Green supply chain management: pressures, practices and performance within the Chinese automobile industry

Qinghua Zhu a,*, Joseph Sarkis b,1, Kee-hung Lai c,2

a Institute for Eco-planning and Development, Dalian University of Technology, Dalian, Liaoning Province 116024, P.R. China
b Graduate School of Management, Clark University, 950 Main Street, Worcester, MA 01610-1477, USA
c Department of Logistics, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong

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Abstract

Increasing pressures from a variety of directions have caused the Chinese automobile supply chain managers to consider and initiate implementation of green supply chain management (GSCM) practices to improve both their economic and environmental performance. Expanding on some earlier work investigating general GSCM practices in China, this paper explores the GSCM pressures/drivers (motivators), initiatives and performance of the automotive supply chain using an empirical analysis of 89 automotive enterprises within China. The results show that the Chinese automobile supply chain enterprises have experienced high and increasing regulatory and market pressures and at the same time have strong internal drivers for GSCM practice adoption. However, their GSCM implementation, especially with consideration of external relationships, is poor. Therefore, GSCM implementation has only slightly improved environmental and operational performance, and has not resulted in significant economic performance improvement. In furthering this analysis we investigate one specific organization in this supply chain, the Dalian Diesel Engine Plant, and how this pioneering company has addressed the issues identified by the broader empirical analysis.

Keywords: Environmental sustainability; Green supply chain management; Automotive supply chain; China

1. Introduction

The automotive industry together with its supporting supply chains is expected to encounter what is conceivably the largest growth of any industry in China and potentially represents the most lucrative automotive market in the world during the next few decades [1,2]. Commensurate with this growth is an environmental burden, which is unequaled since China’s move towards a market economy integrated with the rest of the world (i.e. China’s entry into the World Trade Organization (WTO)). The management and planning to mitigate this nascent environmental burden caused by the Chinese automotive industry and their respective supply chains will require significant thought and foresight.

Environmental issues ranging from local, regional and global implications of air emissions, solid waste disposal and natural resource usage will all have to be monitored and managed during these growth phases. Scarcity of resources and this environmental burden have caused Chinese governmental agencies to further tighten environmental regulations or offer innovative programs to address these issues [3,4]. Simultaneously, there has been increased environmental awareness by the Chinese public and communities further pressuring industry to alleviate their environmental burdens [5,6]. Through economic globalization, Chinese companies have also experienced environmental pressures through their international customers or partners [7]. For example, Bristol-Myers Squibb, IBM and Xerox have encouraged their Chinese
suppliers to develop environmental management systems consistent with ISO 14001, while Ford, GM and Toyota have required their Chinese suppliers to obtain the ISO 14001 certification [8].

China, still considered as a developing nation, has also increased its emphasis on economic development, while seeking to maintain a balance with environmental protection. These many-faceted pressures have made it a struggle for organizations to balance economic benefits and environmental performance [9], and China’s automotive industry and supply chains have not been excluded from this balancing act.

All stages of a product’s life cycle will influence a supply chain’s environmental burden, from resource extraction, to manufacturing, use and reuse, final recycling, or disposal. To improve their environmental performance, Chinese manufacturers have implemented various kinds of environmental practices such as ISO14001 certification and cleaner production. As a more systematic and integrated strategy, green supply chain management (GSCM) has emerged as an important new innovation that helps organizations develop ‘win—win’ strategies that achieve profit and market share objectives by lowering their environmental risks and impacts, while raising their ecological efficiency [10].

Rigorous investigation of environmental sustainability issues facing the automotive supply chain in China is virtually non-existent. We focus on these issues in this paper. Even though we parlay this study within the context of GSCM, many of the practices and policies that are investigated are broader in scope covering numerous dimensions of corporate environmental sustainability. To explore the environmental sustainability issues we enhance (through a larger sample size) some of our previous empirical work focusing exclusively on the automotive supply chain. The empirical results provide an overview of the general industry and its practices. To provide some depth to these results and our analysis, we further detail a case study investigation of one organization’s operations in the automotive supply chain and its focus on environmental sustainability issues defined by our empirical study. Both the empirical study and the more detailed case study will help to inform our discussion on managerial, policy, and research directions for environmental sustainability in the Chinese automotive supply chain.

After a brief description of China’s automotive supply chain implications for environmental sustainability in industry, we provide an overview of drivers, GSCM practices, and performance issues in Section 2. Then in Section 3, we provide details of an empirical study on the GSCM pressure/drivers, initiatives and performance of the industry based on a survey for 89 enterprises in China’s automotive supply chain. To further enhance the depth of the survey evaluation, we provide a detailed analysis on one Chinese automobile engine manufacturer, the Dalian Diesel Engine Plant (DDEP) evaluating some of their practices in Section 4. In Section 5, implications of results are discussed and suggestions for enhancing environmental sustainability of Chinese automotive supply chains are presented. Summaries and conclusions are presented in Section 6.

2. The Chinese automotive industry and supply chain

Vehicle production has seen a dramatic increase in China [11]. Thus, environmental burdens and resource shortages related to the Chinese automotive industry have become increasingly serious. Greening the supply chains is one important strategy for the Chinese automotive industry’s sustainability, environmentally, economically and socially.

