1. The Fortune 500 metal / automotive manufacturers in the region (60%) 2. Other metal manufacturers (20%) 3. Metal collectors (20%) for used, waste and scrap metals 60% Contracted

Attributes	Company R_{M1}	Company R_{M2}	Company R_{AL}	Company L_{3PRL}
Incoming Supplies	20% from China 80% Imports from overseas	30% from China 70% Imports from overseas	100% from China	80% from China 20% Imports from overseas
Customers	1. Secondary metal market / Remanufacturer (80%) 2. Directly to metal manufacturers (20%) 100% in China	1. Secondary metal market / Remanufacturer (90%) 2. Directly to metal manufacturers (10%) 80% in China 20% Exports	Manufacturers using $Al(OH)_3$ and Al_2O_3 for production 100% in China	1. Secondary metal market (50%) 2. Directly to metal manufacturers (50%) 85% in China 15% Exports
Supply Chain Network	Majority of the secondary used products and parts are imported from developed countries, which enable higher quality material to be recovered; The dismantled and resized metals are sold onto the next level of remanufacturer for further regeneration; or directly to other manufacturers	In addition to local collection, a large percentage of secondary metals and materials supply are from overseas Due to high requirement from secondary metal buyers in developed countries, the supply chain network for exporting regenerated product is limited at the moment	Collection from the aluminium manufacturing process of R_{AL} and other aluminium manufacturers in the region; Finished products are sold to other manufacturers which use those materials as their input material for their productions	On-site collections for some of the Fortune 500 companies in the region, recovering high quality left-over and scrap metals and parts; Half of the recovered and regenerated metals and materials are sold directly to SMEs in the region, which seek for low-cost high-quality materials.

Attributes	Company R_{M1}	Company R_{M2}	Company R_{AL}	Company L_{3PRL}
Reasons for Recycling and Recovering Secondary Materials	Generate profits from buy-in waste and scrap metals at low price, 10-30% of the selling price of the final remanufactured metals; Secondary metals have competitive price advantage (normally 30% or 50% less) compare to the primary metals Minimising waste and disposal to the environment, maximising utilisation and recoverable value of resources	There are excess profits to be recovered by recycling and regenerating secondary metals from waste metal products and parts; The price for secondary metals are at least 10% to 50% less than primary metals Minimising waste and disposal to the environment, maximising utilisation and recoverable value of resources	By collecting, remanufacturin g hazardous waste residue into non-hazardous [Al_2O_3] which can be used as input materials for other production, it utilises resources and gains profit; More importantly, it's a solution to the disposal of the hazardous wastes; Minimising the hazardous damage to the environment, maximising utilisation and recoverable value of resources	Provide reverse logistics services for large size manufacturing companies so that those companies can concentrate on their competitive advantages. It helps companies to reduce production costs, while committing more to the society as a whole; By collecting at source and performing the whole supply chain of reverse logistics services, it minimise the operating costs and maximise the recovery rate
Responds to Customers in the Market	Due to the price sensitivity in the secondary metal market, the turnaround time need to be very short	The price is changing all the time, which affects the demand and supply in the market	Much more stable market place compared with the secondary metal market	Customers are very price sensitive but with relatively less strict requirements when buying secondary metals
Production Lead Time	Depends on the characteristics of the incoming secondary metals and materials, it	Depends on the characteristics of the incoming secondary metals and materials, it	The daily productivity for remanufacturin g hazardous aluminium	Depends on the incoming secondary metals and materials, the lead-time for handling is

	usually takes 2 or 3 days for sorting one container (Max. 26 tons) of secondary products / parts	usually takes 2 or 3 days for sorting one container (Max. 26 tons) of secondary products / parts	residues into non-hazardous Al_2O_3 is 100 tons / 24 hours	minimise to 2 or 3 days and a maximum of 7 days.
Technology Factors				
Attributes	**Company R_{M1}**	**Company R_{M2}**	**Company R_{AL}**	**Company L_{3PRL}**
Means of Process	90% Manual 10% Machinery	85% Manual 15% Machinery	20% Manual 80% Machinery	70% Manual 30% Machinery
Production Process	Dismantling and recycling from secondary metal products: 1. Unload waste or used metal products / parts 2. Sorting 3. Dismantling 4. Grouping 5. Resizing (Machinery) 6. Packaging 7. Despatch to next level or secondary metal market	Dismantling and recycling from secondary metal products: 1. Unload waste or used metal products / parts 2.Sorting 3.Dismantling 4.Grouping 5.Resizing (Machinery) 6.Packaging 7.Despatch to next level or secondary metal market	Remanufacturing hazardous residue into non-hazardous Al_2O_3: 1. Residue enter production 2. Screening 3. Magnetic Separation 4. Dehydration 5. Chemical Reaction 6. Sintering 7. Cooling 8. Grinding 9. Leaching 10. Filtering 11. Refinement 12. Separation 13. Calcination 14. Storage / Package 15. Despatch to other manufacturers	Provide reverse logistics services for manufacturers: 1. Sorting at site 2. Collection 3. Transport to site 4. Unload metals 5. Magnetic Separation (Machinery) 6. Dismantling 7. Grouping 8. Resizing (Machinery) 9. Remanufacture (Melting Machinery) 10. Packaging 11. Despatch to SMEs metal manufacturers or secondary metal market
Technology Applications	Resizing machinery Transports between workstations	Resizing machinery Transports between workstations	R&D with academic research and invented the remanufacturing machinery system for recovering	Magnetic Separation Resizing machinery Melting machinery

			hazardous residues to non-hazardous Al_2O_3	Transport from supplier to sites, and in between workstations
Future Process Goal	80% Manual 20% Machinery	70% Manual 30% Machinery	10% Manual 90% Machinery	20% Manual 80% Machinery
Recycling Or Disposal Rate	Depends on the quality of incoming waste, left-over, scrap metals and materials, the complexity of parts and components; The dismantling of these parts would recover 95% of the recyclable and reusable metals; Other non-recoverable metals would be disposed in landfill	Depends on the quality of incoming waste, left-over, scrap metals and materials, the complexity of parts and components; By better information sharing with suppliers of the secondary metals enable better grouping of the metals, which increase the rate of recovery (>95%) The non-recoverable materials would be disposed in landfill	All the input aluminium residue would go through the remanufacturing system which has been designed to recover residue for Al_2O_3 The system is designed in a loop operations so that all the left-over residues, materials, even chemicals and waste water during the remanufacturing process would be reused; which maximising utilisation of resources in the system to 95%	Sorting at source is essential as it enables accuracy of further dismantle and grouping for recovery of various metals and materials; With higher level of machinery system for dismantling and remanufacturing process increase the recovery rate; The turnaround time for secondary metal is really fast in the secondary metal industry. The cash flow is less than 15 days
Environment Factors				
Attributes	**Company R_{M1}**	**Company R_{M2}**	**Company R_{AL}**	**Company L_{3PRL}**
Health and Safety	Strongly based on manual operations, but the level of protection is not up to high standards;	Strongly based on manual operations, but the level of protection is not up to high standards;	Safety protections for operators who handles hazardous residue materials;	At least 3 days intensive training for operators on-site to ensure they understand the health and safety issues when handling

	Operators are with limited protection and some are directly in contact with secondary metal products / parts / materials; There are healthy and safety issues to concern and improve	Operators are with limited protection and some are directly in contact with secondary metal products / parts / material; There are healthy and safety issues to concern and improve	Input materials are processed through the automatic operating system;	their operations. Basic protection including gloves, helmets, masks and protection clothing are used for health and safety reasons
Production Materials Utilisations	Since all the dismantling processes are done manually, the components and materials can be dismantled to smaller features because of the flexibility of labour work; Application of resizing machinery can maximise the recycling and recovering metals and materials	Since all the dismantling processes are done manually, the components and materials can be dismantled to smaller features because of the flexibility of labour work; Application of resizing machinery can maximise the recycling and recovering metals and materials In-house remanufacture process enable further recovery of metals before selling to market	Inevitable emission but the majority of water and materials throughout production can re-enter and be reused in the production loop, which maximise the utility of materials and resource; Largely reduce the damage of hazardous materials to the environment and reduce the level of disposal to landfill	Due to sorting at source and all the dismantling processes are done manually, the components and materials can be recovered to a higher level because of the flexibility of labour work; Application of resizing machinery can maximise the final recycling and recovering metals and materials In-house remanufacturing process enable further recovery of metals before selling to market

Attributes	Company R_{M1}	Company R_{M2}	Company R_{AL}	Company L_{3PRL}
Control of Wastes and Emissions	There are limitations of using manual labour work for dismantling and recovering metals and materials as: 1. Some of the complex products need higher level requirement and power for dismantling process; 2. Some products / parts can be hazardous especially when handling by hands; Hence, operators need to have proper training and skill in order to handle their operations	There are limitations of using manual labour work for dismantling and recovering metals and materials as: 1. Some of the complex products need higher level requirement and power for dismantling process; 2. Some products / parts can be hazardous especially when handling by hands; Hence, operators need to have proper training and skill in order to handle their operations	Cooperation between the practitioner and academic developed the system that operates in a loop cycle, which maximises the utility of resource and materials throughout the production flow; The level of inevitable emission is very limited, and only occurs during the sintering stage	By sorting at source at the sites of manufacturers, it eases sorting and increases recovery rate of metals and materials; There are inevitable emission and waste during transportation, resizing and remanufacturing; Hence, higher level of machinery system will be implemented to increase the efficiency level of recovery and remanufacturing
Future Technology Applications	Implementation of Information System However, it would not be possible to implement higher level machinery system for production	Implementation of Information System and management of input metals and materials	Higher computerised machinery for production	Computerised handling machineries; dismantling, and resizing machines which can automatically handle various metal remanufacturing processes

As in Table 5.2, there are similarities and differences between the four case companies which are in the reverse logistics operations. Company R_{M1} and R_{M2} have very similar operating natures in the dismantling and resizing remanufacturing processes. Their main operations are the on-site dismantling and resizing, basic remanufacturing of a wide range of metals which would then be sold onto next level of remanufacturing, or directly to the secondary metal market. There is high level of complexity especially with the varieties of metals and other materials they receive from local collection and overseas imports. To certain extent, as there are less than 30% suppliers which have signed contracts with them for regular supply of materials, Company R_{M1} and R_{M2} have very limited control over the quality and the characteristics of used and waste metals they receive. Therefore, their operations need to be very flexible in order to deal with the varieties of input materials in the dismantling and remanufacturing operation. That is why more than 85% of their operations are strongly based on the manual labour work.

On the other hand, Company L_{3PRL} has better control over the source for its operation. It provides the whole package of reverse logistics services and dedicates its workers to work at customers' sites. In doing so, those workers sort waste, left-over and scrap at the source before transporting the collections by its own logistics and transportation team to its site. Further dismantling, remanufacturing and recovery operation can then be carried out on the grouped metals and materials with the application of machinery system. Therefore, as mentioned in the interviews, the long-term development goal for Company L_{3PRL} is to achieve over 70% of automation in the near future (L_{3RPL}.02, Appendix 5). Whilst for Company R_{M1} and R_{M2}, only a limited level of affordable technology would be implemented for their operation (R_{M1}.01, Appendix 5).

Last but not least, the production system in Company R_{AL} only deals with the hazardous residues from its own aluminium production and other aluminium producers in the area. These supply all the incoming waste residues for the company to produce renewed non-hazardous chemical which can be sold to other manufacturers as input materials. As the company developed the system with the academic research support and the implication of technology, less than 20% of the processes require manual labour handling.

Hence, various methods and operating systems can be applied in handling waste, left-over, scrap and even residue which used to be overlooked as valueless resources. Depending on the different nature of the resources and operations, there are different levels of technology and manual labour operation for the collecting, sorting, dismantling and remanufacturing processes. To a certain extent, it can be argued that manual labour provide flexibility especially when dealing with complex and mixed products and components. However, technology development for remanufacturing processes would increase the efficiency and effectiveness, and provide better health and safety protections both to the operators and the environment. Managing and controlling the source for remanufacturing processes are essential, which would largely reduce the complexities during the processes and ensure better quality of finished secondary products for the market.

Consequently, there should be better cooperation between the forward manufacturers and reverse logistics operators. For example, on the issues of DFD and DFE from the design and manufacturing perspectives, used and waste products and parts can be dismantled easier through the application of technical machinery. These would increase the remanufacturing efficiency especially when dealing with large quantity of recycling and remanufacturing operations. In addition, there are responsibilities for both manufacturers and remanufacturers in collecting and sorting at the source, which would reduce the mixture and complexities of the waste and used products, left-over parts and materials through the reverse logistics operation.

5.2.3 The Forward and Reverse Logistics Operations

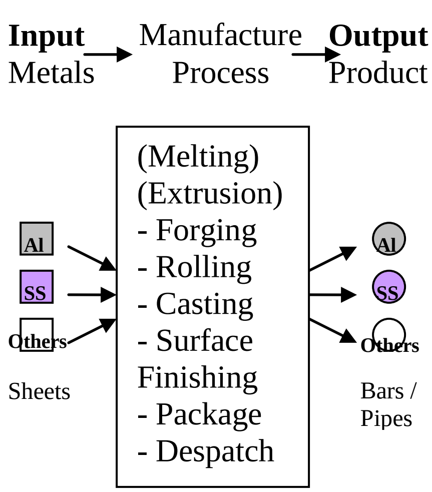
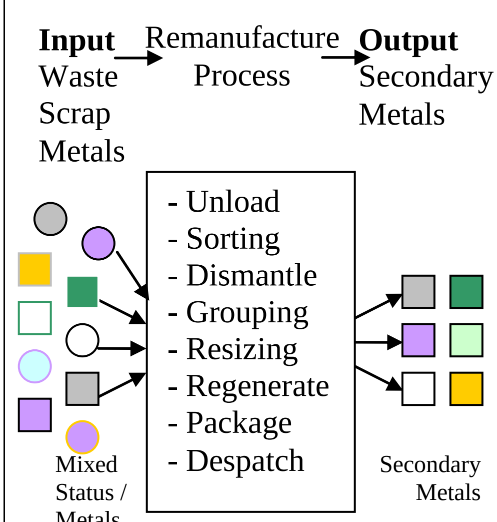
As discussed before and by comparing figures in Table 5.1 and 5.2, a number of issues can be observed between the forward metal manufacturing operation and the reverse remanufacturing processes. First of all, although with regard to the company size and employee numbers, these case companies are identified as SMEs with under 500 employees and factory sizes of less than 100,000m^2, the metal manufacturers tend to handle higher volumes of metal as production input material and have higher manufacturing capacity. These would be because of the high level (more than 70%) of technological system and machineries in the metal manufacturing processes operations; whilst for remanufacturing processes, more than 70% of the operations are based on manual labour processes. Although Company L_{3PRL} has the intention to invest in higher level of machinery system for its remanufacturing processes, some smaller size remanufacturers, such as Company R_{M1} and R_{M2} will be still mainly based on manual operations in the near future (R_{M1}.01, Appendix 5).

Secondly, almost all of the buy-in input materials for the metal manufacturing processes are supplied from within China. On the other hand, as mentioned by a number of interviewees (R_{M1}.02, R_{M2}.02, R_{M2}.06, Appendix 5) in the remanufacturing companies, they prefer to buy in imported secondary metals and materials from developed countries, because they tend to have higher quality for recovery processes. Although these dismantlers and remanufacturers do have established cooperative relationships with local manufacturers for wastes collection and recovery, the percentage is limited at around 30% (<30,000 tons per year). Some other SMEs manufacturers are still struggling in dealing with their production left-over and scrap; some of those materials are handled by lower level reverse logistics operations. The low efficiency and damage of these operations can cause severe negative effects to the society and the environment.

Moreover, the recovered secondary metals are mostly sold in the secondary market within China. This is partly because of the high demand for metal resources for various manufacturing within China, especially among SMEs metal manufacturers. Additionally, some secondary metals are of lower quality in comparison to the primary ones. They would not always meet the high standard requirements when exporting to overseas countries, especially for those well developed manufacturing processes. Hence, in order to provide more stable and sustainable supply and demand for secondary metal industry, the quality of wastes supply and the recovered secondary metals must be of higher quality. Eventually, the future goal for the industry and government is that larger amounts of wastes from the Chinese metal manufacturing processes would be recovered with higher levels of technology application for the efficient and effective reverse logistics operations. There would be more active cooperation among manufacturers and remanufacturers in participating throughout the CLSC operation. As a result, it would increase the rate of recovering secondary metals and for dismantlers and remanufacturers to achieve sustainable development in the long term.

In order to develop sustainable CLSC for the metal manufacturing and remanufacturing industry, it is important to understand the similarities and differences between the players in the CLSC network. Table 5.3 compares and contrasts the operating natures between the metal manufacturers and remanufacturers, based on the research and findings from the case companies. Issues such as production demand and supply, operation flows, production activities and capacities are presented for further discussion.

Table 5.3 Case Studies Analysis – Metal Manufacturers and Remanufacturers

Attributes	Metal Manufacturers	Dismantlers and Remanufacturers
Case Examples	Company M_M Company Mss Company R_{AL}	Company R_{M1} Company R_{M2} Company R_{AL} Company L_{3PRL}
Market Demand	Continuous growth for metal products throughout different industries	Higher level of environmental protection concerns and utilisation of resources by the industries and government
Production Input Material	Single Type of Metal / Varieties of Metal	Complex and Mixed Incoming Metals and Materials
Operation Flow		

Attributes	Metal Manufacturers	Dismantlers and Remanufacturers
Production Input Supply	**Pull Based** Buy-in input metals and materials according to customer order, quantity and quality requirements Influence by price fluctuation because of the increasing demand and reducing metal resources	**Push Based** Limited control over the time, quantity and quality of the used and waste products and parts collected Influence by price fluctuation in both primary and secondary metal markets
Production Output and Finished Products	**Make to Order** **Make to Stock / Forecast** Production according to customer order, requirements and quality standards	**Make to Stock / Forecast** Resized or Remanufactured Secondary Metals for various customers and demands in the market
Supply Network	Limited 100% in China	Wide Range China and Overseas
Customer Network	Limited 70% in China, 20% overseas	Wide Range 80% in China, 20% overseas
Machinery vs. Manual	70% Machinery vs. 30% Manual	20% Machinery vs. 80% Manual
Production Capacity	110,000 tons to 800,000 tons (per year)	50,000 tons to 500,000 tons (per year)
Lead Time	7 to 15 Days	2 to 7 Days
Productivity	800 to 2,200 ton / Day	135 to 1,300 ton / Day
Rate of Waste/Scrap	2% to 10%	< 1% to 6%
Value Added Processes	- Forging - Rolling - Casting - Surface Finishing	- Grouping - Resizing - Regenerate
Reasons for Recycling / Collecting Waste, Left-over, Scrap during production	1. Reduce production costs 2. Utilisation of resources 3. Solution for disposal 4. CSR for the society and environment	1. Profit from remanufacturing 2. Market demand for waste and disposal handling 3. Utilisation of resources 4. Reduce damage to the environment

As illustrated in Table 5.3, according to the empirical research of case companies in the PRD region, there have been increasing market demand for both metal products and secondary metal and materials production. Hence, there have been expanding growths in all of the companies in the research. However, it should be pointed out that because of the price fluctuation for both primary and secondary metals, the manufacturing and remanufacturing operations would vary in response to those changes.

When comparing the production input and supply, it should be clear that the metal manufacturers tend to focus on and produce single type of metal products. For example, Company Mss produces stainless steel plates and pipes, and Company R_{AL} is specialised in the production of aluminium bars and pipes. Although there are metal manufacturers such as Company M_M which handles a number of different metals for its metal hardware manufacturing, the metal remanufacturers are dealing with much more complex and mixed kind of incoming waste, left-over, scrap and used metal products and parts. These are shown in the operation flow graphs for the metal manufacturing and remanufacturing processes in Table 5.3.

Due to the operating nature of metal manufacturers and remanufactures, as described in Table 5.3, the production inputs for metal manufacturers tend to be pull based. The input metals are ordered for the manufacturing process to produce products according to customer order, quantity and quality requirements. Manufacturers can be more active in managing their operation when manufacturing for their customers. As SMEs with smaller batch production, they can react quickly to the changing supply and demand in the market, and maintain low levels of inventory when carrying out Just-In-Time production and a relatively good cash-flow. On the contrary, secondary metal remanufacturers have less control over the time, quantity and quality of the used and waste products and parts they receive. They can only work on the incoming metals and materials collected by manufacturers, collectors, or themselves. Therefore, in order to reduce the level of inventory on-site and achieve quick turnaround time, the dismantling and remanufacturing processes on-site are kept within 7 days.

With regard to these operating natures, it should be obvious that the supply network and customer network are fairly limited for metal manufacturers as they normally buy and sell in some particular metal markets and to certain customers in the industry. Whereas for metal remanufacturers, their incoming secondary metals for production come from a wide range of industries, manufacturers and end users. The secondary metals they remanufacture and regenerate can be sold and used for various purposes. It should be pointed out that the supply and demand for both primary and secondary metal industries are influenced by the price fluctuation of these metal resources, which have been causing instabilities in these industries.

There are some appealing figures which show the differences between the production capacity and productivity among these SMEs. Company M_M, Mss and R_{AL} have developed automated systems for their productions. The rate of scrap can also be reduced by higher level technology in production. As a result, they can produce around 800 to 2,200 tons of metals per day. On the other hand, the productivities in Company R_{M1}, R_{M2} and L_{3PRL} are much lower, as they largely base on manual labour operations. Although with the current limitation of technology, it can be argue that when dealing with complex used products and parts, the sorting and dismantling processes by manual labour provide higher flexibilities than machineries. However, the implementation of technology systems would increase the production capacities in these companies to a larger extent, especially for them to expand to larger batch production.

Last but not least, it is useful to clarify value added processes during the manufacturing and remanufacturing processes. Therefore, actions can be taken in order to manage and limit non-value added operations. Eventually, activities such as transportation between suppliers and customers, within operating plants and work stations should be minimised. There should be better factory design and cooperation between players in the CLSC in order to develop a sustainable long term future for parties involve. After all, the reasons for recycling and remanufacturing processes are to utilise resources and properly disposing waste, left-over, scrap and used products and parts. Production costs can be reduced by generating additional resource value which would otherwise be lost as valueless wastes. These would eventually motivate manufacturing industries to reduce the level of pollution and damage to the society and the environment.

5.2.4 Operation Flow of Metal Manufacturers and Remanufacturers

The material flows between metal hardware manufacturer Company M_M and R_{M1}; stainless steel manufacturer Company Mss and R_{M2}; aluminium manufacturer Company R_{AL} and its department of residue recovery; and the suppliers of Company L_{3PRL} are illustrated in Figure 5.1, 5.2, 5.3 and 5.4 below [The tons per day are approximate figures]. These are the CLSC flows of waste, left-over and scrap, and residues from the forward metal manufacturers to the remanufacturers who would sell the secondary metals to the market, with regard to the framework discussed in the literature review (Figure 2.1). The collaboration between the forward metal manufacturers and reverse metal remanufacturers enables and increases the utilisations of waste and used products and even residues, by recovering reusable resources and reducing damages to the environment.

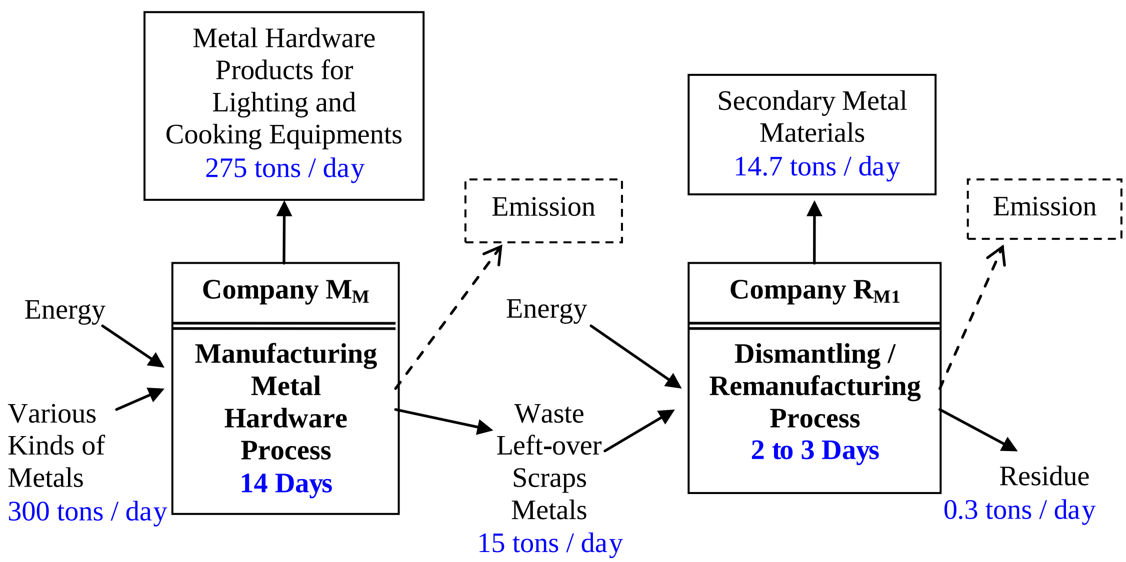


Figure 5.1 Material Flows in Company M_M and R_{M1}

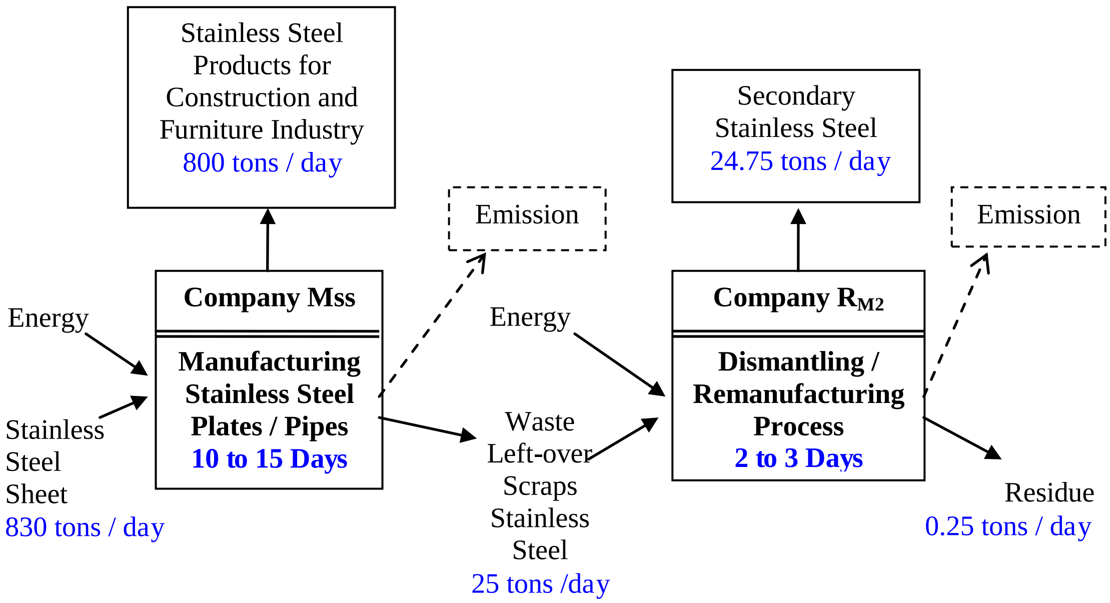


Figure 5.2 Material Flows in Company Mss and R_{M2}

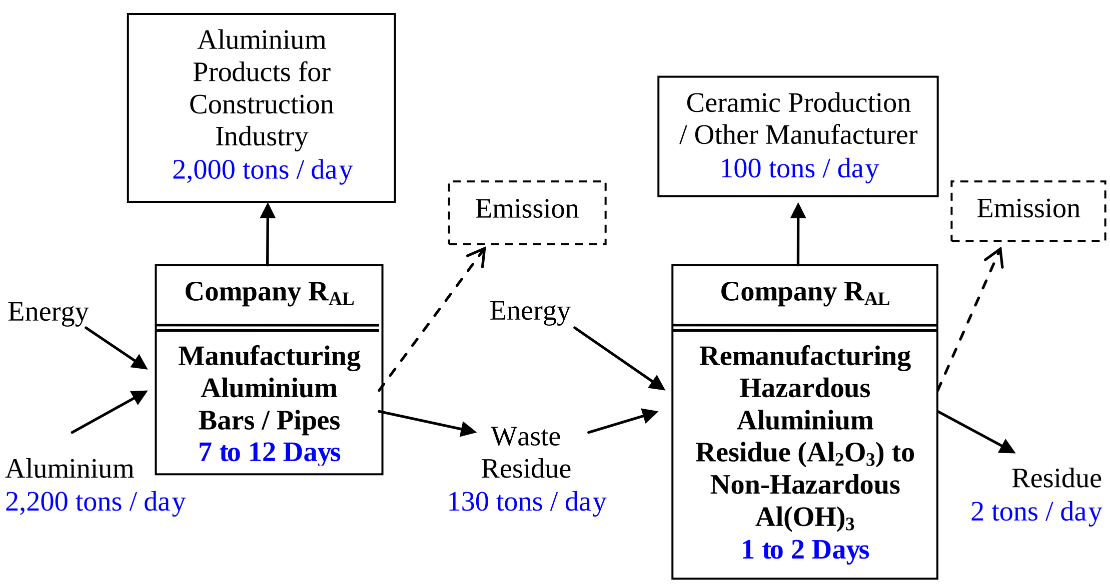


Figure 5.3 Material Flows in Company R_{AL}

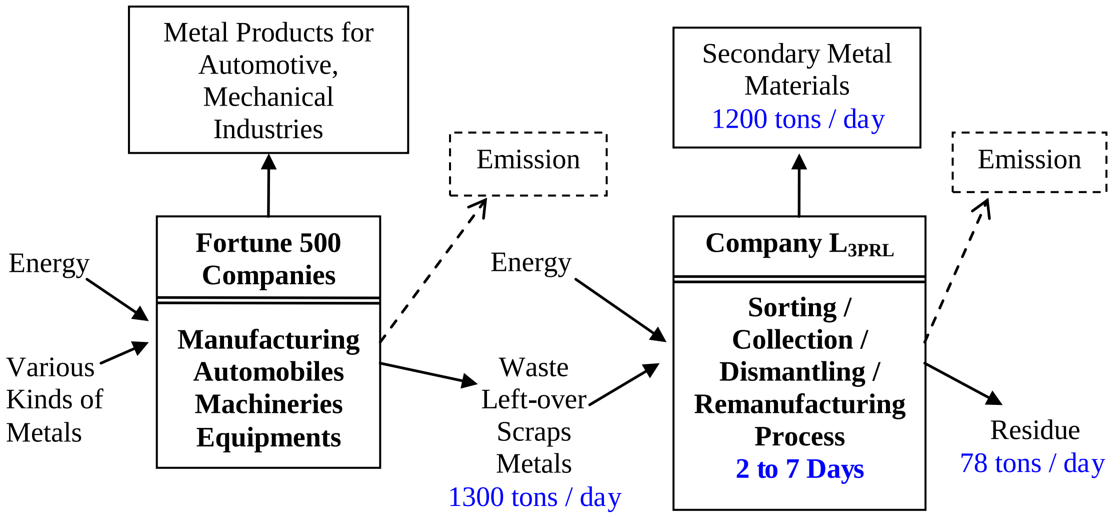


Figure 5.4 Material Flows in the Fortune 500 Companies and Company L_{3PRL}

As illustrated in the operation flows, these are the average daily productivity and lead-time figures in different operations between the case study metal manufacturers and remanufacturers. The short distance transportation of those waste metals from the manufacturers to the dismantlers and remanufactures in the region are mostly done on a weekly base. It should be obvious, as discussed in Table 5.1, the total amount of metal manufactured in the three metal manufacturers is significant: over 1 million tons per annual, and over 3,300 tons in total per day. In addition to these, a considerable amount of wastes and residues are produced during their manufacturing processes. By simply adding the amount of waste and residues these four metal remanufacturing companies deal with every day, the total figure is as big as 1500 tons. Imagine the consequences and negative affects it might incur if these wastes are not collected, remanufactured and dealt with properly. However, as a result of the remanufacturing processes, more than 90% of these metal waste and residues can be recovered and regenerated as secondary metals and materials, which create value to the companies and secondary metal market. Eventually, the total amount of residue after the remanufacturing processes among these four remanufacturing companies can be reduced to as low as 80 tons per day.

