

# Study on Performance Evaluation of Green Supply Chain in Steel Industry

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**Abstract**—The production of steel industry is closely related to integration and promotion of supply chain. Reducing cost and reusing wastes of the supply chain are one of the most significant challenges the steel enterprises need to overcome. Nowadays, green supply chain for the steel industry appears to be a wide open research area with no definitive solution yet. This paper provides a performance evaluation system of green supply chain, and the system is applied to a study on a steel enterprise where the performance of green supply chain is evaluated. At first, the paper analyzes the influencing factors of the performance on green supply chain of Chinese steel enterprises. On the basis of these factors, researchers construct a model for evaluation of performance on green supply chain, which covers the important indices in the economy, operation, and environment aspects. Finally, this paper provides the steel industry with some suggestions in using the green supply chain, which can further benefit the Chinese steel enterprises in adjusting their supply chain.

**Keywords**—Green Supply Chain; Performance Evaluation; Steel Industry; Improvement Strategies; Index System

## I. INTRODUCTION

With the increasing environment pollution and energy shortage, it becomes necessary and important to protect the environment and save energy. To this end, the theory of green supply chain management has been developed for manufacturing industry to protect environment and save energy.

The production of steel industry is closely related to integration and promotion of supply chain. As one of the heavy industries which strongly consume energies and produce enormous wastes, the steel industry has to face a difficulty of improving its supply chain for cost-effective reason. Reducing cost and reusing wastes of the supply chain is one of the most significant challenges the steel enterprises need to overcome.

Nowadays, green supply chain for the steel industry appears to be a wide open research area with no definitive solution yet. A green supply chain management in steel industry covers all phases in manufacturing from raw materials procurement and manufacturing to distribution, transportation, warehousing, and consumer recycling. The framework of a green supply chain for the steel industry is shown in Fig .1. Up to now, a lot of steel enterprises have adopted green supply chain in their management, while the effectiveness of the chain still remains unclear. