Aalto University
School of Business

Greening the supply chain - evaluating sustainability in supply chain for Chinese electronics industry

Logistics

Master's thesis

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2014

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ABSTRACT

Objectives of the Study

Today the green supply chain management (GSCM) is gaining increasing interest and awareness by companies not only as a source of cost saving, but also as a competitive advantage obtained by efficiency improvement. Together with the pressure from various stakeholders like customer and government, companies are becoming more environmentally friendly. In China, how to balance the economic development and environment protection is a critical problem and often discussed in the media. Electronics industry in China is probably a good representation of the development of GSCM practices for Chinese players since most of them are hugely export-driven and need to strictly comply with international regulations. Therefore, this thesis is focused on firstly exploring the current status of GSCM practices and adoptions in Chinese electronics industry. Then it moves the discussion to constructing an evaluation model/framework for measuring the GSCM practices for Chinese electronics equipment manufacturers (OEM). Finally, the paper also offers three examples (Huawei, ZTE and Lenovo) on how to apply this model to evaluate Chinese players. To conclude, the study is set to identify the most important strategic elements for evaluating Chinese OEMs.

Academic background and methodology

The paper applies qualitative methods with some techniques from case study. The evaluation model is developed by studying the relevant operational management and environmental management literature and books, especially the ones under Chinese context. The empirical information and statistical data discussed and explored in the exemplifying part are mostly obtained from official websites, official reports, green/white papers and other reliable sources such as journals.

Findings and conclusions

In the end of the paper, four main strategic elements for GSCM are defined and they are: sustainable product development process, green purchasing and supplier management, organization involvement and regulations, and product recycling and life cycle management. Three companies' performances of GSCM are examined by a form of checklist. The result shows that Lenovo has the highest points among three in its GSCM practices.

Keywords

Green supply chain management, sustainability, Chinese OEMs, Chinese electronics industry

ACKNOWLEDGEMENTS

During the course of writing my Master's thesis, I have been through a lot of changes in my life. I would like to thank Professor Markku Kuula who gave me many great ideas on how to define the thesis topic, where to find out topic related literature and materials, and finally how to revise the thesis into a more academic structure. Then I would like to thank Professor Anu Bask. I was taking her course "Coordination of Supply Chain" when I started to write, and I have to say it was a truly interesting course for somebody like me who would like to practice supply chain management skill into real working life. Of course, I am also sincerely grateful to other faculty staff who gave my assistance of any kind.

Finally, the motivation for me to complete my thesis with full speed comes from my family who is always supportive. I really appreciate it.

The thesis has many insufficiencies, but I really enjoyed the research process, which most likely indicates the end of my school life. It has somewhat changed my life style to a more sustainable way. GSCM is a small piece in CSR, and I truly hope other students could continue the study in sustainability since business ethics and CSR of companies are in my opinion critically important for the whole society. A harmonized society and a green environment are not only the keys to future success, but also necessities for any corporation.

Jue Wang

Helsinki, 4th Dec, 2013

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1. INTRODUCTION

How to manage the green supply chain or sustainable supply chain has become an increasing concern for many business enterprises, and it is indeed a big challenge from logistics perspective for many companies that are experiencing the phase to become more competitive and socially responsible. In this thesis, it is aimed to discover the current status of green supply chain management (GSCM) in China and construct an evaluation model for GSCM practices in Chinese electronics industry. This evaluation model is further tested and exemplified by applying to three globally operated electronics enterprises, namely OEMs[1], from China, and they are Huawei, ZTE and Lenovo. The paper focuses on developing a theoretical framework and model for evaluating the strategic elements in green supply chain management of the chosen companies.

1.1. Background

It has been proved by much recent research that today's consumers and corporate stakeholders are becoming more and more socially and environmentally conscious. As a result, many business enterprises, especially those operating in manufacturing industry, are constantly seeking for a better way to manage their supply chain in order to become more socially responsible. According to Lee and Kim (2009), supply chain management should be managed in a strategic way and placed in the center of the competitive analysis of an enterprise. Since companies cannot achieve the goal of decreasing cost or increasing profit by managing their supply chain coordination with their partners, thus they seek to become more competitive as a whole in their industry by managing effectively their supply chain coordination. The strategic significance of supply chain management also reflect on the fact that the supply chain coordination and its network is rapidly increasing as companies and suppliers throughout the supply chain are working ever close. Thus, GSCM is also becoming an inter-company matter rather than a stand-alone problem for any

[1] OEM: original equipment manufacturer. They are manufacturers producing or acquiring products or components to reuse or incorporate into a new product with their own brand name.

single firm. The modern competitive business environment requires sustainability of supply chain and greenness of the products.

As a result, many companies have already made some strategic changes and movements towards green supply chain (GSC), such as redefine the concept of products and services, re-design the procedures of supply chain operations and product life cycle, and adopt the latest international standards. Along with the pressures from the cost reduction, globalization, and intense competitions, many companies have developed and changed their sourcing strategies in order to stay competitive and acquire new abilities. In the consumer electronics industry, product life cycles have shortened to a large extend while the speed of new production process has been also increased to a huge extend. Thus, the new environment and evolvement in the electronics industry lead to the change in supply chain management significantly, especially to the areas such as material management and product end-of-life management. The academia defines "*recovering values from returned products*" as the closed-loop supply chain (CLSC) (Van Wassenhove and Guide, 2003), and as a field of study, its concept and theory reveal the urgency to develop a suitable practice process in such a business environment to optimize the material management and re-use in product recycling and product take-back.

Additionally, globally branded companies are under the public and media's supervision, which could be explained as an extra pressure. There are many well-developed corporate social responsibility (CSR) regulations and standards. Some of the most commonly used standards are listed below.

> *ISO 14001* belongs to ISO 14000 family, which addresses the importance of different areas of environmental management. It offers some very practical tools and methods for organizations to control and improve their environmental impact and performance. ISO 14001: 2004 defines the criteria and drafts the framework for environmental management system. It is said that organizations can follow the framework of ISO 14001: 2004 to build up an effective environmental management system internally. Through implementing ISO 14001: 2004, it is expected to achieve some important

benefits, such as decreased cost of waste management, savings in energy and material consumption, reduced distribution cost, and better public image. (ISO, 2013a)

ISO 26000, also called CSR Guidance, gives the essential guidance on how to act and operate in a socially responsible way for organizations. By applying ISO 26000, firms are expected to perform and act in an ethical and transparent way to contribute to the society. It also encourages companies to take an active role in discussion and negotiation of social responsible issues with various stakeholders. (ISO, 2013b)

SA8000 is a social certification standards for working environment covering all industrial sectors. It is a common language used by many companies and corporations to measure the socially responsible performance. It discusses topics like child labor, forced & compulsory labor, working health & safety, working freedom, discrimination, working hours, and remunerations. It aims to protect some basic human rights of workers. SA8000 is administered by Social Accountability International. (SAI, 2013)

AA1000 contains a series of standards used to help organizations become more accountable, responsible and sustainable with a specific focus on issues with governance, business/operation models and strategies. (AccountAbility, 2013)

In addition to these internationally recognized standards, many companies that intend to operate globally also have to pay attention to regional specific regulations. In Europe, it is mandatory for the manufacturers to adopt the Restriction of Hazardous Substances (RoHS) and Waste Electrical and Electronic Equipment (WEEE) Directives.

In China, the expectation on enterprises to act socially responsible and have positive impact on the society is consistently rising. This increased interest from the society and enterprises themselves has led to a higher awareness of international CSR regulations and standards. Many of the Chinese manufacturers are now complying with the latest guidelines for instance the guidelines published by OECD (The Organization for Economic Cooperation and Development), SA 8000, and regulations made by International Labour Organizations about workers' wellbeing. In addition to the international standards, the local governments also have been working on

developing local regulations about CSR. These local standards include the series of CSC9000 (Corporate Social Compliance for different industries), which is similar to SA 8000. CSR includes issues related to social, economic and environmental. However, in this paper, the focus is only placed on environmental aspect of CSR and GSCM.

How to effectively balance the environmental influence and economic growth is a critical issue in China. Air pollution, water pollution and other industrial hazardous pollution are quite severe in developing countries like China. Government and corporates are gaining awareness and trying to work together to emphasize the importance of GSCM. As a manufacturing and export-oriented country, China is facing not only domestic pressure but also international pressures on environmental sustainability. Requirements from foreign customers are an important element for Chinese producers to improve their supply chain strategy. One problem has been diagnosed for Chinese manufacturers as the lack of infrastructure and tools for effectively implementing GSCM practices, especially in the aspect of product end-of-life management (Puckett et al., 2002). Therefore, an appropriately developed model or tool will definitely help countries like China to better improve their environmental sustainability.

Currently, most of the research has been conducted under the context of European environmental and American environmental impact. Comparatively, only a few of the reports have been concentrated on the situation in Eastern Asia. Lee and Kim (2009) discuss the current status of GSCM in South Korea with the focus on Samsung as the leader in mobile industry; Rao (2002) in his report explores the GSCM in South East Asia with the focus on countries namely The Philippines, Indonesia, Malaysia, Thailand and Singapore; both reports from Zhu and Sarkis (2004) and Zhu et al. (2005) touch the GSCM practices and performances in Chinese manufacturing firms in general. Thus, in the light of the discussed above, it is both feasible and essential to study and report the sustainability in the context of electronics industry in China by framing the conceptual / evaluation model and exemplifying it by some industry leaders in China.

1.2. Research objectives

This thesis is aimed to discover firstly the current practice and adoption situations in GSCM in electronics industry in China, and then based on the current status it is hoped to build up an appropriate evaluation models for GSCM practices for Chinese OEMs. Finally, the evaluation model will be applied to three industry leaders in China to give proper examples.

The first main objective of the thesis is to provide a thorough and recent research on the most topical aspect of supply chain management and logistics management, with the particular focus on electronics industry in China as the mobile and telecommunications fields have been rapidly developing in the this region. Alongside, it will also try to construct the evaluation model of GSCM practices under the Chinese context. The second main objective of the study is to try to bring the evaluation model to test the GSCM practices and evolvement in three international OEMs in China: Huawei, ZTE and Lenovo with the hope to generate some useful managerial implications for other Chinese producers who are on their way to improve their supply chain management.

In order to achieve the first main objective, it is valuable to go through and study the related literature and previous research about GSCM practices and modelling. From that starting point, I continue to identify the important strategic elements and driven pressures in the GSCM process and its sustainability. Only after that, it is possible to construct the theoretical framework for the conceptual model and evaluate the three companies based on the information and data collected.

The second main objective is met through collecting real time data from the publicly available information like reports from these three companies and carefully evaluating them according to the model constructed. After the evaluation, some important and useful managerial implications will be provided in the end.

1.3. Research methods

The first objective section of this thesis is approached through qualitative methods based on the nature of the research objective and problem, namely through information gathering from previous related literature about supply chain management, CSR and GSCM. With the help from literature review and information gathering, the metrics under Chinese electronics industry context that are used to evaluate the level of strategic involvement of GSCM are finally determined.

After the first objective is fulfilled, the second objective is also conducted by using qualitative approach to study the GSCM adoption for electronics manufacturing companies originated from China: Huawei, ZTE, and Lenovo. The empirical information and data are collected through companies' publicly available information, such as official website, investment reports, CSR / GSCM reports, and other analysis articles from reliable journals or newspapers. Each company will be evaluated based on the unified model in order to make more consistent comparison and draw the conclusion in the end of this paper.

1.4. Structure of the report

The rest of the thesis is presented in the following way: section two is aimed to provide more background information of the topic and help clear out some critical concepts that are mentioned and discussed in the report. It will provide a clearer and more logical theoretical flow for the reader in a concise way. Section three is about building the evaluation model and metrics for evaluating Chinese OEMs based on the concepts and theories explained in section two. In next section Chapter four, each company is studies and analyzed based on the unified model and metrics defined in Chapter three regarding its sustainability of the supply chain from a strategic level. In the end of Chapter four, some managerial implications will be provided with the hope to give some guideline to companies that are aiming to build a more sustainable supply network. Then the study moves to section five which is the final section that concludes the whole paper.

In the final section, it also provides some possible topics and areas for future research in GSCM field.

2. LITERATURE REVIEW

This section will lead the reader to go through the relevant literature and review the theories that help build up the evaluation model later in this paper. It tries to explain the trend and the impact to strategy management originated from green supply chain. It starts by firstly introducing the board and overall concept of green supply chain and how it is integrated to environmental management and operations management processes. Then this chapter narrows down and presents the idea and concept of reverse logistics. In the part of reverse logistics, it contains the elements and theories that are closely relevant to the metrics developed later in the evaluation model. Finally, it explains how organizations could transmit and expand their current and reactive supply chain strategies to a new and proactive green supply chain strategies and its theoretical benefits.

2.1. Green supply chain management

The focus has been redirected to the overall performance of the sustainable supply chain. And along with the regulatory requirements and consumer's awareness, many researchers and industry practitioners have realized that GSCM is not any more a cost center but a business value driver (Srivastava, 2007; Shang et al., 2010). Srivastava (2007) defines the concept of GSCM after reviewing the most contemporary literature of the topic. He reports the GSCM is a joint discipline of both supply chain management and environment management. It addresses the importance of managing both operation and influence between supply chain and the natural environment. To be more specifically, Srivastava (2007) defines GSCM as "*integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life*". In addition, Hervani et al. (2005) in their report define GSCM as a formula:

"*Green supply chain management (GSCM)*

= *Green Purchasing + Green Manufacturing / Materials Management*

+ Green Distribution / Marketing + Reverse Logistics"

Further, Srivastava (2007) classifies GSCM into three essential categories shown in Figure 2.4: the importance of GSCM[2], green design and green operations. Following his steps, this paper will review GSCM by the same manner.

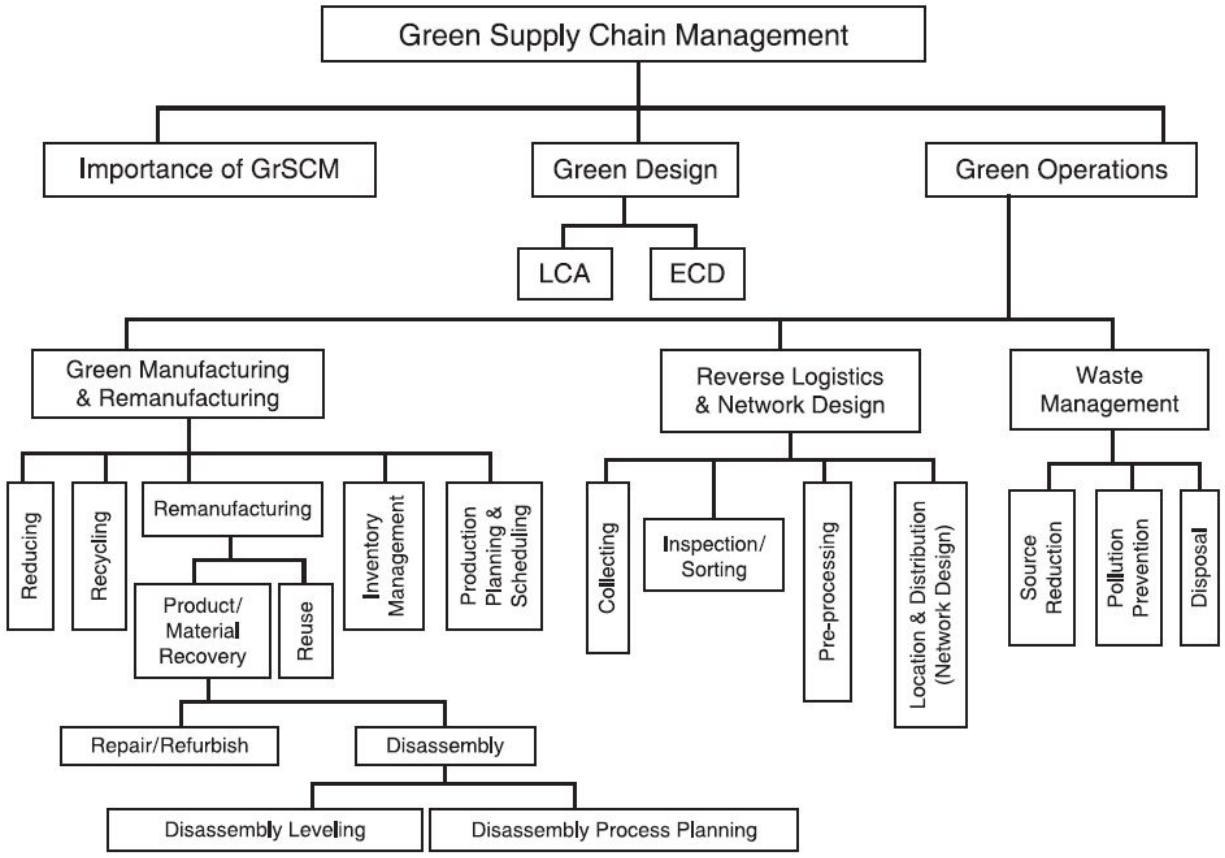

Figure 2.1: Classification based on problem context in supply chain design (Srivastava, 2007)

There are many benefits of GSCM discovered already by previous research papers and articles, such as resource saving, efficiency improving and waste eliminating. The importance of GSCM

[2] Srivastava (2007) abbreviates green supply chain management to "GrSCM", while most commonly it is abbreviated as "GSCM". Here the paper follows the more common rule.

is sufficiently addressed and explained in Section 2.2. Therefore, the rest of this section will be mainly focused on green design and green operations.

