

# Case Studies of Green Supply Chain Management in China

Xianbing Liu<sup>#1</sup>, Leina Wang<sup>\*2</sup>, Yanli Dong<sup>†3</sup>, Jie Yang<sup>\*4</sup>, Cunkuan Bao<sup>\*5</sup>

<sup>#</sup> Kansai Research Centre, Institute for Global Environmental Strategies (IGES), Japan

<sup>\*</sup> College of Environmental Science and Engineering, Tongji University, China

<sup>†</sup> Graduate School of Economics, Kobe University, Japan

<sup>1</sup>liu@iges.or.jp

**Abstract**-This paper describes case studies on green supply chain management (GSCM) of three companies based in the Yangtze River delta of China. After clarifying major supply chain relationships of each company, we identified their internal and external GSCM practices. The corresponding changes of environmental and economic performances are summarized quantitatively or in a narrative manner. The case studies confirm that the multinational and foreign-funded companies have more active GSCM practices than the domestic one. Although the current mandatory policies are effective in enhancing company's environmental management in China, market actor-driven model seems more sustainable for the diffusion of GSCM practices.

**Keywords**-Green supply chain management, case study, China

## I. INTRODUCTION

Green Supply Chain Management (GSCM) is an advanced form of corporate environmental management (CEM). It addresses the communication between focal companies and the upstream suppliers as well as downstream customers aiming to provide greener products and services cooperatively [1]. There is no uniform definition for GSCM so far. However, common understandings have been formed theoretically and in practice. GSCM may be separated according to the stages of production, distribution and utilization and thus can be categorized into internally green manufacturing activities, green procurement, eco-design, green retailing and green consumption [2]. Academic and business interest in GSCM has been rising considerably in recent years, which can be observed from the number of related papers published [3]. Previous GSCM studies focused on the following aspects: General topics like the design of framework of GSCM [4]; implementation of GSCM strategies [5]; environmental assessment of GSCM practices [6]; relationship between a company's performances and GSCM practices [7]; and specific GSCM activities like green purchasing [8], total quality and environmental management [9], green marketing [10] and environmental performance evaluation of suppliers [11]. Reference [12] analyzed the motivations for the implementation of GSCM in developed economies. They found that GSCM is strongly complementary with the application of environmental management system (EMS) and contributes to the improvement of company's environmental performance. Reference [13] explored the opportunities to improve environmental performance linked in the supply chains of three small and medium-sized enterprises

(SMEs) in Nova Scotia, Canada. The authors confirmed that time and financial resources are the greatest limitations for the companies to deal with environmental issues like solid waste and energy management. Reference [14] reported the case of a printed circuit board manufacturer in Taiwan. Their result shows that choosing the suitable suppliers is a strategy of the company in minimizing its environmental impact. Reference [15] explored the capacity development for the greening of supply chains. It is confirmed that GSCM capacities are jointly developed by proactive environmental management and strategic purchasing and supplying. In spite of the comprehensive literatures in developed countries, research on GSCM remains sparse in developing countries [1], [16].

GSCM study in China is also at an infancy stage. The GSCM practices adopted by the companies in North China was once examined by a questionnaire survey carried out in power generation, petrochemicals, electric & electronic and automobile industries. The result indicates that Chinese companies in different sectors have different drivers for GSCM practices [16]. It is difficult for the surveyed companies to integrate their environmental management into daily business operations with the suppliers and customers. Most companies just begin to consider the external GSCM activities although some leading companies have practiced internally proactive CEM such as pursuing ISO14001 certification. Reference [17] confirmed that the GSCM is poor for Chinese automobile supply chain enterprises, especially in terms of external GSCM practices like green purchasing. Their GSCM practices have slightly improved environmental and operational performances. Reference [18] further analyzed the determinants for GSCM practices in China by focusing on a company's internal drivers such as support of top managers. It is stated that the pressures from external stakeholders bear further studies due to their importance in determining a company's environmental behaviors [18].

In order to close the existing research gap, we carried out an empirical study during 2008-2009 to examine GSCM practices of the companies in another region, Yangtze River delta, where has a relatively developed economy in China. Our studies were carried out in two phases. At the first stage, we conducted a questionnaire survey in two places of the study area: Taicang City of Jiangsu Province and Shanghai Kangqiao Industrial Park. One hundred and sixty five valid responses

were obtained, with 50.3% of them from machinery processing, chemical, paper and textile & dyeing industries. The collected data was used to measure GSCM practice levels of the companies and analyze the determinant factors. The result indicates that the companies are still at a preliminary stage of GSCM practices. The company's GSCM is significantly and positively associated with the external pressures from regulatory, domestic clients and business competitors and the company's learning capacity as an internal factor [19]. At the second stage, we selected three companies and carried out in-depth case studies. The main objective of the case analysis is to identify GSCM activities of the target companies and evaluate the corresponding effects. An additional topic is to discuss the possible reasons differentiating GSCM practices of the focal companies. The detailed descriptions and discussions may provide meaningful implications for the diffusion of good GSCM practices in China.

This paper describes the three case studies of GSCM and is structured as follows. Section 2 explains the analytical framework and evaluation method. After introducing the focal companies and their major supply chain relationships in section 3 and 4 respectively, section 5 describes the results of individual cases. The findings are discussed in section 6 lastly.

## II. ANALYTICAL FRAMEWORK AND RESEARCH METHOD

The importance of case study has been highlighted by a number of scholars (e.g., [20]). This kind of research shall be conducted in a structured way to ensure its rigor and quality. According to the case study classifications by [21], this research may be viewed as an exploratory study comprising

data bearing on cause-effect relationships and discussing how things happened. It applied a process proposed by [22], similar to many field researches. The linear and sequential process is composed of five steps including definition of research question, analytical instrument development, data gathering, data analysis and possible case dissemination.

The analytical framework of this study is depicted in Fig.1. There are two major components, namely 'Task A' and 'Task B'. 'Task A' is to identify the practices and opportunities of GSCM of focal companies. The same as [19], four categories of GSCM practices are considered: internally proactive environmental activities, evaluation and selection of upstream suppliers, eco-design in cooperation with the suppliers and supplier managed inventory services. 'Task B' is to evaluate the effects of GSCM practices in terms of economic and environmental performance changes but not excluding improvement of business process and client services. Informed by our questionnaire survey in earlier, we are aware that the focus shall be given to the company's internal environmental management activities and the external GSCM practices in cooperation with direct business partners. The case studies are thus limited within the focal company and its 1st tier of suppliers and clients.