2.1. An overview of the Chinese automotive industry

China’s automotive industry started in the 1950s, but rapid modernization and development began in the 1990s. The value added of China’s auto industry in 2002 was US$19.1 billion, 50% higher than the previous year, and accounting for 6% of all value added from manufacturing [12]. As of 2002, 33.5 million Chinese were employed in the automotive industry and directly related sectors; one out of 22 workers in China worked in these sectors. The Chinese auto industry has become the world’s fourth largest vehicle producer, with an exceptionally high projected growth rate of 20–30% annually for the next 10 years. The auto sector’s contribution to China’s total GDP growth could be as high as 20% [13].

In 2003, total automobile sales in China were about 4.45 million, including 4.39 million made in China (an increase of 34.2% over 2002). These sales rank third following the USA (12 million), Japan (8 million), and more than those in Germany (3.5 million). It was estimated that China will soon become the second largest producer in the world given current growth rates [14]. In 2004, the Chinese automotive industry continuously expanded. From January to August of 2004, total production and sales of automobiles in China were 3.40 million and 3.28 million, respectively, increases of 21.1% and 19.2% compared to automobile production and sales in 2003 [15].

The Chinese automotive industry has focused its efforts on its domestic market. However, some companies have started to export products by cooperating with international partners. Assembling BMW cars, Brilliance Jinbei announced the plan to export the Zhonghua sedan to Europe with a tentative target of 20,000 vehicles. Jianglei Motors, in a partnership with Ford, has supplied an independent importer and distributor in the Netherlands with the Landwind SUV, and has plans to expand into Germany. FAW-Hongta Yunnan Automobile hopes to sell up to 10,000 vehicles of the Happy Emissary minicar [16]. These extended partnerships have both economic and environmental influences on operations throughout the Chinese automotive supply chain, as described in Section 2.2.

2.2. Environmental sustainability of the Chinese automotive industry

The Chinese automotive industry’s rapid growth relates to two major dimensions affecting environmental sustainability, environmental burden and resource shortage.

The number of vehicles produced and used in China has been sharply increasing [13,17]. Thus, air pollution has
become a serious problem, especially in big cities. Such continuous or even accelerating growth in vehicles in China has added to concerns regarding further environmental degradation. Even though air quality has improved in recent years, it is still a major concern. Vehicles, replacing industrial pollution, have become a major source of air pollution in China. A report of the World Bank in 2002 indicated that China has made progress in lowering industrial pollution and coal-burning, but vehicle-related pollution has risen [18]. For example, NO\textsubscript{x} emissions in Beijing were decreased by 17% from 1988 to 2000, but increased by 7.1% in 2002 and increased again in 2003 [13]. These environmental burden statistics have implications for the automotive supply chains in attempting to design more environmentally sound products through eco-design practices by cooperating with and learning through their supply chain partnerships.

The growth in car production and usage has been a critical factor in the growth of consumption of numerous resources, especially metals. Given an estimate that China will produce over 6 million vehicle units in 2005, it is expected that there will be significant increases in imports of metals. For example, most of the high-quality galvanized sheet metal used in vehicle bodies has to be imported [19]. The rapid and continuous growth of China’s vehicle population has also brought great challenges to China’s energy resource security. The large transportation system in China is based on gasoline and diesel fuels, which would dramatically increase China’s dependence on oil imports. A sobering fact is if China’s vehicles per capita were the same as the United States, the oil demand in China would exceed the worldwide oil production by 18% [13]. The consumption of these resources has implications for resource recovery and more efficient use of materials throughout the automotive supply chain.

With globalization, Chinese automobile companies have to compete with their international counterparts. After China’s entry into the WTO, the automotive industry is one of the most affected industries [20]. As a result, the Chinese automobile supply chains have struggled to improve their economic and environmental performance simultaneously. Thus, GSCM practices have emerged as a systematic approach within the automobile industry in China to balance the economic and environmental sustainability of firms.

As China’s automotive market continues to mature, the role of GSCM will also evolve. That is, with the greater availability of spare parts and older cars, the linkage of resource recovery systems with suppliers and customers will need to be made collaboratively. Improving (effectiveness and efficiency) this collaborative relationship and infrastructure will be required for global competitiveness.

2.3. GSCM pressure, practices and performance in the Chinese automobile industry

Chinese automobile companies have experienced increasing environmental pressure while simultaneously recognizing various benefits and incentives to green their supply chains [21,22]. Internal awareness is a key dimension for enterprises to implement environmental practices such as GSCM. Proactive companies usually have greater implementation of environmental practices beyond requirements of laws and regulations, while reactive companies only seek compliance with regulatory requirements. In China, the diversity in the adoption rates has seen some automobile supply chain companies proactively implementing environmental strategies such as green purchasing and eco-design [23]. Yet, compared to some other industries, e.g. the Chinese electronic industry, GSCM practice in the Chinese automotive supply chains is lagging [21,22]. Many automotive supply chain enterprises considered or initiated some GSCM practices such as investment recovery, eco-design and internal environmental management. However, investment recovery and development of recycled material markets in China have not received much attention. One main reason is due to the nascent Chinese consumer popularity of automobiles, and recycling of used cars is not currently under careful consideration. That is to say the maturation of the automotive market is still progressing and has yet to create a critical mass to be economically worthwhile for development of a used parts market. However, a regulated automobile take-back system has been in operation in China since October of 2004. This take-back system forces manufacturers to consider environmental effects in the whole life cycle [23], and thus providing motivation for organizations to further pursue GSCM practices and closing the automobile supply chain loop.

Following China’s entry into the WTO, Chinese enterprises have more opportunities to establish relationships with foreign enterprises in the same supply chain. An automobile company, DDEP, which is the case study company introduced in this paper, established a close relationship with their downstream customers and cooperated with international partners such as Mercedes-Benz by GSCM initiatives such as green purchasing [24]. However, exporting products or becoming suppliers of foreign customers in China requires Chinese enterprises to address and overcome ‘green barriers’ and increase their international competitive ability [25]. Ford, GM and Toyota have required their Chinese suppliers to be certified with ISO 14001 [8]. Environmental advantages can bring opportunities for suppliers. We now address these and other issues using empirical information and a case study analysis.

3. Methodology and survey results

3.1. Research methodology

3.1.1. Questionnaire development

The empirical data used in this study consist of questionnaire responses from managers in Chinese automobile supply chain enterprises. The questionnaire contained three sections: (a) items affecting or motivating implementation (pressures/drivers); (b) current GSCM practice adoption; (c) corresponding performance. Eighteen items in part one (pressures/drivers) were developed on the basis of a number of sources from the literature [7,26–28] and questions were answered using a five-point Likert-type scale (e.g. 1 = not at all important,
shops can generally represent situations in China for these industries. Throughout China, we can argue that responses from them during two work-involved in training programs are representatives from these industries provided training for manager in the Chinese automotive industry. Since managers of Management at Dalian University of Technology was established in 1980. The Center was directly proposed by Mr. Deng Xiaoping, and is the first joint training project between Chinese and American stakeholders. Since 2001, it introduced to the targeted respondents to ensure that they had a full present with the study respondents while they were completing the survey questionnaire, and answered the questions they had about the survey questionnaire. Subsequent to the survey, we followed up those returned questionnaires containing unclear answers and interviewed the respondents concerned.

A majority of the respondents belonged to state-owned enterprises or publicly owned enterprises who were transitioned from state owned enterprises (n = 77) accounting for 86.5% of our study samples. Company sizes of the respondents in terms of employee establishment range from under 1000 to over 5000 employees. A majority of the respondent enterprises fall into the medium-sized and large-sized company categories, i.e., between 1000 and 5000. In sum, 15 respondent enterprises have less than 1000 employees (16.9%), 58 respondent enterprises have between 1000 and 5000 employees (65.2%), and 16 respondent enterprises have over 5000 employees (17.9%).

3.2. Survey results

3.2.1. Descriptive statistics

Descriptive statistics, alpha coefficients and item-total correlations are used to initially analyze the survey data after application of a principal components factor analysis (see Table 1). All of the factors for GSCM drivers/pressures, practices and performance have a reliability (alpha) value above 0.70, the threshold value recommended by Nunnally and Bernstein [35]. All the factors of GSCM practice and performance have high item-total correlation values, i.e., >0.60, to their corresponding higher-level constructs. Although the four factors of GSCM drivers/pressure have relatively low item-total correlations, their values were considered acceptable, i.e., >0.40, for an exploratory research study like this study. On the basis of the alpha coefficients and item-total correlations, we confirmed the four factors on GSCM pressures/drivers, i.e., regulation, market, supplier drivers and internal incentives, and the five factors for GSCM practices, i.e., internal environmental management, green purchasing, customer cooperation with environmental concerns, investment recovery, and eco-design. We also classified company performance into four dimensions, namely, environmental, positive economic, negative economic and operational.

As seen in Table 1, Chinese automotive supply chain enterprises have experienced significant pressures and incentives to implement GSCM, with mean values over 4.00 for the four driver factors. Among these drivers/pressures, regulative (legislative) pressures are the highest with a mean value of 4.38. Market pressure is the second important driver for the Chinese automotive supply chains to implement GSCM, with a mean value of 4.28. Legislative (coercive) and normative (image/marketing) pressures seem to play larger roles as drivers in this industry. Supply chain pressures (e.g. from customers and suppliers) do not seem to play as large a role.

GSCM practices’ adoption rate lagged, with mean values below 3.55 for all the five GSCM factors, especially for green purchasing with the lowest mean value of 2.82. The relatively higher standard deviations for the GSCM practices, i.e., over 1.00, indicate that the implementation level of GSCM is imbalanced, with organizations covering the spectrum of innovation

1 The National Center for Industrial Science and Technology in the School of Management at Dalian University of Technology was established in 1980. The Center was directly proposed by Mr. Deng Xiaoping, and is the first joint training project between Chinese and American stakeholders. Since 2001, it has been one of nine training bases for industries in China designated by the State Economic & Trade Commission. In recent years, the center has provided training for manager in the Chinese automotive industry. Since managers involved in training programs are representatives from these industries throughout China, we can argue that responses from them during two workshops can generally represent situations in China for these industries.
Table 1: Descriptive statistics and Cronbach alpha values