Green design in supply chain management indicates the designing process of a product that takes environment into serious consideration (Handfiled et al., 2001). It is a topic that is usually associated with safety regulations and product innovative design. The strategic essentiality of product ecological design and use of efficient recourses have already been explored by much previous literature such as Tischner (2001), Handfiled et al. (2005) and Scott (2008). Both LCA and ECD[3] are discussed in much literature in order to address the importance of developing an understanding of the impact of product design on its environmental compatibility (Srivastava, 2007). However, the green design here does not restrain itself to solely product design; it also involves the material design/recovery, (dis-)assembly design and waste minimization design (Ljungberg, 2007). Its scope involves tracking all the energy and raw material flows of any product from extracting raw materials to the disposal of the final products. There are many common and useful approaches for implementing green design. Srivastava (2007) reports that the most prevailing way is to replace the hazardous raw materials with the safe ones to reduce the occurrence of possible problems. Nevertheless, this is not always the optimal option due to the associated cost increment. Other approaches for green design may be based and focused on legislations and regulations, new product redesign or solid waste management.

Further in this field, Lenox et al. (1996) define DFE (Design for Environment) as "*the systematic process by which firms design products and processes in an environmentally conscious way*". Based on Lenox et al.'s theory and findings, Horvath et al. (1995) further report three main objectives for DFE: 1) to reduce the use of nonrenewable resources and energy; 2) to manage well the use of renewable resources and energy; 3) to reduce the toxic release to the nature. From various previous research, it is evident that many researchers and professionals have agreed that DFE can be analyzed by environmental metrics and data, and thus assist in decision making when developing the products (Zhang et al., 1997). Table 2.1 presents a detailed aspects and practices of DFE summarized by Zhang et al. (1997).

[3] LCA indicates "life-cycle assessment/analysis", while ECO means "environmentally conscious design".

Table 2.1: Overview of DFE practices (Zhang et al., 1997)

- Design for Recovery and Reuse
  - Design for material recovery
    - Avoid composite material
    - Specify recyclable materials
    - Use recyclable packaging
  - Design for component recovery
    - Design reusable containers
    - Design for refurbishment
    - Design for remanufacture
- Design for Disassembly
  - Facilitate access to components
    - Optimize disassembly sequence
    - Design for easy removal
    - Avoid embedded parts
  - Simplify component interfaces
    - Avoid springs, pulleys, harnesses
    - Avoid adhesives and welds
    - Avoid threaded fasteners
  - Design for simplicity
    - Reduce product complexity
    - Reduce number of parts
    - Design multifunctional parts
    - Utilize common parts
- Design for Waste Minimization
  - Design for source reduction
    - Reduce product dimensions
    - Specify lighter weight materials
    - Design thinner enclosures
    - Increase liquid concentration
    - Reduce mass of components
    - Reduce packaging weight
    - Use electronic documentation
- Design for Separability
    - Facilitate identification of materials
    - Use fewer types of materials
    - Use similar or compatible materials
- Avoid Material Contaminants
- Design for Waste Recovery and Reuse
- Design for Waste Incineration
- Design for Energy Conservation
  - Reduce energy use in production
  - Reduce device power consumption
  - Reduce energy use in distribution
    - Reduce transportation distance
    - Reduce transportation urgency
    - Reduce shipping volume required
  - Use renewable forms of energy
- Design for Material Conservation
  - Design multifunctional products
  - Specify recycled materials
  - Specify renewable materials
  - Use remanufactured components
  - Design for product longevity
    - Extend performance life
    - Design upgradable components
    - Design reusable platform
    - Design for serviceability
    - Design for durability
  - Design for closed-loop recycling
  - Design for packaging recovery
  - Design reusable containers
  - Develop leasing programs
- Design for Chronic Risk Reduction
  - Reduce production releases
  - Avoid toxic/hazardous substances
  - Avoid ozone-depleting chemicals
  - Use water-based technologies
  - Assure product biodegradability
  - Assure waste disposability
- Design for Accident Prevention
  - Avoid caustic and/or flammable materials
  - Provide pressure relay
  - Minimize leakage potential
  - Use childproof closures
  - Discourage consumer misuse

Broader than green design, green operations include almost every aspect from product manufacturing/remanufacturing, reverse logistics & network design to waste management, after the green design of the process has been finalized (Srivastava, 2007). In addition to green raw materials, green operations are more related to green technology and process implementation used in manufacturing and recycling.

Green manufacturing and remanufacturing is the most essential elements for green operations. There are often advanced technologies involved in the manufacturing process to reduce the energy and resource consumption. On the other hand, recycling is often driven by cost factors and legislations, and it helps extract and recover the useful materials from disposed products (Xu et al., 2008). Especially in consumer electronics industry, the management of recycled materials and products is critical for cost reduction (Johnson, 1998). Furthermore, remanufacturing is an integrated manufacturing process for recycling, and it is widely applied in sectors like automobile and electronics. According to Figure 2.4, remanufacturing consists of two sub-concepts: product recovery and reuse. The definition of product recovery varies in different industries and contexts, the most commonly understood explanation is that product recovery indicates all the activities related to value reclaim from the products at the end of its valuable life (Srivastava, 2007). Options for product recovery can be categorized as five forms: repairing, refurbishing, remanufacturing, cannibalizing and recycling (Thierry et al., 1995). All the five options are suitable for both consents and finished products. Table 2.2 summarizes the various characteristics of the five product recovery approaches. Moreover, reuse of materials and products consists of four types: direct reuse, repair, recycling and remanufacturing (Srivastava, 2007). Reuse here may be interpreted in many different forms, such as reuse of assemblies, components, raw materials and even system reuse.

Table 2.2: Comparison between five product recovery options (Thierry et al., 1995)

	Level of disassembly	Quality requirements	Resulting products
Repair	To product level	Restore product to working order	Some parts fixed or replaced by spares
Refurbishing	To module level	Inspect all critical modules and upgrade to specified quality level	Some modules repaired/replaced; potential upgrade
Remanufacturing	To part level	Inspect all modules and parts and upgrade to *as new* quality	Used and new modules/parts combined into *new* product; potential upgrade
Cannibalization	Selective retrieval of parts	Depends on process in which parts are reused	Some parts reused; remaining product recycled/disposed
Recycling	To material level	High for production of original parts; less for other parts	Material reused to produce new parts

Reverse logistics and network design refers to the coordination design for, supply chain uncertainties, return dispositions and other speculations in the reverse logistics flow. It is

highlighted by much literature because of the importance of optimal design that could facilitate the product returns, remanufacturing and reuse of product components. Thus, the transportation and location links in the logistics networks need to be carefully considered and planned so that the products can move easily from previous consumers to manufacturers, and finally to markets for sale again. Reverse logistics and network design has four stages: collection, inspection, pre-process and location & distribution. Collection is the first stage where product types are chosen, collected and transported to remanufacturing locations. Inspection/sorting is the next step in which the relevant techniques are used to inspect the used products and sort them according to their situations. It also can be classified into "separation at source" which consumer separate the components, and "mixed waste processed" which materials are still centralized (Cairncross, 1993). The third stage pre-processing is closely related to the second stage and it is also largely technology driven. The fourth stage location & distribution, as mentioned before, is associated with coordination and planning, so that it could accommodate better the product recovery management process.

Waste management system is a solid system that includes three progressions: source reduction, pollution prevention and disposal. Based on what Zhang et al. (1997) discover, there are four preference hierarchies in waste management, and source reduction and pollution prevention are the highest preference. The second preference is to recycle and reuse the waste that cannot be eliminated from the source. The third preference is then to handle the existing waste, and the last preference is to dispose the wasted products and components. The first two progressions source reduction and pollution prevention emphasize the importance of reducing the negative impact right at the beginning and try to prevent pollution from happening. Unlike removing the waste, it avoids the production and creation of waste. There are usually two ways to achieve the source reduction, which are product changes and process changes, as shown in Figure 2.5. Both of the methods can efficiently reduce the volume and toxicity of the materials and production wastes through their life cycle. There are also some techniques used to prevent pollution. Zhang et al. (1997) introduce two most commonly applied methods: waste minimization and clean technology. Many companies who address the importance of GSCM are aimed to reduce the amount of product disposal since disposal handling and management are rather costly. Many

inventory techniques are developed to reduce the disposal volume such as the appliance of economic order quantity (EOQ) and Wagner/Whitin model (Ilgin and Gupta, 2010).

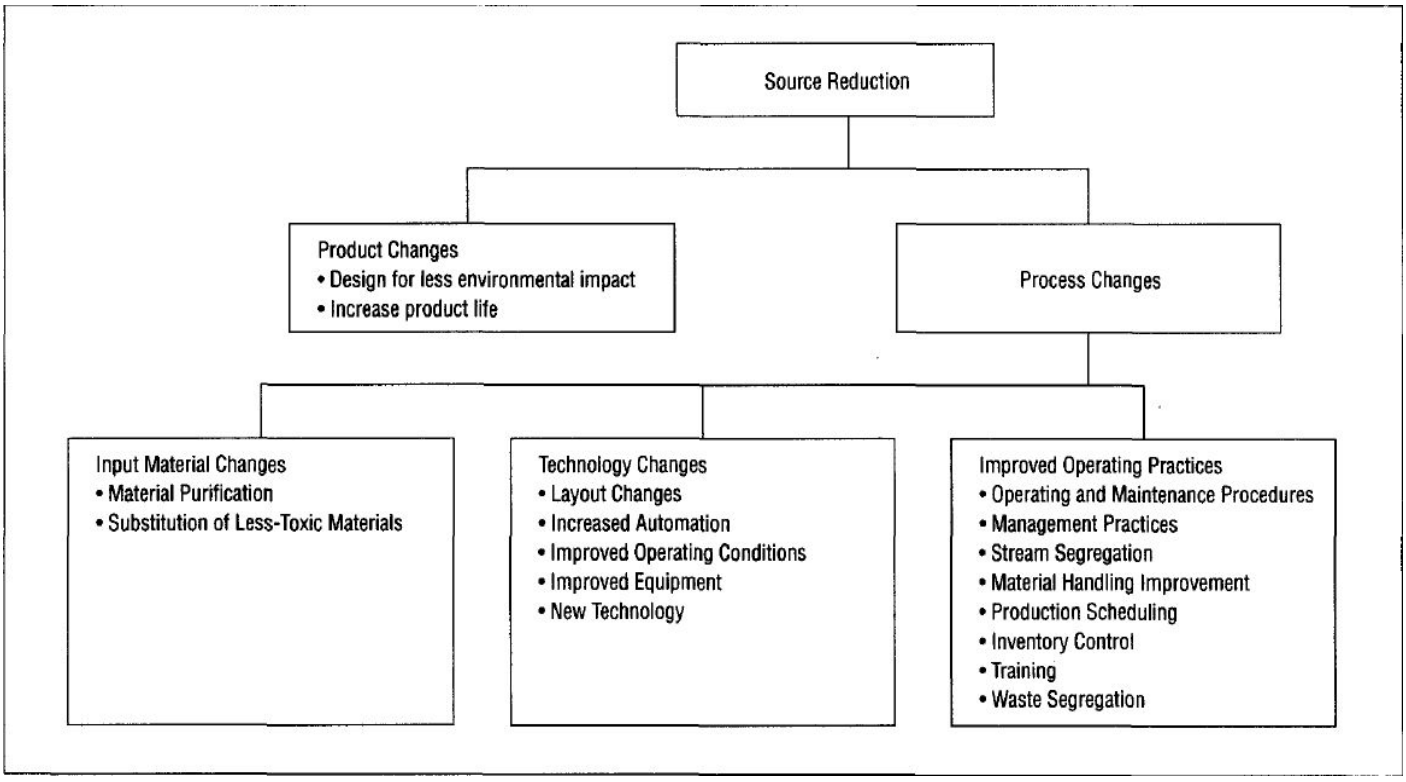

Figure 2.2: Methods for source reduction (Zhang et al., 1997)

Therefore as a conclusion, GSCM is by far the most effective and efficient way to reduce the negative environmental impact of company activities without sacrificing profits and performances (Srivastava, 2007; Azevedo et al., 2011; Carvalho et al., 2010; Testa and Iraldo, 2010). It is a transforming process from ecological impair to economic benefits. It is usually a long-term goal that requires the change of mind-set in a corporation. To achieve such an efficient supply chain, companies, especially those who operate in innovative industries with non-standard products, need to raise the environmental consciousness into another higher strategic level through careful planning, designing and monitoring.

2.2. Reverse logistics

Reverse logistics is an essential topic under green supply chain, and the theories of reverse logistics are important for building the evaluation model later in this paper. Many organizations and academic research have tried to define reverse logistics. In the 1980s, Lambert and Stock (1982) originally define reverse logistics as "*going the wrong way on a one-way street*" with emphasis on reverse. However nowadays, a well-accepted definition of reverse logistics is referring to the general reverse process of logistics, and the exact definition varies across different industries. For electronics (or any) manufacturers, reverse logistics, as defined by Dowlatshahi (2000), indicates "*the process in which the manufacturers systematically accepts previously shipped products or parts from the point for consumption for possible recycling, remanufacturing, or disposal*". It includes the management of processes and segments in supply chain such as recycling, disposal, repackaging, redesigning and remanufacturing. More precisely, Rogers and Tibben-Lembke (2001) complement the definition of reverse logistics as "*the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing or creating value or proper disposal*". Both definitions are well accepted, but this paper is following the second definition of reverse logistics.

Reverse logistics has gained quite much attention from supply chain managers and executives in recent years since it greatly affects the efficiency, cost advantages and other competitiveness of a company's operation. Thus, it needs to be differentiated from other traditional logistics (Carter and Ellram, 1998). Along with the development of many environmental legislations and consumer's awareness, the need for recycling of disposed goods has been increased sharply. Since many of the disposed goods are being recycled and remanufactured by the original manufacturers, the handling responsibility of such goods falls onto the manufacturers' shoulder. Therefore, the management of materials, residuals and final products becomes more essential than ever before (Dowlatshahi, 2000). Therefore, how to make the most of our disposed goods becomes a universal problem for many companies.

Nevertheless, an effective redesign of product life cycle extension could be very beneficial and helpful for solving this kind of dilemma, and reverse logistics is exactly promoting this kind of thinking and logic in supply chain management – to maintain both environmentally friendly and cost saving. Dowlatshahi (2000) and Foulds and Luo (2006) both argue that the cost saving achieved by implementing reverse supply chain is hugely different from the ones achieved by quick-fix methods such as layoffs. It gives the company strategic and long-term benefits that include strategic cost-saving, overall quality assurance, satisfied customer service, environmental benefits, and complying legislative actions (Daugherty et al., 2001).