One method examining the relationships between GSCM and environmental and economic performance is regression analysis using questionnaire survey data (e.g., [23]). For describing the effects of specific GSCM activities, we used cost and benefit analysis in this study. The cost includes capital investment and management inputs like labor cost, while benefit includes direct and indirect ones. Reduction of raw materials, energy consumption and waste disposal expenditure may be viewed as direct benefit. Indirect benefit

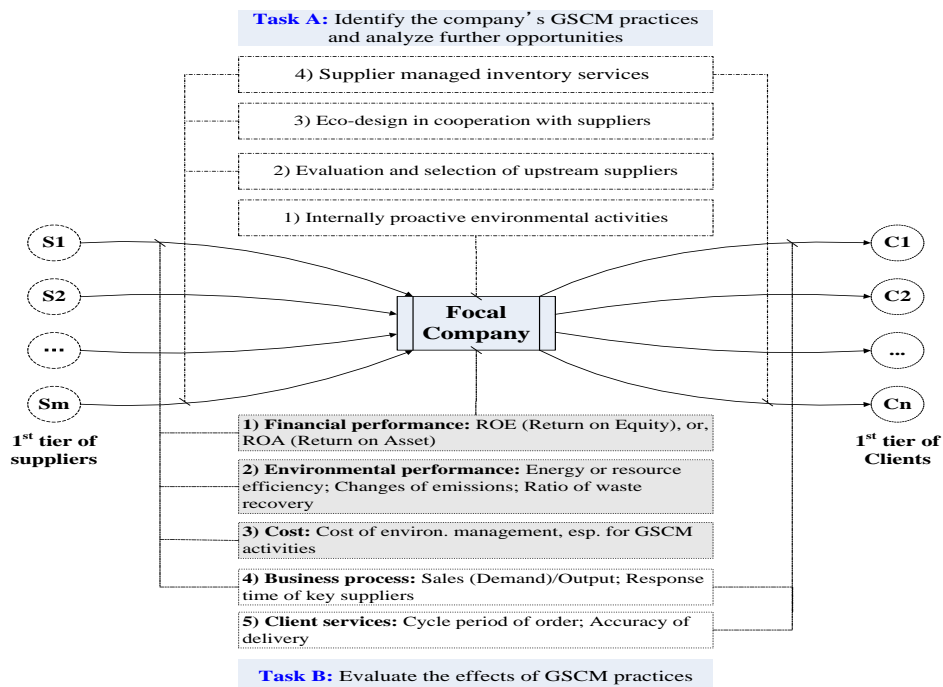


Fig.1 Overall analytical Framework for GSCM Case Studies

is complex for quantification. As examples, GSCM may improve the business image. In return, the company may get rewards and subsidies from the government. Their products may be chosen by more customers. The company can accumulate experiences in environmental management by communicating as well as collaborating with suppliers and clients. These experiences are important knowledge assets for the companies.

The data used in this study comes from various available documents, including environmental impact assessment reports, cleaner production audit reports, energy audit reports and yearly environmental reports of the target companies. We visited all the three companies twice in August and November of 2009 respectively, and interviewed the environmental and operational managers with relevance. The hearing interviews concentrated on the questions for understanding the company's major supply chain relationships, GSCM activities adopted in recent years, opportunities for further GSCM practices and the changes of environmental and economic performances due to GSCM practices. The following communications by e-mail and phone call are applied for further data gathering and confirmation.

### III. SELECTION OF FOCAL COMPANIES FOR THE CASE STUDIES

We tried to follow the criteria suggested by [21] in selecting the case companies in this study. The referred criteria include: if the case is representative, standing as an example of a wider group; and, if it is a revelatory case, where the investigator has an opportunity to observe a phenomenon inaccessible so far [21]. Practically, as the GSCM case studies require internal management information of companies, a primary factor in selecting the cases is whether the company would cooperate or not. The second concern is that the candidate company should be environmentally advanced and has practiced certain GSCM activities. The representativeness of the cases in the study area is another factor for consideration. As mentioned earlier, machinery manufacturing, paper making and chemical companies are typical industries of the study area [19]. We finally selected three companies, with one from each of three representative sectors. They are Shanghai GKN Drive Shaft Co., Ltd., Taicang Zhenhui Chemical Fiber Co., Ltd. and Nine Dragons Paper Industries (Taicang) Co., Ltd., abbreviated as SDS, Zhenhui and Nine Dragons respectively. During our preliminary visit in August, 2009, all the three companies agreed to cooperate in this study.

SDS is a manufacturer of automotive components based in Shanghai Kangqiao Industrial Park. Zhenhui is a chemical fiber company and Nine Dragons is a large paper-making plant, with both situated in Taicang City. The background of the three companies is listed in Table 1.

### IV. MAJOR SUPPLY CHAIN RELATIONSHIPS OF THE TARGET COMPANIES

#### A. Major Supply Chain Relationships of SDS

Major supply chain relationships of SDS are depicted in

Fig.2. Raw and supplemental materials of SDS mainly come from the domestic suppliers. Different types of steel are bought from Shanghai Fifth Steel Works of Baosteel Group. Whereas, lubricating oil and grease are imported from Germany. The other product parts purchased by SDS mainly include different types of besides-star wheel from Shanghai Automotive Forging Factory, dust cap from the 1st Branch Factory of Hualing Mechanical Works, different types of clamps from Oetiker Industries Tianjin Ltd., steel ball from Shanghai Bearing Works. Products of SDS are CVS, propshafts, industrial shaft, universal joint drive shaft assembly and other automotive components. Downstream customers are major car makers domestically including Shanghai-Volkswagen (SVW), SGM, FAW-Volkswagen (FAW-VW), Chery, Dongfeng Honda, Nissan, B-BMW, BJC, HN-Mazda and Guangzhou Honda. SDS's main customers, SVW, FAW-VW and SGM, have a large share of market in China. These automobile makers have already practiced strict management in the design, manufacturing, parts supply, sales service process, with mature GSCM practice regarding new product design & development, manufacturing and material management, pollution control and energy saving.

#### B. Major Supply Chain Relationships of Zhenhui

Major supply chain relationship of Zhenhui is described in Fig.3. Main raw and supplemental materials of Zhenhui include purified terephthalic acid (PTA), ethylene glycol (EG), and the major accessories including JN-D301 POY oil, JN-D202 FDY oil, titanium dioxide, antimony triacetate and liquid heat medium. The raw material PTA is mainly bought from multinational companies and domestic suppliers as Ningbo Mitsubishi. The suppliers of supplemental materials are not listed here due to the reluctance of the company's managers to provide more specific information. The products of Zhenhui are various types of polyester chips, polyester pre-oriented yarn (POY), low elastic polyester filament (DTY), polyester fully drawn yarn (FDY). Most clients are small and medium-sized enterprises and a third party is responsible for the logistics between Zhenhui and the clients.

#### C. Major Supply Chain Relationships of Nine Dragons

As described in Fig.4, the main raw materials of Nine Dragons are imported waste paper and unbleached softwood pulp, with 70% of them being from Europe, the U.S. and Japan, and the rest 30% from the eastern provinces of China. The major supplier of waste paper in abroad is the America Chung Nam, Inc., which is the holding company of Nine Dragons. The key domestic supplier is Jiangsu Renewable Resources Co., Ltd. The supplemental materials purchased by Nine Dragons are dispersed rosin size, chemical additives for papermaking, industrial oxidized starch, polyester wire mesh, blankets, dry nets, etc. The suppliers of these supplemental materials are not listed here due to the reluctance of the company's managers to provide more specific information. The company's products are corrugated cardboard and kraft linerboard, all for domestic market. Its customers are mainly located in eastern China as well as the other provinces. The fixed customers have a share of 80% of the total. The indirect

customers are mainly home electronic appliance producers, such as Asus, Foxconn and Samsung, etc.

## V. RESULTS OF THE CASE STUDIES

### A. Results of the Case Study of SDS

#### 1) GSCM practices of SDS and their effects:

SDS has carried out various internally proactive environmental management activities. The company passed ISO14001 certification in 2001 and set up a division in responsible of environmental management in 2002. In 2004, SDS set up a leading team on environment, safety and occupational health with a full-time engineer and a few other part time environmental staffs.