5.2.5 The CET Factors and the Sustainable Closed-Loop Supply Chain

As has been discussed throughout the literature review and the case studies, the interrelationships among the CET factors are the main concerns for this research. There are issues with regard to the CET factors which influence the sustainable CLSC operations, as illustrated in Figure 5.5.

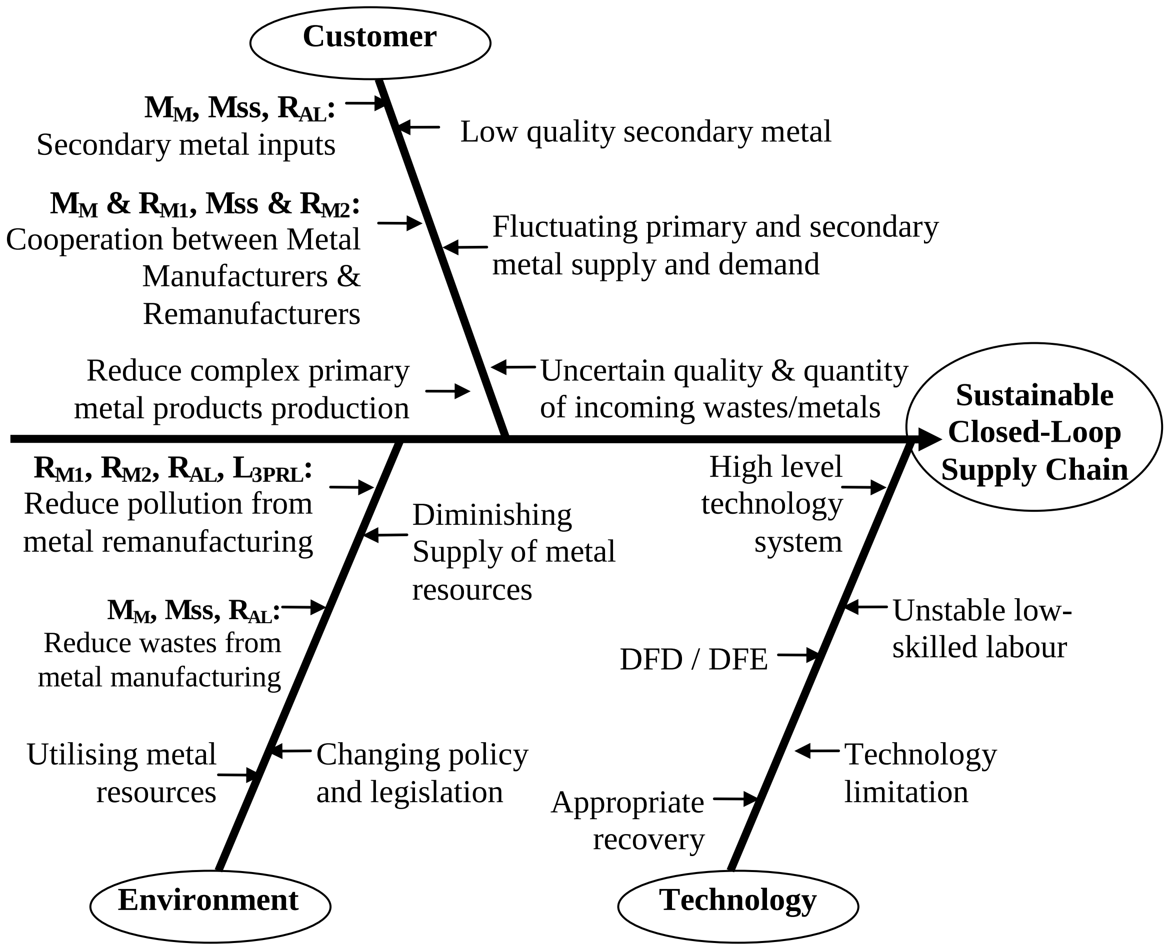


Figure 5.5 Factors Influencing Sustainable Closed-Loop Supply Chain

First of all, from the customer perspective, manufacturers can use good quality secondary metals for their production which are cheaper alternatives to primary metals. For example, in the case of producing keys and metal hardware, Company M_M applies secondary iron and copper in order to reduce costs. Hence, the supply chain becomes a closed-loop system as secondary metals re-enter the operation flow. In addition, it is essential to reduce the complexity of the primary metals products, which would ease the sorting and dismantling processes. On the other hand, as analysed from the case study finding, manufacturers and remanufacturers face the uncertainties of price fluctuation in both primary and secondary metal industry, which affect the quantity and quality of supplies and demands in the market. Although it seems that little can be done to control the changes in market, firms can aim to achieve higher sustainability by establishing collaboration with their suppliers and customers for better information sharing and process flows. For instance, in the case of Company M_M and R_{M1}, Mss and R_{M2}, planning and controlling as well as forecasting in short and long term are essential. More study by the industries and academics are needed in order to research for the quantitative methods with regard to these issues.

Secondly, from the environment perspective, Company M_M, Mss and R_{AL} face the increasing price and diminishing supplies of metals for their operations. Hence, they are anticipating in utilising materials, reducing production wastes, and applying secondary metals for production. In the mean time, Company R_{M1}, R_{M2}, R_{AL} and L_{3PRL} are developing better methods for their remanufacturing processes. As a result, not only the waste and EOL products and parts, but even the hazardous waste residue can be recovered and reused. These help to reduce pollution and develop sustainable CLSC in the long term. However, since the profit margin for remanufacturing activities varies between different resources, governments should establish policies and legislation in order to reinforce and motivate public and private firms to participate in the remanufacturing and recycling of wastes with the aim to achieve sustainability.

Last but not least, the application of higher level technology system and machineries for manufacturing and remanufacturing processes, and the appropriate recovery methods and techniques also help to develop sustainable CLSC. Although as in the case studies for Company R_{M1}, R_{M2}, and L_{3PRL}, they are benefiting from flexible manual labour operations for the sorting and dismantling operations, the long term development requires high technology systems for their operations. Especially for hazardous waste and used products and parts handling that require higher level of health and safety concerns. Moreover, the implementation of technology also include the initiative of applying DFD and DFE at the early manufacturing product design stage, which would simplify the remanufacturing processes at the end of the product life cycle. Consequently, in the sustainable CLSC, metal products and parts should be handled by machinery systems and higher skilled labour operation which provide more efficiency and stability than the current operations.

5.2.6 Summary

The interactions between metal manufacturers and remanufacturers in the CLSC in the PRD region are analysed and discussed by the demonstration of figures and graphs. The CET factors have impacts on developing efficient and effective remanufacturing process for waste management and reverse logistics. As there are increasing demands for metal products, while there are decreasing supplies of primary metals for the industrial market; there are escalating needs for better utilisation of resources, recovering and remanufacturing of reusable secondary metals. As a result, companies would not only save costs on the energy and resource consumption, but also help to reduce the level of pollution and damages to the environment. Although the application of manual labour operations especially for sorting, dismantling and recovering waste and used products and parts can provide higher flexibility than machinery, it is essential for further production technology development in order to assist the remanufacturing processes so that it can achieve higher efficiency. This is very important especially when dealing with increasing amounts of waste and used products. After all, by developing close collaboration between the Chinese metal manufacturers and remanufacturers, as well as suppliers, distributors, retailers and consumers throughout the CLSC, it would lead to further sustainable development for the society and the environment.

5.3 Analysis of the Chinese Aluminium Industry

5.3.1 Aluminium Supply Chain Development in Dali

In order to evaluate the Chinese metal industry from a macro development perspective, this part of the analysis would use the development of the aluminium production in Dali as an example. The manufacturing and remanufacturing of aluminium in Dali has a history of over 30 years since the 1970s when China started to develop. It was very remarkable when collecting the historical data and information from the Guangdong Non-ferrous Metal Technology Innovation Centre and some of the interviewees from the case study companies. As a result, data and information could be analysed for drawing up pictures according to historical development which contextualise the aluminium supply chain in Dali. With unique characteristics of the aluminium industrial development, the aluminium industry actually started from the reverse operations of collecting, dismantling and recycling of aluminium products and materials in the 1970s, then developed in the forward aluminium manufacturing in the 1980s with further improvement and expansions in the 1990s. Eventually, a more sustainable CLSC of both forward and reverse logistics had been developed by the beginning of the 21st century.

5.3.1.1 Collecting, Dismantling and Recycling Aluminium in the 1970s

As mentioned in the previous section, it was until the 1970s when there were scattered small workshops for metal (particularly aluminium) productions starting up in the PRD region. At that time, due to the low level of productivity and techniques, the capability for Chinese firms to manufacture metals and aluminium products were extremely limited. The main operations of aluminium were the collection of waste, used and scrap aluminium materials, dismantling of old machineries and mixed daily productions mostly imported from overseas to China. There were mostly manual dismantling processes, in which the mixed aluminium materials and old machines were separated by hand into small parts, sorted according to their characteristics. Then they were cleaned manually before re-melting into aluminium liquids or resizing into different forms, for recycling and reuse, as shown in Figure 5.6. The processes were inefficient, time consuming and only a limited amount of low quality secondary aluminium were recovered. There were quality issues with the remanufactured secondary aluminium in terms of quality standard, the level of impurities and hardness. In addition, there were hazardous actions in these old methods of reverse logistics operations, as there were waste residue which polluted the land, water resource and air. After all, these were negative effects to the society and the environment, when China was an underdeveloped country in the 1970s.

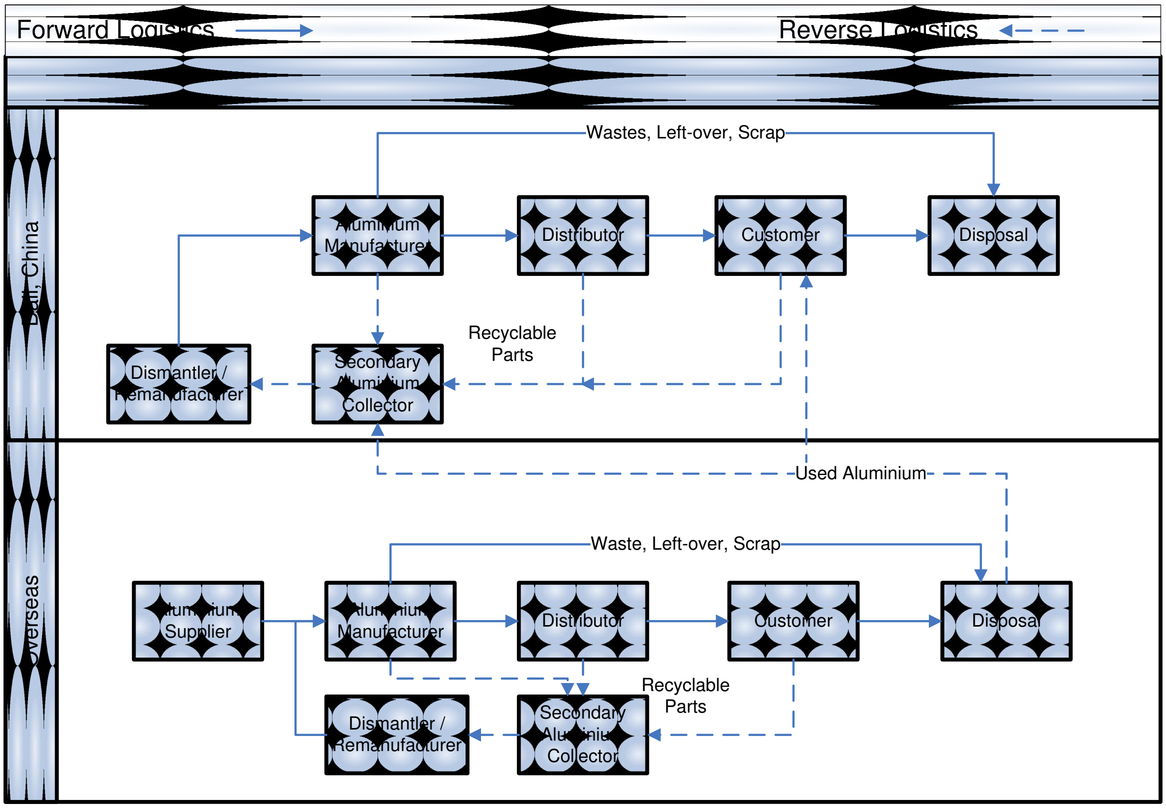


Figure 5.6 Aluminium Supply Chain in the 1970s

<u>5.3.1.2 Development of Aluminium Production in the 1980s</u>

Since the booming economic development in China from the 1980s, more dismantlers found that as they were getting more familiar with their dismantling processes, they were able to modify and improve their dismantling operations. In addition, as some of them have been dismantling old machineries imported from overseas, they accumulated more knowledge in mechanical engineering and machinery designs. Some of the dismantling plant operators started to summarise and analyse their work and find out the logic behind their operations. As they were getting the limited value added profits from recycling aluminium, they realised that it would be more profitable to produce first hand aluminium products and machinery parts. Therefore, some of them began to investigate in ways to develop better machineries and processes for producing primary aluminium and aluminium products.

As a result, there were production and development of machineries for manufacturing aluminium products. An increasing number of producers moved from the dismantling industry to the production of aluminium, especially in manufacturing aluminium products for the construction industry and some other light industries. The development of aluminium supply chain in the 1980s is illustrated in Figure 5.7. In addition to the secondary aluminium collectors in the 1970s, there were aluminium suppliers in the 1980s which provided input resources for manufacturers for their production.

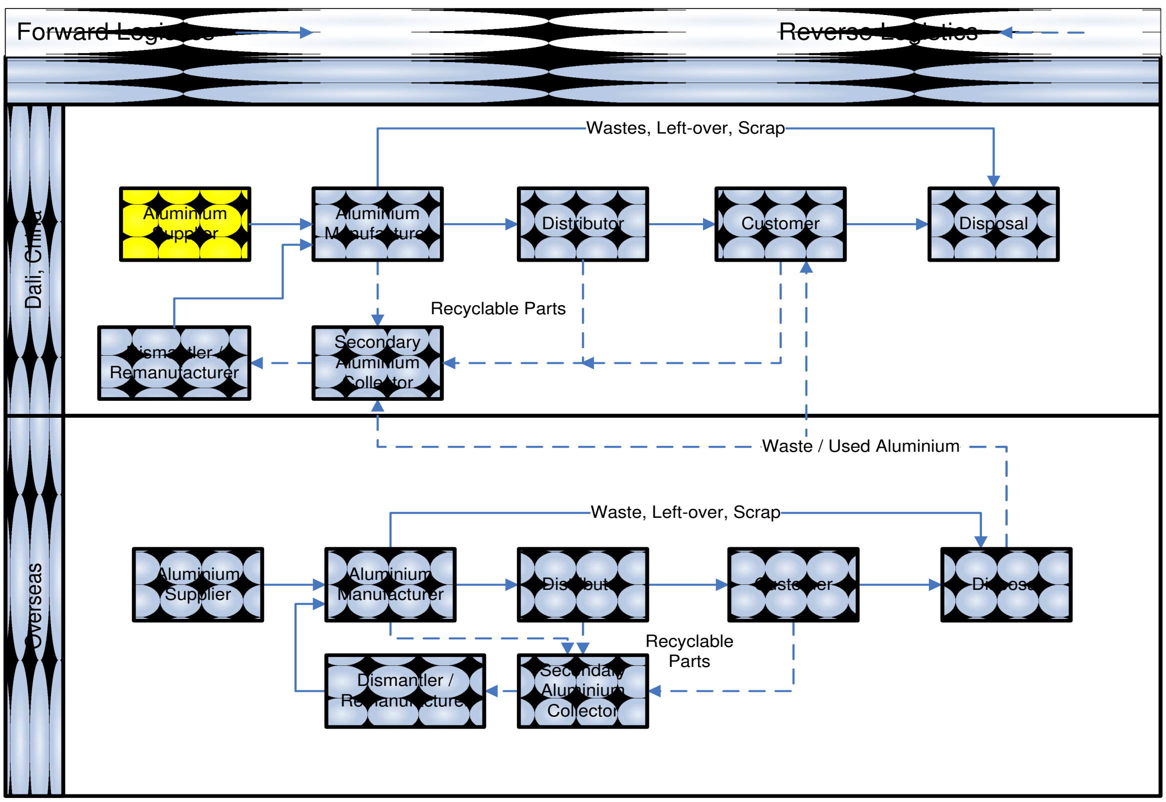


Figure 5.7 Aluminium Supply Chain in the 1980s

5.3.1.3 Industrial Expansion in the 1990s

From the 1990s, as there were further developments in technology, manufacturing equipment, techniques, human labour and resource, it has been a golden era for the aluminium production in the PRD region. The quality level and the complexity of aluminium products have been increasing rapidly, and the production quantity has been growing fast every year. More public and private investments have been attracted to the industry, and the market has been heated up with corporation and competitions among companies in the region. As a result, Dali has become one of the essential centres for aluminium manufacture in China because of the geographic location, labour resource availability, and technology implementation. It produces large quantities of various aluminium products and alloy materials for both Chinese and overseas markets.

In the mean time, the development in the reverse supply chain for aluminium recycling and remanufacturing have been tremendous. Along with the technology development in aluminium production in the region, the process of collecting waste, used and production left-over in the region, sorting and remanufacturing, and applying secondary aluminium into production contributed in developing a relatively high level CLSC flow, as shown in Figure 5.8.

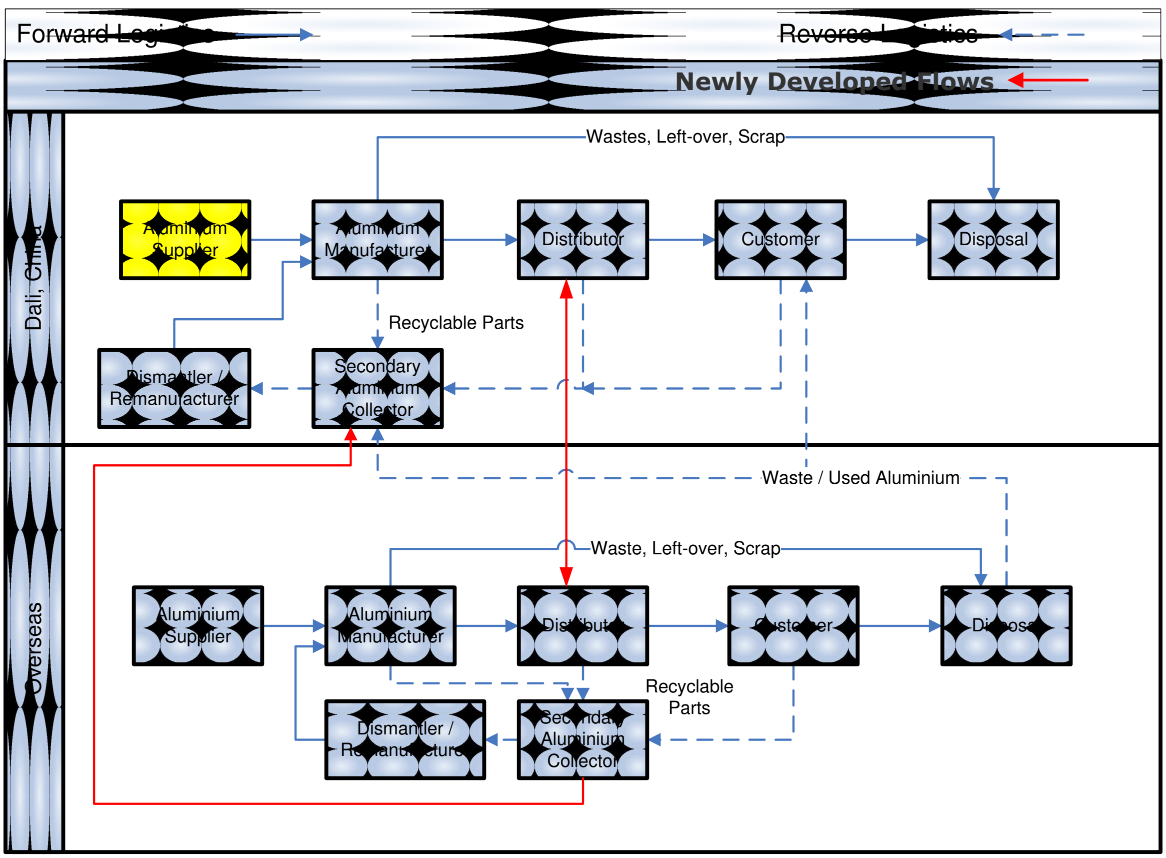


Figure 5.8 Aluminium Supply Chain from the 1990s

Comparing with Figure 5.6 and 5.7 for the process flows in the 1970s and 1980s, there are more interactions in Figure 5.8 between players, and there are imports and exports of primary and secondary aluminium products between Dali and customers in the overseas countries. Especially with the technology and machinery availability, the labour costs and time for collecting, sorting and remanufacturing aluminium have been reduced significantly. Dali has been one of the important centres in China for secondary aluminium recycling, reuse and remanufacturing.

On the other hand, while the forward and reverse supply chain flows for primary and secondary aluminium have been developing rapidly in Dali, some issues have been raised. Most importantly, especially at the beginning of the 1990s, when all those manufacturers were investing in aluminium production, not much environmental concerns were taken into account. As the production of aluminium went through physical or chemical processes, aluminium waste residues occurred during manufacturing stages, which were harmful to the land, water and air environment. Some of the companies did not apply appropriate environmental protection activities when dealing with those hazardous residues, and some of them even dumped the residues in landfill or polluted the water system in the region. These caused dangerous health issues and damages to local residents and the environment. There were also pollution from companies dealing with the collecting, sorting and recycling of waste, used and scrap aluminium, as they were not aware of properly disposing the waste, production residues and cleaning materials. These created terrible damages to the environment. Consequently, it has become the responsibilities of the government, the aluminium producers, and those operators in the recycling and remanufacturing aluminium processes to tackle the problems caused by the forward and reverse logistics of aluminium operations.

As mentioned in the case studies, Company R_{AL} has been a leading manufacturing company which also takes into consideration the production residues during its aluminium production. It has developed its own research and development team, and has been working along with a leading university in China, to develop ways to recycle the hazardous waste residue. The operation would turn hazardous aluminium residue into non-hazardous reusable materials Al_2O_3 for other manufacturing productions. During the regeneration of aluminium residue, it also produces a number of side chemical products which Company R_{AL} sells to other companies in the region as production material resources for their operations. More importantly, the operation also helps the company to solve the problem of handling the hazardous production residues, and greatly reduced its production damage to the environment. It should be obvious that by developing this new method of recycling and remanufacturing waste residue for aluminium production, Company R_{AL} generates economic benefits, and environmental friendly activities, value-added application of materials and provides recycled sources for other operations.

5.3.2 The Spiral Cycle of Closed-Loop Supply Chain

Regarding to the discussions above, with all these forward and reverse logistics flows between the metal manufacturers and remanufacturers, as well as the operations of aluminium production in Dali, in the PRD region, a framework can be developed accordingly. As in the case of aluminium production and remanufacturing in Dali, the supply chain started from the reverse side ([A]→[B]) in the 1970s as in Figure 5.9.

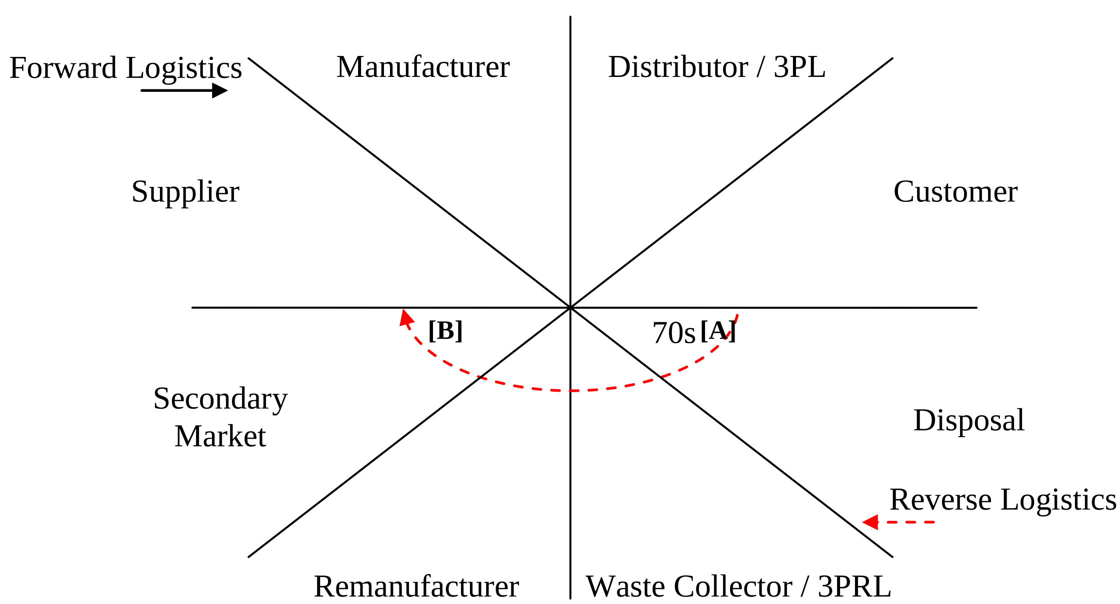


Figure 5.9 The Reverse Supply Chain in the 1970s

And from the 1980s, as technology, production techniques and resource developed, a CLSC was completed in the region ([A]→[B]→[C]) as in Figure 5.10. From then on, there were developments in the aluminium manufacturing and remanufacturing, recycling and reusing secondary aluminium, as according to the CLSC theory.