Jayaraman and Luo (2007) suggest that reversed logistics should not be considered merely a business cost, rather it is a way to achieve operational efficiency. However, there are still some financial advantages that could be achieved by reverse logistics. Jayaraman and Luo (2007) summarize them as increased revenue realized by fresh stock based on the assumption that newer stocks cost more. Further, green image earned by acting in socially responsible way will help boost customer loyalty. Finally, cost saving could also be achieved by the reduced cost of goods sold and operational expenses assuming that some product materials and components could be reclaimed.

In addition to financial advantages, Jayaraman and Luo (2007) further identify three main non-financial reasons for implementing reverse logistics: competitive pressure, environmental regulations, and corporate citizenship. For competitive pressure, it is essentially true that facing the intensive competition, companies who wants to win customers have to keep up with their competitors on the level of sustainability management. It is also an important part for building the green image to show to the public. Environmental regulations are especially a pressure for manufacturing companies whose business is mainly export-driven. Thus, being compliant to regulations from foreign markets like EU and the US is critical. In order to become a corporate citizen, companies need to establish a positive public image by showing their philanthropy and goodwill. Becoming a corporate citizen, company is able to further increase its market value (Jayaraman and Luo, 2007).

Once these essential strategic factors and benefits are taken seriously consideration, the company is able to move forward and concentrate on other practical operational factors of reverse logistics. These operational factors, as concluded by Dowlatshahi (2000), are shown in Figure 2.1, and they are cost-benefit analysis, transportation, warehousing, supply management, remanufacturing and recycling, and packaging.

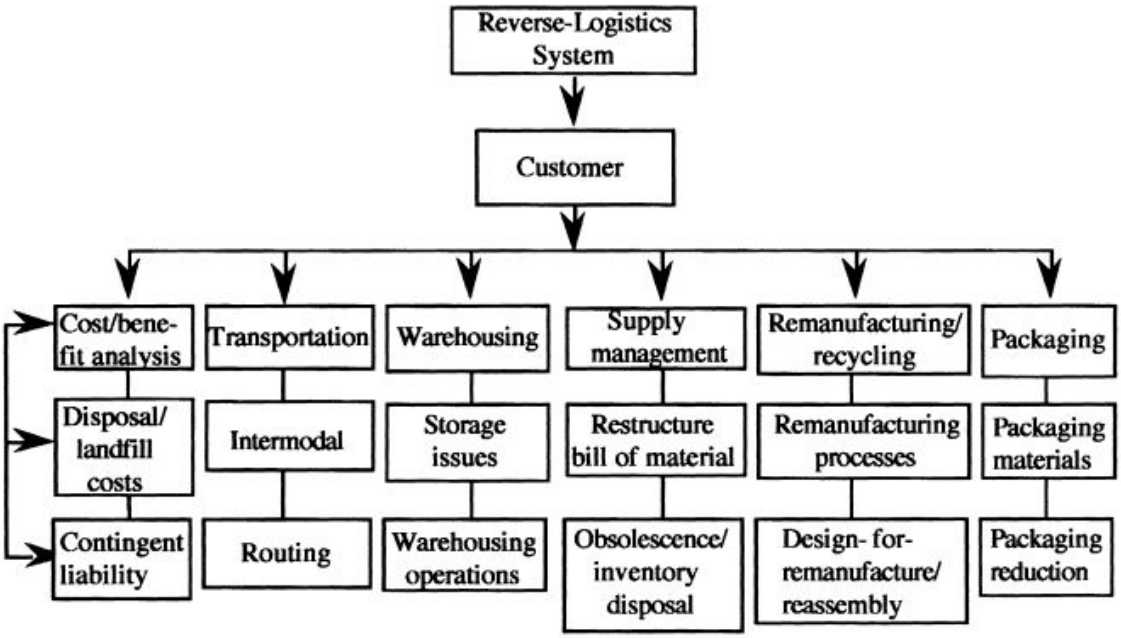

Figure 2.3: The operational factors of reverse logistics system (Dowlatshahi , 2000)

Dowlatshahi (2000) reports that the operational factors of reverse logistics system consist of one external factor – customer, and six internal factors – cost analysis, transportation, warehousing, supply management, remanufacturing/recycling and packaging. According to Figure 2.1, each of the internal factors are further divided into two sub-components. Each company should assign different weight to these seven factors according to the specific organizational environment.

However, much literature also believes that reverse logistics alone may not be sufficient to represent the entire green supply chain. Van Hoek (1999) is one of the professionals in this area who holds the same opinion. He believes that reverse logistics is one segment of the entire supply chain and the strategic and operational factors of reverse logistics apply to single companies. On the other hand, the holistic green supply chain approach is especially suitable in

the cross-company and cross-border supply chain. In the subsequent part of literature review, the paper continues to discuss the holistic green supply chain and its sustainability.

2.3. Develop a green supply chain

As already mentioned, many professionals and researchers believe that reverse logistics alone cannot represent the whole supply chain and its theory is more suitable for single companies. On the other hand, greening and sustainability of a supply chain can start right at the beginning of the supply chain management that is the supply conditions. Then it continues along the way through various stages such as storage, packaging and distribution to the final end-consumers (Van Hoek, 1999). Below is the Figure 2.2 that is discovered by Wu and Dunn (1995). It illustrates the most well-known and well-practiced stages and steps for being environmentally friendly for a certain firm.

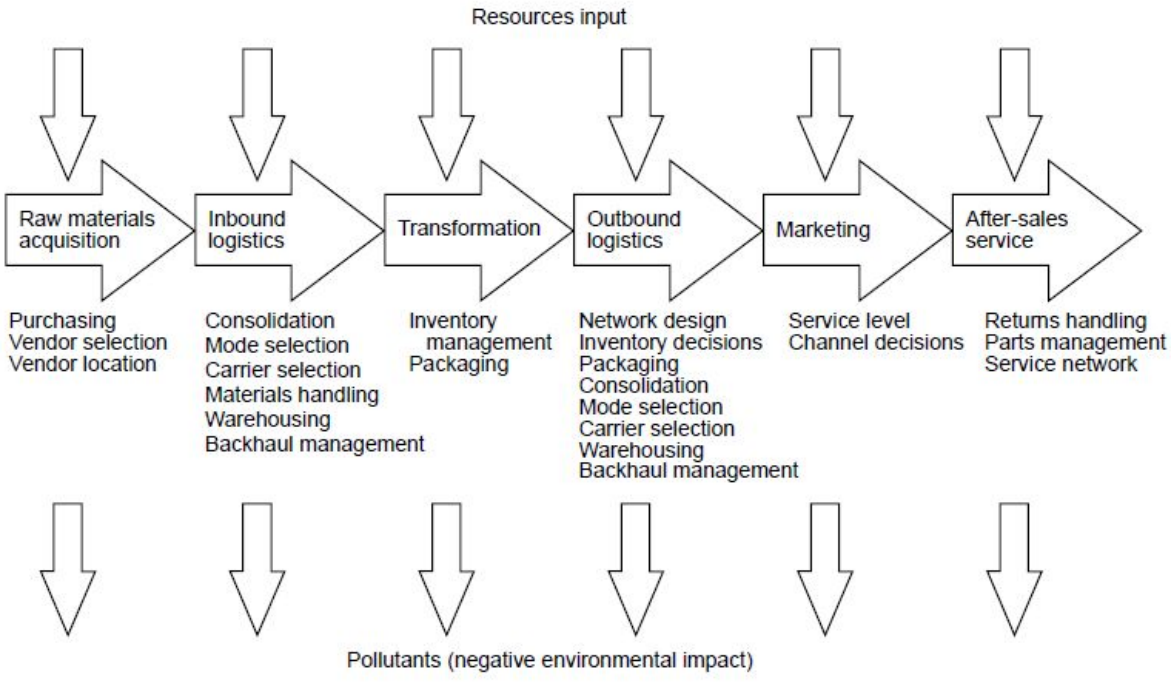

Figure 2.4: Environmental friendly chain (Wu and Dunn, 1995)

According to Figure 2.2, it is obvious that there are much more effort and focus needed in the supply chain than what are needed in the pure form of reverse logistics flow from the first phase "raw material acquisition" to the last phase "after-sales service". Moreover, each phase owns several steps and releases various pollutants. As addressed in Figure 2.2, two most complex phases in the chain are "inbound logistics" which emphasizes materials, and "outbound logistics" which focuses on inventory, packaging and transporting. In these two phases, the trade-off between cost and profits is extremely difficult for companies to evaluate and adjust (Jayaraman and Luo, 2007; Rogers and Tibben-Lembke, 2001). For most of the companies who aim at higher level of sustainability, it becomes more and more essential to expand their horizon to minimizing the total environmental impact throughout their supply networks. New fields that increasingly require additional attention are for example CO_2 emission, fuel mileage, functionality and durability. Together with the reverse flow of materials and goods from own manufacturing and vendor's manufacturing and transporting, it is possible to build up a green supply network from a total system perspective, thus to improve overall efficiency.

In addition to the holistic view of sustainability of supply chain, Van Hoek (1999) also suggests several changes needed for a firm to develop from reverse logistics strategy to green supply chain strategy, as illustrated in Figure 2.3.

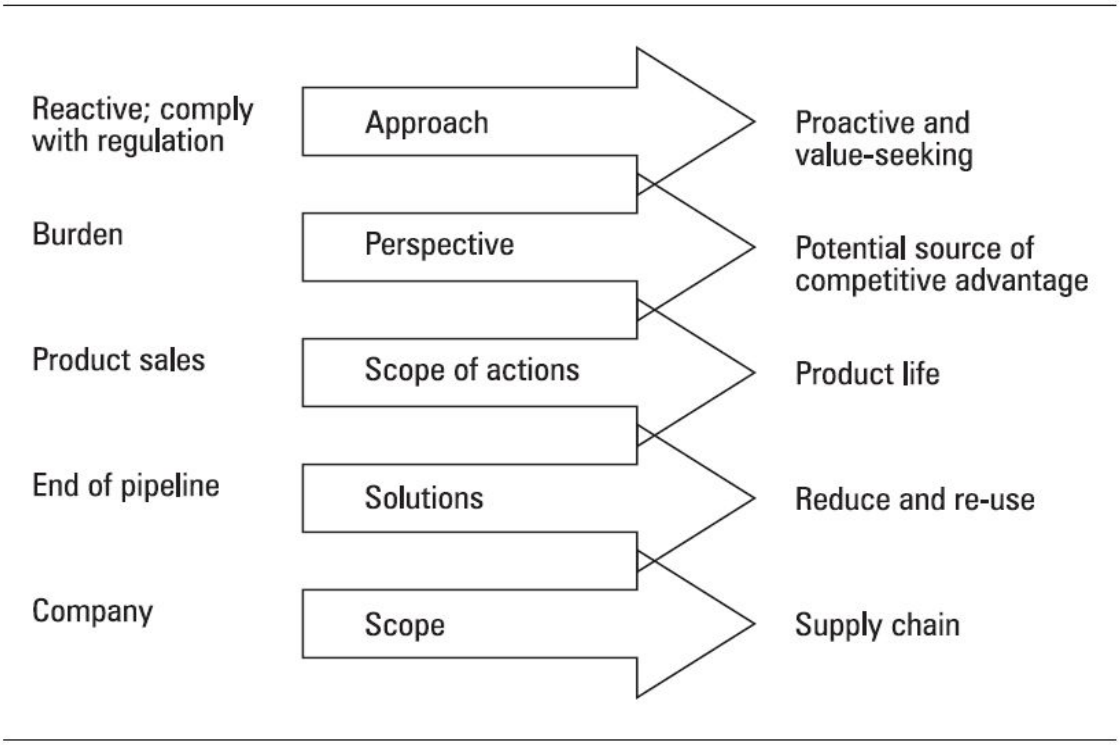

Figure 2.5: Develop to green supply chains (Van Hoek, 1999)

First of all, it is required to change the reactive attitude towards supply chain to a far-reaching proactive attitude that is desired for value seeking and competitive advantages creating. In that sense, supply chain is no longer a burden that is solely about cost reduction, but rather about value creation and competitiveness advancement. Van Hoek (1999) summarizes three primary competitiveness that could be acquired by the evolution from reverse logistics strategies to green supply chain strategies:

1) It is a unique marketing selling point since the awareness of environmentally friendly concept is growing among consumers;
2) It is to innovate smarter products that could help reduce the manufacturing and (dis-)assembling waste, even decreasing the lead-time;
3) Due to the savings on various resources, cost reduction is thus achieved.

Secondly, the scope of action in supply chain is experiencing a transformation from product sales to the entire expand of product life cycle. It emphasizes the importance of future product return

rate. By lowering the return rate through extending product life cycle, a solid customer relationship would be expected to increase the customer loyalty. Thirdly, if the company is taking the initiative to expand the existing product life cycle and reduce the waste, the logistics or supply chain solution is progressing from "end of pipeline" strategy to "reuse" strategy (Van Hoek, 2001). The difference between the two is that the latter one takes emission reduction into consideration. It proves that the "reuse" strategy is greening the supply chain right from the beginning, throughout the processes and reaches the end at the product disposal, recycle and reuse. Finally, greening the supply chain is not merely about any individual companies, rather it concerns a supply networks including various stakeholders like vendors, distributors, wholesalers, retailers and end-consumers (Vachon and Klassen, 2006).

As the supply chain becomes more global and it usually involves a variety of companies from different geographical locations, sustainability of supply chain deserves a much broader attention than before. Especially, the problem with CO_2 emission and footprint will never be merely about any single company or country, rather it is an increasingly important global issue. Therefore, the emphasis is transforming and progressing towards a more holistic perspective, which is to green the supply chain throughout the networks to satisfy various stakeholders' interests.

3. EVALUATION MODEL OF GSCM FOR CHINESE ELECTRONICS INDUSTRY

In this chapter, it is aimed to firstly emphasize the specific development situation in GSCM in electronics industry, and then in China. After the general introduction of the current status, it will move to the most important part of the thesis that is the framework and evaluation model formation. Here it will also provide some detailed explanations and implications of model construction, specifically under the Chinese context. There are four related areas in supply chain management that are discussed in this Chapter: sustainable product development process, sourcing and supplier management, organization involvement and regulations, and product recycling and life cycle management. In the rest of this Chapter, particular metrics will be defined in each area. This model will later in Chapter 4 facilitate in conducting a brief yet valid model testing with an empirical study about three electronics manufacturing companies which are originated in China.

3.1. GSCM in electronics industry

Along with the growing importance of sustainable supply chain, more and more corporates have realized that an effective and sustainable supply chain is not a way to reduce the cost nor increase the profit, rather it helps the firm to become more competitive as a whole. This is especially evident in electronics industry where due to the frequent technology updates, the turnover rate of products is usually high and at the same time, the life cycle of products is often short. Therefore, the electronics, particularly mobile phones, producers are putting a great amount of work and effort in GSCM. And how to effectively manage the supply chain and vendor networks to improve the efficiency and stay competitive becomes critical for players in the field.

Electronics products are usually composed of many different kinds of raw materials and components that are provided by a large range of suppliers. How to manage the local suppliers so

that they could follow the code of conduct regarding environmental and social issues from headquarters' global supply management is another main characteristic of GSCM in the electronics industry.

Another criterion used to evaluate one company's supply chain operation is to use the Electronic Industry Code of Conduct (EICC). It was initially introduced to electronics manufacturers worldwide by the coalition founded by HP, Dell, IBM and five other globally branded manufacturers in year 2004 to respond to the external demands and criticism about their supply chain management (Lee and Kim, 2009). There are five major categories of Code of Conduct defined by EICC (Lee and Kim, 2009), and they are:

- Labour;
- Health and safety;
- Environment;
- Management system;
- Ethics

By adopting the regulation and requirements of EICC, a company is claiming that it is being socially and environmentally responsible for its stakeholders, and its voice and stand about GSCM will become valid and credible. The capacity building and adopting is also crucial for suppliers.