TABLE I BACKGROUND OF THE THREE COMPANIES

Item	SDS	Zhenhui	Nine Dragons
<b>Establishment time</b>	May, 1988	July, 2002	April, 2002
<b>Location</b>	Shanghai Industrial Park	Kangqiao Taicang city, Jiangsu Province	Taicang city, Jiangsu Province
<b>Ownership</b>	Joint-venture	Private, domestic funded	Private, fully foreign funded
<b>Number of employees</b>	1,747	1,100	2,200
<b>Major products</b>	Auto constant velocity sideshafts (CVS), propshafts and others	Polyester chips, polyester pre-oriented yarn (POY), polyester fully drawn yarn (FDY), polyester DTY, etc.	Corrugated paper, corrugated cardboard and kraft linerboard
<b>Production capacity in 2008</b>	4 million pieces of CVS and 0.6 million propshafts	30,000 tons of polyester chips, 140,000 tons of POY& FDY	3 million tons of corrugated paper
<b>Annual sales</b>	2.1 billion CNY (2008)	1.85 billion CNY (2008)	3.3 billion CNY (2007)

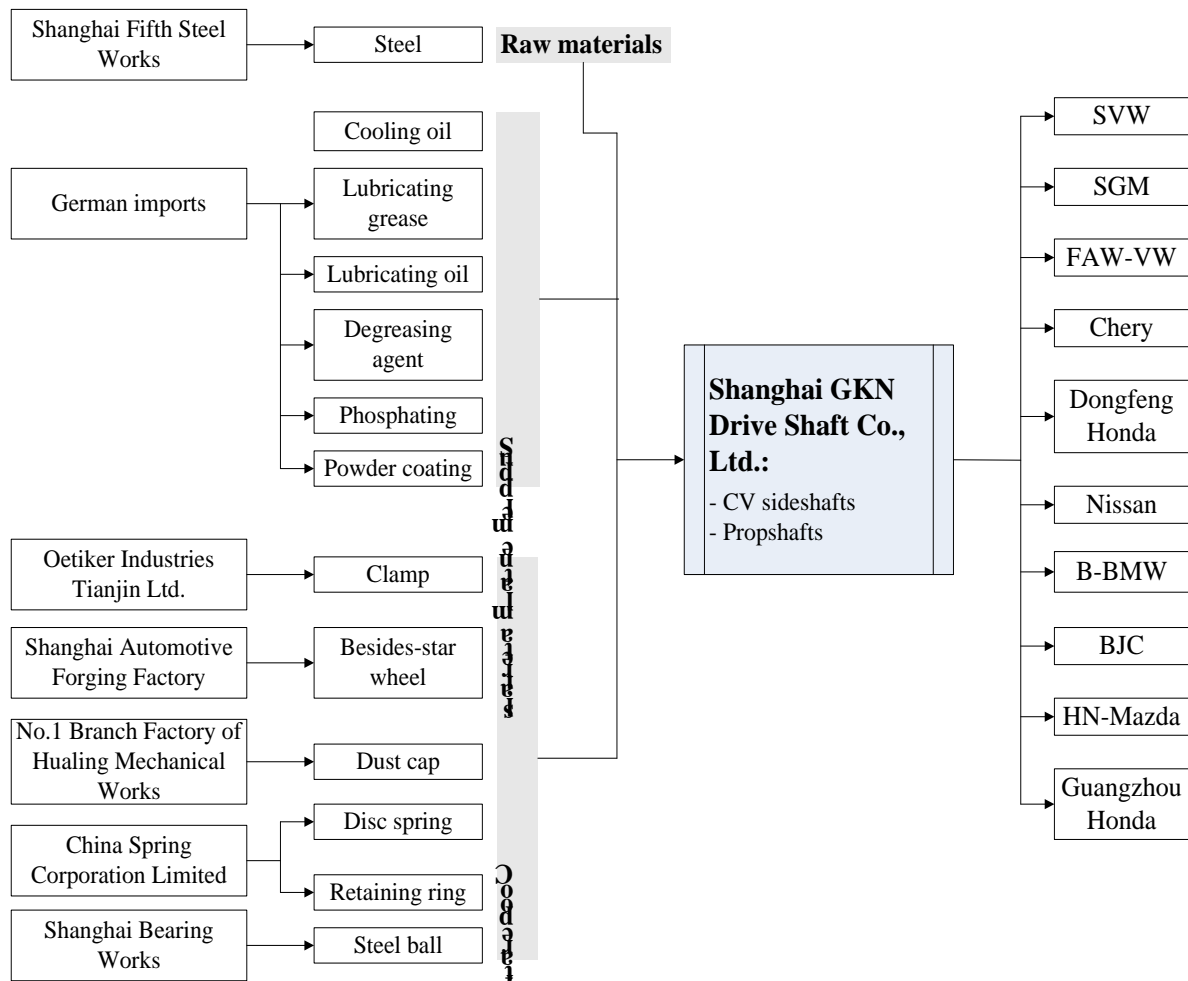


Fig.2 Main supply Chain Relationships of SDS

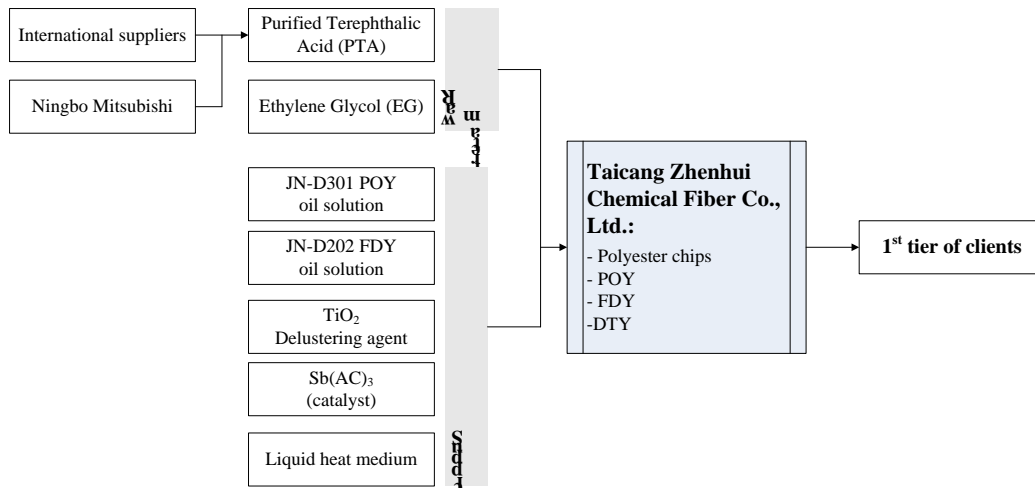


Fig.3 Main supply Chain Relationships of Zhenhui

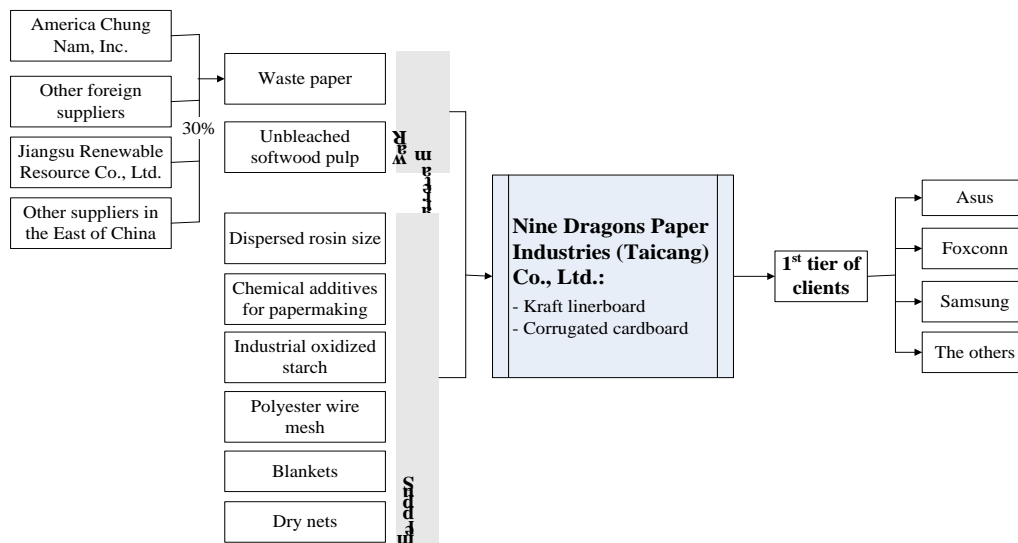


Fig.4 Main supply Chain Relationships of Nine Dragons

Two initiatives stand out as GSCM practices of SDS in recent years. One is the “SAIC-35% Energy Saving Plan” launched by its holding company, Shanghai Automotive Industry Corporation (SAIC). The other is the “SGM-Greening the Supply Chain Project” organized by a major client, Shanghai General Motors (SGM). The former is an internal GSCM practice for improving energy efficiency of SAIC as a whole. On August 5, 2007, SAIC published its goal of energy saving, to reduce the comprehensive energy use per 10,000 CNY output by 35% based on 2005 level by the end of 2010. The second is the company’s GSCM practices jointly implemented with SGM as an external business partner. SGM launched the “SGM-Greening the Supply Chain Project” in January of 2008. SDS formally participated in the project of SGM and took a variety of actions.

## 2)Energy Saving Activities of SDS Based on “SAIC-35% Energy Saving Plan”

The energy saving activities of SDS under “SAIC-35% Energy Saving Plan” are listed in Table 2, which include

managerial measures, structure modification and technological upgrading. During January to May, 2009, SDS put forward 48 proposals on energy saving, among which, 43 (around 90%) have been completed for achieving the goal set by SAIC. The energy saving programs saved money in terms of cost reduction of electricity and raw materials. In addition, energy saving and pollution reduction are current focus of environmental policy of central and local governments in China, becoming better environmental performances would help the company earn more subsidies from the governments. SAIC performs a monitoring role for energy saving activities of SDS. SDS is required to follow the environmental policies of the holding company and to appropriately report its comprehensive energy use. In 2008, SAIC arranged training for SDS employees on energy management.

Table 3 exhibits the achievements of energy saving of SDS. Using the fixed price of 2005, the comprehensive energy use per 10,000 CNY of output declined by 13.9%, 27.7% and 28.9% in 2006, 2007 and 2008, respectively, compared with the level of 2005. Further energy efficiency improvement can

be observed in the first half of 2009. During January to May of 2009, the company's total energy use indicated a decrease of 7.8%, and the energy use for making every set of CVS decreased by 4.1%.

### 3) Involvement of SDS in "SGM-Greening the Supply Chain Project"

SDS participated in "SGM-Greening the Supply Chain Project" as an important supplier of SGM. The activities and corresponding achievements in 2008 are listed in Table 4. The GSCM practices of SDS include: participation of