<table>
<thead>
<tr>
<th>Factors</th>
<th>No. of items</th>
<th>Cronbach’s alpha</th>
<th>Inter-total correlations</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure/drivers&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Regulative(DRI1)</td>
<td>4</td>
<td>0.81</td>
<td>0.52</td>
<td>4.38</td>
</tr>
<tr>
<td></td>
<td>Market (DRI2)</td>
<td>4</td>
<td>0.75</td>
<td>0.43</td>
<td>4.28</td>
</tr>
<tr>
<td></td>
<td>Suppliers (DRI3)</td>
<td>4</td>
<td>0.84</td>
<td>0.57</td>
<td>4.06</td>
</tr>
<tr>
<td></td>
<td>Internal (DRI4)</td>
<td>6</td>
<td>0.85</td>
<td>0.55</td>
<td>4.18</td>
</tr>
<tr>
<td>Practices&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Internal EM (PRA1)</td>
<td>8</td>
<td>0.95</td>
<td>0.69</td>
<td>3.22</td>
</tr>
<tr>
<td></td>
<td>Green purchasing (PRA2)</td>
<td>5</td>
<td>0.90</td>
<td>0.64</td>
<td>2.82</td>
</tr>
<tr>
<td></td>
<td>Customer cooperation (PRA3)</td>
<td>4</td>
<td>0.87</td>
<td>0.64</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td>Investment recovery (PRA4)</td>
<td>3</td>
<td>0.84</td>
<td>0.63</td>
<td>3.55</td>
</tr>
<tr>
<td></td>
<td>Eco-design (PRA5)</td>
<td>3</td>
<td>0.87</td>
<td>0.63</td>
<td>3.53</td>
</tr>
<tr>
<td>Performance&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Environmental (PER1)</td>
<td>6</td>
<td>0.93</td>
<td>0.70</td>
<td>3.57</td>
</tr>
<tr>
<td></td>
<td>Positive economic (PER2)</td>
<td>5</td>
<td>0.90</td>
<td>0.70</td>
<td>3.24</td>
</tr>
<tr>
<td></td>
<td>Negative economic (PER3)</td>
<td>4</td>
<td>0.90</td>
<td>0.65</td>
<td>3.39</td>
</tr>
<tr>
<td></td>
<td>Operational (PER4)</td>
<td>6</td>
<td>0.94</td>
<td>0.72</td>
<td>3.58</td>
</tr>
</tbody>
</table>

<sup>a</sup> 1 = not at all important; 2 = not important; 3 = not thinking about it; 4 = important; 5 = extremely important.

<sup>b</sup> 1 = not considering it; 2 = planning to consider it; 3 = considering it currently; 4 = initiating implementation; 5 = implementing successfully.

<sup>c</sup> 1 = not at all; 2 = a little bit; 3 = to some degree; 4 = relatively significant; 5 = significant.

from pioneering firms at the cutting edge of practice to those who are lagging considerably. Further analyses indicate a fraction of Chinese automotive supply chain enterprises have initiated GSCM with mean values over 4.00 (4 = initiating implementation). Seventeen enterprises indicate a mean value over 4.00 (19.1%) for internal environmental management, 10 enterprises (11.2%) for green purchasing, 9 (10.1%) for customer cooperation, 22 (24.7%) for investment recovery and 29 (32.6%) for eco-design. Table 1 indicates that negative economic performance with a mean value of 3.39 is slightly more significant than positive economic performance with a mean value of 3.24 as a consequence of organizations implementing GSCM.

In summary, our initial survey results show that Chinese automobile enterprises have experienced high regulatory and market pressures and at the same time have strong internal drivers for implementing GSCM. However, their GSCM implementation, especially on external relationships such as green purchasing and customer cooperation with environmental concerns, is weak. These enterprises have only planned to consider or at most are considering corporate environmental management and GSCM implementation. Therefore, GSCM implementation has only slightly improved environmental and operational performance, but has not resulted in significant improvements in economic performance.

3.2.2. Relationships among drivers, practices and performance: a regression analysis

To examine if GSCM pressures are related to the GSCM practices and, in turn, if the practices are related to performance, we performed regression analyses to examine the relationships. In the regression models, each factor for GSCM pressures/drivers, GSCM practices, and performance were averaged from their underlying measurement items to form a single indicator factor. The summary factors were subsequently used for the regression analyses. The use of the summary factors can reduce the model complexity and allow us to test the relationships based on small sample size (n = 89).

We include company size as a control variable in the regression analysis. This is to account for the possibility that the size of the firm may influence the extent of their implementation of GSCM practices. The four factors of GSCM pressures/drivers (regulative, market, suppliers and internal) were treated as independent variables and we examined their impact on the GSCM factors (Internal environmental management, green purchasing, customer cooperation, investment recovery, and eco-design) in five regression models. Similarly, the five GSCM factors were defined as independent variables and regressed on each of the performance dimension (environmental, positive economic, negative economic, and operational) in a second set of four separate regression models. Nine total regressions are determined with the following functional forms:

\[
GSCM \text{ PRACTICE}(N) = F(\text{DRIVERS organizational size, error}) \quad \text{for } N = 1 \ldots 5
\]

\[
\text{PERFORMANCE}(M) = F(\text{GSCM PRACTICES organizational size, error}) \quad \text{for } M = 1 \ldots 4
\]
Before proceeding, we examined the variance inflation factor (VIF) to determine the potential existence of multicollinearity. The largest of the resulting VIF scores in all of the regression models in Tables 2 and 3 were 2.49 and 3.31 respectively, i.e., well below the maximum level of 10.0 suggested by Mason and Perreault [36], indicating that multicollinearity should not be a problem with our data. The intercorrelations between the study variables are summarized in Table 4.