In addition to the various internal reasons for electronics industry to adopt a more strict and comprehensive standards in GSCM, external political environment has changed along the years too (Lee and Kim, 2009). The electronics manufacturers in China are hugely OEM (original equipment manufacturing) and ODM (original designing and manufacturing) driven, that is to say they are often export-oriented (Chien and Shih, 2007). Therefore, the relevant regulations in exporting destinations like EU and US should be closely studied. For example, RoHS (Restriction of Hazardous Substances) was introduced in year 2003 with an objective to reduce or even prohibit the use of some seriously hazardous raw materials in producing electronics goods. Two years later in 2005, in order to minimize the environmental impact of disposed and wasted electrical and electronic equipment, EU introduced the WEEE – waste electrical and

electronic equipment. Due to the introduction of the two new legislations, electronics producers from Greater China Area who want to export their products to EU have to include these two directives into the product designing and manufacturing processes (Chien and Shih, 2007).

However, it is reported by Hsu and Hu (2008) that similar regulations and directives are also forming in countries like the US, China, Japan and Korea. The increasing awareness and emphasis on GSCM are witnessed in many Asian countries. Nonetheless, it is also believed by many firms that implementing GSCM will lead to increment of overall product cost and risk.

3.1.1. GSCM in electronics industry in China

It is reported by OECD (2004) that the manufacturing of electronics goods and its related services are shifting to low-cost destinations like China. Besides, the economic and market growth in this area also makes it a desirable place for production, development and sales. There are many international brands operating in China, such as Apple, Samsung, LG, Nokia and Sony. Further, the development and growth of domestic brands are also impressive. Names like Huawei, ZTE, Lenovo, OPPO, TCL and Xiaomi are actively gaining market share globally and becoming strong competitors in this field.

Analyzed by Yu et al. (2008), it is found that EP (electronics manufacturers[4]) like Huawei and ZTE belong to the ICT players together with other four groups: operators, AP, SP and CP[5]. EP is an important member in the supply chain network. As illustrated in Figure 3.1, there are notably three essential players in Chinese ICT supply chain network: regulators[6], end users and intermediaries. It is worth noting that the oval shaped dotted line around EP and AP indicates that the distinction and boundary of these two players are not significant, EP like Huawei and ZTE are also acting and operating as AP. However, here in this paper, only the EP function of these firms will be taken into further consideration.

[4] In Yu et al. (2008)'s report, electronics manufacturers are denoted as EP, as also shown in Figure 3.1.
[5] AP are companies providing applications, software, etc.; SP are companies providing service platform; CP are firms providing contents: music, pictures, mobile games, etc., as denoted by Yu et al. (2008).
[6] Regulators such as MII – the Ministry of Information Industry of the People's Republic of China.

Electronics manufacturing is a sector under ICT industry, thus its supply chain management is also influenced by regulators. Take Mainland China as an example, the most influential regulator in this area is MII - the Ministry of Information Industry of the People's Republic of China. It was established in year 2008 and it functions as a governmental department to deal with issues within the IT industry in China, such as GSCM standards and regulations for producers and other service suppliers (Yu et al., 2008).

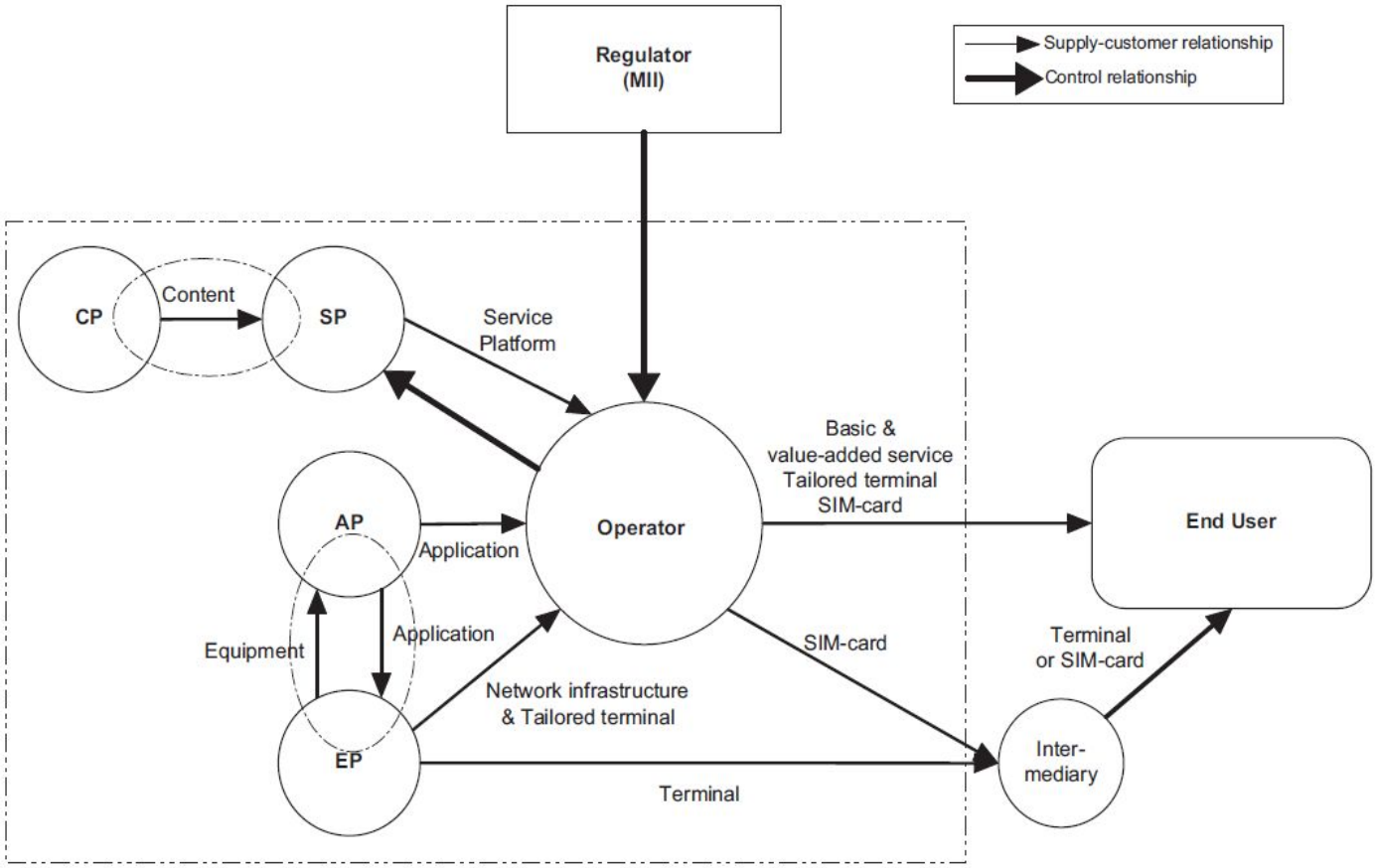

Figure 3.1: Supply chain network for the Chinese ICT sector (Yu et al., 2008)

Like in the ICT industry, end users in supply chain of electronics sector are the ordinary consumers who purchase a certain electronics device. They are located in the end of the supply chain. In addition, it is discovered by Yu et al. (2008) that due to the direct control of MII over

domestic operators, end users actually have limited bargain power on aspects such as service fee. They just need to accept the rate MII determines. Other intermediaries are mainly selling accessories, batteries, headsets, etc.

Along with the rapid development of the electronics industry in China, balancing the economic benefits and environmental performances are becoming significantly important for both the regulators and the companies. There are lot of pressure coming from global competitors and communities. As mentioned before, many Chinese electronics producer are OEM and ODM kind that are export-driven, thus one of the GSCM adoption drivers for Chinese firms would be the exporting and sales to foreign customers. Chinese manufactures need to meet the international environmental standards in order to win cross-board deals. According to Zhu et al. (2005), other drivers like consumer pressure is rather low in China compared to other more developed countries like the US. However, younger generation is becoming more and more aware of the concept of "sustainable products" and starting to prefer green products. Finally, all these pressures have caused the Chinese government to give GSCM more serious consideration. The legislative bodies in China have introduced regulatory and tax policies with the hope to control the over consumption of resources (Zhu et al., 2005).

Similar with other manufacturing companies, the firms operating in electronics sector in China are also in their infancy in GSCM. However, as mentioned by Zhu and Sarkis (2006), unlike other industries, electronics sector is more globally driven, thus the motivations and pressures are different in this sector when applying GSCM practices. To be more specifically, Zhu and Sarkis (2006) in their research find a similar result as Yu et al. (2008) that regulations have a statistically significant impact on electronics industry in China[7]. It is also acknowledged that, comparing to other industries such as automobile, companies in electronics industry have a higher than average awareness of environmental and sustainable issues due to their nature of being export-driven and their established relationship with many foreign customers (Zhu and Sarkis, 2006). Another important driver is marketing. Found by Zhu and Sarkis (2006), electronics firms, generally speaking, have also pressure from green marketing and building a

[7] In Zhu and Sarkis (2006)'s paper, they focus on comparing three different industries: automobile, thermal power and electronic/electrical industry in China. The statistical result shows that regulation as a pressure on the electronic/electrical industry has a mean of 4.27 in a scale from 1 to 5, and 5 indicates extremely important.

good environmental image in order to win more foreign deals. Other two defined pressures/drivers are from suppliers / competitors and internal environmental missions and strategies with less significance found in electronics industry (Zhu and Sarkis, 2006).

It is concluded by Zhu and Sarkis (2006) that GSCM adoption and practices in Chinese electronics industry are slightly more mature than other industries, but it is still in early developing stage because most of them are lacking related experiences and tools/management skills. Domestically, although there are not any established comprehensive standards or regulations specifically focused on this field, producers are still bound to international legislations particularly from more environmentally aware countries.

3.2. Theoretical framework and model of evaluation

Many previous research papers and articles have studied different areas of GSCM, but there is still lacking a comprehensive evaluation model or assessment tools of the practice of GSCM. Many of them have only focused on one or several particular aspects in the supply chain, such as green design and material management. These studies are usually more empirical oriented and could not provide an overall perspective on modelling and network designing. Some companies in the countries with more mature GSCM practice actually apply their own indicators for assessing their related sustainable business issues (Verfaillie and Bidwell, 2000), but these indicators are usually firm specific and difficult or impossible to apply to other situations. In Chinese context, the situation is not any better since GSCM adoption and practice among Chinese companies are still in its early developing phase. Academic reports about GSCM in Chinese firms are rather limited. Therefore, this section aims to gather some useful information and try to provide an evaluation model that could be used to evaluate the GSCM practice of a certain Chinese electronics manufacturer.

In Kulmala's Master's Thesis (2009), which is about sustainability in material management, she developed three strategic elements of a sustainable material management that are used to evaluate companies' performance. The three strategic elements are sustainable sourcing, product

eco-design and product recovery and end-of-life management, and under each strategic element there are some metrics defined accordingly. Additionally, Bask and Kuula (2011) continue with this evaluation model and further develop and evaluate the sustainability of Nokia's supply chain in three aspects: sustainable product design, sustainable sourcing and supply chain coordination, and sustainable product end-of-life management. The metrics developed and modified by both thesis and article under each strategic element are shown in Table 3.1.

Table 3.1: Evaluation metrics defined for three sustainability aspects (adapted from Kulmala, 2009; Bask and Kuula, 2011)

Sustainable product design	Use of renewable resources (e.g. bio-plastics, waterborne paints) (Tischner, 2001; Andersen and Skjoett-Larsen, 2009)
	Use of recycled materials (Tischner, 2001; Andersen and Skjoett-Larsen, 2009)
	Structured environmental impact assessment tool in place (e.g. LCA) (CSR criteria; Hervani et al., 2005)
	Design for disassembly / recycling (Tischner, 2001; Defee et al., 2009; Andersen and Skjoett-Larsen, 2009)
	RoHS compliance on all newly designed products (CSR criteria)
	Third-party certified substance analysis methods in place (CSR criteria; Tischner, 2001)
	Eco-design targets in place (CSR criteria)
Sustainable sourcing and supply chain coordination	Supplier certification program (CSR criteria; Hervani et al., 2005)
	Supplier monitoring (CSR criteria; Spence and Bourlakis, 2009)
	Audits conducted regularly (1st tier) (CSR criteria; Spence and Bourlakis, 2009)
	Audits conducted regularly (2nd tier)

	Supplier training in environmental issues (Handfield et al., 2005; Scott, 2008; Lee and Kim, 2009; Andersen and Skjoett-Larsen, 2009)
	Information sharing on controlled (hazardous) substances (Handfield et al., 2005; Scott, 2008)
	Resource use and / or waste level targets for suppliers in place (Scott, 2008)
Sustainable product end-of-life management	WEEE compliance (CSR criteria)
	Voluntary take-back program in operation
	Reuse of products (sales to secondary market) (Tischner, 2001; Defee et al., 2009)
	Refurbishment of products (sales to secondary market) (Tischner, 2001; Defee et al., 2009; Rogers and Tibben-Lembke, 2001; Hervani et al., 2005)
	Reintegration of recycled materials (Tischner, 2001; Hervani et al., 2005)
	Company-specific collection rate target in place
	Participation in global development initiatives

These metrics used by Kulmala (2009) and Bask and Kuula (2011) are seen as the baseline for model building in this paper. With the additional help from other previous inputs from various researchers and professionals, some metrics will be modified and additional metrics will be added to this list according to the research objectives of this paper given the context of Chinese electronics industry. Therefore, the GSCM practice evaluation model for Chinese electronics producers incorporates four big areas in supply chain management: sustainable product development process, sourcing and supplier management, organization involvement and regulations, and product recycling and life cycle management. In the rest of this Chapter, particular metrics will be defined in each area.

3.2.1. Sustainable product development process

Product eco-design and product development process are situated at the very beginning in the supply chain processes. It is estimated that 80% of the product and process cost spent in the production process is determined in the designing phase (Cater and Ellram, 1998). Products can come out in many forms and can be manufactured with various kinds of materials and components. However, what is more important than technical know-how and material technology is the innovation that is happening at the product design phase. It entails the integration of sustainability into the beginning stage of producing a product already. It usually brings benefits such as reduced use of resources, minimized pollutions / waste and simplified recycling and disposing process. So in this paper, aspects related to resource use, material recyclability, hazardousness, easiness for disassembly / recycle / disposal and packaging are being considered.

For product development, it is something noteworthy to emphasize under the Chinese context (or any other regions with less sustainability awareness). By product development process, this paper refers to a slightly broader concept than product design. It includes activities like inventory control, raw material improvements / modifications, product improvements / modifications, process improvements / modifications, and repairability improvements. The hypothesis behind is that the importance of GSCM is only recently emerging among Chinese electronics firms, thus unlike other more sustainability advanced regions where the old models are already replaced by green practices, many of the old raw materials, production and processes may still be in use in Chinese factories because of the old and less sustainable product models are still in sale. However, along with the increasing awareness of GSCM in China, it would be useful to check if any producers are willing to modify their raw materials, production and processes of some old but popular models to meet these new standards.

Therefore, seven metrics in this area are defined as follow:

- New product design for reduced use of resources
- New product design for recycled materials (Tischner, 2001; Andersen and Skjoett-Larsen, 2009; Bask and Kuula, 2011; Kulmala, 2009)

- New product design for avoidance or reduced use of hazardous materials/components (RoHS compliance) (CSR criteria; Bask and Kuula, 2011; Kulmala, 2009)
- Design for easy disassembly / recycling / disposing (Tischner, 2001; Defee et al., 2009; Andersen and Skjoett-Larsen, 2009; Bask and Kuula, 2011; Kulmala, 2009)
- Reduced packaging
- Inventory control practices for sustainability
- Production improvement (including materials, products, processes or repairability improvements / modification)

3.2.2. Green purchasing and supplier management

Green purchasing or green procurement sets up the sustainability standards for a corporation to procure related goods, services and utilities. The most critical issue relevant to green purchasing for companies is the fact that it requires the incorporation of not only cost and quality, but also environmental impact. The practice of green purchasing could yield some benefits for firms in areas such as risk management, cost minimization and revenue generation. Green purchasing engages many players in the supply chain and the most important player here is the supplier.