environmental trainings of the suppliers provided by SGM; preparation of an action plan of GSCM practices; review of the plan and onsite guidance by SGM; implementation of the examined action plan; implementation information sharing; and, performance evaluation and feed back by SGM. In 2008, SDS implemented three projects: water balance, energy audits, and saponification instead of spraying oil before cold sizing for achieving zero emission of washing liquid. The total investment was 0.41 million CNY. The gross benefit was

TABLE II APPROACH, FOCUS AND ACTIVITIES OF ENERGY SAVING OF SDS DURING 2008 TO JUNE OF 2009

Approach	Focus	Activities
Managerial measure	Establishment of energy saving institution and plans, training and education	<ul style="list-style-type: none"> <li>◆ Establishment of energy management team;</li> <li>◆ Three levels of energy management network: company, factory and workshop;</li> <li>◆ Establishment of energy management files based on ISO14001;</li> <li>◆ Qualification certificate for energy management members, regular training of the management team;</li> <li>◆ Training of related staffs in 2008;</li> <li>◆ Electromechanical energy saving training of related workers in 2009;</li> <li>◆ Monthly check of energy saving and emission reduction;</li> <li>◆ Monthly meeting on energy saving.</li> </ul>
Structural modification	Adjustment of equipment, product and energy structure	<ul style="list-style-type: none"> <li>◆ Restructuring energy use, phase-out of coal-boiler and phase-in of oil-fired boiler;</li> <li>◆ Introduction of precision forging equipment to replace hot forging equipment;</li> <li>◆ Rationalization of production in the second half of 2008 in the market recession.</li> </ul>
Technological upgrading	Identification and implementation of feasible projects	<ul style="list-style-type: none"> <li>◆ Adjustment of fan controller in the cooling tower to operate the fans based on water temperature;</li> <li>◆ Improvement of continuous carburizing furnace;</li> <li>◆ Improvement of air-cooling control;</li> <li>◆ Improvement of flow gate control;</li> <li>◆ Reuse of residual heat of air compressor;</li> <li>◆ Upgrading electricity meters;</li> <li>◆ Reuse of reclaimed water.</li> </ul>

TABLE III COMPREHENSIVE ENERGY USE OF SDS DURING 2005-2008 (WITH FIXED PRICE OF 2005)

	2005	2006	2007	2008	2010
Output value (10,000 CNY)	132,616	184,228	243,296	230,479	--
Comprehensive energy use (tce)	25,831	30,914	34,272	31,922	--
Energy use per 10,000 CNY output	0.195	0.168	0.141	0.139	--
Goal of energy use per 10,000 CNY output	0.2	0.175	0.151	0.127	0.127
Growth rate of output value	--	38.9%	83.5%	73.8%	--
Growth rate of energy use	--	19.7%	32.7%	23.6%	--
Decline rate of energy use per 10,000 CNY output	--	13.9%	27.7%	28.9%	35% (planned)

0.7135 million CNY due to the energy saving, water saving and waste generation reduction. SDS thus achieved 0.3035 million CNY net profit. The environmental benefit was significant, including a reduction of 904.4 tons CO<sub>2</sub> emissions and 50.1 thousands tons wastewater, and a saving of 562,417 KWh electricity and 19 tons coal annually.

### 4) A comparison of GSCM practices of SDS under "SAIC-35% Energy Saving Plan" and "SGM-Greening the Supply Chain 2008 Project":

Under "SGM-Greening the Supply Chain 2008 Project", SDS applied the activities by itself with the support from SGM in information, technology and management. This is a kind of flexible, voluntary and mutually beneficial style. Besides the fact that SGM is an important customer of SDS, the potential benefits, including direct cost savings and indirectly stable supply chain relationship and advertising effects, are commonly recognized. Comparing with SDS-SGM cooperation model, "SAIC-35% Energy Saving Plan" is a requirement of the largest shareholder of SDS. Even the

proposed energy saving target is not mandatory, SDS actively joined in this plan due to benefit from energy saving and technical support from SAIC.