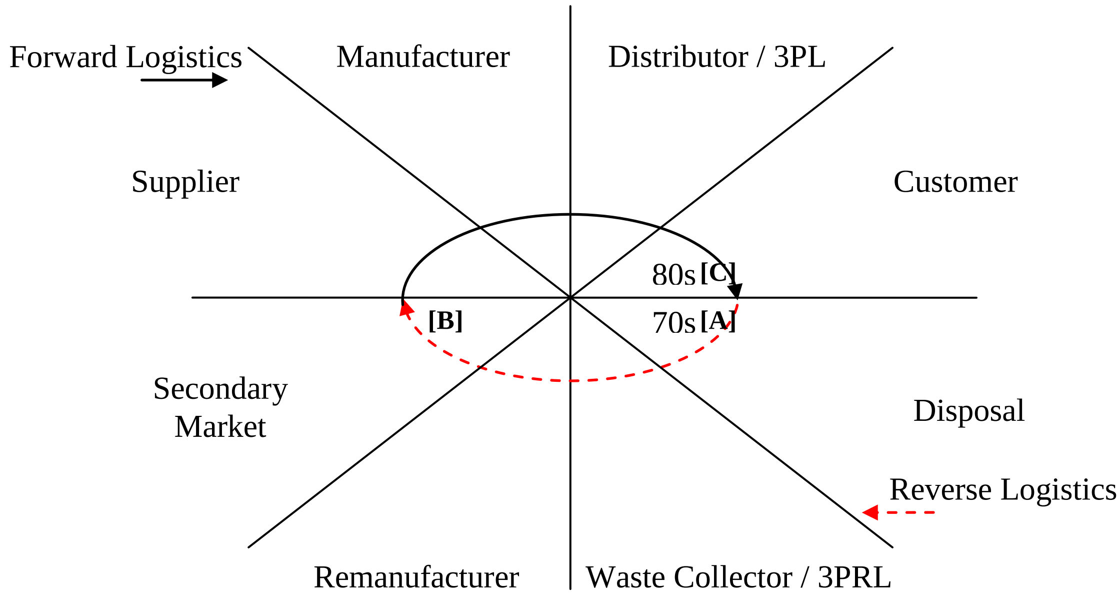


Figure 5.10 The Closed-Loop Supply Chain in the 1980s

In addition, from the case findings, this research shows that the circle of supply chain continues to grow, and in a spiral circle pattern, as higher levels of technology have been developed for the operation. There has been a higher efficient flow of production implemented in both forward and reverse operation since the 1990s ([D]→[E]→[F]) as in Figure 5.11. The CLSC has been expanding and becoming more comprehensive. There are better collaborations between players in the closed-loop cycle.

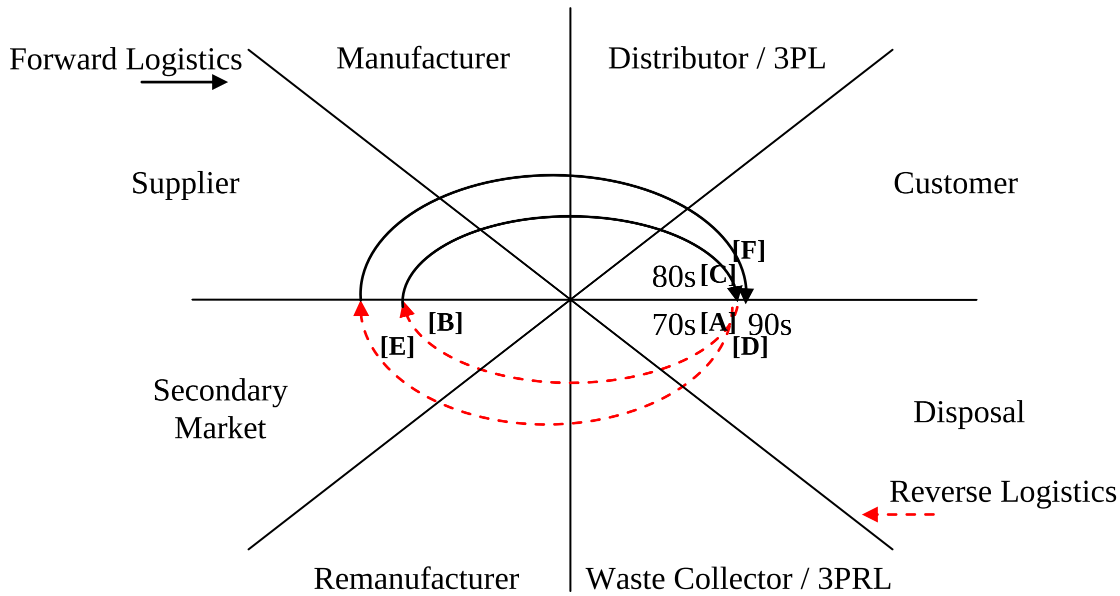


Figure 5.11 The Growing Closed-Loop Supply Chain in the 1990s

Hence, in addition to the CLSC framework, case studies in this research suggest that the flow of forward and reverse logistics can go further beyond a closed-loop. It can be illustrated as a "Spiral Cycle of Supply Chain", as in Figure 5.12.

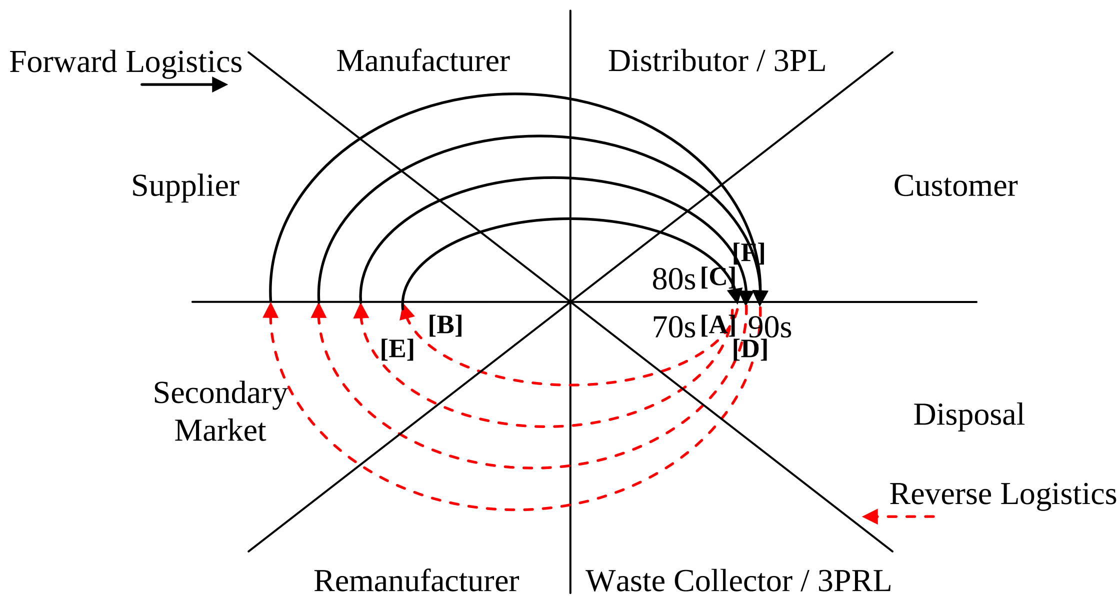


Figure 5.12 The Spiral Cycle of Closed-Loop Supply Chain

When looking at the spiral from a 3-Dimension perspective, as all the factors are considered, issues such as level of sustainability, the development of production efficiency, level of technology, human resource, knowledge and techniques will be continuously growing and pushing the CLSC circles upward, which eventually becomes a virtuous cycle, as illustrated in Figure 5.13.

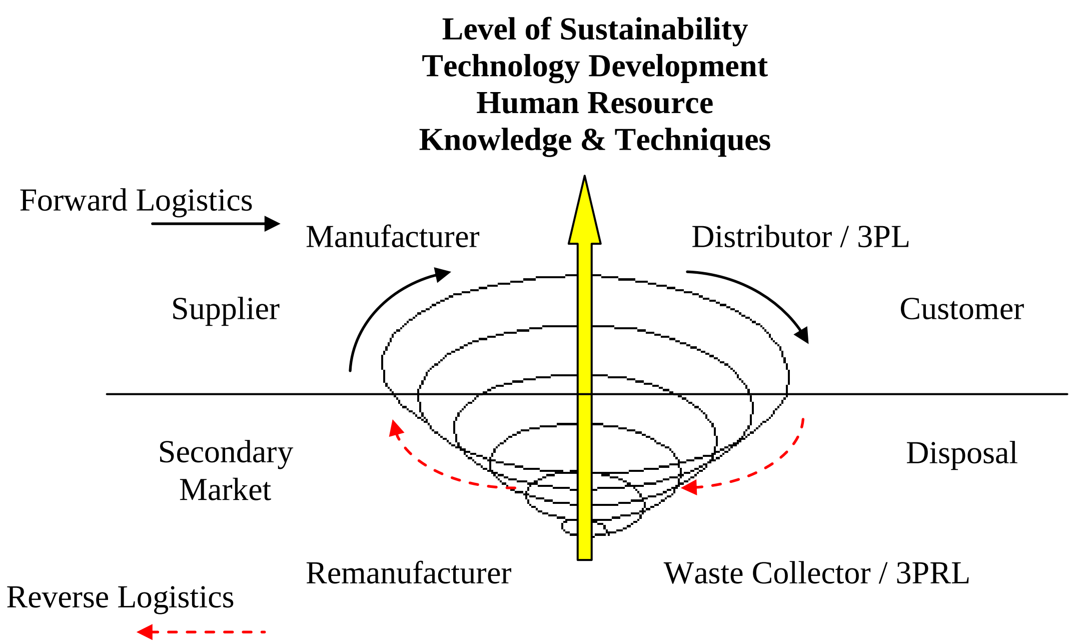


Figure 5.13 The Virtuous Spiral Cycle of Closed-Loop Supply Chain

It should be pointed out that the supply chain must be completed in a closed-loop in order to go upwards in the virtuous spiral cycle. The closed-loop system can either be external cooperation between companies in the forward and reverse supply chain, or internally with all in-house operations between the forward and reverse supply chain departments within a company. Having either forward or reverse supply chain, would not move up to the higher level but eventually drag down the whole supply chain operation. That is to say, manufacturing without recycling and remanufacturing of wastes, or simply recycling used or waste materials without developing better methods for manufacturing, have negative impacts which would force a virtuous cycle to be a vicious cycle. However, the negative factors that affect the spiral cycles are beyond the scope of this research and would not be discussed further at this point.

For instance, as in the case Company R_{AL}, if the waste residue were not collected and remanufactured with the technique the company developed, there would not be proper disposal of those hazardous materials. The materials would be piled up and cause increasing damage to the environment and industry. Similarly, as if all the Chinese metal recycling and remanufacturing processes were only based on imports from other countries, for example, in the case of the 1970s, the process flow for those remanufacturing processes would be very slow and inefficient. Although to a certain extent, the supply chain was still completed in a closed-loop with the forward supply chain at overseas countries and the reverse loop in Dali, the level of sustainability remained really low. Companies would indeed be struggling for survival in the industry. After all, there must be better collaboration between both forward and reverse flows in the CLSC in order for firms and industries to move upwards in a virtuous spiral cycle for higher level sustainable development. As a result, Table 5.4 presents the dimensions and levels of sustainability from the Operations Management perspectives, as adding to findings of Sutton (1998) in Table 2.1, as discussed in the literature review chapter.

Table 5.4 Dimensions and Levels of Sustainability

<table>
<tr><th rowspan="7">Sustainability</th><th>Environmental</th><th>Social</th><th>Economic</th><th>Operations Management</th></tr>
<tr><td colspan="4">Level 1: Survival Sustainability</td></tr>
<tr><td>Protection of life support systems, Prevention of species extinction</td><td>Capacity to solve serious problems</td><td>Subsistence</td><td>Work on existing primary and secondary resources</td></tr>
<tr><td colspan="4">Level 2: Maintaining Quality of Life</td></tr>
<tr><td>Maintenance of decent environmental quality</td><td>Maintenance of decent social quality (e.g. vibrant community life)</td><td>Maintenance of decent standard of living</td><td>Maintenance of efficient flow of CLSC</td></tr>
<tr><td colspan="4">Level 3: Improving Quality of Life</td></tr>
<tr><td>Improving environmental quality</td><td>Improving social quality</td><td>Improving standard of living</td><td>Improving production quality and wastes remanufacturing</td></tr>
</table>

(Adapted: Sutton, 1998)

The CLSC can also be illustrated as the sequence of circles at different levels of the operation stages being pushed up by various factors. The level of CLSC operations (L) is determined by the Force of Factors (F) between two particular time periods (T), as shown in Figure 5.14.

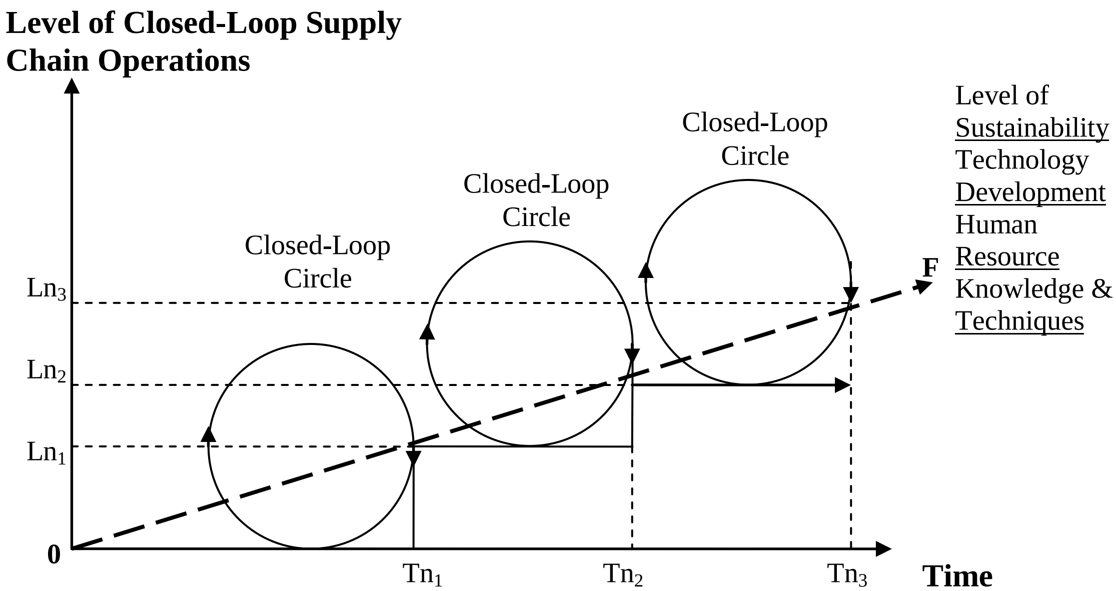


Figure 5.14 Closed-Loop Supply Chain Development Cycle

As a result, the Level of CLSC Operation (L) is directly proportional to the Force of Factors (F). Further research can be carried out to determine the combination of factors that influences the supply chain operation, in order to manage the sustainability of the CLSC. As a result, it can be developed progressively as a virtuous spiral cycle towards a higher level in the longer term. However, at this exploration stage of researching in the CLSC in the context of the Chinese metal industry, this research would only be analysing issues and factors that were identified by our interviewees from their experiences of their internal and external company operations. Further discussions of these factors are in Chapter 6 for the development of the CLSC Positioning Tool.

5.4 Summary

This chapter presents the analysis and evaluation based on the research findings from the case study in Chinese metal companies in Dali, the PRD region. Issues with regard to the CET factors are examined according to the case companies and their internal and external cooperation in the CLSC in the Chinese metal industry. Narrative and pattern matching analysis methods are applied in order to develop process maps of the flows and activities in the supply chain among these metal manufacturers and remanufacturers. In addition, the macro level of the market environment is also explored, using the development of the aluminium manufacturing and remanufacturing operation as an example. The framework of Virtuous Spiral Cycle of CLSC is developed referring to the findings and development in the industrial environment context.

CHAPTER 6

EVALUATION AND DISCUSSION

6.1 Introduction

This chapter is the evaluation and discussion on the theoretical and empirical findings and analysis from this research. As discussed in the previous chapters, it should be obvious that the operating flows within the CLSC can be very complex, especially as it requires management and control between the interactive forward and reverse supply chain in order to achieve sustainability. By setting the boundaries and mapping the processes using the reverse logistics framework, with particular focuses on the CET factors, this thesis presents data and information for the existing CLSC flow in the context of the Chinese metal industry. In addition, with reference to the case study and research development, a CLSC Positioning Tool is proposed for companies to position themselves with regard to the CLSC and for their sustainable development. Verifications have been performed with case companies in order to verify and refine the model. As a result, the research questions, aims and objectives of this research can be accomplished from the theoretical and empirical findings, and the CLSC Positioning Tool has been modified to help companies to identify their positions for long term sustainable development and further improvement.

6.2 The Closed-Loop Supply Chain in the Chinese Metal Industry

In addition to the case study analysis of individual case companies, the reverse logistics operation, the process flows and patterns among the manufacturers and remanufacturers can also be evaluated and mapped. These include the internal and external operation flow within these companies, as well as in the macro environment level.

6.2.1 Reverse Logistics Framework for Manufacturers and Remanufacturers

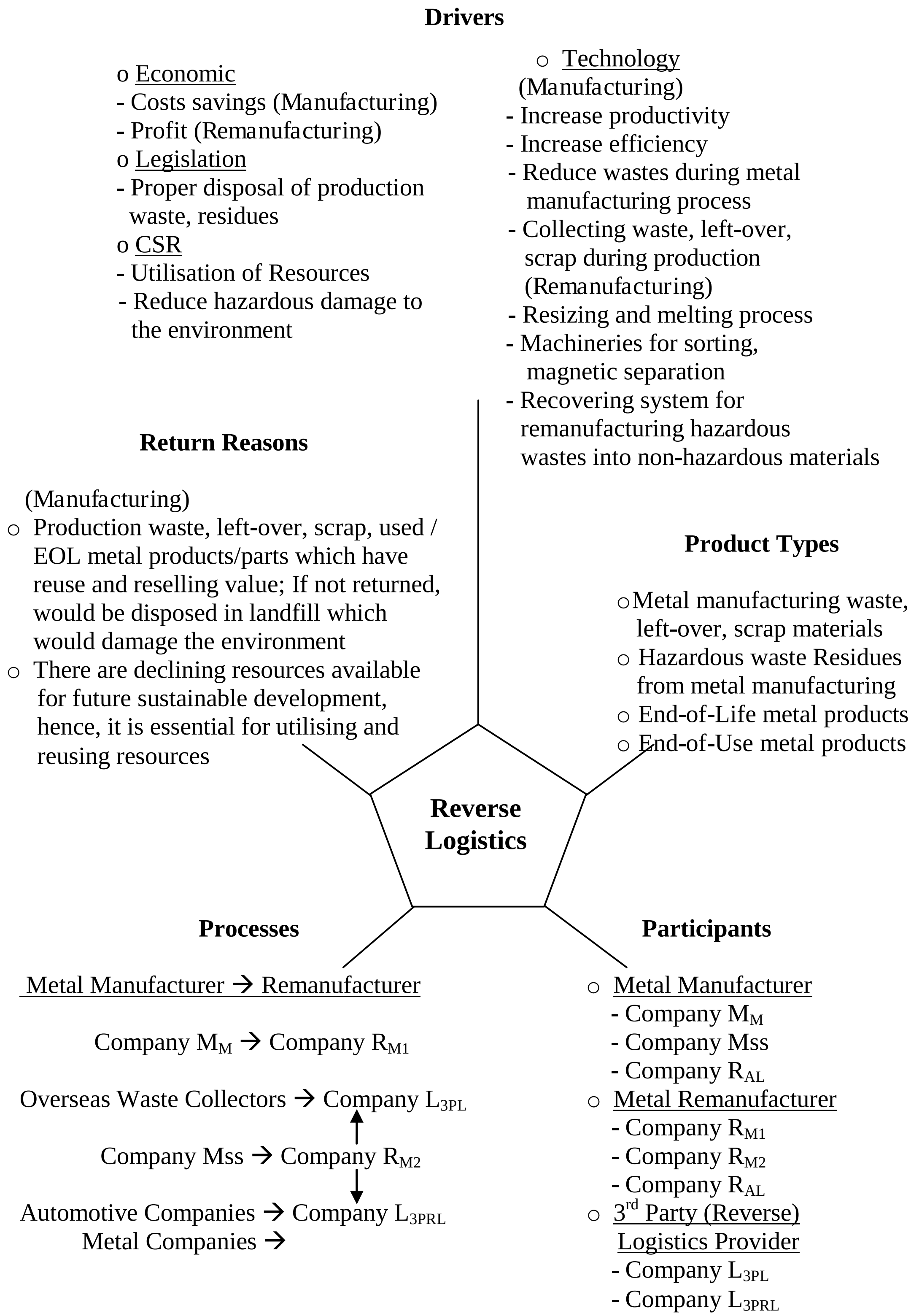


Figure 6.1 Reverse Logistics Framework in the Chinese Metal Industry

Regarding to the Framework for Reverse Logistics developed by De Brito and Dekker (2002) as in the literature review (Figure 2.4 and 2.5), the five basic dimensions of reverse logistics in the context of the Chinese metal industry can be evaluated according to the data and information by the case study research, as illustrated in Figure 6.1.

6.2.1.1 Participants

During this research, three groups of participants of the Chinese metal industry are studied. These are the metal manufacturers: Company M_M, Mss and R_{AL}, metal remanufacturers: Companies R_{M1}, R_{M2}, R_{AL}; and third party (reverse) logistics providers: Company L_{3PL} and L_{3PRL}. Hence, the illustration in Figure 6.1 is based on these companies and the findings from the research.

6.2.1.2 Product Types

In the context of the Chinese metal industry, the types of returns among the metal manufacturers and remanufacturers, as well as the third party reverse logistics providers mainly include: the metal manufacturing waste, left-over and scrap during the production process, such as Company M_M for its production of metal hardware products and Company Mss for its production of stainless steel products. There are also hazardous waste residues as in the case of Company R_{AL} which produces aluminium bars and pipes. In addition, Chinese metal remanufacturers also receive EOL and used metal products imported from overseas for their remanufacturing and regeneration processes in order to recover secondary metals and value.

6.2.1.3 Return Reasons

Unless the manufacturing processes could reach zero-defect in production, there are inevitable waste materials during the metal manufacturing processes. Hence, there are needs for remanufacturing operations for recovering those metals and wastes which would otherwise be disposed in landfill, and would cause damage to the environment if they were not handled properly. Moreover, because of the process technology development in metal manufacturing and remanufacturing, higher percentages of waste metals can be recovered and remanufactured into secondary metals and be reused. Hence, the recovery of secondary metals not only generate additional value from the 'valueless' wastes, but also increase the utilisation of resources which contribute in the sustainable development in the long term. Metal remanufacturing processes have become very important especially as there have been diminishing supplies of resources, due to increasing demand of metal products in various applications in China and globally.

6.2.1.4 Processes of Return

There are collaboration between these Chinese metal manufacturers and remanufacturers as discussed in the case study and illustrated in the Process of Return in Figure 6.1. The main flow of waste, left-over, scrap and used metals are moving from metal manufacturers to remanufacturers. These including those metal wastes and scraps from Company M_M to R_{M1}, from Mss to R_{M2}, as well as those cargo containers from overseas waste collectors arriving at R_{M1} and R_{M2} through the distribution of the third party logistics provider L_{3PL}. In addition, L_{3PRL} is a third party reverse logistics provider which collects waste, left-over and scrap metals mainly from large size automotive and metal manufacturing companies in the region for its remanufacturing processes.

6.2.1.5 Drivers

As a result, the drivers for the CLSC operation in the Chinese metal industry can be summarised in several points. Due to the fact that the Chinese legislation for proper disposal of production waste and residues are not as strict as those in the developed European and North American countries, one of the main driving force for metal manufacturers (such as Company M_M and Mss) to apply reverse logistics in their supply chain operation is to save costs. In doing so, they collect the waste, left-over and scrap metals from their production, then sell to metal remanufacturers. Although these secondary materials are normally sold at very low prices (as low as 10% of the incoming raw material price), there are still certain level of savings on the total production costs. The collaboration between Company M_M and R_{M1}, Mss and R_{M2} enable the smooth flow of secondary metals within the supply chain loop.

Although one can always argue that the incentives of remanufacturing processes are to achieve the additional profit and value, Company R_{M1}, R_{M2} and L_{3PRL} help metal manufacturers to handle those wastes and scrap metals which can be reused and remanufactured. Without these remanufacturing processes, those materials would become valueless and would be wasted and disposed in landfill. Especially in the case of Company R_{AL}, without properly handling the hazardous waste residue during its aluminium production, there would be severe damage to the environment in terms of water, air and landfill resources. However, it should be pointed out that as the metal remanufacturers are operating for profit maximisation, they are very sensitive to the price of the secondary metals in the market. If the costs for producing a unit of secondary metals were greater than the price in the market, remanufacturers would be forced to shut down their operation.

Last but not least, in order to motivate companies to participate in the reverse logistics and the CLSC operation, technology must be developed to enable those process operation and requirements. It should be noted that the first action for metal manufacturers to contribute in the sustainable CLSC would be reducing the level of wastes in their production processes. Hence, higher levels of technology and machineries are essential in increasing the productivities and efficiency during metal manufacturing, with the aim to minimise production defects and wastes. With higher level of machinery systems in manufacturing processes, the rate of scrap in Company M_M, Mss and R_{AL} can be as low as 2%.

On the other hand, the application of machinery usages in Company R_{M1}, R_{M2} and L_{3PRL} are very limited, more than 70% of their operations are strongly relying on manual labour operations. This figure is very significant especially when comparing with the metal manufacturing companies M_M, Mss and R_{AL}, as the technology and machinery usages have reached 70% in their operations. As a result, there are strong needs for developing higher levels of applicable technology and machinery system for the remanufacturing processes, especially for the dismantling and sorting processes which have been largely based on manual operations. The development of process technology would drive up the level of remanufacturing efficiency and productivities, particularly when handling those hazardous wastes such as in the case of Company R_{AL} in remanufacturing the aluminium residues from its aluminium production.

6.2.2 The CET Relationships

On the other hand, the flow of process operations between the metal manufacturers and remanufacturers can be very complex. Especially as discussed throughout the literature review and case studies, the CET factors and other uncertainties have influences on the sustainability of the CLSC. Hence, further and detailed mapping of the sustainable CLSC is to be developed. With reference to Figure 2.8 developed in the literature review, the relationships of the CET and the collaboration between each pair of the metal manufacturers and remanufacturers are illustrated as in **Appendix 9, 10, 11** and **12**.

6.2.2.1 Metal Manufacturing and Remanufacturing

The illustrations are very similar in **Appendix 9, 10** and **12**, among Company M_M and R_{M1}, Mss and R_{M2}, as well as those the Fortune 500 companies in the PRD regions which deliver waste, left-over, scrap metals and parts to Company L_{3PRL}. The customers of the metal manufacturers (such as Company M_M, Mss) include the manufacturers of lighting products, cooking equipment, furniture, and those in the construction industry, as well as those large corporations which are specialised in the production of automobile, various equipments and machineries.

There are loops of metal products and materials in both forward and reverse logistics flows. Energy and metals are the elements of production inputs. At the end of the production process, metal products are produced and by selling these products to the customers in the metal market, it generates incomes for companies. Information and requirements received from customers determine the product quality and characteristics of the manufacturing processes.

On the other hand, there is the reverse logistics flow. During the production process, there are inevitable emissions, waste metals and residues. Moreover, as the red arrows in the figures, some of the EOL or used products are either returned to the metal manufacturers, or being collected through distributors (such as Company L_{3PL}) and collectors, and then being sent to the metal remanufacturers (such as Company R_{M1}, R_{M2} and L_{3PRL}). The majority of these waste, scraps and used products can be collected for remanufacturing processes in order to recover the reusable metals and materials, as well as to reduce the total amount of wastes and damages to the environment. In the context of the Chinese metal remanufacturing operations, more than 70% of the remanufacturing processes of collecting, dismantling, sorting, grouping of waste and used metals and parts are done manually. The operations of melting, resizing and remanufacturing the grouped metals are done by machineries which consume electricity and power. Further internal loop might occur especially when some of the wastes and residues at the end of process are re-entering the remanufacturing operation flow for further refinement and regeneration. Consequently, similar to the findings of Shang (2007), as in the case of Company R_{M1}, R_{M2} and L_{3PRL}, the recovery rate of remanufacturing processes in the PRD region also reaches 95%. A significant amount of wastes which would otherwise be disposed in landfills are reduced.