The regression analysis shows that there is one significant relationship between GSCM pressures/drivers on the practice, i.e., a significant positive impact of internal pressures on investment recovery (b = 0.636). We also note that firm size has a significant negative impact on internal environmental management (b = –0.335), green purchasing (b = –0.302), customer cooperation (b = –0.230) and eco-design (b = –0.365). The GSCM pressures/drivers seem to have no significant impact on the GSCM practices with respect to internal environmental management practices, green purchasing, customer cooperation and eco-design. An explanation is that the Chinese enterprises may face similar and very early pressures/drivers, but react at a different pace when adopting GSCM practices. Since most of these organizations are at early adoption stages in implementing GSCM practices, the impact of these pressures on the extent of their GSCM implementation may be more obvious as the pressures become more prevalent and adoptions mature. The variance explained in each of the regression models are: 10.1% of the variance in internal environmental management, 4.7% of the variance in green purchasing, 4.8% of the variance in customer cooperation, 27% of the variance in investment recovery, and 16.3% of the variance in eco-design. The variance explained indicates the percentage of change in a dependent variable (e.g. GSCM performance) to our empirical findings.

The results in Table 3 indicate that Internal environmental management has significant positive impact on environmental performance (b = 0.663), positive economic performance (b = 0.467), and negative performance (b = 0.630), but not on operational performance. The two factors of GSCM on green purchasing and customer cooperation have significant impact only on environmental performance, but not on the other performance aspects. It should be noted that the impact of green purchasing on environmental performance is negative (b = –0.482), while the impact from customer cooperation is positive (b = 0.443). As for impact of investment recovery and eco-design, the former only has negative impact (b = –0.303) on negative economic performance, while the latter has no impact for all the four performance aspects. Lastly, the control variable of firm size only has impact (b = 0.399) on negative economic performance among the performance aspects. The variance explained in each of the regression models are: 42.9% of the variance in environmental performance, 26.1% of the variance in positive economic performance, 32.7% of the variance in negative economic performance, and 32.0% of the variance in operational performance.

4. Case study

To provide depth and enhancement (e.g. initial evaluation of causal relationships among factors) to our empirical findings, we provide a detailed analysis on one Chinese automobile engine manufacturer, the Dalian Diesel Engine Plant (DDEP), evaluating some of their GSCM practices. This company has initiated GSCM practices that exemplify various performance improvements.

DDEP, established in 1951, was one of the key plants for the design and manufacture of diesel engines in China. The plant has over 2000 employees with total assets of 2 billion RMB (about US$0.24 billion) and production capacity of 150,000 engines per year. DDEP produces over 140 types of diesel engines, and each type needs over 2000 components and more than 100 raw or auxiliary materials. In the past, the plant produced most of its components and materials. However, the plant currently outsources over 90% of its parts,
representing over 70% of the value of the product. The plant classifies suppliers into three categories, strategic partners, long-term close cooperators, and contractors. The plant currently has 120 suppliers including 16 strategic partners.

The plant has over 300 products, covering three series (light, middle and heavy), and including five models (CA4DC, CA4DS, CA6DE, CA6DF, and DEUTZ). The power of manufactured engines ranges from 62 to 236 kW, and thus the plant has enough product flexibility capability to supply engines for trucks, cars, special vehicles and engineering machines. Besides its main customer, First Automobile Works (FAW) of China, the plant also supplies parts and engines for over 50 domestic vehicle manufacturers that export vehicles to dozens of countries and regions. Thus, we can observe that the influence of this one engine manufacturer has the potential to be quite broad. Even though at this time it primarily supplies one OEM, there is movement to develop additional partnerships that can cause its products to influence even greater number of transport vehicle supply chains.

In the next section we describe the increasing pressures causing DDEP to initiate various GSCM-related practices. As a result, the plant has improved their environmental image and gained economic benefits.

4.1. GSCM drivers/pressure in the Dalian Diesel Engine Plant

Diesel engine vehicles are traditional heavy polluters. In China, the Air Pollution Prevention and Abatement Law was enacted in 1987, and has been modified twice in 1995 and 2000, becoming increasingly strict. The law requires all companies to manufacture vehicles with air emissions below specified standards. At the same time, the law encourages production of vehicles using cleaner energy. The plant facility is also located in Dalian, a region with a reputation as one of the cleanest and greenest cities in China. Thus, the municipality has exerted extra pressure for the plant to improve and maintain its environmentally sound image. This type of pressure varies by municipalities, but is clearly evident in Dalian. DDEP has also been quite cognizant of the automobile take-back system that has been implemented since Oct. 1 of 2004 in China, which forces manufacturers to consider environmental effects in the whole life cycle of their products.

Managers within DDEP have also experienced motivational drivers and pressures from their customers. For example, the director of the Purchasing and Supply Department, informed the interview team that the environmental requirements from customers and regulations are immense challenges for the plant, but he was also aware that they can bring opportunities such as competitive advantages within the market, if they are appropriately implemented.

As a subsidiary of the First Automobile Works (FAW), DDEP sells over 90% of its products to its parent company. FAW and Dongfeng Motor Corporation are two main manufacturers producing medium and heavy diesel vehicles in China. With globalization, especially after China’s entry into the WTO, international manufacturers such as Volvo, Isuzu, Hitachi and Hyundai have entered into the Chinese market by directly selling vehicles and gradually establishing joint ventures. DDEP recently established a plant on May 26, 2005 that is expected to be a joint venture between DDEP and DEUTZ, further expanding DDEP’s influence. Increased globalization and partnership formation is evidence of high volatility in the Chinese automotive market with competitive pressures continuing to increase. In designing and developing products, major requirements for product functionalities from consumers include reliability, durability, diesel consumption, and air emissions. As a result, diesel vehicle manufacturers have tried to improve their environmental image to keep or gain market share. This pressure is currently channeled from customers to FAW through DDEP.