The identified GSCM activities of SDS are consistent with the finding of our earlier questionnaire survey. SDS is actively

practicing internally proactive environmental management like energy saving [19]. SDS situates in a restricted position on the supply chain of automobile industry. Besides SGM, large clients, such as Toyota, also require SDS to refrain from using toxic substances in the products according to European regulations. Accordingly, SDS has to require its major raw

TABLE IV THE PRACTICES OF SDS UNDER 'SGM-GREENING THE SUPPLY CHAIN PROJECT'

Project No.		1	2	3	In total
	Action plan	Water balance of Zhoupu plant	Energy audit	Saponification instead of spraying	
Content	Action content	Searching water saving potentials in the plant	Increasing ability of CC inside wheel in P6 furnace	Saponification instead of spraying oil	
<b>Implementation</b>	Department on duty	Planning department	Heat treatment workshop	Forging workshop	
	Start time	April, 2008	May, 2008	May, 2008	
	Finish time	September, 2008	September, 2008	December, 2008	
<b>Economical performance</b>	Investment (CNY)	60,000	0	350,000	410,000
	Raw materials saving (CNY/year)	--	--	170,000	170,000
	Energy saving (CNY/year)	--	330,000	21,280	351,280
	Water saving (CNY/year)	127,215	--	1,542	128,757
	Waste charge saving (CNY/year)	51,480	--	12,000	63,480
	Total saving (CNY/year)	178,695	330,000	204,822	713,517
	Investment payback period (year)	4 months	--	16 months	--
<b>Environmental performance</b>	CO <sub>2</sub> reduction (ton/year)	--	562.4	342	904.4
	Energy saving	--	562,417KWh/year	19 tce per year	--
	Water saving (ton/year)	49,500	--	600	50,100

materials suppliers like Baosteel Group to follow similar standards and conduct supplier assessment on quality, safety and environmental risks. As a giant corporation, Baosteel Group is also the raw materials provider of automobile makers. The relationships of SDS and its major raw material providers and clients are interactive. SDS just starts to consider to provide environmental training or technical assistance for its suppliers but more likely to receive supports from the more capable clients at current phase.

##### 5) Further GSCM Opportunities of SDS:

The GSCM activities of SDS to be implemented further include: implementation of cleaner production audit; to reclaim the metal, wooden and cardboard boxes and other containers; to reclaim the byproducts; and, to collaborate with the suppliers to purchase environment-friendly materials.

Although SDS is not on the list of compulsory cleaner production audit, it still has potential to save energy and reduce emissions by using this approach. Currently, the containers for product transportation are all used for one time and the reclaiming system has not been established. The containers have high angular rigidity and are hard to deform. It is possible to reuse them. SDS could collaborate with its clients for collecting these containers. The product of SDS is automotive transmission shaft which is made from steel. The byproducts like scraps and used products can be recycled. SDS should collaborate with the car assemblers in recycling and remanufacturing of the vehicle parts. SDS is the final user of various lubricants and parts. It could require green products

from the suppliers, set standards and evaluate environmental behaviors of suppliers and even provide technical assistance to the suppliers.

#### B. Results of the Case Study of Zhenhui

##### 1) Internal GSCM Practices of Zhenhui and Their Effects:

In December 2004, Zhenhui established a leading team for environmental management headed by the company top manager. Zhenhui passed ISO14001 certification in 2006. GSCM practices of Zhenhui focus on internal activities like cleaner production audit and energy audit.

In April 2007, Zhenhui started the work of cleaner production audit. In September 2007, "Cleaner Production Audit Report of Zhenhui" was finalized. In the same year, the company carried out several technological upgrading projects including the renewal of boiler auxiliary equipments, air compressor modification of elasticizing plant and reuse of the reclaimed water. The detailed activities of Zhenhui for cleaner production are listed in Table 5.

In March 2008, Zhenhui finished its energy audit report and proposed several energy saving advices. The main contents of energy saving audit are listed in Table 6, which include energy management status, energy consumption structure and energy measurement and statistics. The significant parts are the audit of energy management status, potential analysis of energy saving and technological upgrading proposals. In November 2009, Zhenhui was selected as a pilot company for the

development of circular economy. This indicates that the efforts of Zhenhui in energy saving and cleaner production have been recognized by local government.

TABLE V  
CLEANER PRODUCTION ACTIVITIES AND THEIR EFFECTS OF ZHENHUI

Audit time	April-July, 2007
<b>Contents and procedures</b>	<p>Planning and Organization: Established a team for cleaner production in May, prepared the audit plan and arranged training.</p> <p>Pre-Assessment to find cleaner production opportunities: Decide filament process as audit focus; formulate cleaner production objectives and measures; encourage the employees to propose suggestions.</p> <p>Assessment: Material flow analysis and identification of waste sources.</p> <p>Programs screening: Selected 20 feasible programs with no or low cost and 3 medium or high-cost programs.</p> <p>Program implementation: Allocation of funding and implementation department; assessment of implementation effect.</p> <p>Continued cleaner production: Establishment of organization; keep cleaner production working group; incorporate cleaner production into daily operation; establish incentives; make sustainable cleaner production plan.</p> <p>Experience: Cleaner production audit can improve environmental management dramatically.</p>
<b>Specific programs</b>	<p>20 low-cost programs: Including substitution of cooling water by desalinated water; construction of sealing walls for coal storage space; waste separation and recovery, etc.</p> <p>2 medium-cost programs: Replenishment of air blower in spinning plant; substitution of finisher component by sand cup.</p> <p>1 high-cost program: Reuse of the reclaimed water.</p>
<b>Effects</b>	<p>The value from coal, energy, material and water saving and reduction of wastewater and solid waste reached 9.4373 million CNY in 2007. From January to August 2007, the wastewater discharge was 108,300 tons, declined by 42.57% from the same period of 2006. Since July 12, 2008, the daily sewage reduced to 13 tons and COD concentration was 14 mg/l, greatly decreased from 30 mg/l in previous year. Waste silk per ton of product was 8.79 Kg, better than the level 3 in 'Cleaner Production Technical Guideline of Fiber Industry'.</p>

There are five major technological upgrading projects for energy saving and pollution reduction in Zhenhui. The first one is to reuse the reclaimed water using the domestically advanced wastewater treatment equipment. It is the first water reclamation facility in the textile industry of China. Water reclaimed per day is 600 m<sup>3</sup>, which can save 504,900 CNY of water fee and 50.91 tce (ton of coal equivalent) per year. The total investment of this project was about 609,000 CNY. The second project is to reuse the exhaust gases. The residual gas is combusted in the coal stove to reduce air pollutants and save energy. The third one is to reuse residual heat. In this project, atmospheric steam is utilized as the source of heat to reduce the operating cost. The rest are two electricity-saving projects. One is to change the air compressors to be frequency convertible ones. According to the actual needs, two air compressors and related pipes were added. This can save 1.0512 million KWh electricity per year, equaling to 378.43 tce of energy and 0.5359 million CNY of electricity fee. The investment was 1.0 million CNY. The other is to optimize the pump system using high efficient pumps. Automatic control system was also installed.

Zhenhui achieved good economic and environmental performances by the end of 2008 due to above efforts. Zhenhui got at least 9.4373 million CNY benefits by reducing the use of water, electricity, coal and raw materials, and minimizing wastewater discharge and waste silk. Due to the

implementation of technological upgrading projects, Zhenhui saves 965.89 tce of energy, 0.198 million m<sup>3</sup> of water and 4.5005 million CNY per year. Accordingly, the pollutant emissions were stable during 2005-2007 and showed an obvious improvement in 2008. The wastewater discharge amount exceeding national and local standards was around 0.215 million tons per year before 2008. This number decreased to 0.0135 million tons in 2008 with the operation of new water purification facility.