Although at the moment, the Chinese metal remanufacturing industry are benefiting from the low-cost labour and the flexibilities of manual dismantling and separation for the remanufacturing processes, the importance for implementing applicable technology into production is emerging. Especially as higher levels of technology and machineries are designed for sorting and dismantling processes, there should be increasing needs for higher levels of process technologies in the remanufacturing processes for better production efficiency and shorter lead-times. In particular, for large quantity reproduction and batch remanufacturing processes.

Hence, there are interactive relationships and collaboration between the metal manufacturers and remanufacturers in the CLSC operations. The motivation of remanufacturing processes are to generate additional profits, meeting customer’s needs in the secondary metal markets and utilising metal resources while reducing the amount of pollution and damages to the environment. The expansions of the remanufacturing processes also encourage better designed systems and machineries for assisting processes to reach higher efficiency and remanufacturing productivities. Referring to Zhu, et al., (2008), there is certain level of efficiency in the metal industry with regard to internal and external environmental management, supplier and customer relationships.

6.2.2.2 Metal Manufacturing and Waste Residue Remanufacturing

In the case of Company R_{AL} as in **Appendix 11**, the operating flows are relatively less complicated when comparing with the others. The production of aluminium bars and pipes from the inputs of energy and aluminium are mainly sold in the construction industry. The EOL and used aluminium products would be collected and remanufactured through similar operations as those in Company R_{M1}, R_{M2} and L_{3PRL}. However, since the awareness of the owners of Company R_{AL} on the recovery of production wastes and residues, the company has developed the technology which is capable of regenerating the hazardous residues into non-hazardous Al_2O_3, which can be sold to other manufacturers and operating flows for other manufacturing proposes. In doing so, it maximises the utilisation of raw materials while minimising the pollution and damages of hazardous wastes to the environment. Most importantly, it is not just a solution for the disposal of hazardous waste residues from the aluminium production, but it also generates additional values and resources for Company R_{AL}. As manufacturers such as in the ceramic production would buy those materials from Company R_{AL} and apply those materials for their production inputs.

6.2.2.3 Summary

It should be obvious that the CET factors motivate and have influences on the development of the process operations among metal manufacturers and remanufacturers, as well as the distributors and logistics service providers in the CLSC. There are flows and movements of metal products, wastes, left-over, scraps, used products and even waste residues. In addition to information, customer requirements and feedbacks which form different loops in the supply chain operations. A summary of the CET relationships in the case companies and the flows in between these companies are shown in Figure 6.2.

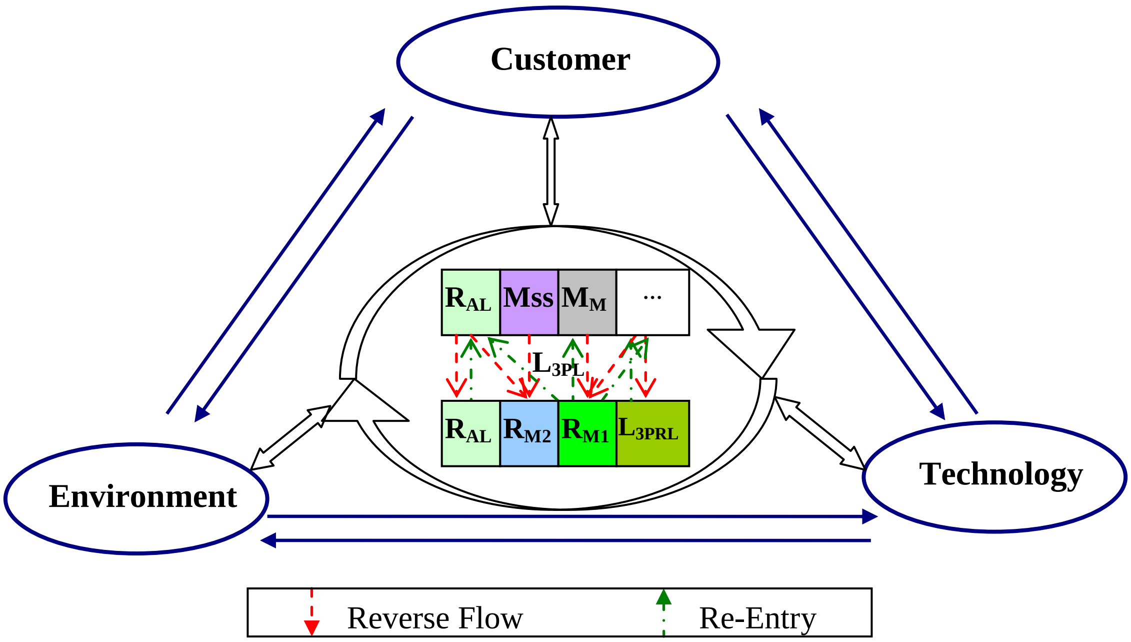


Figure 6.2 The CET Relationships Among Case Companies

With regard to the case companies and their operation flows in the supply chain, more detailed process and material flows in the forward and reverse logistics operation can be developed with reference to the Figure 2.2 Closed-Loop Supply Chain (Rahman, 2004) in the literature review chapter. As illustrated in Figure 6.3 following, metal suppliers provide various types of metals to metal manufacturers, such as Company M_M, Mss and R_{AL}, for their production of metal hardware, stainless steel and aluminium products. The metal products would be sold onto retailers and reach a number of customers in the market. The EOL and used products would be disposed in landfills, or through the reverse logistics flow by re-entering the supply chain loop and being recycled and recovered. On the other hand, the wastes, left-over and scrap metals would be transferred from metal manufacturers to dismantlers and metal remanufacturers, such as Company R_{M1}, R_{M2} and L_{3PRL}. These processes are either done directly between the two parties, or through the collectors and distributors, such as Company L_{3PL}. Eventually, through the remanufacturing processes, the regenerated secondary metals would re-enter the supply chain loop, and be delivered to metal manufacturers and used as input materials for production. Hence, Figure 6.3 illustrates the flow of CLSC generalised from the case study.

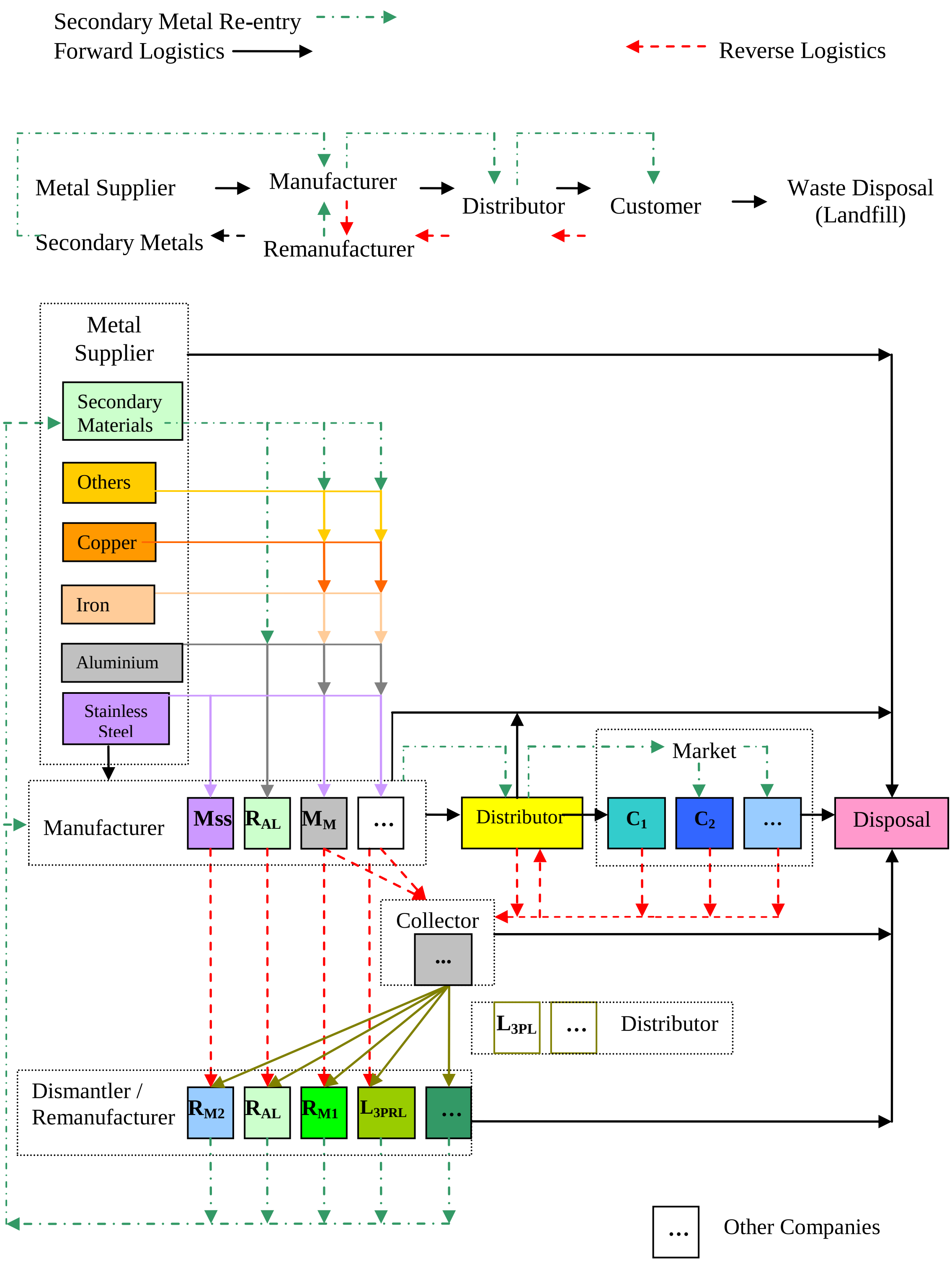


Figure 6.3 Closed-Loop Supply Chain Flows for Case Companies

6.2.3 Transportation from Overseas

In addition to the local collections, Company R_{M1}, R_{M2} and L_{3PRL} also receive cargo containers of waste and used products and parts from overseas countries. As shown in the International Shipping Transportation Map (Figure 6.4), the cargo containers are shipped from Europe, UK, USA, Canada and Australia. It takes at least 9 to 33 days for the transportation from these countries to the international ports in the PRD region, depending on the geographic location of the departure ports and the schedules of the container liners. Then it normally takes up to 3 days for these containers to go through customs and be delivered to the remanufacturing sites in the PRD region.

(Adapted: Shipping Gazette, 2006)

Figure 6.4 International Shipping Transportation Map

6.2.3.1 Reasons for Wastes and Used Products Transportation

There are several reasons for the long distance transportation of the used metals and products being shipped all the way from different parts of the world to the remanufacturers in the PRD region. First of all, as mentioned in the literature review chapter, there are tighten legislations such as ELV Directive (2000/53/EC) and WEEE Directive (2002/96/EC) in the European countries that automotive, electrical and electronic manufacturers are responsible in dealing with their EOL products and equipments. Although there are remanufacturers in these countries who are specialised in dealing with the waste and used products and parts, there are increasing amounts of used and return products in these countries, as well as the left-over and scrap metals produced in the manufacturing processes that need to be properly handled and disposed.

Due to the fact that the operating costs for remanufacturing processes in the developed countries are high because of expensive technology systems and labour workforce, a growing percentage of waste and used metals and products are being shipped to developing countries. Especially for remanufacturers such as those in the PRD region, since they are operating based on low-cost labour, and have developed reverse logistics networks and secondary metal market for their remanufacturing operations. There are demands for waste, used metals and products importing from overseas to generate value from remanufacturing secondary metals. As mentioned in the case study interviews, because of the higher quality and recoverability of the incoming materials, Company R_{M1} and R_{M2} are in favour of importing high quality secondary metals, products and parts from developed countries for their dismantling and remanufacturing production.

Moreover, since the requirement and quality standards for manufacturing input metals are relatively high for manufacturers in Europe and other developed countries, the demand for secondary metals are relatively limited. Hence, it is important to minimise the costs for remanufacturing processes of secondary metals especially when the profit margin of remanufacturing operations is very low compared to the manufacturing processes. As a result, manufacturers are more likely to send those waste metals overseas for remanufacturing and disposal.

In addition, as China has become the world's biggest manufacturing factory, there are significantly large amounts of goods being exported from China to European and Western countries. To certain extent, instead of shipping the unloaded empty containers back to China for further exporting of goods, filling those containers with wastes would increase the efficiency of the international freight distribution operations. That is why countries such as China have become one of the popular outsourcing countries not only for the manufacturing processes, but also for the remanufacturing operations.

6.2.3.2 Negative Effects

On the other hand, it should be pointed out that although by exporting the waste and used metals and products to developing countries such as China would enable the global processes flows of the CLSC, there are negative affects if these processes are not managed and controlled appropriately.

First of all, as discussed in the case study analysis, Company R_{M1} and R_{M2} have little control over the time, quality and quantity of the waste and used metals from the cargo containers they receive from overseas. Despite the fact that the Chinese government and customs have strict legislation on preventing the imports of non-reusable and hazardous metals and materials, it is still very difficult to manage and control the quality of waste and used materials from the imported cargo containers. Some of the hazardous materials along with other wastes are still imported illegally which would create severe damages to the health and safety of the public and the environment.

Secondly, although it can be argued that container liners can gain more efficiency and profit by shipping the reloaded containers instead of empty containers, the long distance transportations of all those waste and used materials generate pollution and damages. There are increasing energy consumption and pollution because of the shipping transportation to the sea water and global environment. In addition, with the increasing price on oil and fuel, the costs for transportation is growing all the time, which directly impact on increasing transportation costs for the Chinese remanufacturers to obtain those containers of wastes for their production. Alternative options are needed in order to create sustainable development for the CLSC, especially at the global level. Hence, local collection and recovery should be encouraged to ensure the transportation of waste materials to the other side of the world would be minimised. Government funding and support need to be promoted in developed countries, so as to motivate businesses in participating in the remanufacturing operations.

Furthermore, as China has been experiencing dramatic growth in manufacturing and producing large amounts of products for domestic and overseas markets, there are increasing levels of waste metals generated from the manufacturing processes, as well as at the end of the product life cycle. Hence, there are also growing demands for remanufacturing processes to handle all those domestic wastes, used products and parts. If the main productivities of the Chinese remanufacturers are diverted to handle all those imported wastes and used products, there are concerns of how to manage, recycle and recover those domestic wastes from within China. After all, it is essential to find the balance between efficient operation of the CLSC for long term sustainable development, while the incentives of generating profits is still the initiatives for remanufacturers to carry out reverse logistics operations. Therefore, legislations need to come into force and to enforce more comprehensive remanufacturing processes to handle not only high profit margin waste recoveries, but also for those low value and hazardous wastes for recycling. Both manufacturers and remanufacturers must take up their responsibilities in minimising their production wastes and participating in properly handling their production wastes and EOL products.

6.2.4 Summary

By pattern matching and mapping the operation flows between the metal manufacturers and remanufactures, both within the PRD region and overseas, it should provide more perspectives and dimensions for the understanding of the processes of these various players in the CLSC. The metal manufactures and remanufacturers can benefit from the local sorting and collection of waste, left-over, scrap and used metals and products, which would reduce the production costs and increase the utilisation of metal resources. There are established collaboration between firms and networks in the industry. Hence, metal manufacturers and remanufactures are actively participating in the secondary metal market and the CLSC in the PRD region in China.

On the other hand, there are pros and cons for importing wastes and used metal and materials from overseas. Although the high quality wastes and used metals and materials from developed countries would normally generate more recoverable metals and profits, sometimes it is difficult to control the quality and quantity of these importing cargos. There are risks of harmful pollution especially if the imported cargo contains hazardous and non-reusable materials. Therefore, it is important for both government and industrial practitioners to pay special attention to manage and control these operations. Consequently, all the players in the CLSC and the government need to cooperate with each other and find the balance between the operations flows in order to achieve sustainable development.

6.3 Answering the Research Questions

It should be noted that although there are existing research in the operation and supply chain management concerning the reduction of wastes and defects through the production system, the majority of them refer to the forward supply chain flow. This research draws attention to both forward and reverse flows in the supply chain. The remanufacturing processes can be considered as the auxiliary processes because of the imperfect supply chain operation. As long as the supply chain operation could not achieve zero-defects, there would be wastes and scraps occurring from the processes which need to be handled with the help of reverse operations processes. It would not be a possible solution for simply disposing those wastes in landfills, as the earth would eventually be piling up with the polluting and damaging thrown-away materials. Not to mention all those used and EOL products which would also need to be handled properly. Moreover, metal resources from the environment cannot be consumed continuously and infinitely. However, because of the development in manufacturing techniques and technology, various types of metals are subjective to be recovered and reused, which enhance the chance of utilisation. Hence, recycling, recovering and remanufacturing the value from those wastes which used to be valueless materials is a favourable option in dealing with disposal on one hand. And at the same time, these activities maximise material utilisation and reduce the demand for primary materials. These are the reasons for the existence of the CLSC, which is the integration of both forward and reverse logistics flows. Nevertheless, CLSC is obliged with the goal of achieving sustainability which would enable it to be operating in the trend of a virtuous spiral cycle.

As a result, it is essential to understand the processes within the CLSC, before further investigation and knowledge can be developed to help companies in their production planning and control, inventory management, scheduling and other management and improvement of process operations to achieve sustainable development in the long term. Based on the information and evaluation from the research findings, each of the sub-questions regarding to the CET factors can be answered individually, then the general picture for the research findings and understanding can be generated. These evaluations would construct the answers to the research question from the investigation and analysis of the specific approaches and techniques the Chinese metal manufacturers and remanufacturers adopt for developing the CLSC for sustainable development.

6.3.1 Customer

1) What reverse logistics and waste management approaches and techniques are integrated and adopted by the Chinese Metal Manufacturers / Remanufacturers in order to meet customer requirements and achieving sustainability?

6.3.1.1 Identifying Customers for Metal Remanufacturers

As mentioned in the literature review, because of the complexity of the CLSC, products and wastes are flowing in from both forward and reverse logistics directions. That is why there are changing roles between the suppliers and customers. Therefore, it is necessary to clearly identify these changing roles before discussing the research questions. The remanufacturing, recycling and recovery processes provided by the metal remanufacturers and dismantlers are the reverse logistics services for metal manufacturers dealing with their wastes and used products. Therefore, metal manufacturers such as Company M_M, Mss and those from the Fortune 500 are considered as the customers of remanufacturing service provided by Company R_{M1}, R_{M2} and L_{3PRL}. In other words, the customer here in the first sub-question is referring to those customers who are having wastes metal collection service provided by metal dismantlers and remanufacturers, in addition to those customers who buy secondary metals after the dismantling and remanufacturing processes. Hence, the customer relationship management is essential for metal remanufacturers while dealing with those metal manufacturers who provide wastes and left-over metals for the remanufacturing operation; and those who have quality requirements and standards for the secondary metal after the remanufacturing processes.

6.3.1.2 Competitive Advantages of Chinese Metal Remanufacturers

As one of the countries which produce large amount of goods and services to the global market, Chinese companies are actively participating in both manufacturing and remanufacturing operations in the CLSC. From the case study findings, profitability is still the main incentive for SME metal manufacturers and remanufacturers. As long as the remanufactured metals meet the required quality and are lower in price than primary metals, there will always be demand in the market from customers who are willing to buy them for their production to save costs. In addition to the current limited law and regulation in China, the furious competitions between these thousands of SMEs in the market motivate remanufacturers to compete for meeting the demands in the secondary metal market for profit.

In order to achieve sustainability, developing close relationships and networks between metal remanufacturers and their customers are crucial. As discussed in the case study, Company R_{AL}, R_{M1}, R_{M2} and L_{3PL} are operating in fast-pace small-batch production in response to the demand in the market and the supply available from their suppliers. These SMEs are very flexible and can react much quicker to the changes in market, in comparison to large size companies. Especially as there are fluctuations in the prices and supply of primary and secondary metals in the market, the manufacturing and remanufacturing processes need to be very flexible in order to work on the available amount and quality of supplies they receive from the market. That is why as described by some of the interviewees, their companies developed close relationships with their suppliers and buyers, which enable the sharing of valuable information of the secondary materials. Information and materials flow forwards and backwards within these firms that facilitate better process operations within the supply chain. As a result, remanufacturers can have a better understanding of the characteristics of the incoming secondary metals for their production, and can remanufacture those metals accordingly. Moreover, they can provide a better description to their buyers when selling the remanufactured secondary metals. In other words, better information sharing and material flow within the Chinese metal CLSC enable fast pace operations and the achievement of long-term sustainable development.

6.3.1.3 Managing Uncertainties

As pointed out from the case study findings that the majority (>70%) of the incoming metal wastes and used materials are imported from overseas. The management of these secondary material supply networks are vital for remanufacturers in the PRD region. As mentioned by some of the interviewees, their operating network with overseas suppliers is very informal. They rely on waste collectors and 3PRLs for their incoming secondary metals, and the supply quantity and price of these secondary metals fluctuate quite often. In addition, there are often changes in the Chinese importing legislations which restrict the amount and types of incoming waste metals. Hence, metal remanufacturers do take up the risks and face uncertainties in the market demand and supply.

Due to the size and operating nature of these SMEs, it would be impossible for remanufacturers to have large amounts of supply and inventory on site. Therefore, high level management and control of the incoming quality and quantity of wastes and used metals, as well as the planning and scheduling for production processes and maintaining a robust supply chain network need to be in place for their operations. At the moment, remanufacturers in the PRD region are working hard to establish wider networks and better customer relationships with overseas suppliers, regional wastes collectors, and direct collaboration with metal manufacturers in collecting their production wastes and left-over. Table 6.1 summaries the customer factors for Chinese metal remanufacturers.

Table 6.1 Customer Factors for Chinese Metal Remanufacturers

Issues \ Customer	Secondary Metal Market	Metal Manufacturers e.g. Company M_M, Mss
Requirement	- High quality - Low price - Quality and quantity delivery	Wastes, left-over, scrap collection service (Weekly / Monthly)
Driver	- Profit - Available technology & techniques	- Profit - Resource utilisation - Disposal solution and service
Strengths	- High quality imported secondary metals - Dismantled to detail - Improving recovery techniques	- Collection at source - Collaborative relationship: Better information / solid waste flow
Weaknesses	- Manual labour operation (>70%) - Limited level of recovery - Low capacity (compared to machinery)	- Manual labour operation (>70%) - Limited level of recovery - Low capacity (compared to machinery)
Opportunities	- Implement high-tech machinery - Network - Customer relationship management	- Low costs - Flexible - Establishing sustainable network
Threats	- Fluctuation in secondary product quality and price - Unsustainable demand and supply - Inevitable pollution and damage to environment during operation	- Fluctuation in secondary product quality and price - Unsustainable demand and supply - Inevitable pollution and damage to environment during operation

6.3.1.4 Collaboration in the Chinese Metal Industry

On the other hand, the control of wastes and left-over at production stage is also very important for metal manufacturers such as Company M_M, Mss and R_{AL}. They are concerned with the minimisation of wastes, left-over, and scrap metals during their production. Hence, the implication of technology and machinery systems for their operation is aim to increase productivity and utilise resources throughout production. More importantly, they are cautious about the wastes collection with the intention to sell them to remanufacturers for recovery of secondary metal, while they can reimburse their production costs at the same time.

In the mean time, for the metal remanufacturers Company R_{M1}, R_{M2}, R_{AL} and L_{3PRL}, they aim to provide better services to their customers and suppliers (i.e. metal manufacturers, recycling centres and collectors) for collecting and sorting the wastes and used materials, as well as increase the recoverability of secondary metals. Sorting at the source would provide better efficiency for solid waste management and ease the remanufacturing processes. Consequently, the application of waste collection promotes environmental management and operation which are beneficial for both manufacturers and remanufacturers in China and overseas countries. Especially with the expanding global supply chain, the movement of metal wastes in between countries facilitate recovery and reuse of secondary materials. Remanufacturers who have the technique and low-cost labour for remanufacturing processes can offer services to those with high costs from wastes recovery. The customer factors are highlighted in Table 6.2.

Table 6.2 Customer Factor for Chinese Metal Manufacturers

Customer	**Metal Markets** e.g. Furniture, Hardware, etc, in China & Overseas
Requirement	- High quality - Durable - Low price
Driver	- Profit - Resource utilisation - Sustainability
Strengths	- High level technology system for production - Machinery batch production (<20% manual operation)
Weaknesses	- Inevitable wastes, left-over, scrap & Returns - Not 100% of wastes can be collected and recycled
Opportunities	- Better production management and control - Better local and international supply chain network - Aim for zero defect - Work with 3PRL to collect wastes
Threats	- Metal supply reduction - Fluctuation of metal price, demand and supply - Hazardous wastes residues generated during production - Inevitable pollution and damage to environment during operation

6.3.2 Technology

2) In what way should process technology be applied to increase efficiency and to reduce the non-value added processes during the forward and reverse logistics flow?

6.3.2.1 Different Implications of Technology

First of all, it should be pointed out that because of the differences between the forward and reverse logistics flow, the level of technology implementation in the forward and reverse logistics in the Chinese metal industry differs. From existing literature and findings from this research, it should be clear that the forward metal manufacturing is the batch production processes that manufacture various input materials into identical products with the same shape, characteristics or functionalities. Hence, the operation processes and the assistance of technology are to construct materials together to produce the final product. On the other hand, reverse logistics deals with a large number of input materials which has their own unique status and characteristics. Therefore, the complexity of remanufacturing processes require more complex technology for handling, as the status and characters of the input metals or used products need to be identified before their individual dismantling and remanufacturing could take place. As a result, the development and implementation of technology system for remanufacturing would not be as straightforward as the forward manufacturing operation.

That is one of the main reasons why the majority of Chinese metal remanufacturing processes are relying on manual labour for flexibility when dealing with various incoming secondary materials. Although there are existing remanufacturing systems in the Western developed countries, as discussed in the literature, the operation and maintenance of these technological systems generate high costs. That is why with legislation reinforcement in the EU, companies are suffering from the expensive disposal costs and have been exporting their secondary metals and other materials to developing countries with lower cost remanufacturing operations.

The issue on the application between manual labour or technology operations has been raised from the case studies. As in Figure 6.5, there are various effects of using labour and technology in production processes both in the manufacturing and remanufacturing operations. The key issue is to find the balance in applying different levels of manual and technology in process operations for maximising the company's benefits, which varies depending on their management and operation characteristics.

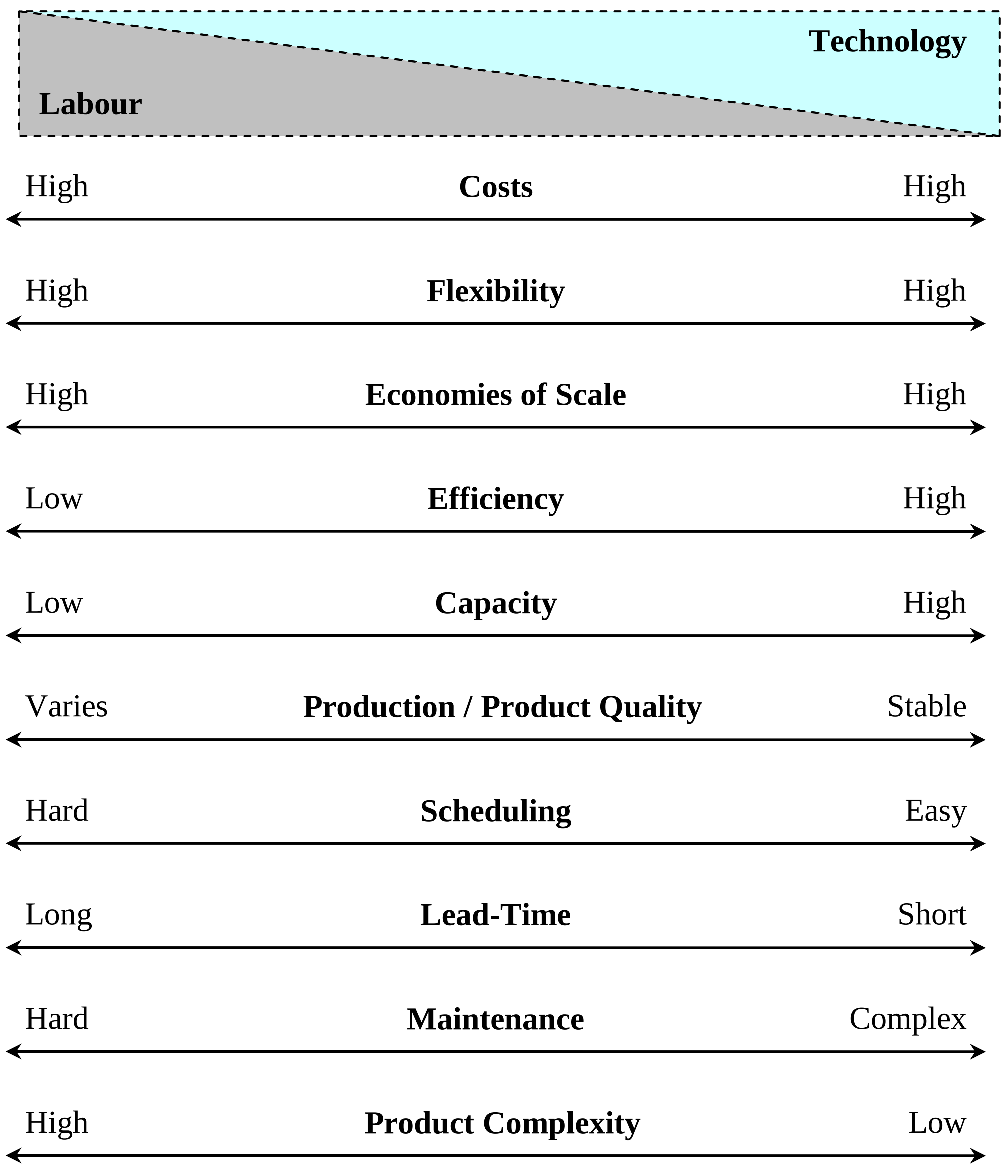


Figure 6.5 Balance between Labour and Technology

First of all, in Figure 6.5, although with the intensity of labour and technology (reaching complete automation), there would be high flexibility and economies of scale for production, the costs for production would be very high when reaching both ends. Therefore, finding the balance between the level of manual operation and technology in the production processes is essential for both manufacturers and remanufacturers. They have to understand their own capacity and available investment capital for managing and controlling their workers and machinery systems. Secondly, companies should recognise the benefits for applying technology in their production, which would generate a higher production efficiency, capacity, as well as more stable production and product quality. In addition, production scheduling and lead-times would be much easier managed when using machinery system as they are set to be constant. These reduce the risks and variations in comparison to manual labour operations, even though maintaining technology production system could be very complex and expensive. Last but not least, it should be pointed out that especially for the remanufacturing processes, the application of manual labour operation would provide better handling of complex products, especially with mixed incoming materials in smaller batch size. Hence, it is essential for companies to identify their operating characteristics, and to apply a balanced labour and technology production method for their processes, regardless to whether the operations are manufacturing or remanufacturing processes.