Supplier is a critical stakeholder in GSCM because companies depend on their vendors' services and goods to continue their production and sales activities. Any environmental risk from the vendors will pass onto the companies. As a result, many sustainable companies would integrate suppliers to their green supply chain strategies and conduct regular audits to their vendors. Due to the frequent emergence and updates in the related legislations, it is essential for the companies to keep their vendors up to date about the new regulations imposed in the geographical region of interest (Bask and Kuula, 2011). With the mutual hope of reducing the use of resources and energy, companies should work closely and openly with their vendors about environmental issues through providing higher level of transparency.

In China, suppliers for electronics manufacturers range from domestic small firms to multinational corporations. First tier suppliers are vendors who hold direct commercial

relationships with the company in question. Electronics contract manufacturing firm is a big group in first tier suppliers who produce electronic components and provide assemblies for OEMs like Nokia. For example, Foxconn, a leading vendor here, is a Taiwanese ODM who provides services to a variety of international companies. Companies rely heavily on these first tier suppliers in sustainability issues, because vendors' performance on environmental and ethical issues will have a direct impact on companies. Thus, many companies have sets of supplier requirements regarding these issues and require the suppliers to fulfill them in order to have a continuous business relationship. Further, in electronics industry, giant OEMs like Nokia, Huawei or Samsung are usually having a rather strong bargaining power, which enables them to have a huge influence on their vendors' behaviors. Another advantage for OEMs is the fact that business relationships in this industry between companies and their suppliers are often long term and stable. A close and stable relationship would result in better communication and mutual trust building. Finally, with the increasing awareness of GSCM in the electronics industry and legislation, many other important clients of suppliers would also place pressure on them to incorporate GSCM practices. There are many ways for an OEM to manage its first tier suppliers such as supplier assessment, training sessions, Codes of Conduct, and regular audits.

Second tier suppliers in electronics sector are vendors that supply raw materials or components to the first tier suppliers. In other words, second tier suppliers won't have direct business relationships with OEMs. One key issue with the second tier suppliers is the hazardous substances management of raw materials, especially in meeting the requirements imposed by RoHS and REACH directives[8] used in EU. The control of the fulfillment of various standards and legislations from second tier suppliers is extremely difficult for OEMs due to the lack of communication and knowledge sharing. Therefore, how a company manage and handle the GSCM related issues with its second suppliers would reflect quite much about the company's attitude and mind-set of GSCM.

In this paper, six metrics are selected to measure green purchasing and supplier management:

[8] REACH is the Regulation on Registration, Evaluation, Authorization and Restriction of Chemicals. It went into force in June 2007 with the objectives to streamline and improve the former legislative framework on chemicals of EU.

- Supplier supporting program and activity (e.g. assessment, training and monitoring) (CSR criteria; Spence and Bourlakis, 2009; Handfield et al., 2005; Scott, 2008; Lee and Kim, 2009; Andersen and Skjoett-Larsen, 2009; Bask and Kuula, 2011; Kulmala, 2009)
- Supplier Codes of Conduct in place
- Collaboration with suppliers (e.g. on new product development and knowledge sharing)
- Supplier audits for 1st tier suppliers (CSR criteria; Spence and Bourlakis, 2009; Kulmala, 2009)
- Supplier audits for 2nd tier suppliers (Bask and Kuula, 2011; Kulmala, 2009)
- Regulation compliance of suppliers in raw materials / components and other certifications (e.g. RoHS, REACH and ISO 14000)

3.2.3. Organization involvement and regulations

In the research of GSCM in other regions, especially western countries, the organization involvement and regulations are not often emphasized. However, in the context of the Chinese electronics industry, the influence of organization involvement with other stakeholders than suppliers, particularly regulation involvement, regarding GSCM is far-reaching. Therefore, in this thesis it is separately listed as a critical measurement / pressure for one company's GSCM practice.

Zhu et al. (2008) in their article indicate that there are two organizational determinants to evaluate the practice of GSCM for a firm, and they are organizational learning from the experience and the support from higher management.

Further according to Zhu et al. (2008), there are typically two factors included in external GSCM relationship that are upstream and downstream factors. Upstream factors are about inbound logistics activities that are mainly conducted by suppliers and vendors. On the other hand, downstream factors include outbound logistics that are about distribution, marketing, and collaborations with customers and society. Zhu et al. (2008) especially point out that the downstream factors are particularly important in China along with the increasing awareness of green products of the younger generation in China and the heightened Chinese regulations about

GSCM. Thus, one metric about collaboration with foreign customers about GSCM is defined and another marketing effort in promoting company's green image to the public is also included.

Another important measuring aspect for Chinese producers discovered by Zhu et al. (2008) is the organizational learning about sustainability. A working learning system within the organization could accommodate the use of existing resources and capabilities. Moreover, it could help transfer the experience and knowledge gained by initial GSCM practices to generate potential commitment to the next level of engagement of GSCM. Organizational learning is also highly related to mind-set changing from passive to proactive towards sustainability within the company. It is evident that many Chinese manufacturers have already tried to build up an organizational learning system in environmental issues such as by adopting ISO 9000 and ISO 14001 (Guan and Ma, 2003). Therefore, the organizational learning system measured by the adoption of ISO 9000 or ISO 14001 could be identified as a metric.

As reported by Bask et al. (2013), the sustainable strategy and policy is also seen as a prominent indicator of companies GSCM practice. Organizations' sustainable strategy and policy usually include aspects like the company's vision, mission and policy regarding sustainability in general (Angell and Klassen, 1999; Bask et al., 2013); the investment made in waste and emission management (Bask et al., 2013); the participation to globally influential development discussion or forums (Bask et al., 2013); and the constructive and detailed CSR reports published regularly (Chen and Bouvain, 2009; Bask et al., 2013).

In addition to setting up overall sustainable policy, management support is claimed as another important metric here too. It is relevant to any organizational change management. Chinese manufacturing companies, especially OEMs, are facing the transition period from economic growth to sustainability growth. Thus, the support and emphasis given by the senior management is absolutely necessary for adopting the new sustainable mind-set throughout the company. Senior management could facilitate the adoption of new mind-set by empowering employees, promoting new cooperate cultural shift, having incentive plans and employee training sessions. The aim of the management support is to facilitate the internal communication and knowledge sharing about sustainability in order to make the implementation work easier.

Finally, Chinese government has also established some CSR regulations related to manufacturing industry. However, it is still in the initial stage of developing a comprehensive and systematic CSR movement. Regulations in force are such as Cleaner Production Promotion Law[9], Air Pollution Control Regulation[10] and some other specific regulations such as regarding the use reduction of lead battery for mobiles phones deployed by MII together with the Ministry of Environmental Protection in China. Therefore, as a measurement for Chinese OEMs, it is necessary to check if they comply with the domestic laws and regulations about sustainability.

Afterwards, there are five metrics defined for the aspect of organization involvement and regulations:

- Collaborations with consumers for sustainable product development (e.g. eco-design and packaging) (Zhu et al., 2008; Zhu and Sarkis, 2004)
- Establishment of green image through PR / marketing activities and advertisement (Zhu et al., 2008)
- Organizational learning by acquirement of such as ISO 9000 and ISO 14001 (Zhu et al., 2008)
- Sustainable strategy and policy in place (Bask et al., 2013)
- Commitment of GSCM from senior management (Zhu and Sarkis, 2004)
- Compliance of governmental environmental regulations (domestically) (Zhu et al., 2008)

3.2.4. Product recycling and life cycle management

Product recycling and end-of-life management is located in the end of green manufacturing and in the beginning of green remanufacturing. It is about how the products are being handled and managed after when they are returned to the producers as used, unused or damaged. It is also a part of the reserve logistics flow and this important phase in reverse logistics is especially critical for both environmental impact and economic value. First of all, the improved design for product

[9] It was issued on 29th June, 2002 with the objective to promote cleaner production, increase the efficiency in resource use, and avoid / reduce the generation of pollution.
[10] It is still a draft regulation which is open for comments from 8th Feb, 2013. This directive is aimed to reduce the use of energy like coal-fired energy.

life cycle will help reduce the use of resources and the amount of industrial waste. Secondly, in terms of economic value, it will extend the length of product life cycle, usability and even functionality (Bask and Kuula, 2011).

One characteristic about electronics industry is the products are usually having a shorter length of life cycle comparing to other products. This is due the rapid development of technology and innovations that are being sold in the market. Besides, there are consistently new models with new features coming to the market, the disposal and return rate for electronic goods are also high. Therefore, EU has introduced the decree WEEE to regulate in product take-back and disposal. In this paper, the compliance of WEEE is also used as an effective metric.

Another important measurement is called investment recovery (IR). By definition, it means the strategy related to the use of recycling, remanufacturing, redeployment and reselling to generate value from materials, components and products (Zhu et al., 2008). By apply IR, companies are able to turn some of the idle assets into profits and decrease the level of inventory. In countries like the US and Germany, IR is considered to be the most critical practice of green purchasing (Zsidisin and Hendrick, 1998). However, the adoption of IR in China is still behind the development of other developed regions. One reason would be the lack of proper infrastructure and systems for especially waste management and product recycling. Nonetheless, Chinese government has imposed some new regulations such as tax levying on use of resources like coal and natural gas. This has led to some new attention paid by Chinese producers to IR practices. Thus, IR practice is seen as an important metric to evaluate the evolvement of GSCM for Chinese firms.

Finally, the last metrics in this aspect is reintegration of recycled material, which is consistent with the choice of Kulmala (2009) and Bask and Kuula (2011). In order to meet this measurement, material efficiency should be paid high attention. Reported by Busch et al. (2006) that around 60% of the cost is contributed to materials, and personnel in manufacturing industry occur only 25% of the cost. Thus, it is evitable that increasing material efficiency could lead to substantial cost savings in production, even up to 25% in some cases (Busch et al., 2006). Therefore, the ability to reintegrate the recycled materials is considered a metric.

In total three metrics are used to evaluate one producer's performance regarding Product recycling and end-of-life management:

- WEEE compliance (CSR criteria)
- Investment recovery (sales of excess inventories / materials, sales of scrapped or refurbished products / materials) (Tischner, 2001; Defee et al., 2009; Rogers and Tibben-Lembke, 2001; Hervani et al., 2005; Bask and Kuula, 2011; Zhu et al., 2008; Zhu and Sarkis, 2004; Kulmala, 2009)
- Reintegration of recycled materials (Tischner, 2001; Hervani et al., 2005; Kulmala, 2009)

To summarize, the section identified four general elements that are important to measure one company's sustainability performance given the Chinese context. These four aspects are sustainable product development process, green purchasing and supplier management, organization involvement and regulations, and product recycling and life cycle management. Under each aspect, several detailed metrics are then defined in order to evaluate Chinese OEMs. They are illustrated in Table 3.2.

Table 3.2: Evaluation model constructed in this paper (by author)

Sustainable product development process	New product design for reduced use of resources
	New product design for recycled materials
	New product design for avoidance or reduced use of hazardous materials/components (RoHS compliance)
	Design for easy disassembly / recycling / disposing
	Reduced packaging
	Inventory control practices for sustainability
	Production improvement (including materials, products, processes or repairability improvements / modification)
Green purchasing and supplier management	Supplier supporting program and activity (e.g. assessment, training and monitoring)

	Supplier Codes of Conduct in place
	Collaboration with suppliers (e.g. on new product development and knowledge sharing)
	Supplier audits for 1st tier suppliers
	Supplier audits for 2nd tier suppliers
	Regulation compliance of suppliers in raw materials / components and other certifications (e.g. RoHS, REACH and ISO 14000)
Organization involvement and regulations	Collaborations with consumers for sustainable product development (e.g. eco-design and packaging)
	Establishment of green image through PR / marketing activities and advertisement
	Organizational learning by acquirement of such as ISO 9000 and ISO 14001
	Sustainable strategy and policy in place
	Commitment of GSCM from senior management
	Compliance of governmental environmental regulations (domestically)
Product recycling and life cycle management	WEEE compliance
	Investment recovery (sales of excess inventories / materials, sales of scrapped or refurbished products / materials)
	Reintegration of recycled materials

4. GSCM IN THREE ELECTRONICS MANUFACTURERS IN CHINA

Chapter 4 is about applying the evaluation model to three Chinese OEMs and conducting a brief yet valid model testing with a short empirical study about these OEMs who are originated from China. The choice of the three companies is mainly based on the size, global presence and global reputation in the electronics market. Besides, after a pre-scanning of the possible candidate companies, it is found that these three companies – Huawei, ZTE and Lenovo are able to provide the most comprehensive information in GSCM in both Chinese and English. Therefore, the publicity and availability of related information for conducting the model testing is essentially important. In addition, both ZTE and Lenovo are invited companies for the assessment of Dow Jones Sustainability Indices for year 2013 (DJSI, 2013a). ZTE is one of the only two accessed Chinese companies that are categorized as communications equipment producer by DJSI[11]; Lenovo is then the only firm under the categorization of computers & peripherals and office electronics by DJSI.

It is also noteworthy that both ZTE and Lenovo have applied the DJSI Emerging Markets Universe index, which is a tool offered to investors for measuring the performance of companies that are recognized as leaders in the industry they operate in in terms of corporate sustainability. It is also an effective engagement platform to encourage companies from emerging markets to adopt more sustainable practices (DJSI, 2013b). Further, Lenovo has also applied both the index from DJSI World Universe and DJSI World Enlarged Universe. The first one is a starting DJSI universe that consists of 2,500 companies around the world after some assessment of sustainability performance, and the latter is then designed to accommodate the increasing interests from stakeholders in a broader sustainability benchmark, so it tracks the performance of the most sustainable companies[12]out from the 2,500 companies (DJSI, 2013c). That is to say that the sustainability of Lenovo, as seen by DJSI, is considered quite satisfactory.

[11] Another Chinese company chosen in this industry section is AAC Technologies Holdings Inc.
[12] It is said that it tracks the performance of top 20% of the sustainable companies from 2500 companies in the Dow Jones Global Total Stock Market Index.

Although Huawei is not accessed by DJSI in year 2013, it is however a listed company on the DJSI World Universe in year 2012. On Huawei's official website, it is also claimed that Huawei has been performing great according to the DJSI.

To conclude, it is evident to see that these three manufacturers are the most suitable options to present the current situation and adoption of GSCM in globally operated Chinese electronics manufacturers. They most likely represent the highest standards and best practices of green supply chain in Chinese electronics industry. By studying their practices and strategies, it is hoped to provide more knowledge and insights about GSCM for Chinese companies under a predetermined context.

4.1. The three electronics manufacturers

The rest of the chapter will be structured firstly with a short introduction of the company of interest, and each metrics defined in Chapter 3 will then be used to evaluate the performance regarding a specific area. Finally, a short summary of each company's performance will be discussed in the end.

The evaluation of the sustainability performance is measured by a rather simple sum up calculation. Each metric on the checklist will be ticked off if it is the matter described in the metric is met or in active use in the company. After all the metrics have been checked, the final total score will be summed up by the number of ticks a company has. The final sum will then represent the overall result for each company. All the metrics will be evaluated based on the fact that whether or not the requirements or situations described in the metrics are already in implementation correspondently, rather than whether or not these companies are preparing to implement them.