## 2) Other GSCM Activities of Zhenhui:

Zhenhui constructed an elasticizer industrial park near the company, which is equipped with 100 sets of high-speed elasticizers. Most companies in this park are small household workshops as clients of Zhenhui. Zhenhui provided workshops, financial guarantees and environmental service like sewage collection and treatment for them. Environmental management experiences of Zhenhui may be learned by these small companies in the future.

## 3) Further GSCM Opportunities in Zhenhui:

The environmental activities that Zhenhui plans to accomplish in the next stage are further energy saving and emission reduction. One is to install energy monitoring instruments for major energy-using equipments, such as circulating pumps, water pumps, air compressors, cooling



tower blowers and freezers, to strengthen the daily energy management. The other is to continue to identify energy saving potentials and implement the necessary projects.

Zhenhui is a raw material producer with heavy pollution intensity. The downstream customers are small workshops, which largely rely on Zhenhui in capital, working place and related infrastructures, and lack power in shaping the supply chain relationships. Nevertheless, the internally environmental practice of Zhenhui since 2006 is a good start for further

GSCM practices with the company's suppliers and clients. Zhenhui may request the suppliers to provide environmentally-benign materials, set criteria and evaluate their environmental performances of the suppliers and provide environmental trainings for the suppliers. Recently, the Research & Development Center of Zhenhui was recognized as technology diffusion center of fiber industry at provincial level. This center may collaborate with suppliers and clients for developing green products in the future.

TABLE VI ENERGY AUDIT RESULTS OF ZHENHUI

<b>Energy management institution</b>	Current situation	The leading group consists of general manager, deputy general manager and department leaders. Daily working team is founded. The part-time energy managers are equipped. Responsibility of energy management is clear.
<b>Energy management system</b>	Current situation	An internal energy management system has been set up by issuing various standards, guidelines and assessment methods, etc.
	Problems	Continuous improvement is needed.
	Suggestions	The company should collect new regulations and update its management system accordingly.
<b>Energy measurement</b>	Current situation	The monitoring instruments for total energy use are completely equipped; the rate of meters for sub energy-using equipments is 77.5%, and the rate for all the energy-using equipments is 22%.
	Problems	The rate of measuring instruments for the second and third level energy using equipments is low. The detailed data collection is difficult.
	Suggestions	The existing measuring instruments should be managed appropriately. The files of measuring instruments shall be established.
<b>Energy statistics</b>	Current situation	The energy consumption is reported by each sector, the financial department counts the energy purchase, use and inventory quarterly and sends the data to parent company and local statistics agency.
<b>Energy quota management</b>	Current situation	Internal assessment method of materials and energy use of the company and specific method for elasticizer department have been formulated.
	Problems	Assessment items and basic data are not accurate and complete.
	Suggestions	To equip with measuring instruments and improve the monitoring; to specify the indicators for products, main processes and equipments.
<b>Technological measures for energy saving</b>	Current situation	Several technological measures have been made in 2007, including application of frequency convertor, reasonable choice of air pressure for elasticizing, etc. The total investment is 9.399 million CNY. They can save 965.89 tce, 0.198 million m <sup>3</sup> water, and 4.5005 million CNY of cost annually.
<b>Training for energy saving</b>	Current situation	Energy saving training is promoted; the newsletter is utilized to promote the awareness; advanced departments and individuals are awarded.

### C. Results of the Case Study of Nine Dragons

#### 1) GSCM practices of Nine Dragons and Their Effects:

Nine Dragons is a fully foreign-owned company and sensitive to the change of environmental policies of the government due to high energy and pollution intensities. During 2003 to 2006, Nine Dragons passed ISO14001 certification, OHSAS (Occupation, Health and Safety Administration System) certification and China Environmental Labeling certification. Nine Dragons established the Department of Environmental Protection and Resource Recycling and the Supervision and Management Council within the company. Nine Dragons addresses environmental trainings at the company, workshop and team levels. The company level training targets all department managers usually at a frequency of once a quarter. The workshop level training is arranged once a month by the Department of

Environmental Protection and Resource Recycling. The team level training is conducted for all the related workers frequently.

The GSCM practices of Nine Dragons focus on internally proactive environmental management, including technological upgrading for pollution control and energy audit. The environmental regulations for paper industry in China are becoming much stricter in recent years. In 2006, Nine Dragons was once pended on a blacklist due to the delay in implementing energy saving plan of Jiangsu Province. As the top manager highly concerns the reputation of the company, various environmental efforts have been made since then.

In March 2007, Nine Dragons invested 60 million CNY to reconstruct the wastewater treatment plant by introducing the efficient internal circulation reactor (ICR). The company also built up a water reclamation system which can recycle 36,000

tons of water per day and increase the water reuse ratio up to 47%. Upon the completion of these reconstruction projects, the company treated 1.7235 million tons of wastewater in 2008. The average concentration of COD decreased from 80mg/l in 2007 to 46.2mg/l in 2008. A total of 582.5 tons of COD was removed. 5.405 million tons of water was reused and 249.7 tons of COD was reduced through water reclamation. The total COD reduction was 832.2 tons in 2008. The company won the provincial award due to the high ratio of water reclamation in 2008.

In 2009, Nine Dragons carried out a project collecting and reusing the residual heat from the papermaking lines. The company developed a heat recovery system to reuse the energy resulting from excessive high temperature of steam discharged from paper drying. This system cost 23.06 million CNY for equipment installation. In a packaging product line with a capacity of around 1.0 million tons per year, 180,259 tons of steam is used for heating ultra-clean water for pulp making and clean water for paper making. By this system, the production line can save 22,172 tce of energy per year, equaling to 17.74 million CNY assuming the coal price at 800 CNY/t. The other technological upgrading of Nine Dragons included cooling tower construction to recycle the cooling water. The water used in high quality paper-making process is reused for producing the low quality paper. The wastes, which can not be recycled, are burnt by circulating fluidized bed technology for collecting the heat. The residual of the burned wastes are used to make chopping block of forklift.

As shown in Table 7, the contents of energy audit in Nine Dragons are similar with Zhenhui and focus on the identification of energy management status, energy saving potential and technological measures. According to the analysis of energy saving potentials, Nine Dragons should draw attention to the equipment operations. Six proposals of energy saving and technological modifications were put forward, including reconstruction of pumps in boiler house, reconstruction of pulp pumps, reusing the heat of exhaust vapors, etc. The total investment of the six proposals is estimated to be 16.4 million CNY, which may save 37,176 tce of energy and reduce 738.28 tons of SO<sub>2</sub> every year.

The environmental performance indicators, including the amount of coal use, fresh water consumption, emissions of COD and ammonia nitrogen, had a decreasing trend during 2004 to 2007, especially in 2007. This is because the production capacity was expanding continuously from 2004 to 2006 and several technological reconstruction projects were put into practice in 2007. The details of environmental performance changes are exhibited in Table 8. Accordingly, Nine Dragons obtained several awards and 10 million CNY financial subsidies from the government.

In terms of external GSCM practices, Nine Dragons has cooperated with its customers, mainly the packaging companies. Nine Dragons categorizes its clients based on certain indicators including environmental factors. The Department of Environmental Protection and Resource Recycling set up a unit to collect waste paper from downstream customers as raw materials for reproduction. The company arranges supplier conference once a year for

exchanging the information of material supply and environmental management. This implies that Nine Dragons has started certain external GSCM practices such as 'environmentally preferable procurement' and 'evaluation and selection of suppliers'. More advanced activities, such as 'environmentally conscious design in cooperation with suppliers', have been practiced. Nine Dragons conducted researches for developing environment-friendly products, with the light cardboard as an example, together with the suppliers.