6.3.2.2 Technology for Non-Value Added Waste Management

As wastes from the production system add costs without adding value, the elimination of wastes at the source is essential for manufacturing and waste management. Hence, there are applications of technical manufacturing systems in the Chinese metal manufacturing for producing higher efficiency while minimising waste, left-over and scrap metals. The collection of the inevitable wastes at different stages of the production processes (as in Figure 4.3, 4.4 and 4.5) generates the non-value added wastes for value recovery processes carried out by remanufacturers. Despite the fact that distribution and transportation of waste and scrap metals within regions and between countries are non-value added processes, they enable the recycling and recovery of secondary materials. Especially if these transportations are carefully planned for maximising the utilisation of vehicles and shipments, for example, they would make best use of laden cargo containers with manufactured and remanufactured products in the forward and reverse logistics flows.

6.3.2.3 Technology in SMEs

In addition, even though it can be argued that SMEs tend to lack of capital investment for the application of high level technology and machinery systems, the management and control can be much easier when dealing with less labour resources and maintenance of machineries in contrast to larger size firms. As in Company R_{M1}, R_{M2} and L_{3PRL}, more than 70% of the operations are based on manual labour operations. They can deal with the complicated dismantling and sorting of mixed and complex products and parts with higher flexibility than some of those companies which are using machineries that can only deal with certain types of products. Although there are trends for developing high level and flexible machinery systems for remanufacturing processes, it will still take quite some time before machineries are capable of automatically sorting and dismantling various complex products. Therefore, remanufacturers in the developing countries are still very competitive in dealing with remanufacturing processes as they have large amounts of low-cost labour for these low profit margin operations.

However, as discussed in the case study analysis in Chapter 5, there are strong needs for the applicable technology and machinery systems for the remanufacturing processes; similar to what had happened to the metal manufacturing operations in the 1990s in the PRD region. In particular, as the amount of metal production is increasing and there are growing quantities of wastes and used metal products and parts around the world, better methods for the remanufacturing processes must be developed in order to cope with the amount of wastes and recovering secondary metals as much as possible. In addition, with regard to the issue of health and safety for the workers in the remanufacturing processes, and the trend of increasing production automation in the near future, the replacement of manual labour work by machinery and technology is inevitable.

Hence, it is remarkable to find out that as in the case of Company R_{AL}, which developed the aluminium waste residue remanufacturing processes to transform hazardous residues into non-hazardous materials for reuse in other manufacturing operations. It sets a benchmark for companies especially SMEs that it is possible to work closely with academia in order to develop and improve their processes for beneficial achievements. Consequently, the application of technology in both manufacturing and remanufacturing processes are the major direction for industrial achievements and sustainable development. Hence, this research illustrates the general picture of the current operations in the Chinese context. It should assist further research and development of management methods and technology systems for improving the remanufacturing operations to higher levels of sustainability.

6.3.3 Environment

3) What is the impact of the metal manufacturing and remanufacturing processes on the environment?

6.3.3.1 Impact of Operational Processes

With regard to Figure 2.1, there are inevitable emission, pollution and wastes generated during manufacturing and remanufacturing processes. Although it can be argue that achieving high profit is the main goal for most companies and firms, there have been increasing concerns among the Chinese metal manufacturers and remanufacturers in finding the balance between gaining profit and achieving sustainability for the industry, society, and environment. Companies understand that they can not continuously acquire resources from the environment and the market for their production. Various types of metal and natural resources have been diminishing due to growing production and consumption. Companies are facing increasing metal prices and fluctuating supplies for their production. Therefore, it is essential for companies to develop ways to better manage their operating flows within the supply chain, taking into consideration the goal of achieving long term sustainable development.

From the information collected through the case studies as in Chapter 4 and Chapter 5, both metal manufacturing and remanufacturing operations in the PRD region had no concern with the environmental issues in the past. These activities created harmful effects to the health of the society in the region and severe pollution to the environment. Hence, there are urgent needs for protecting the environment and reduce further pollution and damage from manufacturing and remanufacturing processes in order to develop sustainable CLSC for the long term.

According to the virtuous spiral cycle development (Figure 5.10), the level of CLSC operations would be developed over time to higher levels when more factors are considered and managed. These include the level of sustainability and the level of environmental protection. The development in technology, human resource and knowledge techniques are the force of factors which would enable and encourage higher levels of CLSC operations. As a result, through the case studies, thousands of tons of waste materials from Company M_M, Mss and R_{AL} that would once be piling up in landfills are now being recovered and reduced to a minimum through remanufacturing processes by their cooperating partners. Although it may be argued that profitability is still the main incentive for remanufacturing process that would recover additional value from wastes; however, companies such as R_{AL} and L_{3PRL} do consider the effect and reduce the level of pollution to the environment as one of their return on investment for their technological development of remanufacturing operations. To a certain extent, these case companies are actively participating in waste management activities and trying their best to protect the environment.

6.3.3.2 Legislation on Environmental Protection

In China today, there are still no specific environmental legislations similar to the WEEE or ELV in Europe. The Circular Economy Law of the People’s Republic of China is still in the drafting stages. However, the Chinese government are concerned about developing better legislation systems for environmental protection. The recently established Circular Economy Promotion Law of the People's Republic of China (2008) has come to force on January 1st, 2009. It sets guidelines for environmental protection and circular economy for waste management, water and energy resource protection in manufacturing, electrical and electronic production, chemical industry, petroleum industry, metal industry and mining industry. The Chinese government has the intention to construct further legislation in guiding and enforcing companies in better environmental protection during their operations.

6.3.4 Summary

From the answers to the sub-questions of this research, it should be clear that the interaction between Chinese metal manufacturers and remanufacturers with regard to the CET factors would enhance the operation of achieving sustainable development of the CLSC. Although the existing networks and cooperation among the SMEs in the Chinese metal industry are considered to be informal, the Chinese metal manufacturers and remanufacturers do identify their customers and respond to their needs. As a result, better methods and techniques for processes, flexible and higher efficiency operations are developed in order to facilitate the CLSC in the primary and secondary metal industry in the region. With more concern on cost savings and environmental protection from the initiatives of SMEs, as well as the legislations established by the Chinese government, the environmental damage and misconduct would be under better control and reduced to a lower level. Consequently, with the development of technology, human resource, knowledge and techniques, the level of CLSC operations in the Chinese metal industry would move up to a higher level of sustainability.

6.4 The Closed-Loop Supply Chain Positioning Tool

6.4.1 Development of the Tool

With regard to the efficiency of metal production processes and the interactions between metal manufacturers and remanufacturers, the sustainable CLSC operations matrix can be developed as shown in Figure 6.6. Referring to Table 5.4 Dimensions and Levels of Sustainability, there are the Survival, Maintaining and Improving levels of sustainability. Companies in Zone (1) [Level 1: Survival Sustainability] have low levels of efficiency in production and high production costs because of the wastes they produce. If they could move to Zone (2) [Level 2: Maintaining Quality of Life], that means they become more advanced with higher production efficiencies. In doing so, they have to reduce the level of wastes from their production, for example, by implementing higher levels of technology for their production. In addition, by establishing better cooperative relationship with remanufacturers and applying high quality secondary metals for their production, it would increase the waste recovery rate and reduce the costs for production. Eventually, by moving into Zone (3) [Level 3: Improving Quality of Life], companies are achieving much better competitiveness in the industry and reaching sustainable development and high levels of growth in the long-term.

Efficiency of Metal Production Processes

Interactions between Metal Manufacturers and Remanufacturers	Low	High
Low	**Zone (1) [Scale 0-1]*** - >10% waste, left-over, scrap metal from production - >10% metal waste recovery - Intensive low skilled manual labour operation - Low level technology and machinery system for production	**Zone (2) [Scale 1-4]*** - <10% waste, left-over, scrap metal from production - <90% collection of metal wastes - High level skilled operators - High level technology and machinery for production
High	**Zone (2) [Scale 1-4]*** - >90% waste recovery - Wastes, left-over, scrap collected at the source (Regularly) - Apply secondary metals for production	**Zone (3) [Scale 4-5]*** - >95% waste recovery - Wastes, left-over, scrap and even residues collected at the source - Proper dismantle and disposal operations with minimum emission - Apply secondary metals for production

* Zone (1), (2), (3) are further developed and illustrated in Figure 6.7, 6.8, 6.9

Figure 6.6 Sustainable CLSC Operations Matrix

Figure 6.7 illustrates these 3 different Zones with the factors that affect the efficiency of production for metal manufacturers and remanufacturers. These include: the level of production waste, waste recovery, labour intensity, level of technology and production capacity. In addition, a company's position in the market is also determined by whether manufacturers and remanufacturers are pro-actively or reactively cooperating with the external supply network.

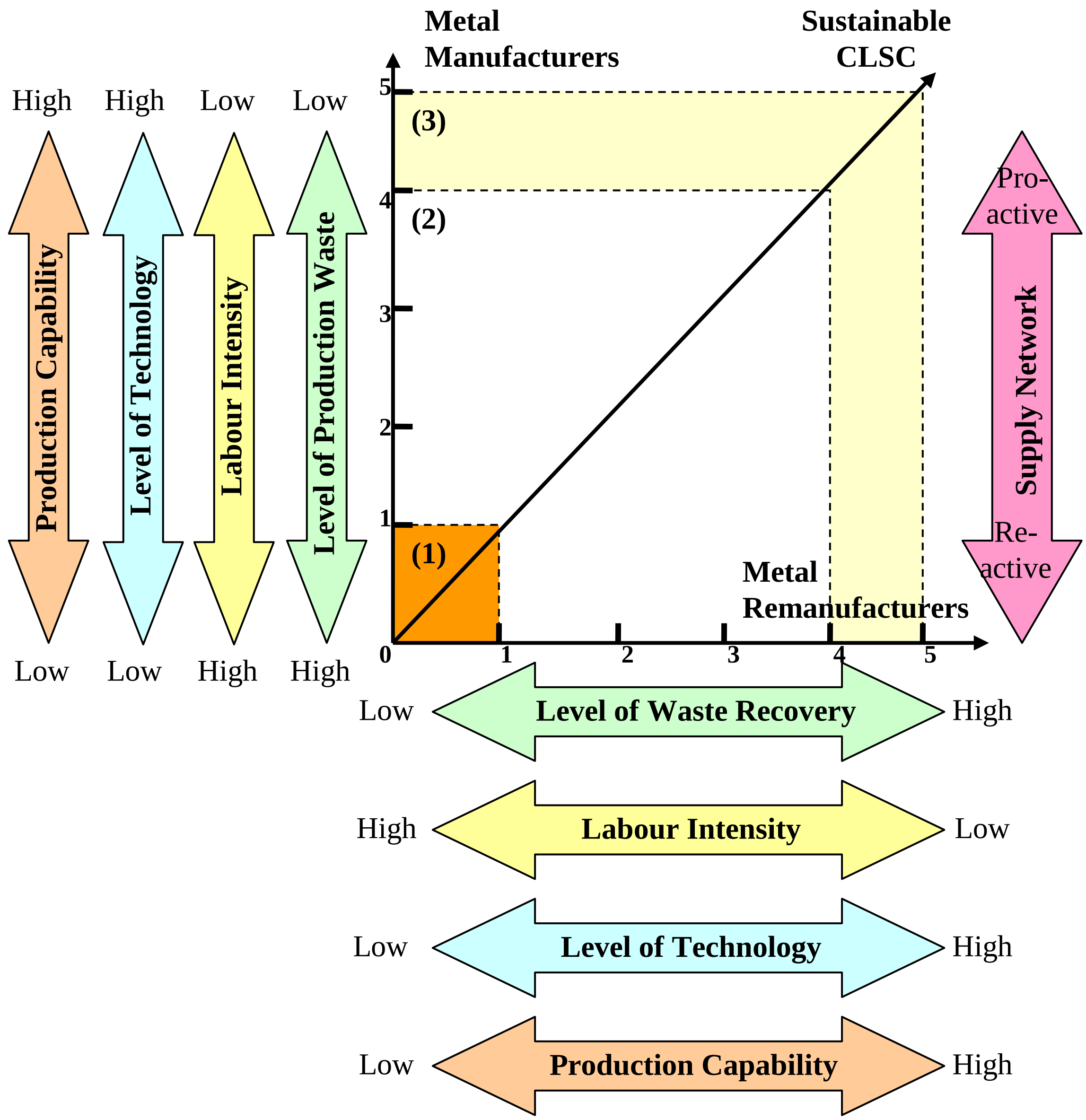


Figure 6.7 Closed-Loop Supply Chain Positioning Tool

Figure 6.7 is also a CLSC Positioning Tool for companies to position themselves based on relevant factors and scales. This tool can be applied to both metal manufacturers and remanufacturers. As in the graph, the sustainable CLSC illustrates the balanced relationship between manufacturing and remanufacturing productions. With regard to the level of labour and technology in operation, as well as the level of wastes generated from production and companies operating capacity, there are scales of 0 to 5 for companies to set their positions. As mentioned before, their level of pro-activeness or reactivity within their supply network determines their position on the graph. According to the findings from the case studies, each of these case study companies is rated according to these scales. The detail scaling processes are presented in **Appendix 13**.

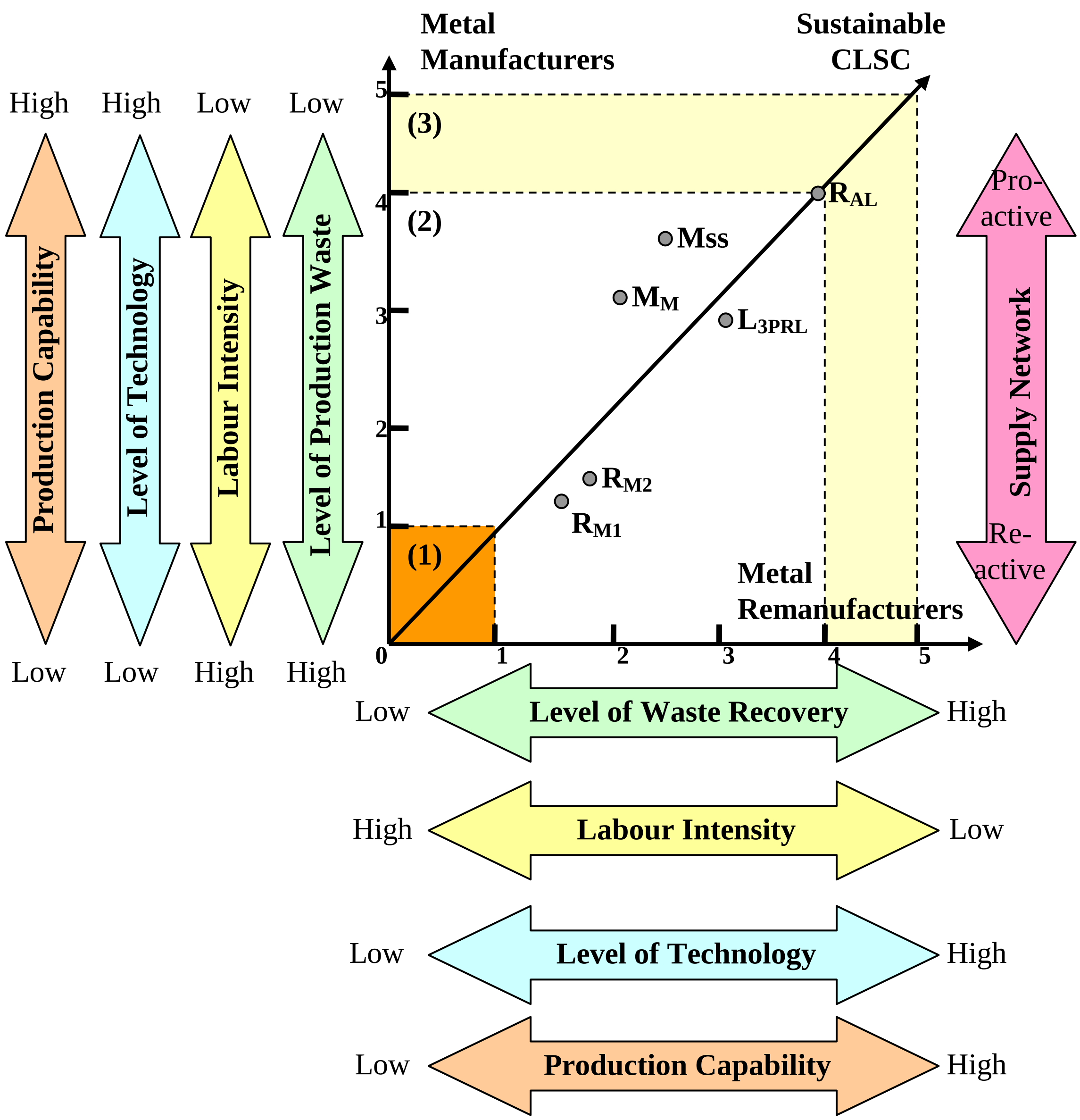


Figure 6.8 Case Companies on the CLSC Positioning Tool (2005-2007)

The majority of the case companies are rated in the Zone (2) area as shown in Figure 6.8. It is important for companies to understand their current position in order to change and improve their operations to get closer to the line for sustainable CLSC, and to be in Zone 3. In doing so, they would need to reduce their level of wastes from their production and increase the waste recovery. They need to increase their level of technology and machinery systems for their production, while finding the balance in manual labour operations for their specific needs. In addition, their pro-active interaction with the supply network would help to provide stable incoming materials for their production, which eventually push up their production capabilities and expand their share in the market. After all, any companies being in the Zone (1) area without the sustainable CLSC would only mean that they have very low levels of competitiveness and are struggling for their survival in the market.

6.4.2 Verification of the CLSC Positioning Tool

6.4.2.1 Initial Verification

Verification of the CLSC Positioning Tool was carried out after the development of the tool. All of the contact persons in the case companies were contacted for feedbacks. The examples of Email, Figure and the Tool (in Chinese) sent to companies for verifications are presented in **Appendix 14**. The majority of the companies commented that the tool does provide better understanding of their positions in the supply chain operation, and reflect their operations and directions for change and improvement. However, the manager from Company R_{M1} would like to see a higher rating especially when comparing its position with Company R_{M2}. It was explained to her that because of the lower percentage of contracted suppliers; and the higher levels of mixed and relatively less informed data and characters of metals waste they receive from Company M_M, which had put her company in a slightly lower position.

6.4.2.2 Updated Changes

A second verification and evaluation of the tool were also performed with these case companies upon the completion of this PhD research in 2008. The updated positions among the case companies are illustrated in Figure 6.9, according to the figures provided by case companies ending June, 2008 (**Appendix 15**).

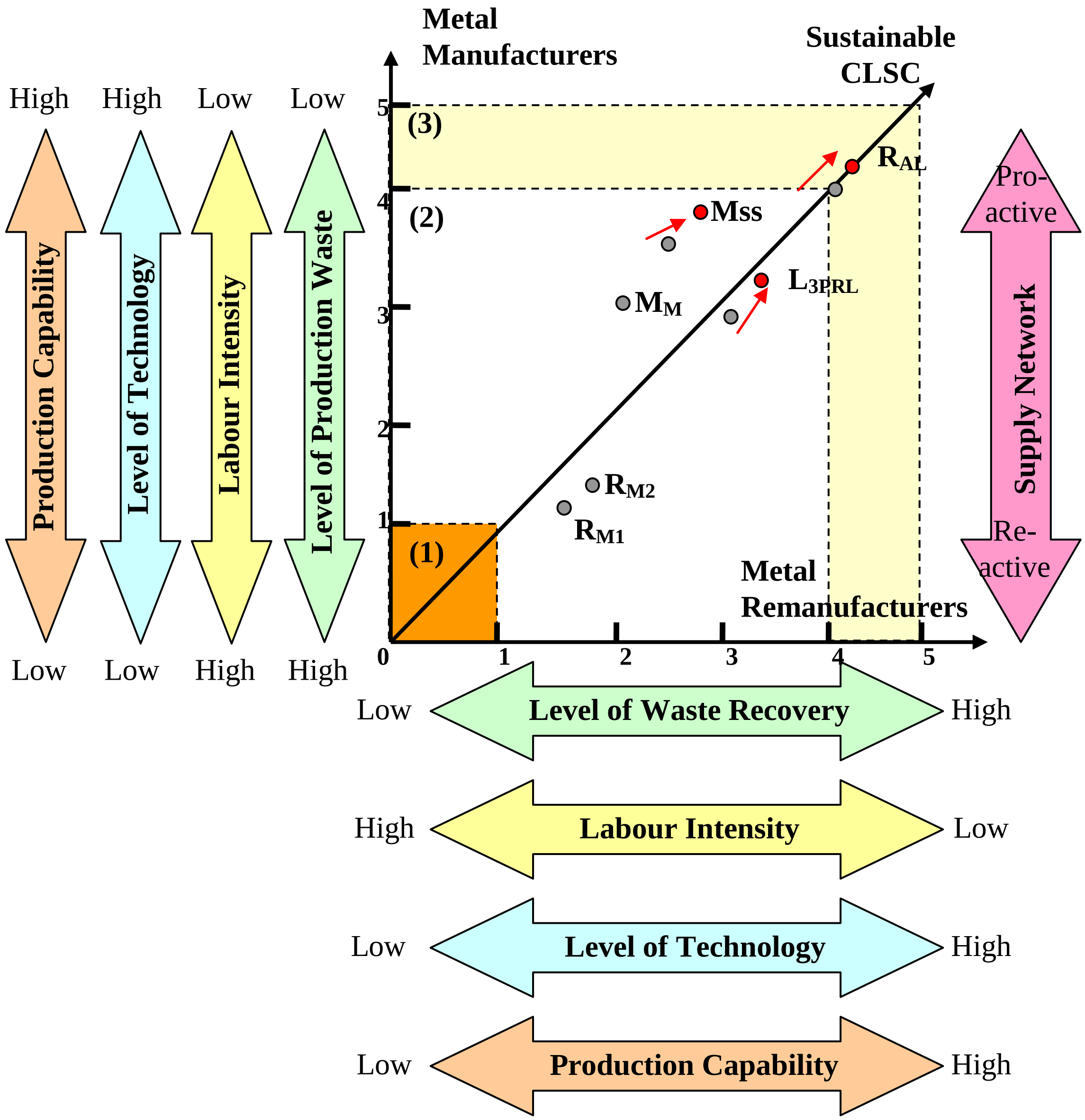


Figure 6.9 Case Companies Positions Updates (June 2008)

As illustrated in Figure 6.9, the changes in the 18 months have not been significant in Company M_M, R_{M1} and R_{M2}. On the other hand, Company Mss, L_{3PRL} and R_{AL} are rated higher on the scale with regard to their investment and development in technology application. As a result, their production capacity and the interaction with their suppliers in their supply chain have increased. The owner of Company R_{AL} said that:

> "We are very pleased to see the increase in our remanufacturing of aluminium residue since your study when we first started the operation. Many local factories have contacted us for handling their production r*esidues… At the moment, we have already doubled our* production capacity to be handling 260 tons per day but there are still high demands in the region. We are considering expanding our production and we hope to add more machinery for the production system *within one or two years… Although we have already reached* a stable production level, we would like to maintain in Zone (3) and see if we can grow further." (R_{AL}.03, Appendix 5)

6.5 Summary

By applying existing frameworks and literature theories to the case study findings and analysis, this research contributes in the existing knowledge using the Chinese case companies as examples for metal manufacturing and remanufacturing in developing countries. The ultimate goal of achieving higher levels of CLSC and sustainable development needs to be developed in close relationships between the forward and reverse supply chain, as well as with certain degrees of legislation and enforcement. After all, companies are mainly profit oriented and it would be very difficult for them to devote themselves to participating in remanufacturing processes, especially if those processes are with expensive costs and low profit margins. It should be obvious that the Chinese metal SMEs do need to take into account the influence of CET factors, in order to move to higher levels in a virtuous spiral cycle of the CLSC for sustainability. The development of the CLSC Positioning Tool helps them to understand their operations and identify themselves among other players within the supply chain and the industry. After all, the tool is designed to assist companies in deciding the direction for improving their productions and to achieve sustainable development in the long term.

CHAPTER 7

CONCLUSION

7.1 Introduction

Referring to the waves of innovation from the First Industrial Revolution to the recent sixth wave of Sustainability (as in Figure 1.1), there have been dramatic changes in supply chain management throughout the years. One of the main concerning issues of sustainable development is that it motivates radical resource productivity, production system design and green production using renewable energy and technology. This research sets a boundary using the Customer, Environment and Technology (CET) relationship, in order to investigate supply chain management in terms of Sustainable Development. It specifically focuses on the CLSC Management while emphasising the existing research in Reverse Logistics and Solid Waste Management. It builds a foundation on existing theoretical literature, mainly from Western developed countries, before further exploration of literature and case studies were performed in the context of developing countries, using the Chinese Metal Industry as an example. Since there are limited theoretical and practical research studies in the field of CLSC and sustainable development, this research aims to contribute in the knowledge for understanding the specific approaches and techniques the Chinese metal manufacturers and remanufacturers adopt for sustainable development of the CLSC.

7.2 Contribution to Knowledge

Figure 7.1 illustrates the overview of this research which has been developed from existing theories and methods.