4.1.1. Huawei

Huawei Technologies Co Ltd. is a multinational networking and telecommunication equipment and service company that is based on China. Its headquarter is located in Shenzhen, Guangdong province. It is originally founded in year 1987, and now Huawei is one of the pioneer Chinese technology companies that went out China and planned to win global markets. Now it is the biggest telecommunication equipment producer in the world with main markets in Americas, Asia, Europe and Africa, according to The Economist (2012). Its operation is expanded to over 140 countries globally with more than 140,000 employees (Huawei Canada, 2013). Huawei, unlike ZTE, is a private company that is owned by its investors and employees. It is a huge corporation with more than 140,000 employees and operations or sales offices in more than 140 countries.

Recent financial figures indicate a consistent revenue increase for Huawei, driven by the significant growth in foreign markets like EU, Russia and the US. Its main business can be divided into three general segments (Huawei, 2013b):

- Telecom Carrier Networks, building telecommunications networks and services
- Enterprise Business, providing equipment, software and services to enterprise customers
- Devices, manufacturing electronic communications devices

Its main customers also consist of three major groups: operators, enterprises and consumers. In addition, it is still a pity that Huawei hasn't yet published any information about detailed corporate structure.

As a leading ICT solution provider, Huawei's mission towards sustainability is to leverage its expertise and innovation know-how to improve its efficiency in developing, manufacturing, and solution providing to be responsible for the society. Huawei said in its official website (Huawei, 2013c) that it is firmly committed to the CSR requirements and sustainability standards. Sustainability requirements in Huawei are incorporated into business operations as well as management system. Next in this section, Huawei's sustainability performance and practices of GSCM will be tested and measured by the evaluation model built in the previous chapter. The

four general elements will evaluate one by one. Kindly notice that most of the discussion below is summarized by Huawei's various official websites, sustainability or CSR reports, and some reliable journal articles or books.

Sustainable product development process

According to Huawei Sustainability Report 2012 (2012), it is mentioned that Huawei has been conducting product life cycle assessment (LCA) and integrate ecological design into its wide product and service range. Huawei also use eco-friendly materials and clean energy for designing new products, and it also promoting the idea of reusing as many resources as possible in its production processes.

By conducting LCA, it is to say that Huawei analyze its product life cycle from "cradle to grave". To be more specifically, LCA accesses the process from raw material collecting, parts manufacturing, product processing, transportation, and usage to disposal and recycling. However, it is also mentioned in the Huawei Sustainability Report 2012 (2012) that it has established and developed a Quick-LCA tool based on its own database with the hope to achieve rapid assessment and continuous optimization. By 2012, Huawei has applies this Quick-LCA tool to access 17 types of products. However, in this report, it is not specified what kind of Quick-LCA Huawei is using and what evaluation components it has. Horne et al. (2009) in their book state that there are many forms of Quick-LCA in use by various organizations, but the quick tool varies hugely in size, shape, techniques and areas of applications ranging from a simple spreadsheet to online software programs. Thus, it is hard to justify whether or not the Quick-LCA used by Huawei is sufficient enough.

Nonetheless, Huawei has a better performance in resource reducing and material recycling. Huawei has developed a model called circular economy to reduce the consumption of resources. Together with the Quick-LCA tool, Huawei conducts ecological product design during all the phases of product life cycle, even after the product has been designed and sold to the market. It is continuously improve the product models sustainability from aspects such as raw material replacing, packaging and transporting.

In the hazardous substance management, Huawei complies with the main product-related environmental regulations over the globe, for instance RoHS. One specific example is that Huawei has asked its suppliers to report on the material composition of the goods they supplied, and switched to lead-free components and products. Its objective is to achieve no lead in products by 2014.

Packaging is firstly reduced in terms of green logistics, that is to say the package size of products are optimized and reduced in order to facilitate the transportation and reduce the emission of CO_2. Then, green packaging is also reflected in the packaging strategy developed by Huawei, which is called "6R1D". As defined in Huawei Sustainability report 2012 (2012), "6Rs" is a strategy which means "*the packaging has right designs is able to be reduced, returned, reused, recycled, and recovered*" (Huawei Sustainability report, 2012), and "1D" means that "*the packaging is degradable*" (Huawei Sustainability report, 2012). Huawei has also used some new green packaging technologies in use, such as circulation racks, turnover trays, and turn over boxes (Huawei Sustainability Report, 2012).

Since there are no relevant information and specification found about design for easy disassembly, recycling and disposing and inventory control techniques used to improve the sustainability and reducing the level of inventory, the two metrics are not ticked off. Thus, Huawei in element of sustainable product development process scores 5.

Sustainable product development process	Huawei
New product design for reduced use of resources	x
New product design for recycled materials	x
New product design for avoidance or reduced use of hazardous materials/components (RoHS compliance)	x
Design for easy disassembly / recycling / disposing	
Reduced packaging	x
Inventory control practices for sustainability	
Production improvement (including materials, products, processes or repairability improvements / modification)	x
Total	**5**

Green purchasing and supplier management

As a global company, Huawei is fully aware of the importance its supply networks and is willing to work closely with its suppliers to build a business ecosystem where they share the risks, benefits, resources and knowledge. In order to do so, Huawei applies three approaches in its green purchasing and supplier management: risk management, efficiency management and business innovation. All three approaches work as a union with risk control serving as a foundation (Huawei Sustainability Report, 2012).

Risk management is achieved by placing focus on high-priority suppliers and managing their sustainability by incorporating the green practices and risk management into procurement process and suppliers life cycle. Huawei provides direct and continuous monitor, integrations and demonstration of industry leading practices. Efficiency management is then about going beyond the expectations set by regulations and customers. Huawei also helps suppliers to dig out the problem in adopting or practicing sustainability and analyze the root cause. Business innovation focuses on product innovation, new market expansion, and new technology development. Together with the suppliers, especially the first-tier suppliers, Huawei is also aiming to work out

new sustainable business models. These activities are further strengthened by a wide range of industry collaboration, such as cross-industry dialogue and seminars.

The suppliers' sustainability performance and incorporation of Huawei procurement strategies are regular reviewed by the chairman of Huawei's Supplier Sustainable Development Committee and Chief Procurement Officer to ensure that all the processes and daily task are under control. It is noteworthy that it is claimed that Huawei's supplier sustainability work team can reach any of its procurement organization around the world to ensure that their conducts meet the sustainability requirements.

In addition, Huawei has also published its Supplier Sustainability Policies in year 2007 as the guiding principle; it also issued a Redline Management Plan a general guideline for suppliers' conduct and sustainability management. Through this guideline, Huawei is able to select its suppliers, appraise suppliers' good performance, or dissolute supplier relationship. In year 2012, Huawei was awarded with the 2012 CSR Best Practice from United Nations Global Compact China Network for its performance in sustainability management, especially in supplier supporting and collaborating.

In addition, Huawei requires all its suppliers, no matter where they are located, to sign the Supplier Sustainability Agreement and it will appraise its suppliers and adjust the business relationships according to the level of compliance with this agreement. It is worth mentioning that the agreement is constructed based on Electronic Industry Code of Conduct, Social Accountability 8000 International Standard, ISO 26000 Guidance on Social Responsibility.

Huawei conducts supplier audits annually. It appointed 29 senior sustainability auditors to check on-site the sustainability status of its suppliers in 2012 and list out the suppliers with high risk. The audit methods include interviewees with employees & managers, document review, filed check, third-party information analysis to give fair assessment about their performances. As a result, all the suppliers are grouped into 4 grades (A, B, C and D). Any suppliers with a grade of D will not be endorsed anymore. If those D suppliers would still want to continue the business relationship, they have to conduct corrective measures with a certain timeframe. They also need to apply Check, Root Cause Analysis, Correct, Prevent, and Evaluate (CRCPE) five-step

approach to take the measures. All qualified suppliers are required to comply with ISO 14001 and OHSAS 18001[13]. In general, during every audit, suppliers need to pass the second-round audit in order to become qualified suppliers for Huawei.

Green purchasing and supplier management	**Huawei**
Supplier supporting program and activity (e.g. assessment, training and monitoring)	x
Supplier Codes of Conduct in place	x
Collaboration with suppliers (e.g. on new product development and knowledge sharing)	x
Supplier audits for 1st tier suppliers	x
Supplier audits for 2nd tier suppliers	
Regulation compliance of suppliers in raw materials / components and other certifications (e.g. RoHS, REACH and ISO 14000)	x
Total	**5**

Organization involvement and regulations

Organization involvement here consists of the collaborations with other stakeholders than suppliers, such as internal employees, customers, government and the general public about sustainable supply chain management.

Huawei emphasizes the importance of the win-win development strategy. Customers are an essential stakeholder and determinant for achieving this goal. As acknowledged by Huawei, many of Huawei's customers, both individual and enterprises, are shifting their focus from product price or quality to overall product sustainability. Therefore, Huawei has conducted regular programs and activities to engagement customers to its sustainability development. In

[13] It is a British standard for occupational health and safety management system during work.

year 2012, Huawei arranged 900 open discussions around the world with its high value customers to discuss the future trend of GSCM. Additionally, Huawei also hires third-party agencies to conduct customer survey on sustainability issues. In year 2012, there were 170 customer groups from over 80 countries taking part in the survey. Huawei is also audited by its high value customers e.g. big carriers for its sustainability performance.

Huawei is complying with ISO 9000 for its sustainability management system learning (ISO, 2006). Based on the research done by ISO (2006), after implementing ISO 9000, the customer satisfaction for Huawei's product and services increased from 79% in 2001 to 83.4% in 2004. Huawei has also passed the requirement assessment of ISO 14001 and become one of the world's leading companies in sustainability management (Huawei, 2003).

Huawei has a separate vision for sustainability management that is "*to bridge the digital divide and promote the harmonious and sustainable development of the economy, society, and environment*" (Huawei Sustainability Report, 2012). In addition, it also employs a mission for sustainable management and it says "*to establish an excellent sustainability management system, operate with integrity and in compliance with applicable laws and regulations, continuously enhance communication with stakeholders, promote a harmonious business ecosystem, ensure sustainable development, and contribute to our customer and society*" (Huawei Sustainability Report, 2012). Besides establishing the vision and mission for sustainability, Huawei has also invested in waste management by establishing the waste scrap disposal center in its headquarter Shenzhen and co-established regional waste scrap disposal centers in other regions like Latin America, Europe and so on. In addition, Huawei has joined four external commitments and initiatives, and they are Global Impact in 2004, GeSI[14] in 2008, Broadband Commission in 2010, and CSR Europe in 2011.

In Huawei, there is a committee called Huawei's Corporate Sustainable Development Committee who takes care of all the sustainability issues during daily work in Huawei's supply network and other routines. The transmission from CSR strategy into corporate sustainable development (CSD) shows the determination form Huawei to adopt a proactive attitude and mind-set towards

[14] Global e-Sustainability Initiative.

sustainability. The Corporate Sustainable Development Committee comprises more than 20 senior managers from different functional departments and units (Huawei, 2013d). Sustainability management systems are supported and implemented throughout the company from top to down.

As an export-driven producer, Huawei is strictly abides by related and applicable sustainability regulations, both from international and domestic. Huawei's Trade Compliance & Customs Compliance Committee and Trade Compliance Office managed by the Chief Legal ensure its compliance to the latest decrees and laws.

Organization involvement and regulations	**Huawei**
Collaborations with consumers for sustainable product development (e.g. eco-design and packaging)	x
Establishment of green image through PR / marketing activities and advertisement	
Organizational learning by acquirement of such as ISO 9000 and ISO 14001	x
Sustainable strategy and policy in place	x
Commitment of GSCM from senior management	x
Compliance of governmental environmental regulations (domestically)	x
Total	**5**

Product recycling and life cycle management

In this elements, three metrics matter. OEMs usually produce a great amount of electronic waste, such as used/scrapped mobile phones, SIM cards, batteries, etc. Huawei has been strictly adhering to the various regulations regarding product end-of-life management and waste management. WEEE directive is one of the international standards that Huawei applies and implements. Further, Huawei has a Waste Scrap Disposal Center in Shenzhen and it has also

jointly established and managed some regional disposal center or platforms with local service providers in Latin America, Europe, Africa and Asia.

Moreover, during year 2012, the result of disposal practice in Huawei is concluded as following "*the total waste Huawei disposed of globally amounted to 7,336 tons. Among the total waster, 96.6% of raw materials were reused and 343 tons of hazardous waste incinerated, with only approximately 3% of waste that was disposed of in landfills*." (Huawei Sustainability Report, 2012).

However, it seems that Huawei is not directly engaged in any investment recovery activities such as resell its scrapped products to the secondary markets. Besides reusing the recycled raw materials, Huawei didn't really specify whether it is reintegrating the recycled materials and feed them to the forward channels either for own use or secondary markets. This might be due to the high cost associated with reintegration process.

Product recycling and life cycle management	**Huawei**
WEEE compliance	x
Investment recovery (sales of excess inventories / materials, sales of scrapped or refurbished products /	
Reintegration of recycled materials	
Total	**1**

4.1.2. ZTE

ZTE Corporation is a Chinese based telecommunications equipment producer and systems service provider that was initially founded in 1985. The headquarter is located in Shenzhen, Guangdong province in China. it is jointly owned by state-owned electronics research institute and another state-owned company (Financial Times, 2012). It has operations in over 140 countries with 78,402 employees and it is said to be the largest listed telecommunications equipment maker in China (ZTE, 2013). Further, ZTE was named the fourth largest mobile

phone maker by unit shipment over the world in year 2012, after Samsung, Nokia, and Apple (ZTE, 2012). Its main business areas include wireless, terminal, fixed access, core network, bearer, optical transmission, communication software and devices.

At ZTE, it is an important issue to ensure that the implementation of environmental protection and energy saving solutions are well designed and implemented. It is acknowledged in ZTE's CSR Report (2012) that sustainability development is a core culture for the corporation rather an a mere accessory. In order to create a sustainable development and future, ZTE joins United Nations Global Compact, Global e-Sustainability Initiative (GeSI), GreenTouch, and other more than 70 international standards organizations (ZTE CSR Report, 2012). To conclude, the vision of CSR at ZTE is to "*operate in an environmentally responsible manner*" and "*conduct all business in an ethical and sustainable way*" (ZTE CSR Report, 2012) by a proactive mind-set.

The four elements will be again used to evaluate the sustainability performance of ZTE of its supply chain and all the information and statistical data are obtained from ZTE official website, ZTE CRS reports and white paper and other reliable sources.

Sustainable product development process

In product design phase, ZTE has adopted ecological design concept in year 2012 in order to reduce the environmental impact. It strictly applies to EU WEEE directives on device recyclability and reuse. As a result, as of the end of 2012, the recycling rate for products at ZTE is more than 75% and the reuse rate of recycled material is greater than 65% (ZTE CSR Report, 2012). ZTE further constructs an internal evaluation standard system for product energy efficiency and integrates this system into product development through R&D phase to entail the ecological product design. According to ZTE's CSR Report (2012), through the efforts put into product ecological design, "*18 products in 10 categories including terminals, wireless, wireline, services and transmission, and the energy efficiency of all products was optimized by 5-10%*".

Regarding hazardous substances, ZTE conducts rigid hazardous substance control over its production. ZTE has environmental protection labs to analyze the chemical combination and components of equipment and device. It also carries out hazardous substance free process

research together with third-party professionals. As a result, ZTE has achieved RoHS capability in year 2005.

Just recently starting from 2012, ZTE has placed a new focus on product recovery in GSCM. It has set up a professional Reverse Logistics Disposal Department who is mainly responsible for product green recovery and recyclability. Further, the company also conducts a range of strict safety and environmental check-ups before disposal to make sure that the process of recycling is safe, the process of disposal is transparent and traceable, and the result of disposal is valid. ZTE has recycled materials disposal network all over the world to guarantee the one-stop disassembly and disposal of products with minimized environmental impact. In its headquarter Shenzhen, there is a recovery disposal master control platform, and in other major cities in China there are regional disposal platforms to achieve local disposal of used or scrapped products and materials. Some disposal methods and practices are applied to Asia, EU, Latin America and Africa.