## 2) Further GSCM Opportunities of Nine Dragons:

According to the energy audit report, there exist problems on energy management of Nine Dragons. Besides reinforcing technological upgrading and pollution control of wastewater, exhaust gas and solid wastes, implementation of the proposals in the energy audit report is an important task for the company in the near future. Cleaner production audit should be also considered. Continuously promoting the GSCM practices under implementation is useful for further improving the company's environmental performance.

## VI. DISCUSSIONS AND CONCLUSIONS

This paper summarized case studies of GSCM practices of three target companies, namely SDS, Zhenhui and Nine Dragons based in the Yangtze River delta of China. These individual cases further confirm the findings of previous statistical analyses by [18] and [19]. Chinese companies are still at a preliminary stage of GSCM practices. Even for the target companies with relatively advanced level of environmental management in this study, their GSCM practices in cooperation with external members of the supply chain are marginal. In overall, the GSCM practice level of SDS is relatively higher than Zhenhui and Nine Dragons. Besides the internally proactive environmental management such as energy saving efforts in response to 'SAIC-35% Energy Saving Plan', SDS practiced certain external GSCM activities together with SGM under 'SGM-Greening the Supply Chain Project'. The GSCM practices of Nine Dragons and Zhenhui are similar, both focusing on the internally environmental management like cleaner production and energy saving activities.

The difference of GSCM practices of the three cases may be partly attributed to the characteristics of the individual companies themselves. Our earlier questionnaire survey indicated that the level of GSCM practices significantly associated with the company's size [19]. All the three target companies are large ones according to the scale definition of China. They have superior resources and capacities for practicing environmental activities. Nevertheless, the three companies belong to different industrial sectors. Reference [16] documented that the pressures and drivers for GSCM practices of automobile industry are the highest. Regulatory pressures have been influential in environmentally sensitive industries including paper making and chemical sectors. In order to compete with the foreign counterparts, Chinese automobile manufacturers, including SGM, have higher motivations to implement GSCM practices jointly with the part producers to gain further advantage. This may explain, at some degree, the reason for the launch of 'SGM-Greening the Supply Chain

Project', which was participated by SDS. The company's ownership may also help differentiate GSCM practices of the companies. SDS is a multinational joint-venture. Nine Dragons is fully foreign-funded while Zhenhui is a local

domestic company. As a fully foreign-funded company, the top manager of Nine Dragons highly concerns its company's image and addresses the implementation of green strategies.

TABLE VII THE CONTENTS OF ENERGY AUDIT OF NINE DRAGONS

<b>Energy management institutions</b>	Current status	Energy management framework has been set up from the top to departments. There are employees working on energy management.
	Problems	Weak in systematic arrangement. There is no specific staff responsible for energy management at workshop level.
	Suggestions	To specify responsible persons at workshop and process level. Extensive training shall be carried out to promote awareness of the staffs.
<b>Energy management system</b>	Current status	Water, electricity, steam, coal, gas and raw materials are covered by energy and resource management system.
	Problems	Lack of systematic management system for energy procurement, use and evaluation
	Suggestions	To enhance the training and information sharing on energy saving
<b>Energy measurement</b>	Current status	Measurement system covers coal, electricity, heating power, water and steam.
	Problems	No measuring system for cooling water and compressed air; the ratio of measuring instruments is 42.15%, with the ratio in good condition being 94.27%.
	Suggestions	To increase the rate of measuring equipments for main electric equipments and processes; enhance the patrol and verification of the meters.
<b>Energy statistics</b>	Current status	Primary statistics was established; data and records are processed electronically.
	Problems	Data recording are incomplete; no systematic statistical analysis; in particular, material flow analysis is not developed.
	Suggestions	To establish detailed formats for energy use statistics of each process; to find out the reasons of excessive energy use for improvement.
<b>Energy quota management</b>	Current status	Quota management is practiced in some departments but not reach team level.
	Problems	No statistical data at the process level due to the product varieties and measuring problems; The index of energy use is rough and can't reflect the actual performance of production processes, major energy-using equipments and energy transformation devices.
	Suggestions	To establish quota management for all processes and develop statistical analysis of energy use; to establish material flow analysis system and reward and penalty system; to integrate energy evaluation with the company management system.

TABLE VIII ENVIRONMENTAL PERFORMANCE CHANGES OF NINE DRAGONS DURING 2004-2007

Year		2007	2006	2005	2004
<b>Total sales (billion CNY)</b>		1.665	2.649	1.706	0.98
<b>Air pollution index</b>	Coal use (10,000 t)	31.82	109.48	46.94	23.3
	Exhaust gas (billion m <sup>3</sup> )	2.546	9.853	4.225	2.09
	SO <sub>2</sub> (t)	51.6	1916.0	267.5	183.2
	NO <sub>x</sub> (t)	549	5474	--	--
	Soot (t)	11.3	396	353	17.5
<b>Water pollution index</b>	Industrial water use (million t)	11.96	58.70	--	--
	Fresh water use (million t)	6.10	16.00	8.20	3.90
	Wastewater treatment amount (million t)	2.83	16.00	--	--
	Wastewater amount below emission standard (million t)	2.83	16.00	8.20	3.90
	COD (t)	11.4	160	82	38.5
	NH <sub>4</sub> -N (t)	--	7.6	7.6	3.6
Industrial solid waste (million t)		0.1438	0.2235	0.2033	0.0751

The structure of a specific supply chain may determine GSCM practices of the supply chain members. It would be easier to adopt GSCM if some suppliers could play a leading role in a group of similar suppliers. Cooperative approaches are likely to be more fruitful if large companies could mandate their suppliers to comply with certain environmental initiatives [24]. Reference [25] suggested that inter-firm trust directly affect the extent of a company's engagement in GSCM. In this study, SDS's major suppliers and customers are large

multinational or state-owned companies, which highly restrict the position of SDS on the supply chain. The external GSCM practices of SDS are mainly motivated by SGM as a large and important client and can be viewed as a kind of market actor-oriented model. The case of SDS shows a mature, flexible and interactive style among raw material suppliers, component manufacturers and automobile assemblers. This is a typical case of a large auto parts producer with its environmental management pushed by both governmental

policies and environment strategies of multinational auto makers. The material suppliers of Zhenhui are large and multinational companies while the customers are small firms. This structure determines that Zhenhui can hardly affect its upper suppliers but merely consolidate the internally environmental management activities. As an environmentally sensitive company, the efforts of Zhenhui aim to avoid environmental risks and minimize the operation cost, which can be greatly attributed to the pressures from central and local environmental regulations. The GSCM of Zhenhui is a case of government policy-driven pattern. Since the environmental policies of China mainly emphasize the end-of-pipe measures so far, the current pressures are limited to push Zhenhui to practice external GSCM activities. In spite of certain similarity of GSCM practices of Nine Dragons and Zhenhui, the difference is that market actor is another important factor of GSCM of Nine Dragons. The GSCM of Nine Dragons may be viewed as a case jointly driven by governmental policies and market actors.