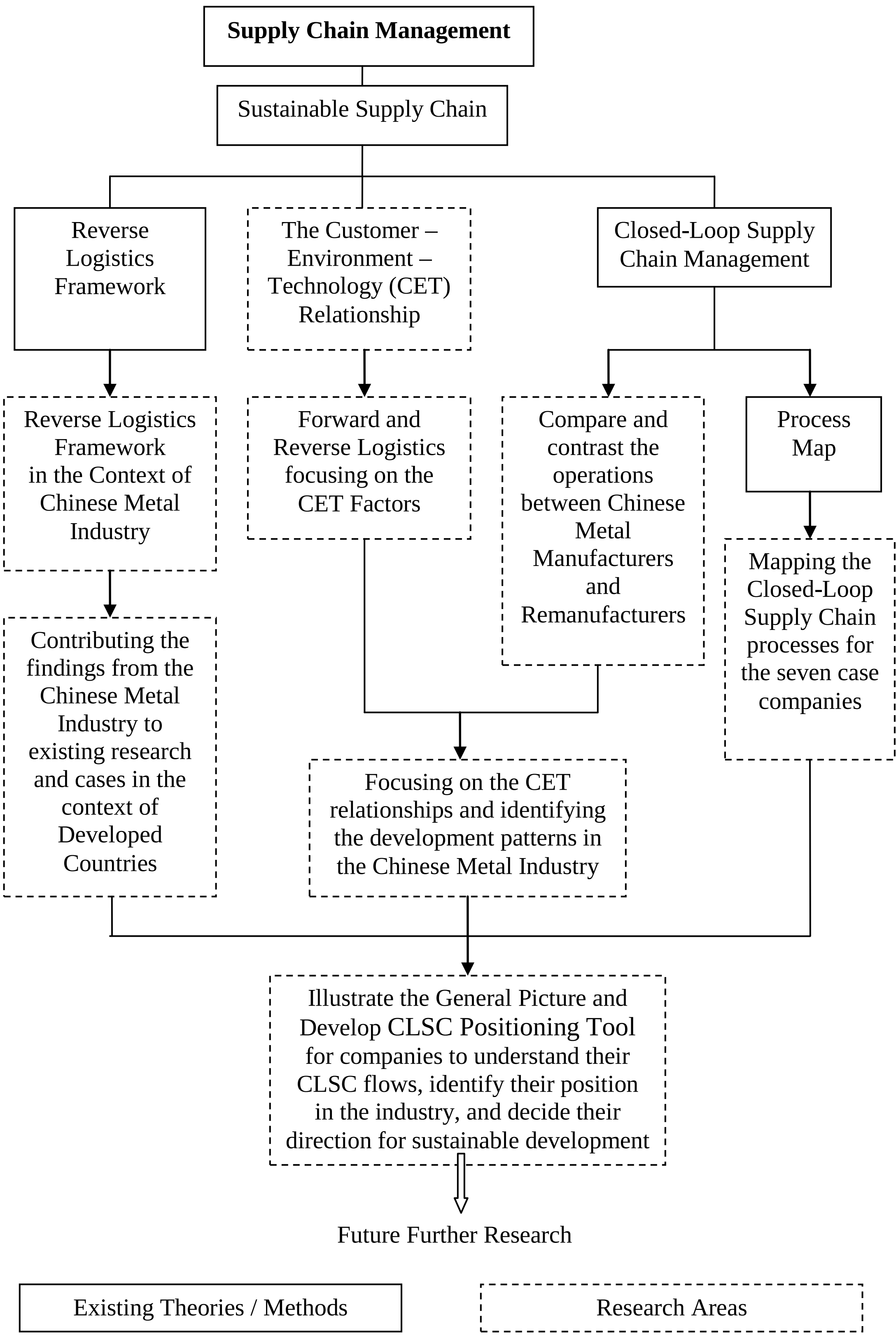


Figure 7.1 Research Overview

As mentioned in Chapter 1, the objectives of this research are to develop process maps, frameworks and tools for companies to improve the efficiency of their value-added activities, as well as social, environmental and economic benefits. From the data and information gathered from the industrial fieldwork in the local government and seven case companies in this research, a list of 12 key findings and frameworks are developed in the context of the Chinese metal industry, as illustrated in Figure 7.2.

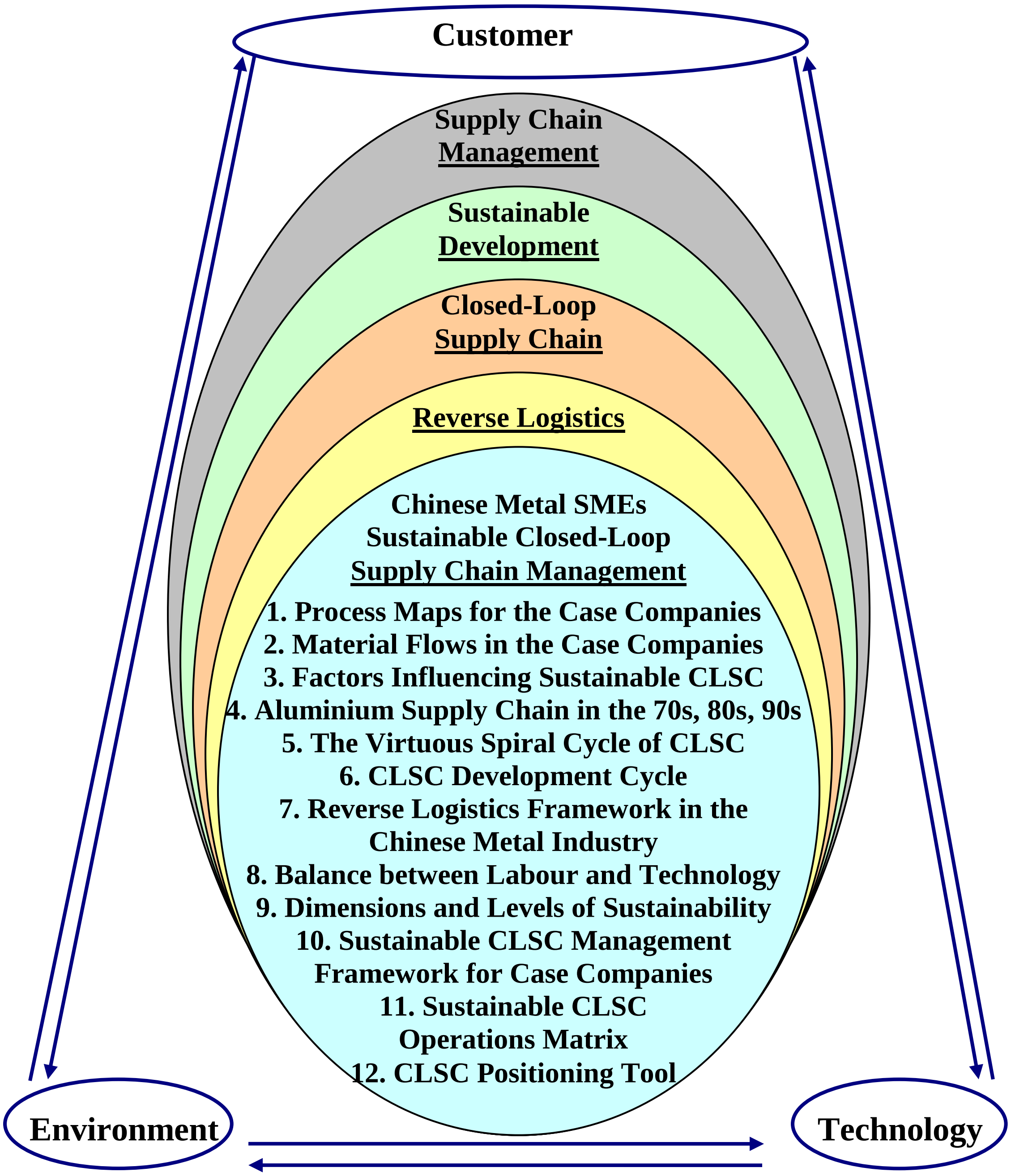


Figure 7.2 Research Objectives – Key Findings and Frameworks

The key contributions to knowledge from this study can be summarised as the following:

- **Factors Influencing the Sustainable CLSC** – The proposed framework illustrates how companies can examine the uncertainties and hindrances from the CET factors. This research emphases the importance for metal manufacturers and remanufacturers to cooperate in the CLSC, especially when facing fluctuating prices, supplies and demands in the metal market, as well as the uncertain qualities and quantities of incoming metals and wastes. The case studies show that the Chinese SMEs are able to achieve high competitive advantages in their CLSC operations by establishing good communication and information sharing with their suppliers and customers. As a result, there are high levels of metal utilisation and waste recovery, which help to reduce the consumption of primary metals, and minimise the pollution to the environment. Although some companies are still largely based on manual operations, the implementation of technology has been gradually taking place.

- **The Virtuous Spiral Cycle of CLSC –** In addition to the concept and models developed for CLSC in existing studies (Kopicki, et al., 1993; Rogers and Tibben-Lembke, 1998; De Brito and Dekker, 2002; Rahman, 2004), this research study suggests that the supply chain development does not simply stop when forward and reverse supply chain integrate with each other. Instead, the CLSC develops further and becomes a virtuous spiral cycle when there are higher levels of sustainability, technology, human resources, knowledge and techniques.

- **Dimensions and Levels of Sustainability** – Sutton (1998) developed different dimensions and levels of sustainability, however, this study adds to these and identifies the existence of three levels of sustainability from the operations management perspective, Level 1: Survival Sustainability – Working on existing primary and secondary metals; Level 2: Maintaining Quality of Life – Maintenance of efficient flow of CLSC; Level 3: Improving Quality of Life – Improving production quality and wastes remanufacturing

These levels have been illustrated using **the Operations Matrix** and **the CLSC Positioning Tool**. These frameworks and tools allow companies to identify their process flows within the CLSC in terms of the Level of Waste, the Labour Intensity, the Level of Technology and the Production Capability. Companies can identify their strengths and weaknesses and decide their directions for improvement and sustainable development.

- **The Reverse Logistics Framework in the Chinese Metal Industry** – This study has contextualised the reverse flows and processes in the Chinese meal industry and this contextualisation provides further understanding of the Chinese SMEs in addition to those discussed in the Chinese literature (Jiang, et al., 2001; Qiu, 2003; Li, et al., 2007; Shang, 2007; Zhao, 2007; Zhu, et al., 2008); as well as those literature from the Western developed countries (Theirry, 1995; Rogers and Tibben-Lembke, 1998; De Brito, et al., 2004; Blumberg, 2005).

- **The Balance between Labour and Technology –** Many researchers have emphasised the importance of technology in helping companies to achieve higher productivities and market competitiveness (Millar, 1985; Meredith, 1987; Powell and Dent-Micallef, 1997; Baldwin and Sabourin, 2001; Guide and Van Wassenhove, 2001; Suttmeier, 2005). However, this study shows that Chinese SMEs are benefiting from the low skilled but low-cost operators for increased flexibility in their sorting and dismantling processes. As far as costs, flexibility, economies of scale, efficiency, capacity, production quality, scheduling, lead-time, maintenance and product complexity are concerned, Chinese SMEs tend to find the balance between the usage of manual operations and the affordability of technology implementation and capital investment.

In addition to these key contributions, Table 7.1 summarises a list of points raised from this research. The case studies show that the Chinese metal manufacturing and remanufacturing operations are mainly profit orientated and are operating in informal CLSC networks. There are close interactions between forward and reverse manufacturers, as reverse logistics is needed to recover those wastes, left-overs and scraps from the forward supply chain. It also reduces production wastes and EOL products and materials. There are high levels of technology and machinery systems for the metal manufacturing companies, whereas for the metal remanufacturing companies, they are still strongly based on low-cost manual operations. These are partly because of the nature of the forward and reverse logistics operations: The metal manufacturing processes tend to use batch production to produce identical metal products; whereas metal remanufacturing processes have to sort and dismantle waste and used metal products with various conditions and characteristics.

There is a lack of clear and stringent legislation and enforcement from the Chinese government to govern and control the metal manufacturing and remanufacturing activities. There are some concerns for health and safety issues in production, especially with a large number of manual operators in the Chinese SMEs.

Table 7.1 Research Findings and Further Research Directions

Research Findings in the Context of the Chinese Metal Industry	Supports for Research Findings	Further Research
CET Factors		
1. General Understanding from Case Companies As far as the level of production waste, waste recovery, labour intensity, level of technology and production capacity are concerned, case companies are operating under a certain degree of sustainability. They are all in Zone (2) and (3): regarding to Figure 6.6 – The Sustainable CLSC Operations Matrix. The production lead-time in these SMEs case companies are very short, normally between 1 to 2 weeks. The annual productivities in these SMEs are under 1 million tons.	Case companies are operating under the influences and interactions between the CET factors. The process maps and CLSC frameworks for the case companies illustrate the internal operations and external interaction of companies in the CLSC for sustainable development. The information and material flow which enable recovering secondary metals through waste manufacturing processes. The rate of the recovery value and quantity of the Chinese metal industry is significant, especially for those wastes which would otherwise be disposed. The CLSC Positioning Tool helps companies to understand and identify their position in the industry, and guide them for future development to achieve higher level sustainability.	Further research should be performed to investigate how to increase the rate of recovering lower quality secondary metal and wastes within domestic Chinese metal industry, while companies such as R_{M1} and R_{M2}, are too busy and occupied with imported metals. The CLSC Positioning Tool should also be tested in different companies and context for validation and further verification. Refinement on the tool should be performed based on these additional findings; so that (if any) essential factors would also be taken into account and measured.
2. Profit Oriented The Chinese metal manufacturing and remanufacturing operations are mostly profit oriented.	Case companies are concerned about collecting and recovering production wastes, left-over, scrap and used metals in order to maximise the recoverable value and utilise metal resources.	Further research should be carried out to explore other wastes, e.g.: How those low value or valueless secondary metals and wastes are handled; and how to develop solution for better control and recovery.

Research Findings	Supports for Research Findings	Further Research
3. CLSC is the integration of Forward and Reverse Logistics By understanding both forward and reverse logistics flow enable better management and control of the CLSC and sustainable development.	(1) The goal for achieving zero-defect in production helps to reduce production wastes. (2) Design for Dismantling and Design for Environment are crucial for EOL products with different status to be recovered. (3) Collection at the source helps to ease the recovering process and reduce level of transportation.	Further research on the interactions between forward and reverse logistics companies and case studies can contribute in more comprehensive understanding of the CLSC and for sustainable development.
4. Future Sustainable Development CLSC is not the ultimate goal: the aim for achieving sustainable development is to develop CLSC into a virtuous spiral cycle and move up to higher levels.	According to the CLSC Development Cycle Framework, level of CLSC operations moves up by higher level of: (1) Sustainability (2) Development in technology (3) Human Resource (4) Knowledge and Techniques	Further research on performance measurement and factors that influence the CLSC sustainable development can provide more in-depth understanding for management and control of the CLSC.
Customer Factors		
5. Supply Chain Networks and Infrastructure The Chinese metal manufacturers and remanufacturers are operating in supply chain networks and cooperation, with the assistance of 3rd party logistics providers.	There are informal supply chain networks, both in the primary and secondary metal industry among Chinese metal SMEs, as well as with overseas countries. There are close network relationships between Company M_M & R_{M1}; Mss & R_{M2}, L_{3PRL} & Fortune 500, which enable better flow of wastes, left-over, scrap metals between these companies. Company R_{M1}, R_{M2}, L_{3PRL} have established 3PRL services with local manufacturers who can provide relatively high quality / valuable secondary metals. Better material and information flow increase efficiency of CLSC.	Further research in different industry, e.g. Plastic, Daily Wastes can be performed to compare and contrast different operating behaviours, pros and cons.

Research Findings	Supports for Research Findings	Further Research
6. Low Costs Shipping The large amount of Chinese goods exports makes it possible for low shipping cost for wastes and secondary metals containers to fill in backward shipments.	In order to maximise the utilities of container liners, the costs for transporting secondary metals remain relatively low. This enables long distance transportation of incoming secondary metals from overseas to China, and some other developing countries, where they can take advantage of the low labour costs for remanufacturing.	Further research on the influences of forward and reverse logistics transportation and the affects on environmental protection would encourage better control and management for eliminating the pollution from transportation activities.
7. Immature Chinese Metal Industry The Chinese metal remanufacturing industry is heavily relying on imports of secondary metals from Western developed countries.	Remanufacturing Company R_{M1}, R_{M2} and L_{3PRL} are still heavily relying on secondary metal imports. More than 70% of their secondary inputs are imported from developed countries overseas, which are considered to provide high quality and value for recovery process. Although there are local cooperation between metal manufacturers and remanufactures, the total quantity of wastes, left-over and scrap from Company M_M, Mss only take up to 30% of production capacity in Company R_{M1}, R_{M2}.	Further research should be performed especially with regard to the recent economic slowdown. With less export demands from China, the costs for containers transporting back to China are increasing. This would reduce the profit and evenutally, the incentives for recycling secondary materials.
Environment Factors		
8. Limited Chinese Legislation Limited legislation and regulation for environmental protection in the Chinese metal industry. The remanufacturing and recycling activities are mainly market and profit driven.	The existing Chinese legislation and regulation for environmental protection during production in China is not as strict as those in the Western developed countries. e.g. There is not yet similar enforcement as the European WEEE, or ELV Directive. Higher level of legislation and guidance need to be established to guide environmental production.	Further research on the impact and guidance of WEEE or ELV Directive on European companies could be performed in comparison in the context of the Chinese companies. In doing so, finding out whether similar legislation can be applied in different contexts.

Research Findings	Supports for Research Findings	Further Research
9. Environmental Protection, Health and Safety Chinese metal manufacturers and remanufacturers are more aware of environmental protection, health and safety during their production processes.	Companies such as Mss, R_{AL} and L_{3PRL} have been investing and designing their processes in order to achieve better protection for their employees as well as the environment.	There should be guidance and promotion of enviornmental protection and CSR to encourage Chinese companies to be more active in achieving sustainable development.
Technology Factors		
10. Metal Manufacturing Using Machinery The Chinese metal manufacturers have applied machinery systems for production.	(1) More than 70% of productions in Company M_M, Mss, R_{AL} are done by machinery system. (2) Higher level production technology and techniques enable higher level productivity and product quality. (3) Machinery and solid waste management enable collection of wastes, left-over, and scrap from metal production: e.g. the scrap rate in case companies are kept below 10%.	Further research can be proposed in looking at methods for applying technology at the production stage considering: DFD and DFE.
11. Metal Remanufacturing Based on Manual Labour The Chinese metal remanufacturers still heavily rely on manual labour operations.	More than 70% of the remanufacturing processes in Company R_{M1}, R_{M2}, L_{3PRL} are done by low costs manual labour. **Advantages:** (1) Low costs; (2) Require low level of skills; (3) Enable flexibility especially when sorting and dismantling complex metal products / parts (4) Easy to manage production schedule especially when supply and demand of secondary metals fluctuate **Disadvantages:** (1) Health and safety for workers (2) Low productivity (3) Limited and low capacity	Further research for finding out solutions especially with the increasing level of costs and reducing amount of low skilled labour in the future, changes remanufacturers need to make in order to develop their processes to higher level efficiency.

Research Findings	Supports for Research Findings	Further Research
12. Differences in Manufacturing and Remanufacturing Due to the nature of manufacturing and remanufacturing, it is easier to develop automation, technology, and systems for the former than the latter.	Manufacturing in Company M_M, Mss, R_{AL}: **Various Inputs** **→ Identical Products** Production process can be complex, but possible to perform batch production Remanufacturing in Company R_{M1}, R_{M2}, L_{3PRL}: **Various Status Inputs** **→ Various Products** Sorting and dismantling process can be very complex and require very high level technology systems to handle those processes.	Referring to the operations in forward logistics, manufacturers would benefit from applying automation for batch production. Further research for solutions to remanufacturing process would be investigating the solutions for how to gather complex secondary inputs with similar conditions / status to enable batch production performance.
13. Cooperation Between Companies and Academia Companies benefit from having collaborative relationships with academia in research and development for more efficient and effective operation.	In the case of Company R_{AL}, by working with researchers and experts from local university, they developed a production system which can remanufacture hazardous waste residues into non-hazardous materials that can be used by other manufacturers.	Further research and study can be encouraged by this research. More research relationships between companies and academia in China should be promoted for the win-win benefits. These encourage further developments in technology and society.

7.3 Research Limitation

As the existing study and research in CLSC, reverse logistics, sustainable development, especially in the context of developing countries, are very limited at the moment, further exploration of all these issues need to be taken step-by-step. Due to time, resource and accessibility availability, this research only focused on the Chinese metal industry. In particular, the case studies were carried out with seven metal manufacturing and remanufacturing SMEs as examples for the primary and secondary metal industry in the PRD region in China. It can be argued that the findings and frameworks developed might be very specific only to this context. However, as discussed previously, developing countries such as China mostly consists of SME operations which contribute a significant amount of income to their GDP. Hence, research in these SMEs would provide different perspectives for management studies.

Since this research was performed using case study interviews and observations on site, there were possibility that interviewees could have been biased or there was a lack of validity from observation. These were overcome by interviewing more members of the companies in order to generate a better understanding of the processes and issues related to the research area, and to achieve the aims and objectives of this research. In addition, "given the large amount of data typically involved in a case study, there is a danger of losing focus in the final interpretation and building a theory that tries to capture everything" (Driva, 1997). Hence, the researcher had to set a boundary and focus on the CET factors and their interactions.

7.4 Direction for Further Research

As listed in Table 7.1, there are many areas that further research can be carried out for more detailed investigations and to provide additional understanding of the CLSC operations in different contexts. For example, these include the sustainable CLSC network development among manufacturers and remanufacturers, the development of applicable technology for remanufacturing processes, and the effects of changing prices, demand and supply of secondary metals in the market.

It can be argued that further laws and legislations need to be established to provide better reinforcement and guidance for the Chinese metal manufacturers and remanufacturers in order to manage and control their operations with the aim to achieve sustainability. From the case findings, there are still low levels of health and safety protections for manual operators in the Chinese SMEs. In addition, profit orientation is still the main driver for remanufacturing processes and for metal manufacturers to deal with their production wastes. However, legislation needs to be established to reinforce, so that companies would not only focus on recovering those metals or materials with high values but neglecting those valueless secondary metals.

Company R_{AL} might be a unique case that pro-actively participates in investing and developing ways for the proper handling of hazardous wastes residues. Further research would be performed in order to investigate in other industries or contexts to find out how the CLSC operates. For example, for lower value plastics and daily wastes which contain hazardous materials that need to be handled effectively.

From the findings and understanding of this research, further investigation and study can be performed in each of these case companies in order to follow-up their development for long term sustainability. For instance, more detailed data and figures can be collected on-site in order to develop better scheduling methods; measuring and structuring the operations and networks between metal manufacturers and remanufacturers; managing and controlling the incoming supply and demand in order to cope with the fluctuating prices, demand and supply of secondary metals in the Chinese and overseas markets.

7.5 Conclusion

The research concludes by presenting the case findings and frameworks which contribute to the understanding of CLSC, in the context of the Chinese metal industry among the SME metal manufacturers, remanufacturers, 3PL and 3PRL service providers.

As identified in the literature review, the existing research in supply chain for sustainable development is very limited. To the author's knowledge, there have not been many detailed research studies in the process flows between the Chinese metal manufacturing and remanufacturing SMEs. This research has analysed the existing literature in the Western developed countries and China, and the patterns of the past and current situation in the Chinese metal industry. These would assist further research development and improvement in the future. After all, this research aims to contribute better understanding of the sustainable CLSC, reverse logistics and SWM in the context of developing countries – using China as an example. Issues with regard to the CET factors were investigated. Hence, the Reverse Logistics Framework was contextualised in the Chinese metal industry. It investigated the interactive activities among the metal manufacturing and remanufacturing companies in their industrial cooperation. These are qualitative data for theoretical and practical references. Especially with the focus on the CET factors and the process maps of the CLSC, the characteristics and patterns of the Chinese metal industry have been evaluated. The data and information collected from the seven case studies are considered to be unique.

Referring to the basic aim of operations management research (Handfield and Melnyk, 1998) as mentioned in Chapter 3, this research has investigated and explored the past and current operations in the Chinese metal manufacturing and remanufacturing activities, with a sense of identifying the causes and issues with regard to these operations. It has also proposed suggestions and benchmarks for SMEs in developing countries to achieve sustainable development in the long term. By mapping and developing frameworks and tools from the theoretical and empirical studies throughout this research, the research question, aims and objectives of this research have been accomplished. It presents a better understanding of the CLSC for further improvement and better control by the Chinese companies and government. It is believed that findings from this research contribute to existing knowledge, and provide a platform for further research to be carried out in order to investigate and further develop the CLSC, in the context of China or other countries. After all, the CLSC is not simply completed by integrating the forward and reverse flows, but it moves up the virtuous spiral cycle for further development. There are continuous developments in the level of sustainability, the development of production efficiency, the level of technology, human resource, knowledge and techniques, which are the issues for companies to take into account for their long term sustainable development.

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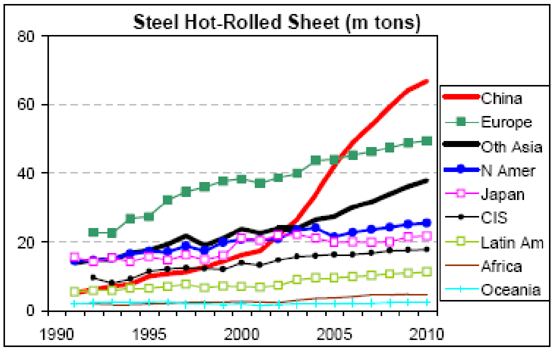
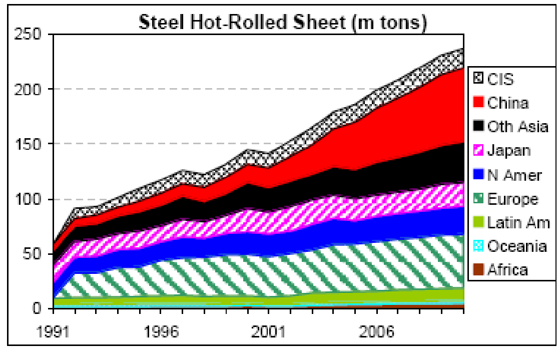
APPENDICES

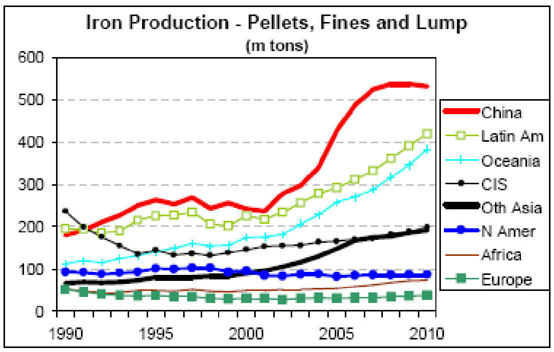
Appendix 1

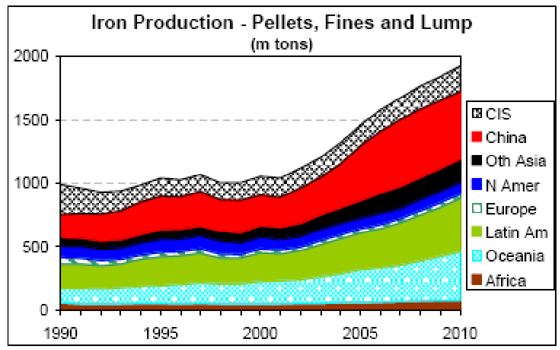
Refined Metals Production 1990 – 2010

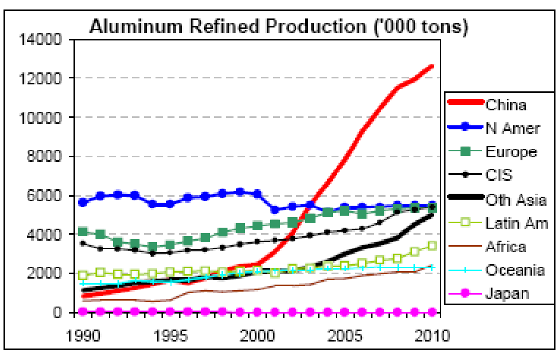
By Countries or Regions | Total

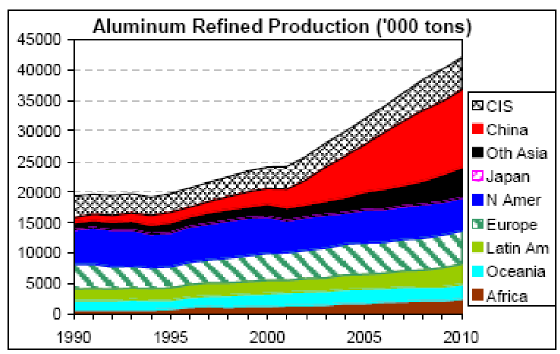


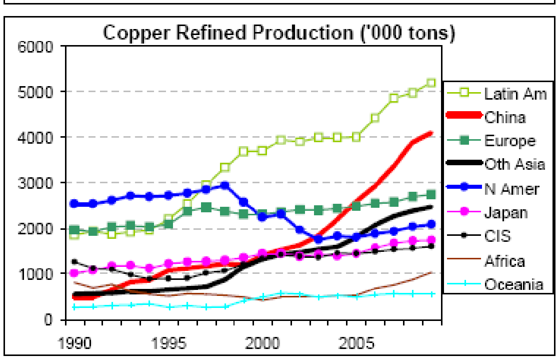


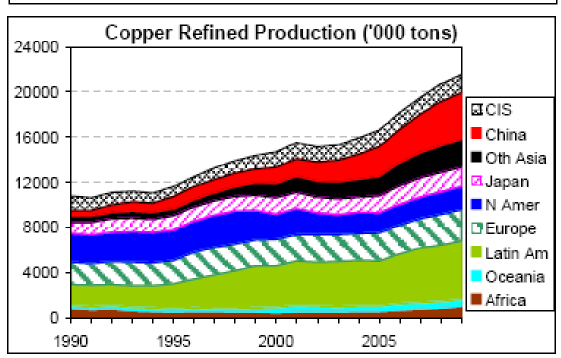












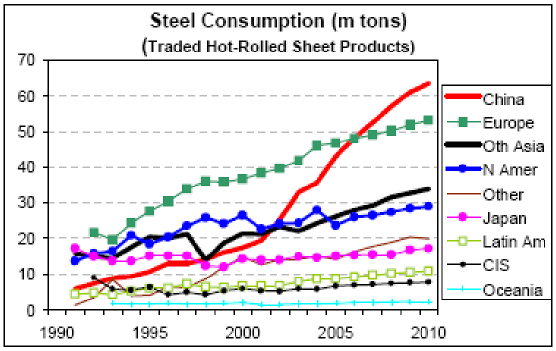
*CIS: Commonwealth of Independent States