In product improvement, ZTE has places a quite strong focus. It has been actively developing innovation technologies to improve the existing production. In its wireless business, ZTE has developed a green technology – SDR[15] based wireless solution which is used by the carriers to reduce at least 50% of the network energy usage. Another example would be the development of green chips. ZTE has self innovated the cross-chips used in WDM[16] devices. This new green technology helps remove the outsourcing redundancy, optimize integration and reduce system power consumption (ZTE, 2011). In addition, many other green technologies are provided by ZTE in its products such as wireless equipment, routers, and switch equipment.

It is also noteworthy to mention that ZTE has also signed the agreement of "Conflict-free Metal Declaration of Commitment" to avoid the use of "conflict minerals" from regions like Congo.

[15] SDR is software-defined ratio. It is a radio communication system where components implemented in hardware are implemented through software on a PC or embedded system.
[16] WDM is Windows driver model. It is a framework for device drivers that were originally introduced with Windows OS to replace VxD.

Sustainable product development process	ZTE
New product design for reduced use of resources	x
New product design for recycled materials	x
New product design for avoidance or reduced use of hazardous materials/components (RoHS compliance)	x
Design for easy disassembly / recycling / disposing	x
Reduced packaging	
Inventory control practices for sustainability	
Production improvement (including materials, products, processes or repairability improvements / modification)	x
Total	**5**

Green purchasing and supplier management

GSCM is achieved in ZTE by close corporation with its various suppliers in areas like CSR, environmental management in order to together build a responsible and transparent green supply chain. In year 2012, ZTE has provided sustainability training and coaching sessions for 181 suppliers, 815 suppliers' top managers and technicians (ZTE CSR Report, 2012). Supplier training topics in 2012 included (ZTE CSR Report, 2012):

- Regular training (152 trainees)
- Carbon management and carbon investigation for green supply chain (37 trainees)
- Key CSR issues (30 trainees)
- Filed auditing and coaching for suppliers (596)

Moreover, other field professionals from third-party are also invited to training sessions to share the most advanced tools and practices in GSCM in the industry. At the end of each training session, a supplier assessment is then evaluated.

ZTE has formed a supplier CSR management expert team who conducts and updates the Supplier Code of Conduct. Each supplier is required to follow the document. Moreover, for new suppliers, they also need to sign another document called "CSR Zero Tolerance Policy" to show their determination and efforts made in GSCM.

ZTE's suppliers around the world are entitled to the auditing program arranged by the firm. ZTE provides "*3 classrooms and 19 field training for part-time CSR auditors*" (ZTE CSR Report, 2012). It also issues the supplier CSR auditing guidance tool kit which is signed with 783 suppliers to facilitate the auditing work (ZTE CSR Report, 2012). In addition, ZTE also continuously updates its audit checklist to follow the latest requirements. However, there is no evidence showing that ZTE is also conducting audits for second-tier suppliers.

Finally, all of ZTE's suppliers are asked to comply with the international and domestic standards, such as ISO 14001. However, it is not further specified which regulations or directives are required from ZTE's official sources. This may be due to the fact that the regulations vary in different countries.

Green purchasing and supplier management	**ZTE**
Supplier supporting program and activity (e.g. assessment, training and monitoring)	x
Supplier Codes of Conduct in place	x
Collaboration with suppliers (e.g. on new product development and knowledge sharing)	
Supplier audits for 1st tier suppliers	x
Supplier audits for 2nd tier suppliers	
Regulation compliance of suppliers in raw materials / components and other certifications (e.g. RoHS, REACH and ISO 14000)	x
Total	**4**

Organization involvement and regulations

Stakeholder engagement at ZTE also helps strengthen the practices of sustainability. Customers are seen as an important group of shareholders. At ZTE, there are a variety communication channels used to hear customers' voice, such as regular meeting (both technical exchanges and symposia), daily communication and visits, customer authentication and reception, questionnaire and customer hotline. The sustainable issued discussed through these channels are internal CSR management system, green energy –saving solutions, reliable product and technology, GSCM, business ethics, IPR[17], and product safety and safe operation.

Internally, ZTE launched its CSR management system in year 2007 after acquiring the certification from ISO 14001 and appointed an executive vice president as the CSR representative for the whole company. The vice president is then leading a team called the CSR promotion team whose job is to promote the concept of CSR and GSCM throughout the company and push downward the GSCM practices. This shows both the organizational learning regarding environmental management system and the support from the top management.

Similarily, ZTE also applies vision and strategy for CSR. Its CSR vision is to "*conduct all business in an ethical and sustainable way that protects and advances the human rights, health, safety, well-bing and personal development of all the people working directly or indirectly for ZTE*" (ZTE CSR Report, 2012), while its CSR strategy is to "*proactively develop, implement and improve CSR compliance throughout ZTE and its supply chain based on the industry's best practices, continuous learning and efforts for improvement*" (ZTE CSR Report, 2012). The company has also invested heavily in waste and emission management. For example, during year 2009 to 2012, ZTE conducted 14 separate projects[18] in reducing the gas emission during production (ZTE CSR Report, 2012). Additionally, ZTE has joined three globally impactful initiatives of sustainability: UN Global Compact in 2009, GeSI in 2011, and GreenTouch in 2011, and ZTE has been publishing its CSR reports on its official website since 2008.

[17] IPR stands for interllectual property rights.
[18] Project details are listed in ZTE CSR Report 2012 from page 39 to 40.

In addition to the customers and management, as a state-own enterprise ZTE is also working closely with governmental communities on GSCM issues. Together with them, ZTE holds regular meetings, seminars, government policy communication meetings, government censorship and company's self-examination. The topics covered are how to be compliant with all applicable laws and regulations imposed domestically or internationally, tax payment, job creation, innovation, IRP, environmental protection, social welfare and local talent training.

Organization involvement and regulations	**ZTE**
Collaborations with consumers for sustainable product development (e.g. eco-design and packaging)	x
Establishment of green image through PR / marketing activities and advertisement	
Organizational learning by acquirement of such as ISO 9000 and ISO 14001	x
Sustainable strategy and policy in place	x
Commitment of GSCM from senior management	x
Compliance of governmental environmental regulations (domestically)	x
Total	**5**

Product recycling and life cycle management

Back in year 2005, ZTE has already adopted the standards published as WEEE directives from EU dealing with electronic waste management. Industrial waste created by ZTE normally includes general waste, hazardous waste, and recyclable waste (ZTE CSR Report, 2012). All kinds of waste are being handled and processed by third-party companies. The general waste and recyclable waste are actually outsourced to third-party experts to handle for disposal and recycling. The hazardous waste is processed by a specialized hazardous substance treatment

company who is authorized by the Environmental Protection Agency. As reported in year 2012 in ZTE CSR Report (2012), "*the recycle rate of the recyclable waste ranged from 80% to 95%*". Unfortunately, ZTE didn't reveal the list of the handling companies. Therefore, there is no obvious information related to investment recovery and material integration.

Product recycling and life cycle management	**ZTE**
WEEE compliance	x
Investment recovery (sales of excess inventories / materials, sales of scrapped or refurbished products /	
Reintegration of recycled materials	
Total	**1**

4.1.3. Lenovo

Lenovo Group Limited is a multinational technology company based in China, Beijing with major research centers in China, Japan, and USA. It was founded in year 1984 and is a publicly listed company in China and Hong Kong with more than 35,000 employees worldwide. It produces a large range of products from consumer products like PC, tablets, smart TV and mobile phones to infrastructure like servers, workstations and electronic storage devices. By the year 2012, Lenovo was ranked the second-largest PC producer by unit sales (Gartner, 2013). It has offices and operations in over 60 countries and its various products are sold to over 160 countries and regions. It is worthy to mention that IBM PC business was acquired by Lenovo in year 2005 (Lenovo, 2013a). The acquisition has made Lenovo one of the top PC makers in the world.

The general sustainability strategy used in Lenovo is to equally dedicate to ensuring that its products and services are following its commitment made to its stakeholders. As said by Lenovo's senior engineer for global environmental affairs, Lenovo's philosophy is "*we don't want to have green products and brown products. All of our products have to meet the same requirements*" (Lenovo Sustainability Report, 2011). Like ZTE, Lenovo is also a member of

United Nation Global Compact and fully follow its requirements and standards. Lenovo claims that it is fully committed to the environment protections from supplier selection, facility management, distribution & logistics to product design and recycling solution (Lenovo, 2013b). The main objectives that Lenovo desires to achieve through its corporate policies of environmental issues are (Lenovo, 2013c):

- Compliance environmental requirements
- Prevention of pollution
- Product environmental leadership
- Continual improvement in environmental protection

The paper will use the same standards to evaluate the GSCM and environmental management at Lenovo. All the statistical data and information are extracted from official and reliable sources such as official website, official sustainability reports, green papers and other trusted websites / journals.

Sustainable product development process

For aspects related to product design and development, Lenovo has a strategy which is focused on three areas: 1) energy-efficient products, 2) the use of environmentally preferred materials, 3) green product packaging, and 4) energy management tools (Lenovo Sustainability Report, 2011). The reduced energy use for Lenovo's products like PC is actually a differentiator in the sales market. The product lines with "ENERGY STAR®" [19] are including notebooks, desktops, workstations, monitor and servers (Lenovo, 2013d). By adopting this practice, many of Lenovo's products have already achieved energy and resources efficiency by a reduction of around 25% to 60% through technology innovation and product ecological design (Lenovo, 2013d). There are some other patented technologies which take control of products' energy consumption, such as Power Manager® and LANDesk®.

[19] ENERGY STAR is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy. By joining the program, Lenovo is helping consumers save money and protect the environment through energy efficient products and practices.

The use of environmentally friendly material is also a focus at Lenovo. It is conducting programs to transit to low halogen components and strengthen post-consumer recyclability. Lenovo has placed strong emphasis on the integration and remanufacturing of these recycled materials in Lenovo's production, for example in the first half of year 2011 alone, "*over 11 million gross pounds (4,990 metric tons) of recycled plastics with net PCC[20] of over 4.6 million (2,087 metric tons) and net PIC[21] of over 80,000 pounds (36 metric tons)*" and they were recycled from Lenovo's products (Lenovo, 2012). More of the related facts will be further discussed in the analysis of the last metric "Integration of recycled materials" in the fourth element.

As an essential priority at Lenovo, RoHS requirements were implemented worldwide in each geography and country of operation. Lenovo has complied with all the requirements of RoHS currently in effect (Lenovo, 2013e). Furthermore, Lenovo also complies with REACH regulations on chemical-restricted materials. Internally, Lenovo has a program called Environmentally Conscious Products Program to support the reduction or elimination of potential hazardous materials during production. Like ZTE, Lenovo is also against the use of conflict materials such as columbite-tantalite (coltan), cassiterite, wolframite, gold, or their derivatives (Lenovo, 2013g).

Worldwide, Lenovo has achieved a product-recycling rate of 81.6% during fiscal year 2010-2011 and (Lenovo Sustainability Report, 2011). In year 2010, 9,600 metric tons or greater than 21 million pounds of the whole processed equipment were returned by its customers, and it showed an increase of 34.8% from year 2009 (Lenovo Sustainability Report, 2011). This satisfactory result is due to the various return and recycling programs, environmentally sound managed asset recovery services (ARS) and product take back programs offered by Lenovo with maximized customization in different geography. Further, Lenovo provides its consumers and commercial clients with end-of-life management solutions especially for PCs through voluntary programs and regulatory programs (Lenovo, 2013f). On Lenovo's official website, visitors could easily find out recycling information such as locations (Lenovo, 2013f). However, this easiness of recycling and disposing are only achieved through better information retrieval for users, and it is

[20] PCC stands for Precipitated Calcium Carbonate.
[21] PIC is short for Particulate Inorganic Carbon.

not through more efficient product design from the beginning of the production. Therefore, there is no point given to Lenovo on this metric.

Further, Lenovo claims the company "*has a proven record of paper and plastic reduction*" (Lenovo Sustainability Report, 2011). During year 2010 to 2011, a global Lenovo project team was assigned with the task to reduce the amount of paper and plastic shipped together with the products. As a result, a total amount of 4 million pounds (around 1,814 metric tons) of paper and plastic were reduced during the two years. By reducing the amount of printed papers, it also eliminated over 12 million pounds (about 5,443 metric tons) of CO_2 emission (Lenovo Sustainability Report, 2011).

Lenovo is involved in making product improvements. Advanced technology used in making new generation of product models like ENGERGY STAR® and Power Manager® are great breakthrough in product development. Besides, the R&D and other learning centers of Lenovo are also discovering new green materials and production techniques to replace the ones used in current products.

Sustainable product development process	**Lenovo**
New product design for reduced use of resources	x
New product design for recycled materials	x
New product design for avoidance or reduced use of hazardous materials/components (RoHS compliance)	x
Design for easy disassembly / recycling / disposing	
Reduced packaging	x
Inventory control practices for sustainability	
Production improvement (including materials, products, processes or repairability improvements / modification)	x
Total	**5**

Green purchasing and supplier management

Lenovo is dedicated to be a corporate citizen in global supply chain. Lenovo has joined the Electronic Industry Citizenship Coalition (EICC) since June 2006. The EICC Code of conduct in use is said to be the best practices in supplier management (Lenovo, 2013g). As a member of EICC, Lenovo is committed to conduct Supplier Self-Assessment Questionnaire (SAQ) for Tier 1 production suppliers and Tier 2 production suppliers. In addition to that, Lenovo also plans regular monitoring programs with its suppliers to synchronize on the sustainable situation. Further, Lenovo also encourage its 1st tier supplier to comply with EICC standards by asking them to fill in questionnaires, sign commitment contracts and take part in training sessions. 98% of 1st tier suppliers are agreed to comply to EICC requirements (Lenovo, 2013g).

Lenovo implements Standard Purchase Order Terms and Conditions Stipulate Supplier Compliance as the Codes of Conduct for its suppliers. It regulates issues like environmental specifications, material declaration processes and other applicable law with exporting and importing legislations (Lenovo, 2012). 100 percent of the suppliers have signed these agreements (Lenovo Sustainability Report, 2013).

At Lenovo, supplier audits are done by third-party agencies. 1st tier suppliers are advised to conduct self-audit using credited EICC audit firms bi-annually. Around 80% of 1st tier component suppliers have conducted third-party audits. In addition, Lenovo also encourages its 1st tier suppliers to ask their suppliers (Lenovo's 2nd tier suppliers) to conduct similar audits and comply with EICC standards. However, there is no evidence showing that Lenovo is involved in audits for 2nd tier suppliers directly.

Lenovo explicitly states that its suppliers must "*implement and maintain documented quality and environmental management systems that meet ISO 9001 and ISO 14001 certification standards*" (Lenovo Sustainability Report, 2013).

Green purchasing and supplier management	Lenovo
Supplier supporting program and activity (e.g. assessment, training and monitoring)	x
Supplier Codes of Conduct in place	x
Collaboration with suppliers (e.g. on new product development and knowledge sharing)	
Supplier audits for 1st tier suppliers	x
Supplier audits for 2nd tier suppliers	
Regulation compliance of suppliers in raw materials / components and other certifications (e.g. RoHS, REACH and ISO 14000)	x
Total	**4**

Organization involvement and regulations

In general, there are three determinants of Lenovo used to determine which stakeholders' engagement is important for sustainability development (Lenovo Sustainability Report, 2013):

- "*Relevance of stakeholder concerns to Lenovo's core business, product set and sustainability strategy and focus areas*
- *Extent of stakeholders'' expertise, both in terms of subject matter and regional knowledge*
- *Importance of issues raised by stakeholders to Lenovo customers and investors*"

Customers, especially high-value customers are definitely an important stakeholder group for Lenovo. Customer involvement is happening actually in the early phase of production at Lenovo. According to Lenovo's Sustainability Report (2013), once after the product development phase is completed, customers are invited to conduct a series of customer-driven tests to exam the product before putting their to manufacturing. The testing methods used are simulation

evaluation and simulation audits to test quality and sustainability. The most discussed issues from customer are packaging, energy efficiency, recycling, use of environmentally friendly materials and carbon emission. By answering to these concerns, Lenovo has improved packaging design and materials; made energy efficiency data transparent; provided free consumer recycling options in countries of operation; increased the use of recycled materials to production; reported data and information of carbon emission to the public.