Consistent with [13], obvious improvements in economic and environmental performances are observed in the three cases. However, their environmental practices basically focused on energy saving and pollution reduction activities, and failed to penetrate into the advanced stage of GSCM. This research indicates the possible way forward for promoting company's GSCM in China. The regulation-dominated environmental policies are effective in improving company's environmental management, like the cases of Zhenhui and Nine Dragons. But reacting to regulations is no longer sufficient and successful environmental management strategies must be integrated into all stages of the value chain [26]. Compared with regulation-driven cases, market actor-oriented model is more sustainable for enhancing GSCM practices as it is based on mutual communications and cooperation among the core companies, suppliers and customers, and can extend the green philosophy through the supply chain rapidly. Besides the enforcement of mandatory regulations, the government should provide more technical supports and try to apply the market mechanisms, which are usually ignored currently in China. There may be two typical strategies for improving the involvement of external GSCM practices. One is to develop environmentally friendly products through joint research. The other is to require the suppliers to satisfy higher environmental standards. The construction of cooperative strategies may help the compatibilities of supply chain to the environment [27].

There are some shortages existed in this study. Two of the cases, Zhenhui and Nine Dragons, entirely focus on the internally proactive environmental management activities as part of GSCM since the external part is not in implementation. Due to the difficulty for data collection, the information from suppliers and customers can not been gathered for the validation of what is provided by the focal companies [21]. Furthermore, the case analysis only limits to identify the cost and benefit of GSCM practices, particularly in terms of environmental performance changes. The other important aspects, such as the interactions between GSCM practices and the change of financial performance, business process and client services, have to be ignored for the evaluations. The following research may extend current analysis to a wider

scope including the focal company and the other related actors on the supply chain for providing a thorough description of GSCM activities of Chinese companies. More indicators shall be applied to have a comprehensive assessment of GSCM practices and clarify their interactions with related economic and social variables. The dissemination of successful GSCM practices is another topic remained for future case-based research.

## REFERENCES

- [1] S. Vachon, R. D. Klassen, "Environmental management and manufacturing performance: The role of collaboration in the supply chain," *International Journal of Production Economics*, Vol. 111(2), pp. 299-315, 2008.
- [2] S. V. Walton, R. B. Handfield, and S. A. Melnyk, "The green supply chain: integrating suppliers into environmental management process," *International Journal of Purchasing and Material Management*, Vol. 34(2), pp. 2-11, 1998.
- [3] S. Seuring, M. Müller, "From a literature review to a conceptual framework for sustainable supply chain management," *Journal of Cleaner Production*, Vol. 16(2008), pp. 1699-1710, 2008.
- [4] J. L. F. Geoffrey, G. A. J. Hagelaar Jack, and V. van der, "Environmental supply chain management: using life cycle assessment to structure supply chains," *International Food and Agribusiness Management Review*, Vol. 4, pp. 399-412, 2002.
- [5] J. Sarkis, "A strategic decision framework for green supply chain management," *Journal of Cleaner Production*, Vol. 11(4), pp. 397-409, 2003.
- [6] R. Vijay, K. Kannan, and C. Tan, "Attitudes of US and European managers to supplier selection and assessment and implication for business performance," *Benchmarking: An International Journal*, Vol. 10(5), pp. 472-489, 2003.
- [7] R. Klassen, C. McLaughlin, "The impact of environmental management on firm performance," *Management Science*, Vol. 42(8), pp. 1199-1214, 1996.
- [8] H. Min, W. P. Galle, "Green purchasing strategies: trend and implications," *International Journal of Purchasing and Materials Management*, Vol. 33(3), pp. 10-17, 1997.
- [9] J. Sarkis, "How green is the supply chain: practice and research. Graduate School of Management," Clark University, Worcester, M.A., 1999.
- [10] Kama, E. Heiskanen, "The challenge of product chain thinking for product development and design: the example of electrical and electronic products," *Journal of Sustainable Product Design*, Vol. 4, pp. 126-136, 1998.
- [11] FF. Hines, R. Johns, "Environmental supply chain management: evaluating the use of environmental mentoring through supply chain," Paper Presented at Greening of Industry Network Conference, Bangkok, 2001.
- [12] F. Testa, F. Iraldo, "Shadows and lights of GSCM (Green supply chain management): determinants and effects of these practices based on a multi-national study," *Journal of Cleaner Production*, Vol. 18(2010): pp. 953-962, 2010.
- [13] R. P. Côté, J. Lopez, S. Marche, G. M. Perron, and R. Wright, "Influences, practices and opportunities for environmental supply chain management in Nova Scotia SMEs," *Journal of Cleaner Production*, Vol. 16(2008), pp. 1561-1570, 2008.
- [14] M. L. Tseng, A. S. F. Chiu, "Evaluating firm's green supply chain management in linguistic preferences," *Journal of Cleaner Production*, article in press.
- [15] F. E. Bowen, P. D. Cousins, R. C. Lamming, and A. C. Faruk, "The role of supply management capabilities in green supply," *Production and Operations Management*, Vol. 10(2), pp. 174-189, 2001.

- [16] Q. H. Zhu, J. Sarkis, "An inter-sectoral comparison of green supply chain management in China: Drivers and practices," *Journal of Cleaner Production*, Vol. 14(2006), pp. 472-486, 2006.
- [17] Q. H. Zhu, J. Sarkis, and K. H. Lai, "Green supply chain management: pressures, practices and performance within the Chinese automobile industry," *Journal of Cleaner Production*, Vol. 15(2007), pp. 1041-1052, 2007.
- [18] Q. H. Zhu, J. Sarkis, J. J. Cordeiro, and K. H. Lai, "Firm-level correlates of emergent green supply chain management practices in the Chinese context," *Omega*, Vol. 36(4), pp. 577-591, 2008.
- [19] X. B. Liu, J. Yang, S. X. Qu, L. N. Wang, T. Shishime, and C. K. Bao, "Sustainable production: Practices and determinant factors of green supply chain management of Chinese companies," *Business Strategy and the Environment*, article in press.
- [20] S. Seuring, "Case study research in supply chains - an outline and three examples," in: Kotzab H, Seuring S, Müller M, and Reiner G (Eds.), *Research Methodologies in Supply Chain Management*, Physia-Verlag, Heidelberg, pp. 235-250.
- [21] R. K. Yin, *Case Study Research: Design and Methods*, 3<sup>rd</sup> edition, Sage Publications, Thousand Oaks, CA, 2003. Stuart, D. McCutcheon, R. Handfield, R. McLachin, and D. Samson, "Effective case research in operations management: a process perspective," *Journal of Operations Management*, Vol. 20(5), pp. 419-433, 2002.
- [22] I. Stuart, D. McCutcheon, R. Handfield, R. McLachin, and D. Samson, "Effective case research in operations management: a process perspective," *Journal of Operations Management*, Vol. 20(5), pp. 419-433, 2002.
- [23] Q. H. Zhu, J. Sarkis, "Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises," *Journal of Cleaner Production*, Vol. 13(2004), pp. 265-289, 2004.
- [24] H. Jeremy, "Environmental supply chain dynamics," *Journal of Cleaner Production*, Vol. 8(6), pp. 455-471, 2000.
- [25] M. P. Sharfman, T. M. Shaft, and R. P. Annex Jr., "The road to cooperative supply-chain environmental management: trust and uncertainty among pro-active firms," *Business Strategy and the Environment*, Vol. 18(1), pp. 1-13, 2009.
- [26] R. B. Handfield, S. V. Walton, L. K. Seegers, and S. A. Melnyk, "Green' value chain practices in the furniture industry," *Journal of Operations Management*, Vol. 15(4), pp. 293-315, 1997.
- [27] R. Lamming, "Squaring lean supply with supply chain management," *International Journal of Operations & Production Management*, Vol. 16(2), pp. 183-196, 1996.