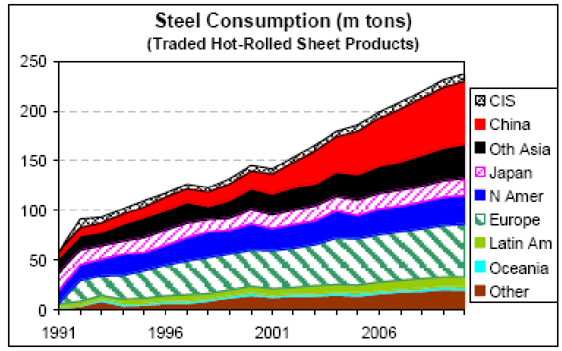
(Source: The World Bank Group, 2006)

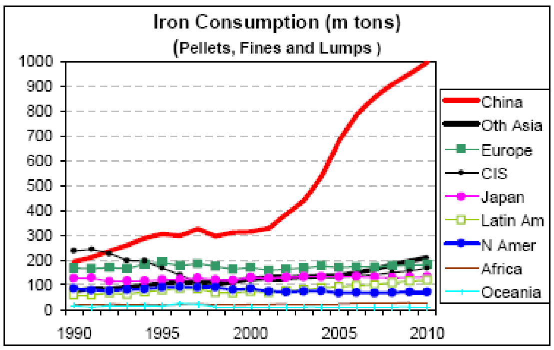
Appendix 2

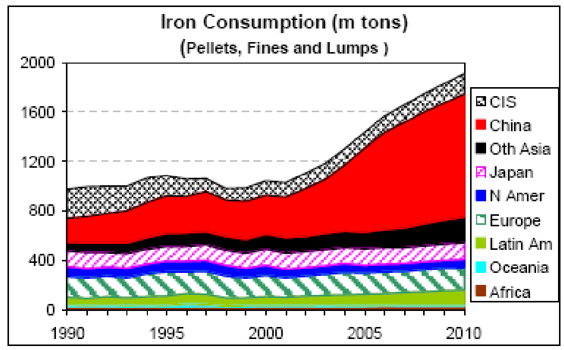
Metal Consumptions 1990 – 2010

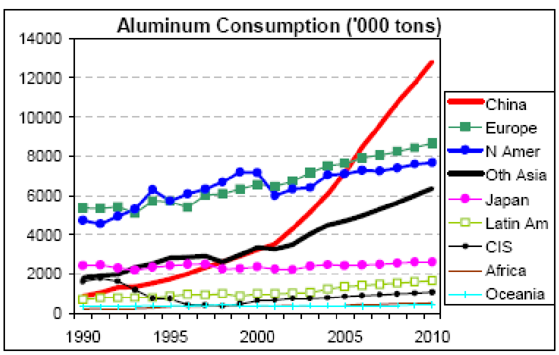
By Countries or Regions | Total

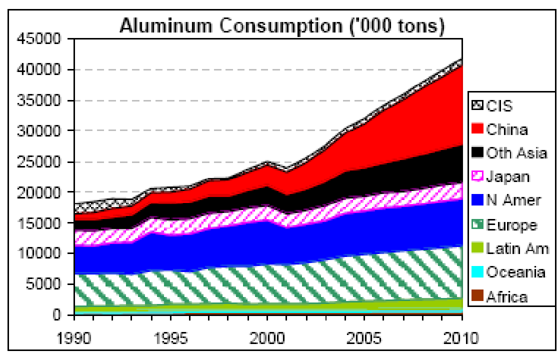


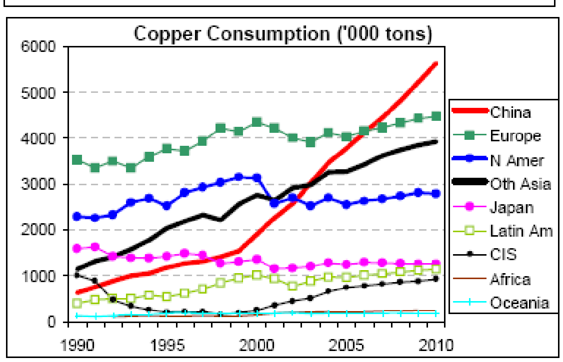


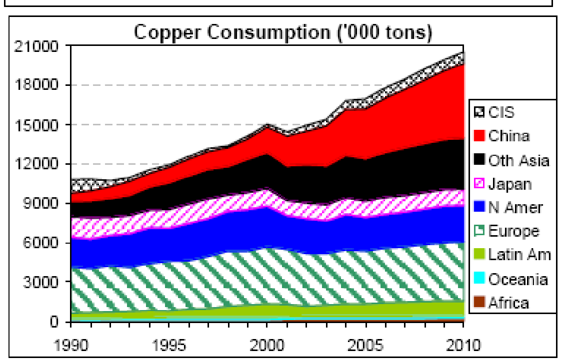












*CIS: Commonwealth of Independent States

(Source: The World Bank Group, 2006)

Appendix 3

Guangdong Non-Ferrous Metal Technology Innovation Centre Semi-Structured Interview Questions (English and Chinese Version)
广东有色金属技术创新中心访问问题(中文)

1. What is the centre about, and what do you do?
   请介绍一下贵中心的职能

2. Who are the members?
   请介绍一下贵中心的成员

3. What is the current situation of the (Non-Ferrous) metal manufacturing and remanufacturing industry in the region? (Please provide some data and figures.)
   请介绍一下目前广东(有色)金属生产和回收的状况，可以提供一些数字吗?

4. How do the metal manufacturers and remanufacturers interact with each other?
   金属生产和回收公司之间是怎样联系的?

5. What is the trend of development for the industry in the near future?
   您认为金属生产和回收的发展状况将会是怎样的呢?

6. What are the issues concerning the metal industry in the region?
   目前有哪些状况和操作是应该改善的呢?

Appendix 4

Guidelines for Case Company Interview Questions (English and Chinese Version)
公司访问问题大纲(中文)

<u>Basic Information 公司基本资料</u>
Managerial Level 管理层:

1. What does your company do?
   请问贵公司的经营范围是什么?

2. What is the company history? How did it start?
   请问贵公司的历史，是什么时候建立的，发展的历史是怎样的呢?

3. How does your company operate in the industry?
   贵公司在这行业中是怎样运作的呢?

4. What are the changes and developments during these years?
   近几年贵公司有什么改变呢?

5. What are your company's competitive advantages?
   您认为贵公司有什么优势?

6. What do you think your company's position in the market?
   您认为贵公司在行业中处于什么位置呢?

7. Which part of the operations do you think your company needs to improve for further development?
   您认为贵公司在哪些方面可以有改进的地方呢?

8. How do you see your company in 5 years time?
   您认为贵公司在五年内会向什么方向发展呢?

Operating Level 操作层:

1. Which part of the production / operations are you working?
   请问你在公司负责什么操作呢?

2. What do you think about your work? Anything you can do to improve it?
   你工作的步骤是怎样的呢? 你认为有哪些东西你(或者公司)可以改进?

3. Have there been changes since you first started?
   自你工作以来，你觉得你的工作方式有什么改变了的呢?

4. What do you see yourself in the company, and in 5 years time?
   你觉得你在公司会有什么发展呢? 比如说，在未来五年内?

<u>More Specific Questions for Customer – Environment – Technology Relationships</u>
<u>关于 客户 – 环境 – 操作技术关系 的问题</u>

Customer 客户

1. Who are your customers and suppliers? How do you handle your incoming materials and finished products?

贵公司的客户和供应商是哪些? 贵公司是如何管理生产原材料和成品的?

2. What are the customer requirements in terms of metal production / recycling?

贵公司的客户对贵公司生产 / 回收 的要求是什么呢?

3. How do you respond to customer requirements?

贵公司如何对待这些客户的要求呢?

4. How does the logistics flow goes between you and your customers / suppliers?

贵公司和客户 / 供应商之间的运作是如何的呢?

5. How does the customers influence on the production capability and lead time?

贵公司的客户对贵公司的生产，运作有什么的影响?

6. Have you (or the company) come across any issues relating to customer factor and your operation, and how do you (or the company) deal with them? (Please give some examples.)

您(或者贵公司)有遇到些关于客户方面的问题吗? 您(或者贵公司)是如何处理的?

Environmental Issues 环境

1. What are the concerns for health and safety issues on site?
   贵公司对生产安全的要求和控制是如何的呢?

2. What are the processes for the control and management of production wastes?
   e.g. Collection and sorting of wastes at source, and how to minimise wastes occurring?
   贵公司是如何处理生产过程中的产生的废料的呢?
   例如：如何收集产生的废料，如何控制废弃物的产生?

3. How do you develop and implement higher level of product / parts / materials utilisations?
   贵公司有研究如何地更高效的运用材料，减少废料的操作吗?

4. Are you aware of the control of the wastes and emissions to landfill, air and water?
   How do you deal with these issues?
   贵公司有注意到生产過程中产生的废气，废料对环境的影响吗?
   贵公司是如何处理这些废弃物的呢?

5. Have you (or the company) come across any issues relating to environment factor and your operation, and how do you (or the company) deal with them? (Please give some examples.)
   您(或者贵公司)有遇到些关于环境方面的问题吗? 您(或者贵公司)是如何处理的?

Process Technology 操作技术

1. What is the process for manufacturing / remanufacturing / Dismantle / handling solid waste and materials?

贵公司在生产 / 循环制造 / 分拆 / 处理固体废弃物或材料 的运作是如何进行的呢?

2. What kind of the process technology has been developed / implemented in the company? e.g. Manual? Automation? Working with other companies / parties / universities for solutions?

贵公司有运用哪些操作技术呢?

例如: 用人工的比例? 自动化的比例? 与其它公司，组织，大学之间有合作吗?

3. How efficient is the production system?

e.g. the lead time for production, the amount of waste / residues created during production

您认为贵公司的操作系统运作得如何?

例如: 贵公司的生产所需时间是否合理? 如何控制生产过程中产生的废弃物料?

4. Have you (or the company) come across any issues relating to technology factor and your operation, and how do you (or the company) deal with them? Please give some examples.

您(或者贵公司)有遇到些关于操作技术方面的问题吗?

您(或者贵公司)是如何处理的? 请举例。

Appendix 5

List of Interviewees

Organisation	Codes	Name	Position	Interview Date	Interview Duration
Guangdong Non-Ferrous Metal Technology Innovation Centre	GD.01	Mr. J.W. Zhou	Officer	Oct 11, 2005	2 hours (Joint Interview)
	GD.02	Mr. H. Chen	Officer	Oct 11, 2005	2 hours (Joint Interview)
Company L_{3PL}	L_{3PL}.01	Mr. C.H. Pang	Managing Director	Oct 17, 2005	1 hours
	L_{3PL}.02	Ms. B.X. Peng	Managing Director	Oct 17, 2005	1 hours
	L_{3PL}.03	Mrs. Q.L. Mok	General Manager	Oct 17, 2005	2 hours
	L_{3PL}.04	Mr. X.L. Zhang	General Manager	Oct 17, 2005	2 hours
	L_{3PL}.05	Mr. X. Zeng	Vessel Manager	Oct 19, 2005	2 hours
	L_{3PL}.06	Mr. P.J. Deng	Truck Manager	Oct 20, 2005	2 hours
	L_{3PL}.07	Mr. C.G. Mo	Sales Manager	Oct 21, 2005	2 hours
	L_{3PL}.08	Ms. Y.H. Huang	Operation Manager	Oct 21, 2005	2 hours
	L_{3PL}.09	Mr. Y.D. Zhong	Operator	Oct 18, 2005	1.5 hours
	L_{3PL}.10	Ms. R.L. Wong	Operator	Oct 18, 2005	1.5 hours
	L_{3PL}.11	Mr. G.J. Wang	Operator	Oct 18, 2005	1.5 hours
	L_{3PL}.12	Mr. N.Q. He	Vessel Captain	Oct 19, 2005	1.5 hours
	L_{3PL}.13	Mr. Z.R. Ma	Truck Schedule Planner	Oct 20, 2005	2 hours
	L_{3PL}.14	Mr. G.M. Pan	Maintenance	Oct 20, 2005	2 hours
	L_{3PL}.15	Ms. L.P. Zhou	Sales	Oct 21, 2005	1.5 hours
Company R_{M1}	R_{M1}.01	Mr. W.G. Chen	Managing Director	Dec 4, 2005	2 hours
	R_{M1}.02	Ms. X.Z. Lin	Production Manager	Dec 4, 2005	2 hours
	R_{M1}.03	Staff 1	Operator	Dec 4, 2005	1.5 hours
	R_{M1}.04	Staff 2	Operator	Dec 4, 2005	1.5 hours

Company M_M	M_M.01	Mr. B. Jian	Production Manager	Jan 12, 2006	3 hours
	M_M.02	Staff 1	Operator	Jan 12, 2006	1.5 hours
	M_M.03	Staff 2	Operator	Jan 12, 2006	1.5 hours
Company R_{AL}	R_{AL}.01	Mr. K.T. Pan	Owner	May 16, 2006	2 hours
	R_{AL}.02	Mr. G.T. Pan	Owner	May 16, 2006	2 hours
	R_{AL}.03	Mr. J.T. Pan	Owner	May 17, 2006	2 hours
	R_{AL}.04	Mr. S.L. Liang	General Manager (Manufacture)	May 16, 2006	2 hours
	R_{AL}.05	Mr. K.Y. Xiao	General Manager	May 17, 2006	2 hours
	R_{AL}.06	Mr. B.L. Deng	Production Manager	May 17, 2006	2 hours
	R_{AL}.07	Mr. M. Pan	Engineer Team Leader	May 17, 2006	2 hours
	R_{AL}.08	Mr. X. Guo	Operations Manager	May 18, 2006	2 hours
	R_{AL}.09	Mr. P. Zhou	Head Engineer	May 18, 2006	2 hours
	R_{AL}.10	Staff 1	Operator (Manufacture)	May 16, 2006	1.5 hours
	R_{AL}.11	Staff 2	Operator (Manufacture)	May 16, 2006	1.5 hours
	R_{AL}.12	Staff 3	Operator	May 18, 2006	1.5 hours
	R_{AL}.13	Staff 4	Operator	May 18, 2006	1.5 hours
	R_{AL}.14	Staff 5	Operator	May 19, 2006	1.5 hours
	R_{AL}.15	Staff 6	Operator	May 19, 2006	1.5 hours
Company R_{M2}	R_{M2}.01	Mr. J.H. Li	Owner	Aug 25, 2006	2 hours
	R_{M2}.02	Mr. S.J. Liang	General Manager	Aug 25, 2006	2 hours
	R_{M2}.03	Mr. L.Y. Zhang	Operation Manager	Aug 25, 2006	2 hours
	R_{M2}.04	Mr. D.P. Wu	Sales Manager	Aug 25, 2006	2 hours
	R_{M2}.05	Mr. C.Y. Ou	Production Scheduler	Aug 26, 2006	2 hours
	R_{M2}.06	Mr. Y. Guang	General Manager	Aug 26, 2006	2 hours
	R_{M2}.07	Staff 1	Team Leader	Aug 26, 2006	1.5 hours
	R_{M2}.08	Staff 2	Team Leader	Aug 26, 2006	1.5 hours
	R_{M2}.09	Staff 3	Operator	Aug 26, 2006	1.5 hours
	R_{M2}.10	Staff 4	Operator	Aug 27, 2006	1.5 hours
	R_{M2}.11	Staff 5	Operator	Aug 27, 2006	1.5 hours
	R_{M2}.12	Staff 6	Operator	Aug 27, 2006	1.5 hours
	R_{M2}.13	Staff 7	Operator	Aug 27, 2006	1.5 hours

Company Mss	Mss.01	Mr. X.L. Zhang	General Manager	Sep 2, 2006	2 hours
	Mss.02	Mr. F. Guan	Production Manager	Sep 2, 2006	2 hours
	Mss.03	Mr. J. Huang	Engineer Team Leader	Sep 2, 2006	2 hours
	Mss.04	Staff 1	Operator	Sep 2, 2006	2 hours
Company L_{3RPL}	L_{3RPL}.01	Mr. J. Chen	General Manager	Feb 2, 2007	2 hours
	L_{3RPL}.02	Mr. H. Huang	Vice General Manager	Feb 2, 2007	2 hours
	L_{3RPL}.03	Mr. L. Jin	Operations Manager	Feb 2, 2007	2 hours
	L_{3RPL}.04	Staff 1	Team Leader	Feb 2, 2007	2 hours (Joint Interview)
	L_{3RPL}.05	Staff 2	Operator	Feb 2, 2007	2 hours (Joint Interview)
	L_{3RPL}.06	Staff 3	Operator	Feb 2, 2007	2 hours (Joint Interview)

Appendix 6

Company Mss – Factory Layouts

Production Materials

Surface Finishing Machinery

Finished Products Storage

Appendix 7

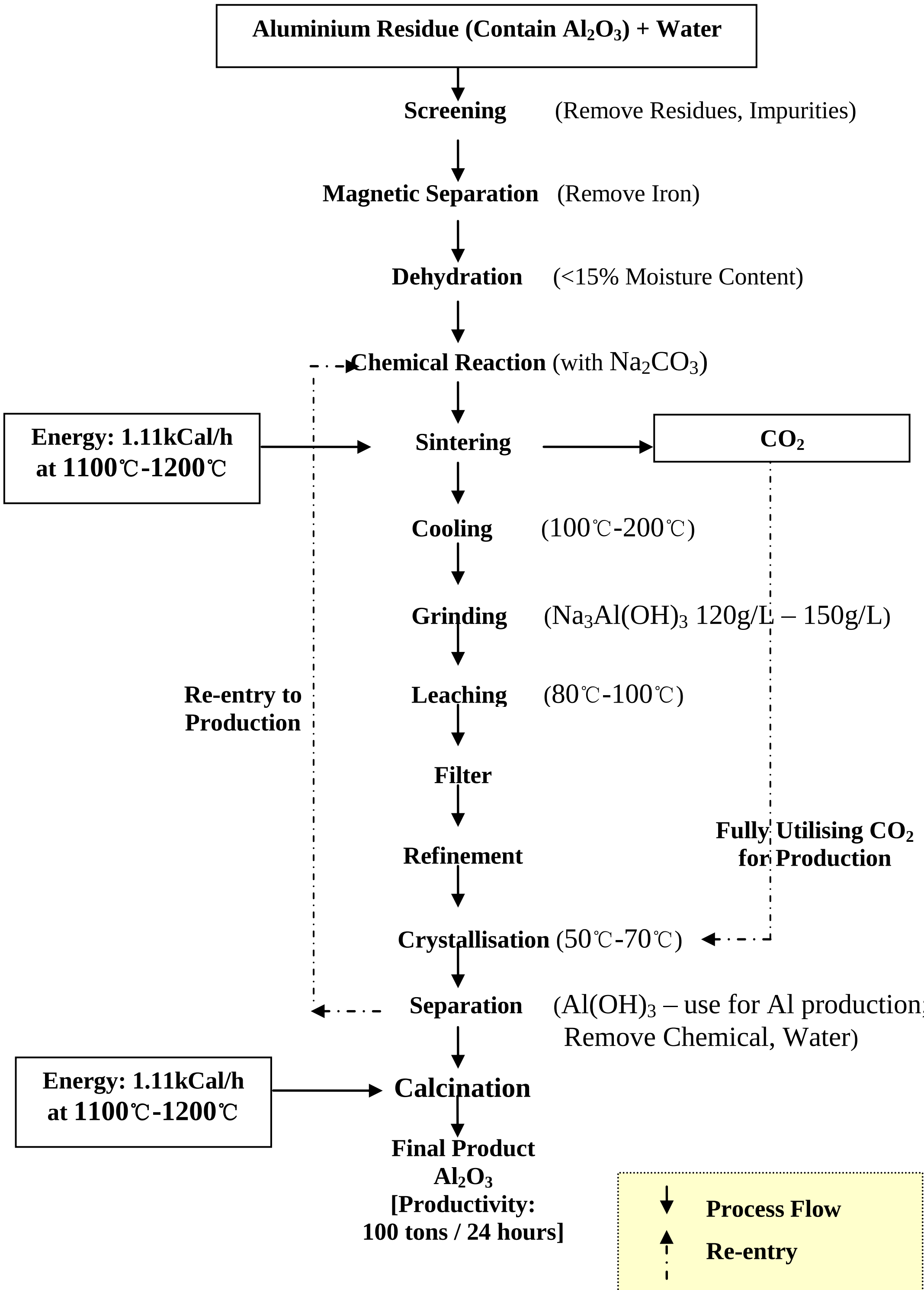
Company R_{M1} – Bought in Materials on-site

Sorted

Unsorted

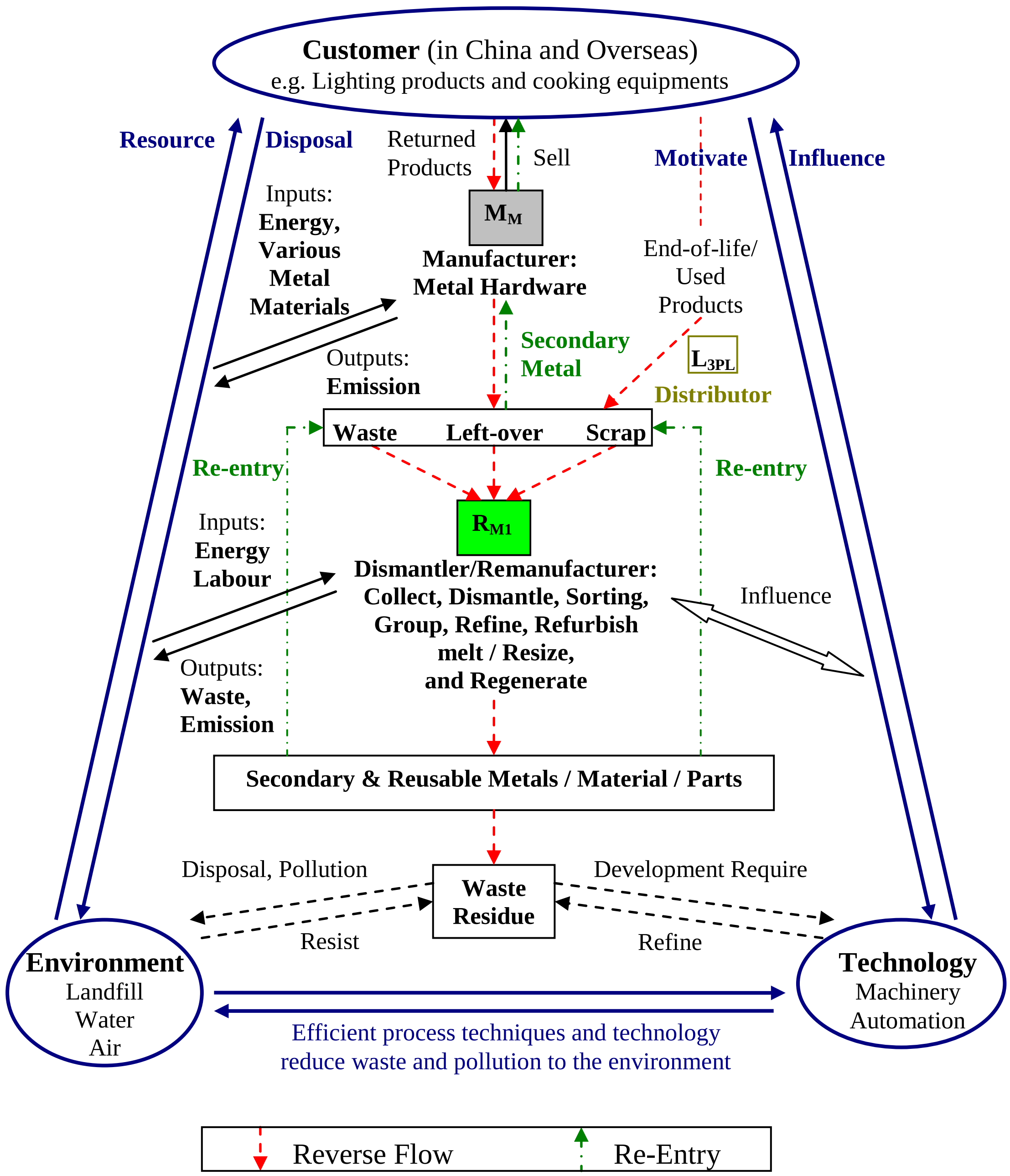
Appendix 8

Aluminium Residue Remanufacturing Process



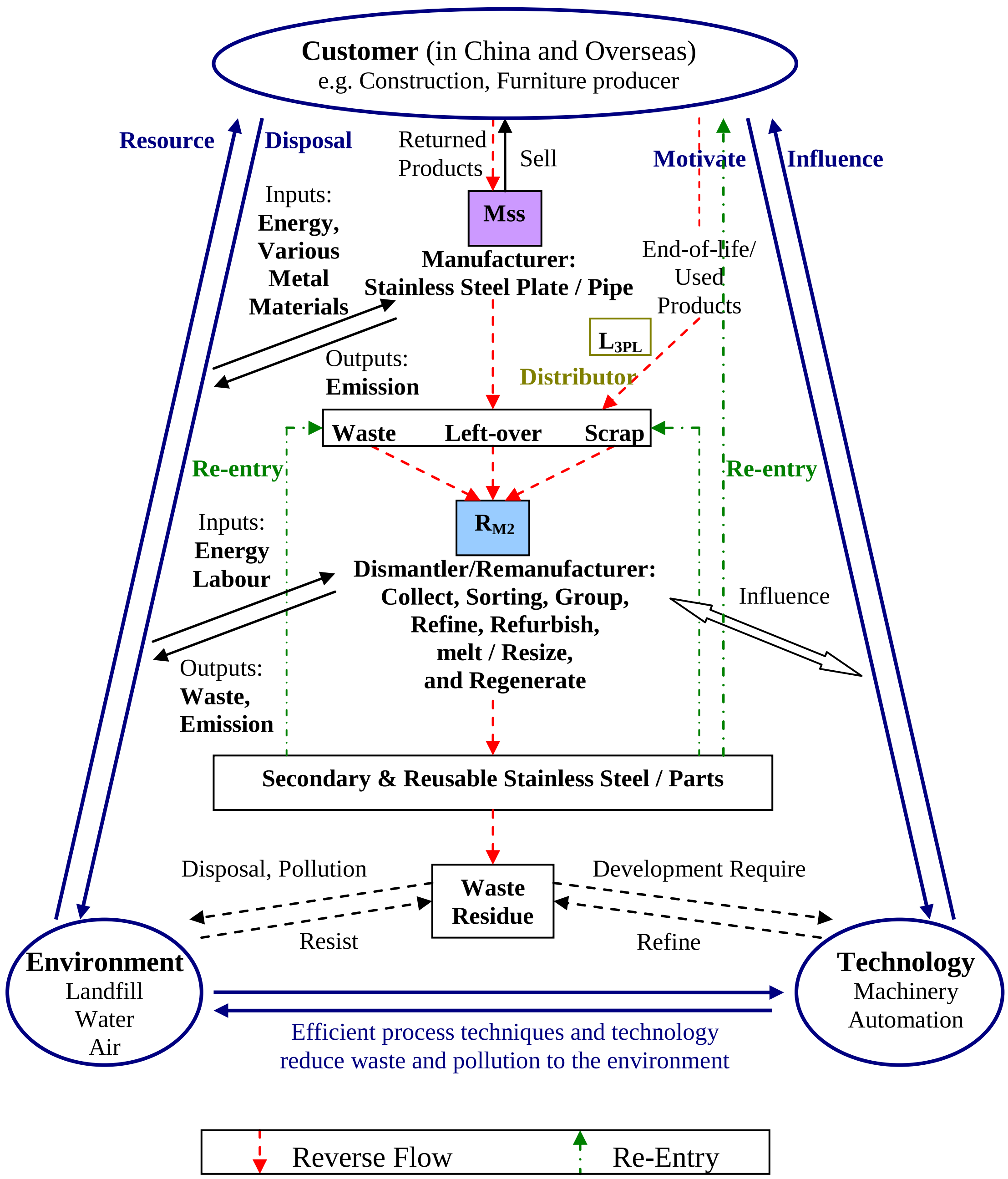
Appendix 9

Sustainable Closed-Loop Supply Chain Management Framework for Company M_M and R_{M1}