Managers made clear that suppliers’ business continuity is also a main concern for DDEP. Diesel engines are complex products, and their environmental performance depends on several key components. Thus, DDEP has the responsibility to ensure that their suppliers meet various environmental standards. The Marketing Department Director made clear that every effort is made to purchase all materials and components from suppliers with strong reputations for both quality and environmental credibility. Thus DDEP practices monitoring of its suppliers’ internal environmental management programs to avoid a situation where suppliers will stop or delay
Table 4

<table>
<thead>
<tr>
<th>Pressure/Drivers</th>
<th>Practice</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.677*** 0.534*** 0.614***</td>
<td>0.642***</td>
</tr>
<tr>
<td>2</td>
<td>0.677*** 0.737*** 0.642***</td>
<td>0.711***</td>
</tr>
<tr>
<td>3</td>
<td>0.677*** 0.737*** 0.642***</td>
<td>0.625***</td>
</tr>
<tr>
<td>4</td>
<td>0.677*** 0.737*** 0.642***</td>
<td>0.531***</td>
</tr>
<tr>
<td>5</td>
<td>0.677*** 0.737*** 0.642***</td>
<td>0.520***</td>
</tr>
<tr>
<td>6</td>
<td>0.677*** 0.737*** 0.642***</td>
<td>0.428***</td>
</tr>
<tr>
<td>7</td>
<td>0.677*** 0.737*** 0.642***</td>
<td>0.333***</td>
</tr>
<tr>
<td>8</td>
<td>0.677*** 0.737*** 0.642***</td>
<td>0.237***</td>
</tr>
<tr>
<td>9</td>
<td>0.677*** 0.737*** 0.642***</td>
<td>0.139***</td>
</tr>
<tr>
<td>10</td>
<td>0.677*** 0.737*** 0.642***</td>
<td>0.048***</td>
</tr>
</tbody>
</table>

* Correlations between GSCM drivers, practice and performance

Production due to environmental issues, that is, to maintain business continuity and reduce risk. Managers also realize that suppliers’ advances in environmental practices can promote the advancement of DDEP’s own environmental practices.

Competitors’ environmental practices were also seen as motivation (pressures/drivers) for DDEP to implement environmental management. The DDEP general manager emphasized that environmental improvement is a core competitive organizational dimension for which they continue to build competency. In his view, DDEP would lose significant competitive advantages if they don’t make continuous improvement efforts on environmental management. For example, the Chaoyang Diesel Engine Plant, a subsidiary of the Dongfeng Engine Corporation and direct competitor to DDEP, has improved its environmental image through technological innovation. Another subsidiary of the FAW and even more direct competitor to DDEP, the Wuxi Diesel Engine Plant, recently marketed its new green motors. Even though DDEP is a pioneering plant on environmental management, in recent years it has continuously observed internal and external competitors with an environmentally competitive dimension. Maintaining this competitive edge and image is a main motivation for DDEP to implement GSCM-based practices.

4.2. GSCM practices in the Dalian Diesel Engine Plant

As a pioneering automobile company, DDEP has initiated multiple dimensions of GSCM practices, including internal environmental management, green purchasing, green marketing and eco-design.

Producing environmentally sound engines is one key dimension DDEP uses to establish their environmental image, and thus gain and keep competitiveness. Within this competitive market, senior managers in the DDEP put forward a call of “Green plant, environmental engines”. They have worked on furthering their environmental image by producing diesel engines with low emissions, low diesel consumption, low noise, as well as high dynamic functions and reliability. To at least maintain and potentially improve its environmental performance, DDEP has invested over 12 million RMB (about US$1.45 million) since 2001. The plant purchased equipment for emission purification, noise elimination and wastewater treatment, which greatly improved its internal environmental conditions. In 2003, DDEP initiated a waste water treatment project, and became the first company realizing “zero emissions” for both industrial and municipal waste water in Dalian, which is very important in a municipality that is consistently threatened with water shortages [24]. To complete this program the plant invested 2.59 million RMB (about US$0.313 million) for a wastewater treatment project by using flocculation, bio-chemical, ultra-filtration and reverse osmosis technologies.

In November 2003, DDEP became TUVMISO/TS16949 certified, which is an international quality management standard for the automobile industry that encompasses product design and development, manufacturing, installation and service
functions within the organization. Such certification facilitates DDEP’s entry into the global automotive market [37]. Leveraging this experience with internationally based standards, DDEP has also been seeking ISO14001 and OHSMS18001 certification.

Environmental issues are main concerns for DDEP during its product design and development. The Product Development Director in DDEP stated that environmental requirements are quickly becoming primary priorities, even over economic benefits. To help them address this management priority the plant closely cooperates with research institutes and universities on eco-design projects. As an example of this success, since April 2004, all products produced by the DDEP meet the Europe II emission standards [37].

The plant has also implemented cleaner production activities in its production stages focusing on source reduction and waste prevention. The plant implements collaborative development efforts with its suppliers, which include environmental considerations, and these efforts and programs are driven by the organization’s internal environmental strategy and policy. Customer collaboration is also evident here. For different types of vehicles, road conditions and consumer characteristics, the plant and its main customer, FAW, jointly develop improved engines that consume less fuel, while maintaining suitable performance standards (including acceleration and cooling systems capabilities).