Lenovo has acquired ISO 9001 certificate for its quality management system to ensure its continuous improvements in product design. In year 2001, it also obtained ISO 14001 certificate for its environmental system management. Its sustainability requirements set by these certificates are studies throughout the organization as a valuable organizational learning process. Employees are required to attend training sessions to raise the awareness and learn the key points in GSCM. Lenovo has implemented four global learning programs: Learning@Lenovo, Managing@Lenovo, Contributing@Lenovo and Leading@Lenovo for employees, executives, managers and individual contributors.

Unlike Huawei and ZTE, Lenovo explicitly states in Lenovo's Sustainability Report (2013) that it is actively engaged in promoting Lenovo's green products and green images through public activities, advertising activities and sponsorships. For example, Lenovo together with Earthera are doing a green product promotion (Earthera, 2013) for ordinary consumers to offset the carbon emissions from their computer equipment. This might be due to the fact that Lenovo is more focused on consumer products such as PC and mobile phones, on the other hand Huawei and ZTE have a much wider range of business with emphasis on B2B service and solution offering. Therefore, promoting the green image to the regular consumer is more essential for Lenovo.

Lenovo's corporate sustainability policies are reflected in three primary values: social, environmental and economic. These three values are further explained in Lenovo's four corporate policies on environmental affairs mentioned before: compliance, prevention of pollution, product environmental leadership, and continual improvements. Lenovo has continuously invested in green environment. As an example said in Lenovo's Sustainability

Report 2013 (2013), in order to reduce the emission, the company has purchased "*10,500 Renewable Energy Credits (RECs) per year for three years and 3,000 wind carbon offsets per year for two years from Earth Energy Resource LLC, targeting to avoid over 25,000 metric tons of carbon dioxide during FY 2010/11-FY 2012/13.*" Lenovo has released more information about its participation and membership of globally sustainability initiatives comparing with Huawei and Lenovo. Globally, Lenovo has joined initiatives such as UN Global Impact in 2009, GFAN[22] in 2012, iNEMI[23] in 2012 and so on. Lenovo has also participated in numerous Chinese environmental initiatives like China Energy Conservation Program, China Environmental Labeling and China Green PC Standard. Lenovo has been publishing its sustainability reports since year 2009.

Chief Sustainability Officer at Lenovo acts like the leader and supporter in sustainability issues including GSCM. In addition to CSO, Lenovo has a dedicated group called Sustainability Working Group that consists of representatives from most major business areas. Their job is to evaluate the stakeholders' input in sustainability issues and ensure these inputs transform into production with related departments.

Comparing to Huawei and ZTE, Lenovo offers more detailed information about their interaction with domestic communities and governmental bodies. There are many awards received by Lenovo from various Chinese sustainability communities and governmental bodies, such as the "Green product" award received in 2004 and 2005 from China Environmental Protection Foundation and the "Green IT Product Award" received from Chines Information World in year 2008. Moreover, Lenovo is fully compliant with domestic laws regarding environmental protection. It is actively engaged in discussion with PC China Energy Efficiency Standard, Energy Saving Work Association of Chinese Institute of Electronics, China Environmental Labelling Program and China Energy Conservation Program (Lenovo's Sustainability Report, 2011).

[22] GFAN is short for Green Freight Asia Network. It is an organization promoting better air quality and more livable cities in Asia.
[23] iNEMI is short for International Electronics Manufacturing Initiative. It helps develop industry-standard approaches.

Organization involvement and regulations	Lenovo
Collaborations with consumers for sustainable product development (e.g. eco-design and packaging)	x
Establishment of green image through PR / marketing activities and advertisement	x
Organizational learning by acquirement of such as ISO 9000 and ISO 14001	x
Sustainable strategy and policy in place	x
Commitment of GSCM from senior management	x
Compliance of governmental environmental regulations (domestically)	x
Total	**6**

Product recycling and life cycle management

Lenovo is rigidly compliant with WEEE directives. All of its products are committed to WEEE requirements in product ecological design, user education about recycling and waste management, information reporting, collection / recycling / disposal facilitation, and information providing to treatment centers (Lenovo, 2013h).

Lenovo offers Product Take Back program. In calendar year 2012, there were 24.5 million pounds (about 11,113 metric tons) of products and components taken back to Lenovo through this program. They were from customers, Lenovo's manufacturing and R&D scraps, and employee equipment (Lenovo Sustainability Report, 2013). There is this program dealing with refurbished and scrapped products, but there is no further information about selling them to the secondary market or how Lenovo treats them in detail.

At Lenovo, product end-of-life management includes a full range of aspects, like "*reuse, recycling, refurbishing, de-manufacturing, dismantling, reclamation, shredding, treatment and*

disposal of products and components" (Lenovo Sustainability Report, 2013). Among the 13,100 metric tons of products and components managed by Lenovo in year 2012, 9.8% were reused as products or components, 84% were recycled as materials, 3.2% were incinerated but recovered with waste-to-energy, 0.3% were incinerated as disposal. Finally, only 2.7% were ended with landfill (Lenovo Sustainability Report, 2013). Therefore, it shows that some of the recycled components and materials are reintegrated into Lenovo's product process.

Product recycling and life cycle management	**Lenovo**
WEEE compliance	x
Investment recovery (sales of excess inventories / materials, sales of scrapped or refurbished products /	
Reintegration of recycled materials	x
Total	**2**

4.2. Results and managerial implications

After the analysis of the GSCM practices for Huawei, ZTE and Lenovo, Table 4.1 shows the results in a nutshell with a grand total of scores in the end.

From Table 4.1, it is easy to conclude that Lenovo has the highest scores among the three while ZTE has the lowest scores. However, the difference is quite minimum. These three companies still are capable of representing the highest level of GSCM practices in Chinese electronics industry. According to the results, they seem to be equally good with the first element which is sustainable product development. However, none of them seems to official reveal any information regarding inventory control practices for sustainability. In the second element green purchasing and suppliers management, Huawei has a slight better performance in collaborations with suppliers in product innovation / development and knowledge sharing. In the third element organization involvement and regulations, Lenovo has an advantage. In fact, Lenovo is the only company who revealed detailed information about engagement with domestic communities /

governmental bodies and green marketing activities. As for the last element product recycling and life cycle management, Lenovo also publishes more relevant information, especially about reintegration of recycled material. What is missing from there of them is the situation with investment recovery – how they handle the excess inventories / materials and scrapped or refurbished products / materials.

Table 4.1: Results of three companies after evaluation of GSCM practices by the model (by author)

Sustainable product development process	**Huawei**	**ZTE**	**Lenovo**
New product design for reduced use of resources	x	x	x
New product design for recycled materials	x	x	x
New product design for avoidance or reduced use of hazardous materials/components (RoHS compliance)	x	x	x
Design for easy disassembly / recycling / disposing		x	
Reduced packaging	x		x
Inventory control practices for sustainability			
Production improvement (including materials, products, processes or repairability improvements / modification)	x	x	x
Total	**5**	**5**	**5**
Green purchasing and supplier management			
Supplier supporting program and activity (e.g. assessment, training and monitoring)	x	x	x
Supplier Codes of Conduct in place	x	x	x
Collaboration with suppliers (e.g. on new product development and knowledge sharing)	x		
Supplier audits for 1st tier suppliers	x	x	x
Supplier audits for 2nd tier suppliers			

Regulation compliance of suppliers in raw materials / components and other certifications (e.g. RoHS, REACH and ISO 14000)	x	x	x
Total	**5**	**4**	**4**
Organization involvement and regulations			
Collaborations with consumers for sustainable product development (e.g. eco-design and packaging)	x	x	x
Establishment of green image through PR / marketing activities and advertisement			x
Organizational learning by acquirement of such as ISO 9000 and ISO 14001	x	x	x
Sustainable strategy and policy in place	x	x	x
Commitment of GSCM from senior management	x	x	x
Compliance of governmental environmental regulations (domestically)	x	x	x
Total	**5**	**5**	**6**
Product recycling and life cycle management			
WEEE compliance	x	x	x
Investment recovery (sales of excess inventories / materials, sales of scrapped or refurbished products / materials)			
Reintegration of recycled materials			x
Total	**1**	**1**	**2**
Grand total	**16**	**15**	**17**

4.2.1. Sustainable product development

The analysis and evaluation results show that well-adopted by the three companies, and they could be used as role models for other less sustainable-advanced Chinese OEMs. All of these

three companies have some assessment tools like LCA in place. In the aspect of innovation in product ecological design, all of these three have invested in R&D or learning centers around the world for discovering new materials and technologies. Moreover, all of them are compliant with related directives and regulations both internationally and domestically. In their sustainability reports, they have always set some targets for the future and review the targets annually, such as the minimized use of a certain hazardous materials in product design and development.

The importance of R&D is full perceived by many foreign companies. Nokia once made eco-designed phones with 100% recyclable materials, such as Lumia 1520 (Nokia, 2013). However, continuous and strong emphasis in R&D seems to be difficult for many Chinese industry players. Reasons might be the lack of some needed expertise and know-how. Huawei, ZTE and Lenovo are companies that have operations all over the world, but more Chinese industry players are only operating domestically or in Asia. Thus, the access to world's top-level technologies and tools is actually quite limited for smaller players. This issue may be mitigated by attending more international discussions about innovation and joining more relevant associations or programs where some of the experiences are shared. Besides, it seems that Chinese industry players don't really pay special attention or reveal more information to inventory practices for sustainability. Inventory techniques used for manufacturing companies are actually quite essential to achieve sustainability by for instance energy saving for storages and reduce of excess materials stored,

4.2.2. Green purchasing and supplier management

The basic practices in supplier management such as assessment tools, monitoring, auditing, supplier training and supplier Code of Conduct are well stated and implement during operations. Further, all of the three companies have also required their suppliers to comply with directives such as RoHS for hazardous substances concern. However, it seems that the collaboration with suppliers in advanced knowledge sharing in still missing in general. One reason may be the nature of innovation knowledge is rather sensitive and companies would like to handle it confidentially. In supply chain management, the general trend is actually moving toward more transparency. It means that the information sharing with suppliers are becoming more prevalent

and win-win partnerships are often seen as a target. Therefore, how to balance the sensitivity and confidentiality with transparence would be an issue for many industry players to study.

In addition, no company has been directly involved in audit for 2nd tier suppliers. Lenovo was the only company who suggests its 1st tier suppliers should arrange audits for their suppliers. The reason behind may be the high cost and effort associated with 2nd tier suppliers auditing and usually company has limited control and information over its 2nd tier suppliers. This problem could be alleviated by more efficient communication with 1st tier suppliers about 2nd tier suppliers and strict and clear requirements agreed with 1st tier suppliers to monitor their suppliers. In this way, companies don't necessarily need to directly involved in managing 2nd tier suppliers, but audit their performances through strict requirements set for 1st tier suppliers regarding their suppliers.

4.2.3. Organization involvement and regulations

The involvement with other stakeholder groups is equally importance for GSCM. The engagement with customers, internal employees, internal senior management and governmental bodies is taken good care of by the three companies from the results. Only Lenovo has shown the specifications on green marketing activities to the general public. As mentioned before, it may be the reason that comparing with Huawei and ZTE, Lenovo is more consumer goods driven. Thus how the general public and ordinary consumers perceive Lenovo is more important and its efforts to sustainability need to be known by them.

Therefore, there is a distinction between B2B manufacturers and consumer-goods manufacturers in promoting green image. An industry player is advised to carefully weigh the cost of green marketing against the benefits based on its business nature. Another important implication from organization involvement is that sustainability in general needs to be supported from top to down, starting from the executive level. This is also helpful for changing the mind-set towards a green company. Any cultural change in organizations is required to implement with senior management's support and appropriate learning system. Thus, Chinese industry players are suggested to think of GSCM as a strategic move that would requires efforts, commitments, and

resources. In order to do so, the company needs to firstly establish the vision, mission or policy for sustainability. If possible, it will be also helpful to set up annual sustainable targets and review the performance from previous year in annual CSR reports. It will streamline the direction of future efforts.

4.2.4. Product recycling and life cycle management

In the last element, three firms are all compliant with WEEE directives about electronics waste management since all of them are exporting their products to EU. However, for investment recovery and reintegration of recycled materials, there are very limited information and data provided officially. Lenovo is the only one who announced some detailed information and statistics about reintegration of recycled materials to its production process.

It seems that none of them has thought of taking the financial and sustainable advantages of investment recovery by selling excess materials and scrapped or refurbished products and components to secondary market. It is somewhat understandable given the fact the fact implementing such a program requires extra effort and resources, and the financial return for companies may be minimum. Another reason may be because of the different situations and facilities in different geography. It will further make it complex and unfeasible to sell to secondary markets. Further, reintegration of recycled material into their own operations seems to be an unfavorable option for many companies. This might be deviated from quality concern, cost concerns and technical concern.

Product end-of-life management is truly essential for practicing GSCM. Industry players should place heavy emphasis in this aspect. However, the practices and tools used in this aspect are still developing and evolving for many industry giants like Nokia. Thus, companies should start from one geography to another, usually start with the countries that have better facilities / infrastructures and more comprehensive legislations for recycling and secondary market selling. After gaining more relevant experiences, the company could then gradually move to countries with less convenience.

To conclude, three of the Chinese electronics companies are representing the highest level of GSCM practices, and the evaluation results also show that their adoption and practices of GSCM are at a competitive level even worldwide. However, it is worth mentioning that these evaluation results are mostly based on information and data extracted from official resources (some are from other reliable sources, like journals). So it is acknowledged that some of the performances mentioned by the company's official reports may be somewhat deviated from reality, but since three of the companies are publicly listed firms in more than one region, it is also further assumed that the information and data provided are monitored and audited by related authorities for the reliability. Finally, some managerial implications are provided for other Chinese industry players who desire to implement their GSCM practices to a higher level.

5. CONCLUSION

This research has firstly discussed the importance of implementing GSCM in general by studying the relevant literature. After a brief introduction of current status of GSCM practices in Chinese electronics industry, the paper constructs an evaluation model incorporated by previous literature and own analysis to evaluate the GSCM practices for Chinese OEMs by four big elements: sustainable product development process, green purchasing and supplier management, organization involvement and regulations, and product recycling and life cycle management. Each element is further divided into several metrics. The model is then used to evaluate the performance of three globally operated Chinese OEMs: Huawei, ZTE and Lenovo. Finally, some managerial implication is provided based on the evaluation analysis and results.

Under this structure, two main objectives of this thesis are well achieved. The first objective is to construct a valid evaluation model for GSCM under the context of Chinese electronics industry. The second objective is to test and exemplify the model with the evaluation of GSCM adoptions and practices of three Chinese OEMs. The first achieved objective is also the theoretical contribution of this paper with the hope to find the element that is Chinese specific and differences between the previous models and the model built up here.

The most important findings from the second objective discovered are the fact that there are lacking effort placed in areas like design for easy disassembly / recycling / disposing, inventory control practices, collaboration with suppliers, auditing 2nd tier suppliers, green marketing, investment recovery and reintegration of recycled materials into own production. This finding is derived from the assumption that Huawei, ZTE and Lenovo are the most sustainability-recognized companies in Chinese electronics industry.

There are some limitations in this research. As mentioned in the beginning, CSR in a concrete discipline includes social, economic and environmental practices. However, this paper only focused on environmental practices in GSCM. In the further, papers focused on other aspects of CSR like social and ethical would also be worth discovering. In addition to complete the discussions of CSR, there are also spaces for developing more metrics to further complete the

evaluation model as GSCM is evolving rapidly. The results derived from this paper is only subjected to the Chinese electronics industry, it may be difficult to apply it to other geography or other industry. Thus, future research could further discover the GSCM situation in other region and other sectors.

Another interesting topic for future research could focus more on the financial or economic performances of companies that have adopted GSCM practices to see if there are also financial benefits that could be retrieved by companies.

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