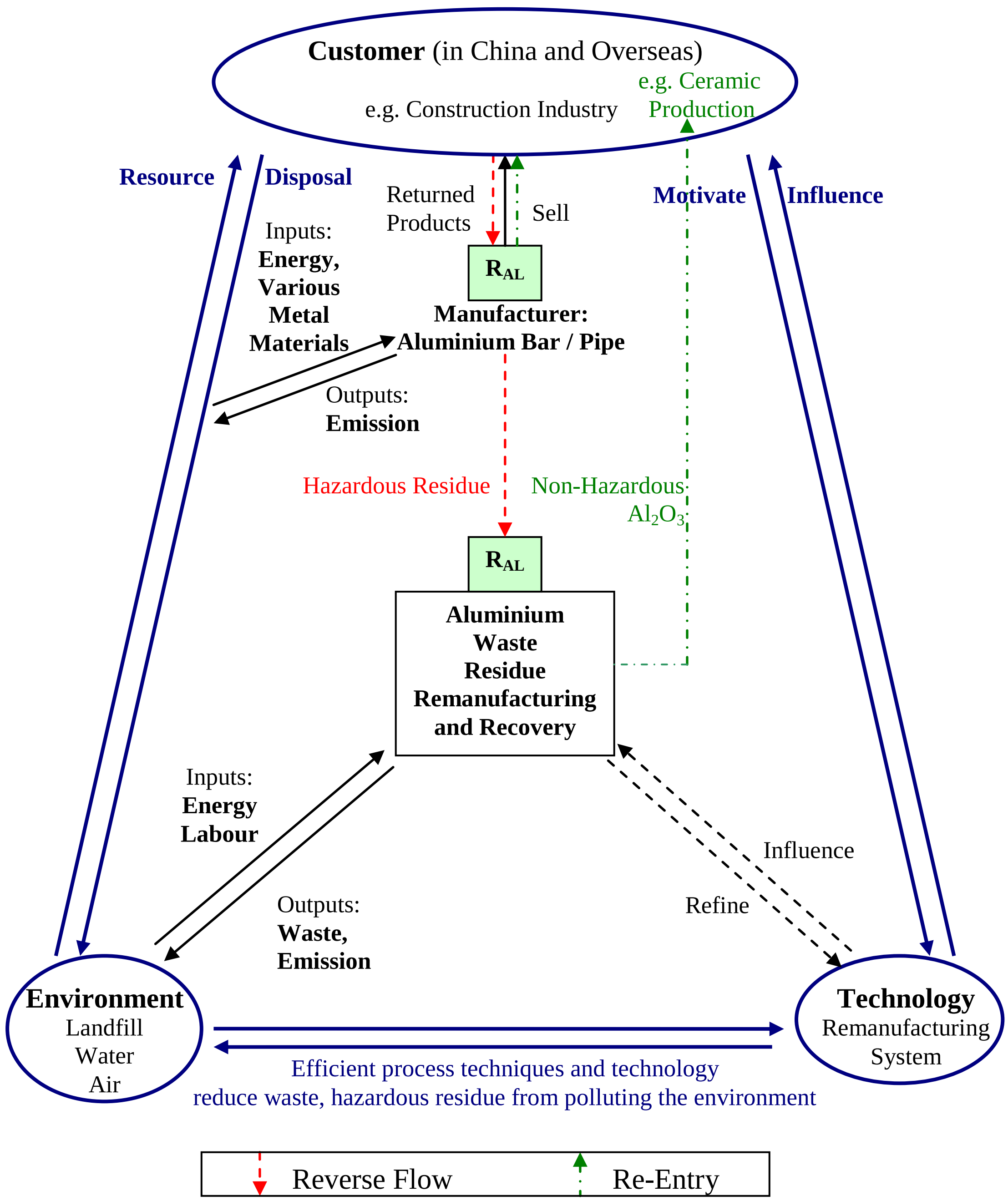
Appendix 10

Sustainable Closed-Loop Supply Chain Management Framework for Company Mss and R_{M2}



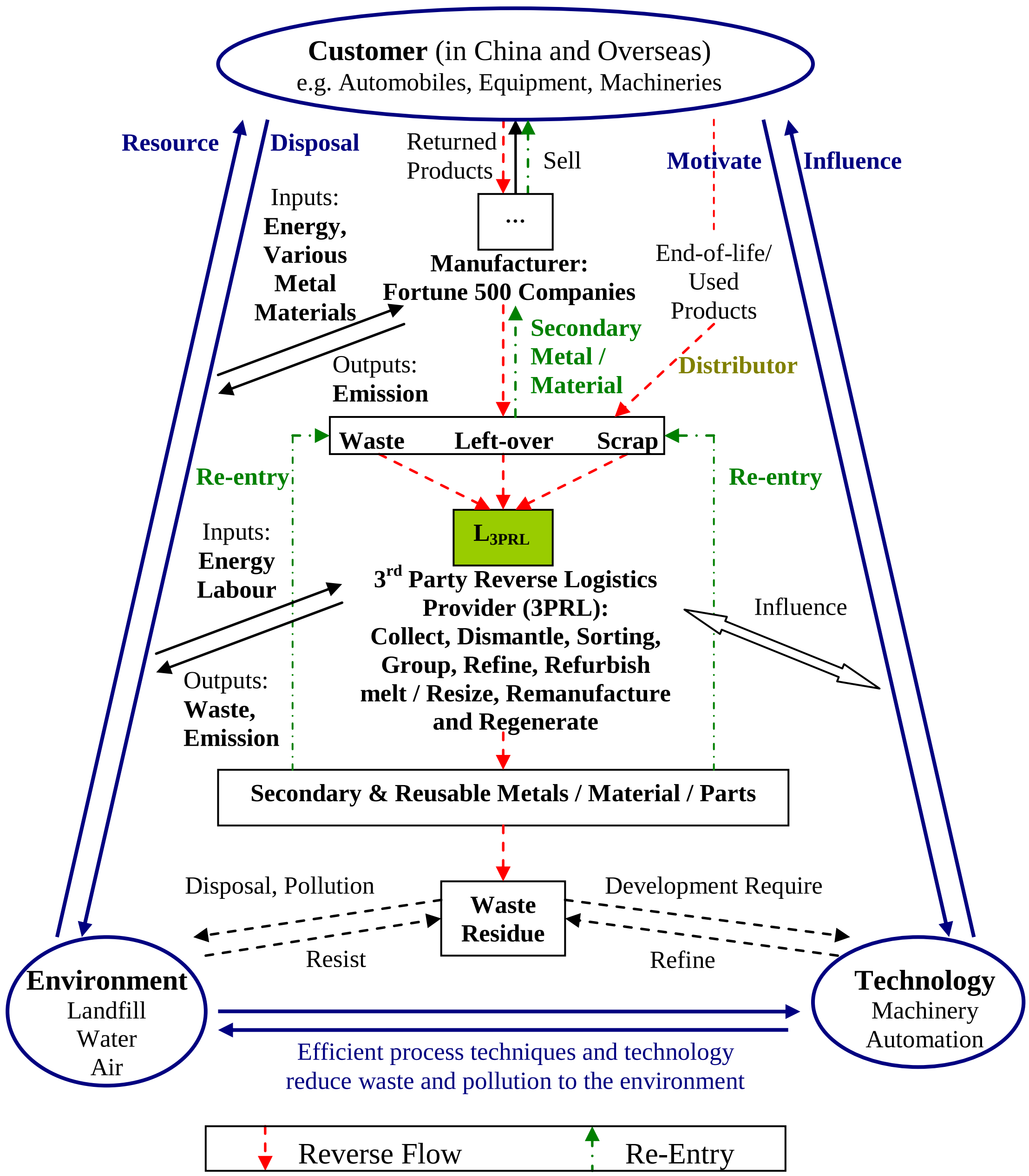
Appendix 11

Sustainable Closed-Loop Supply Chain Management Framework for Company R_{AL}



Appendix 12

Sustainable Closed-Loop Supply Chain Management Framework for Company L_{3PRL}



Appendix 13

The Closed-Loop Supply Chain Positioning Tool Instruction

Re: Figure 6.8 Case Companies on the CLSC Positioning Tool (Data as in 2005-2007)

Table of Data for Positioning Case Companies on the CLSC Positioning Tool (2005-2007) are listed as followed.

Explanation for the Table – Using Company M_M as an example:
Data collected from case companies are presented in the following Tables. They are calculated using these scaling and scoring methods. Referring to the Rate (%) [Approx.], each item can be scaled and then scored accordingly. All of the scores are rounded to 2 places of decimals.

1) "Level of Production Waste" in Company M_M is less than 5%, it is scaled under 1. As it is a positive factor for the company, it has a score of 4.75 (5 being the highest and 0 being the lowest).
2) "Labour Intensity" in Company M_M is less than 30%, it is scaled under 2. As it is also a positive factor for the company, it has a score of 4.00.
3) "Level of Technology" in Company M_M is over 70%, it is scaled under 3. And according to the scaling, it has a score of 3.00.
4) It should be pointed out that this Positioning Tool is developed based on the SMEs in the case studies. Hence, the range for "Production Capacity" is less than 1 million tons. Therefore, "Production Capacity" in Company M_M being 100,000 tons is scaled and has a score of 1.00.
5) "Interactions in Supply Network" is the percentage of established contracted relationships with suppliers, which affects the level of control over the company's incoming materials provided by its suppliers (as in Table 5.1 and 5.2 – Customer Factors: Suppliers). In the case of Company M_M, 40% of their suppliers are contracted. Hence, it is scaled under 2, with a score of 2.00.

Table of Data for Positioning Case Companies on the CLSC Positioning Tool (2005-2007)

Company Name:	Company M_M		
Company Operating Nature:	Metal Manufacturer / Metal Remanufacturer		
Positioning Scale:	0 (0), 20% (1), 40% (2), 60% (3), 80% (4), 100% (5)		
	Rate (%)	**Scale (1-5)**	**Score**
Level of Production Wastes	5%	1	4.75
Labour Intensity	30%	2	3.50
Level of Technology	70%	3	3.50
Production Capability (Annual)	100,000 tons	1	1.00
Total Score:			12.75
Average Score:			**3.19**
Interactions in Supply Network	40%	2	**2.00**

Company Name:	Company Mss		
Company Operating Nature:	Metal Manufacturer / Metal Remanufacturer		
Positioning Scale:	0 (0), 20% (1), 40% (2), 60% (3), 80% (4), 100% (5)		
	Rate (%)	**Scale (1-5)**	**Score**
Level of Production Wastes	3%	1	4.85
Labour Intensity	20%	1	4.00
Level of Technology	80%	4	4.00
Production Capability (Annual)	300,000 tons	2	1.50
Total Score:			14.35
Average Score:			**3.59**
Interactions in Supply Network	50%	2	**2.50**

Company Name:	Company R_{AL}		
Company Operating Nature:	Metal Manufacturer / Metal Remanufacturer		
Positioning Scale:	0 (0) — 20% (1) — 40% (2) — 60% (3) — 80% (4) — 100% (5)		
	Rate (%)	**Scale (1-5)**	**Score**
Level of Production Wastes (Level of Waste Recovery)	10%	1	4.50
Labour Intensity	25%	1	3.75
Level of Technology	75%	3	3.75
Production Capability (Annual)	800,000 tons & 36,000 tons	4	4.00
Total Score:			16.00
Average Score:			**4.00**
Interactions in Supply Network	80%*	4	**4.00**

*80% is the average of the 60% Contracted Suppliers (Manufacturing), and 100% Contracted Suppliers (Remanufacturing) in Company R_{AL}

Company Name:	Company R_{M1}		
Company Operating Nature:	Metal Manufacturer / Metal Remanufacturer		
Positioning Scale:	0 (0) — 20% (1) — 40% (2) — 60% (3) — 80% (4) — 100% (5)		
	Rate (%)	**Scale (1-5)**	**Score**
Level of Waste Recovery	95%	5	4.75
Labour Intensity	90%	5	0.50
Level of Technology	10%	1	0.50
Production Capability (Annual)	50,000 tons	1	0.50
Total Score:			6.25
Average Score:			**1.56**
Interactions in Supply Network	25%	1.25	**1.25**

Company Name:	Company R_{M2}		
Company Operating Nature:	Metal Manufacturer / Metal Remanufacturer		
Positioning Scale:	0 (0) — 20% (1) — 40% (2) — 60% (3) — 80% (4) — 100% (5)		
	Rate (%)	**Scale (1-5)**	**Score**
Level of Waste Recovery	95%	5	4.75
Labour Intensity	85%	5	0.75
Level of Technology	15%	1	0.75
Production Capability (Annual)	100,000 tons	1	1.00
Total Score:			7.25
Average Score:			**1.81**
Interactions in Supply Network	30%	1.50	**1.50**

Company Name:	Company L_{3PRL}		
Company Operating Nature:	Metal Manufacturer / Metal Remanufacturer		
Positioning Scale:	0 (0) — 20% (1) — 40% (2) — 60% (3) — 80% (4) — 100% (5)		
	Rate (%)	**Scale (1-5)**	**Score**
Level of Waste Recovery	95%	5	4.75
Labour Intensity	70%	3	3.50
Level of Technology (For production)	30%	2	1.50
Production Capability (Annual)	500,000 tons	3	2.50
Total Score:			**12.25**
Average Score:			**3.06**
Interactions in Supply Network	60%	3	**3.00**

Appendix 14

Verification Processes (Example: Company Mss)

The verifications of the CLSC Positioning Tool for case companies were performed by sending emails to the contact persons for the case study research. These include:

1) The Email with basic questions for feedbacks and verification
2) The Table of Data for the positioning
3) The Tool itself highlighting the company's position

Comments and feedbacks were collected through emails and telephone conversations with contact persons in each of the case companies.

The Email, Table and the Tool are presented in both English and Chinese as following, using Company Mss as an example. Further responses collected from the contacts in the case companies are also analysed in the following section.

1)a Email (in English)

Dear Mr. Zhang,

Thank you very much again for participating in the research for the Sustainable Closed-Loop Supply Chain in the context of the Chinese Metal Industry.

From all the data and information we collected from you and other case companies, we have proposed a CLSC Positioning Tool for companies in the metal manufacturing and remanufacturing industries. Please check the attachment for your company's position. It is based on the collected data from the case study. It would be really appreciated if you would provide some feedbacks on your opinions and comments on the tool, with regard to these questions:

1. Do you understand the model?
2. Do you agree with the positioning of your company on the model?
3. Is the tool useful for the management of your company and its development direction?
4. Any comments on the data and positioning, and the design of the graph?

I look forward to hearing from you through email. Or may I please book a telephone appointment with you for further discussion? Thank you very much for your valuable time and participation.

Yours sincerely,

Miss Juanling Huang

PhD Researcher

Operations Management Division

Nottingham University Business School

University of Nottingham

United Kingdom

1)b Email (in Chinese)

尊敬的张先生：

再一次感谢您及贵公司参与"中国金属制造业的可持续密闭性供应链"的研究。

从我们在贵公司及其它案例公司收集到的数据和资料，我们提议了一个为金属制造商和回收商的自我衡量定位模型。请查阅附件的模型。贵公司在模型中的定位是按照案例研究中收集的数据计算的。我们恳切地希望您可以为此模型和定位，及以下问题提供宝贵的意见：

1. 您认为这个模型清晰吗?
2. 您同意贵公司在此模型中的定位吗?
3. 您认为这个模型对贵公司的管理和发展方向有帮助吗?
4. 您对数据，定位及模型的设置有什么意见吗?

恳请您以用电邮的形式回复我。或与我预约一个时间，使我们可以以电话的方式联络及交换意见。谢谢您宝贵的时间和建议。

此致

敬礼

黄绢绫
英国诺丁汉大学
商学院运筹管理系
博士研究生

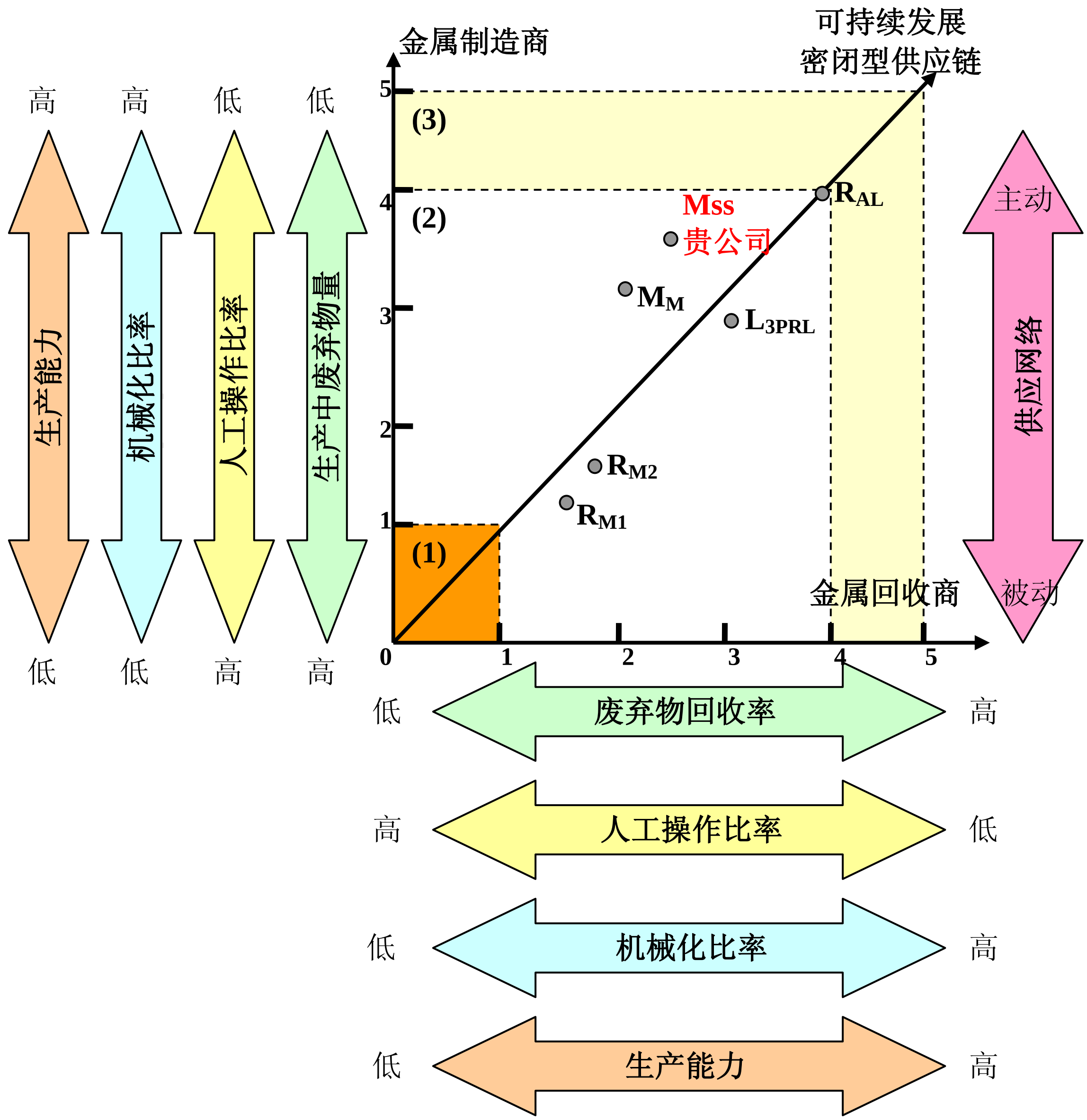
2) Table of Data for Positioning Company Mss (in English and Chinese)

Company Name:	Company Mss		
Company Operating Nature:	Metal Manufacturer / Metal Remanufacturer		
Positioning Scale:	0 (0) — 20% (1) — 40% (2) — 60% (3) — 80% (4) — 100% (5)		
	Rate (%)	**Scale (1-5)**	**Score**
Level of Production Wastes (Level of Waste Recovery)	3%	1	4.85
Labour Intensity	20%	1	4.00
Level of Technology	80%	4	4.00
Production Capability (Annual)	300,000 tons	2	1.50
Total Score:			14.35
Average Score:			**3.59**
Interactions in Supply Network	50%	2	**2.50**

公司名称:	Mss 公司		
公司性质:	金属制造商 / 金属回收商		
定位尺度:	0 (0) — 20% (1) — 40% (2) — 60% (3) — 80% (4) — 100% (5)		
	比率 (%)	**尺度 (1-5)**	**评分**
生产中废弃物量 (废弃物回收比率)	3%	1	4.85
人工操作比率	20%	1	4.00
生产中机械化比率	80%	4	4.00
年生产能力	300,000 tons	2	1.50
总分:			14.35
平均分:			**3.59**
供应网络的主动性	50%	2	**2.50**

3) Positioning Case Companies on the CLSC Positioning Tool (In Chinese)

Example: Company Mss



Mss 公司衡量定位模型

Comments and Feedbacks on the Tool:

1. Do you understand the model?
2. Do you agree with the positioning of your company on the model?
3. Is the tool useful for the management of your company and its development direction?
4. Any comments on the data and positioning, and the design of the graph?

With regard to these questions, some of the answers are analysed as follow:

1. Do you understand the model?

Generally speaking, the model and the scales are quite clear to companies. However, few needed detailed explanation especially on how to rate and score certain items. It seems that especially for the rating of "Interactions in Supply Network", in addition to the percentage of established contracted suppliers, there might require third party audit for the scoring in order to achieve higher levels of objective feedbacks and positioning.

2. Do you agree with the positioning of your company on the model?

As the positioning on the tool is based on the scale and score calculations, contacts generally agree with the model and position for their companies. However, the production manager from Company R_{M1} did express her doubt when comparing their position with Company R_{M2}:

> "It seems to me that our company and Company R_{M2} are operating in *very similar ways, why is that our company's rated lower than them*?"
> ($R_{M1.02}$, Appendix 5)

It was explained to her that because of the higher level of mixed and relatively less informed data their company received from Company M_M and some other clients, that the rating for their "Interactions in Supply Network" is lower than Company R_{M2}. As Company R_{M2} is more active in data exchange with their clients and have better control and knowledge with the secondary metals they receive from contracted suppliers.

3. Is the tool useful for the management of your company and its development direction?

All of these SMEs seem contented to have gone through this research study and expressed that they have gained more than they expected, partly because the majority of them have not been working with any academic or research before. As stated by the general manager of Company R_{M2}:

> "Thank you very much for the research and work. By the theoretical and systematic investigation of our processes, we can have better understanding of our operations. The process map, model and CLSC positioning tool give us more solid vision and we would definitely take into account some of the issues you highlighted here and can improve ourselves on them." (R_{M2}.02, Appendix 5)

The general manager of Company Mss also mentioned that:

> "It is very interesting looking at the model and see our position, *especially with the comparison with other companies. We don't tend to have much data support like this in the industry… Now we can really see* the benefit for working along together with our remanufacturer for a better sustainable development in the long term." (Mss.01, Appendix 5)

4. Any comments on the data and positioning, and the design of the graph?

Case companies express their appreciation of the recent follow-up and updating of their position. They believe that it is a way for them to push themselves for improvement, and also making sure they are on the track for their direction for development. As in the words of the general manager from Company L_{3PRL}:

> "We are pleased with our progress throughout this year. Although it is a *pity that even with our improvement, our position on the graph doesn't* seem to be moving too much, at least we know that we are doing what we *planned to do… Maybe if you take into account more detailed issues such* as production lead-time, turn-around time then we might be rated higher on the scale." (L_{3PRL}.01, Appendix 5)

Additional Information:

Upon the completion of this PhD research study, some of the companies are still being in contact and express their views on the recent economic slowdown and the affects in the market. For example, the general manager from Company Mss mentioned:

> "There has been price falls in the recent months in our primary stainless steel products and for our scrap steels. We do sense the slowdown of demand in the market, although our sales still remain quite strong *compare to some other companies in the area… We also understand that* it is a tough time for Company R_{M2} because of the sharp fall for the price and demand of secondary metals in the market. They have difficulties in keeping up with their production and selling their remanufactured products. That is why, we have to keep some of our scraps in our warehouse and we can only hope that the slowdown will be over soon." (Mss.01, Appendix 5)

The general manager in Company R_{M2} also responded as:

> "It has been quite a tough time since September (2008) and we do see the fall in price and demand for our products in the market. Although we started to receive orders from some new clients requiring for our secondary metals for their production, there seems to be a slowdown in the market. The price and demand are certainly dropping quite a lot. And we have been reducing the amount of secondary metals and materials *importing from overseas because we need to make sure we won't en*d up having a big pile of inventories in our factory site." (R_{M2}.01, Appendix 5)

At the moment, although no one can predict the affect and duration for the global economic slowdown, it is one of the down slope periods that companies must face with. After all, the trend for CLSC development would be towards sustainability in the long term, hence, it shall still be the goal to achieve for the coming future.

Appendix 15

Updated Table of Data for Case Companies on the CLSC Positioning Tool (June, 2008)

[Scaling and scoring methods are with reference to Appendix 13.]

Company Name:	Company M_M		
Company Operating Nature:	Metal Manufacturer / Metal Remanufacturer		
Positioning Scale:	0 – 20% – 40% – 60% – 80% – 100% 0 – 1 – 2 – 3 – 4 – 5		
	Rate (%)	**Scale (1-5)**	**Score**
Level of Production Wastes	5%	1	4.75
Labour Intensity	30%	2	3.50
Level of Technology	70%	3	3.50
Production Capability (Annual)	100,000 tons	1	1.00
Total Score:			12.75
Average Score:			**3.19**
Interactions in Supply Network	40%	2	**2.00**

Company Name:	Company Mss		
Company Operating Nature:	Metal Manufacturer / Metal Remanufacturer		
Positioning Scale:	0 – 20% – 40% – 60% – 80% – 100% 0 – 1 – 2 – 3 – 4 – 5		
	Rate (%)	**Scale (1-5)**	**Score**
Level of Production Wastes	3%	1	4.85
Labour Intensity	15%	1	4.25
Level of Technology	85%	5	4.25
Production Capability (Annual)	**=> 400,000 tons**	2	2.00
Total Score:			15.35
Average Score:			**3.84**
Interactions in Supply Network	**=> 55%**	2.75	**2.75**

Company Name:	Company R_{AL}		
Company Operating Nature:	Metal Manufacturer / Metal Remanufacturer		
Positioning Scale:	0 — 20% — 40% — 60% — 80% — 100% 0 — 1 — 2 — 3 — 4 — 5		
	Rate (%)	**Scale (1-5)**	**Score**
Level of Production Wastes (Level of Waste Recovery)	10%	1	4.50
Labour Intensity	20%	1	4.00
Level of Technology (For production)	80%	4	4.00
Production Capability (Annual)	**=> 900,000 tons** **=> 72,000 tons**	5	4.50
Total Score:			17.00
Average Score:			**4.25**
Interactions in Supply Network	**=> 85%***	4.25	**4.25**

*85% is the average of the 70% Contracted Suppliers (Manufacturing), and 100% Contracted Suppliers (Remanufacturing) in Company R_{AL}

Company Name:	Company R_{M1}		
Company Operating Nature:	Metal Manufacturer / Metal Remanufacturer		
Positioning Scale:	0 — 20% — 40% — 60% — 80% — 100% 0 — 1 — 2 — 3 — 4 — 5		
	Rate (%)	**Scale (1-5)**	**Score**
Level of Waste Recovery	95%	5	4.75
Labour Intensity	90%	5	0.50
Level of Technology	10%	1	0.50
Production Capability (Annual)	50,000 tons	1	0.50
Total Score:			6.25
Average Score:			**1.56**
Interactions in Supply Network	25%	1.25	**1.25**

Company Name:	Company R_{M2}		
Company Operating Nature:	Metal Manufacturer / Metal Remanufacturer		
Positioning Scale:	0 (0) — 20% (1) — 40% (2) — 60% (3) — 80% (4) — 100% (5)		
	Rate (%)	**Scale (1-5)**	**Score**
Level of Waste Recovery	95%	5	4.75
Labour Intensity	85%	5	0.75
Level of Technology	15%	1	0.75
Production Capability (Annual)	100,000 tons	1	1.00
Total Score:			7.25
Average Score:			**1.81**
Interactions in Supply Network	30%	1.50	**1.50**

Company Name:	Company L_{3PRL}		
Company Operating Nature:	Metal Manufacturer / Metal Remanufacturer		
Positioning Scale:	0 (0) — 20% (1) — 40% (2) — 60% (3) — 80% (4) — 100% (5)		
	Rate (%)	**Scale (1-5)**	**Score**
Level of Waste Recovery	95%	5	4.75
Labour Intensity	60%	3	3.00
Level of Technology	40%	2	2.00
Production Capability (Annual)	**=> 700,000 tons**	3	3.50
Total Score:			13.25
Average Score:			**3.31**
Interactions in Supply Network	**=> 65%**	3.25	**3.25**