The significance of outsourcing practiced by DDEP requires them to more closely monitor supplier environmental practices to guarantee both quality and environmental performance requirements. The plant not only collects environmental information related to suppliers, but also establishes a database on environmental situations for main component suppliers [23]. The plant jointly implements research on substitute materials and technologies to improve environmental practices with those partners and even joins in some of these innovation programs with competitors. At the same time, the plant also outsources other non-manufacturing functions, such as logistics functions to help achieve their goals of just-in-time (JIT) production. This outsourcing requires monitoring of its distribution and transportation environmental and economic performance. JIT provides a managerial challenge since JIT’s minimization of waste philosophy is environmentally sound, yet, more frequent delivery requirements weaken transportation energy efficiency, causing environmentally detrimental consequences.

DDEP has also implemented eco-design programs through coordination and cooperation with international pioneers such as DEUTZ. One innovation implemented by DDEP is a joint quality evaluation program with both suppliers and customers. The plant classifies components into three types. The first type of components is related to life and safety; the second type is related to product functions, capability and precision; and the third type is mainly joint (connecting) parts. DDEP considers it necessary to implement quality evaluation for the first and the second types of components due to more importance placed on these characteristics by customers. In the past, suppliers implemented quality evaluation for newly developed products. However, DDEP had to complete quality evaluation as well when components were sent to its warehouse. Now, DDEP sends staff to suppliers to implement joint quality evaluations. This approach avoids a second quality evaluation in the plant, saves additional quality evaluating equipment for DDEP, and also facilitates communication between DDEP and its suppliers. Using similar quality evaluation programs with its customers, DDEP also improves efficiency and reduces costs. DDEP considers such programs environmentally friendly since their philosophy is that improvements in efficiency (while reducing costs) represents improvements in environmental performance, primarily due to fewer resources consumed or wastes discarded.

4.3. GSCM performance in the Dalian Diesel Engine Plant

GSCM efforts by DDEP have improved its environmental performance and created opportunities such as enlarging its market share. This environmental performance improvement is supported through various awards and initiatives achieved. In 2003, DDEP was one of nine companies recognized as an environmental protection model company by the local environmental planning board. In 2004, the plant received another award and was also nominated as one of the hundred best suppliers in the automobile industry in China [38]. Such awards have greatly improved DDEP’s environmental image. As stated above, China will require all vehicles to meet Euro II emission standards. DDEP products have already met these standards as of April 2005 [38].

DDEP has enlarged its market, in part, due to its continuous GSCM practices. In 2004, DDEP produced 100,188 diesel engines, 22.28% more than in 2003 and sold 101,550 diesel engines, 22.35% more than in 2003. Both sales and production are the highest on record in DDEP’s 53-year history of the plant [38]. The limited accounting and performance management operational practices in DDEP make it difficult to determine where GSCM practice adoption has contributed to performance. For example, without meeting certain environmental requirements in their products and processes, it is probably very unlikely that they would be able to stay in business, much less thriving in this environment. What is clear is that they continue to perform well on a variety of performance factors even with GSCM practice increases.

DDEP has improved both environmental and economic performance through GSCM related practices. It is complying with regulatory and market pressures by offering innovative and environmentally sound products. However, the plant has also faced numerous challenges. Prices for energy and raw materials have continuously increased. Emission standards have become increasingly strict. For example, the Federal government recently announced plans to implement Euro III standards on emissions by the end of 2005. These continued pressures and forces will cause not only DDEP to adopt and advance GSCM innovation, but other manufacturers will need to react as well.
5. Discussion

In both the empirical analysis and the case study we have observed that Chinese automotive organizations are feeling multiple pressures and are also reacting with multiple and diverse sets of actions. The organization in the case study is a relatively more innovative organization when it comes to adopting GSCM practices and practicing environmental sustainability. The pressures they feel are similar to other automotive supply chain members, but their size and partnerships seem to allow them advantages that may not exist in other organizations, to respond to these pressures. Yet, these multi-faceted isomorphic pressures faced by the automotive supply chain including regulatory and global market pressures will eventually cause automotive supply chain organizations to adopt a baseline level of many of these practices. Industry-wise we have observed some minor relationships between pressures and adoption rates, but the case study company clearly points to a causal relationship that exists for these relationships with management indicating that many of the GSCM practices were driven by these pressures. This information cannot be gleaned from the empirical data alone. It is expected that these causal relationships probably exist for other organizations within the Chinese automotive supply chain.

Another observation that can be made from the case study and with implications for the overall industry not yet observed in the empirical data, is that different pressures will cause adoption of different practices. For example, we see that domestic regulatory pressures from emissions laws and automobile take-back legislation will influence eco-design and investment recovery practice adoption in the automotive supply chain, whereas supply chain and market pressures will influence cooperative efforts and green purchasing practices. These are issues and factors that can be investigated in later, longitudinal, studies of environmental sustainability within the supply chain.

Another issue that arose from the case study is that even though there are relationships that exist either implicitly or explicitly between GSCM practice adoption and performance in the empirical study, the tangible and direct results are not always clear. The capability to monitor and measure performance and tie them to certain GSCM practices is something that is difficult to do, but may be necessary for further adoption of these practices when other organizations attempt to make a ‘business case’ for adoption of these practices. Our data in the empirical study were perceptually based; the case study brings into question whether these perceptions can be tied to performance. Even within the case study company, environmental performance measurements were not explicitly recorded and that tying the financial measures to specific practices is an extremely difficult proposition. The research value of having these measurements is clear, but practical managerial value is something that is necessary for long-term improvements and practice adoption decisions.

From a more general legislative and policy perspective, it is clear that strict regulations with strict enforcement are important motivators and drivers for companies to consider environmental issues through their whole supply chains. In addition, publicizing pioneer environmentally friendly companies, such as through environmental awards by the Dalian municipality, can be an incentive for companies, whose environmental performance reaches beyond environmental regulations, to make continuous efforts on environmental improvements. This relates to the influence of image of the organization not only from the community’s perspective, but also within the supply chain as an exemplary organization with which to do business, whether it is as a customer or vendor.

6. Summary and conclusions

After China’s entry into the WTO, the Chinese automobile industry, and its corresponding supply chains, has faced challenges instilled by their international counterparts. Entry into the WTO has also meant that the growth in transportation vehicle and component demands by consumers, organizations, and international partners will skyrocket. It is expected that China will become one of the largest producers and users of automobiles and their parts. As a result, Chinese automobile supply chains have struggled to improve their economic and environmental performance (and sustainability) simultaneously. Thus, GSCM practices have emerged as systematic approaches for the automobile industry in China.

Correspondingly, Chinese automobile enterprises have experienced high regulatory and market pressures and at the same time have strong internal drivers for GSCM practice adoption. However, their GSCM practice implementation, especially on external relationships such as green purchasing and customer cooperation focusing on environmental concerns, is lagging. In most cases these enterprises have only planned to consider or, at most, considering corporate environmental management and GSCM implementation. Therefore, GSCM implementation has only slightly improved environmental and operational performance, and has not resulted in significant economic performance. The relationship between pressures and GSCM practice adoption at this time is not entirely clear. It is expected that as time progresses the relationships between the increasing pressures and nascent GSCM practices will become clearer. In our case study, we see evidence of these direct relationships within a more pioneering organization. A detailed analysis on one Chinese automobile engine manufacturer indicates that with the pressures and drivers, pioneering companies such as the Dalian Diesel Engine Plant have initiated GSCM practices, bringing about various performance improvements. The causal relationship, based on discussions with management, between these three factors becomes more evident. Thus, it is our belief that these relationships will also exist in the broader industry and its supply chains.

This study is not without its limitations. The sample only included a convenience sample of organizations. The respondents were not randomly selected. However, it is one of the few studies that has considered the environmental sustainability practices and implications of an emerging economy in the
The automobile industry and provides a valuable snapshot of the situation in China. This initial study calls for a longitudinal and broad-based investigation to arrive at a more lucid picture of environmental sustainability practices in the Chinese automotive supply chain.

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Appendix A. Major questionnaire items

- General Information
  - Your company is (a) state-owned; (b) a joint venture; (c) a FDI enterprise; (d) a private sector
  - Number of employees

- GSCM drivers/pressure
  - Regulations
    - Central governmental environmental regulations
    - Regional environmental regulations
    - Export countries’ environmental regulations
    - Products potentially conflict with laws
  - Market
    - Export
    - Sales to foreign customers
    - Chinese consumers’ environmental awareness
    - Establishing company’s green image
  - Suppliers
    - Supplier’s advances in developing environmentally friendly goods
    - Environmental partnership with suppliers
    - Supplier’s advances in providing environmentally friendly packages
    - Making sure that suppliers will remain in business (business continuity)

- Internal factors
  - Company’s environmental mission
  - Internal multinational policies (subsidiaries or divisions of a multinational firm)
  - Potential liability for disposal of hazardous materials
  - Cost for disposal of hazardous materials
  - Cost of environmental friendly goods
  - Cost of environmental friendly packages

- GSCM Practices
  - If your company has carried out some activities in the below, please indicate how long it was done?
    - Internal management
      - Commitment of GSCM from senior managers
    - Support for GSCM from mid-level managers
    - Cross-functional cooperation for environmental improvements
    - Total quality environmental management
    - Environmental compliance and auditing programs
    - ISO 14000 certificate
    - Environmental Management Systems exist
    - Eco-labeling of products
    - Green purchasing
      - Providing design specification to suppliers that include environmental requirements for purchased items
      - Cooperation with suppliers for environmental objectives
      - Environmental audit for suppliers’ inner management
      - Suppliers’ ISO14000 certification
      - Second-tier supplier environmentally friendly practice evaluation
    - Cooperation with customers including environmental requirements
      - Cooperation with customer for eco-design
      - Cooperation with customers for cleaner production
      - Cooperation with customers for green packaging
      - Cooperation with customers for using less energy during product transportation
    - Investment recovery
      - Investment recovery (sale) of excess inventories/materials
      - Sale of scrap and used materials
      - Sale of excess capital equipment
    - Eco-design
      - Design of products for reduced consumption of material/energy
      - Design of products for reuse, recycle, recovery of material, component parts
      - Design of products to avoid or reduce use of hazardous of products and/or their manufacturing process
    - Performance
      - Environmental performance
        - Reduction of air emission
        - Reduction of waste water
        - Reduction of solid wastes
        - Decrease of consumption for hazardous/harmful/toxic materials
        - Decrease of frequency for environmental accidents
        - Improve a company’s environmental situation
      - Positive economic performance
        - Decrease of cost for materials purchasing
        - Decrease of cost for energy consumption
        - Decrease of fee for waste treatment
        - Decrease of fee for waste discharge
        - Decrease of fine for environmental accidents
      - Negative economic performance
        - Increase of investment
        - Increase of operational cost
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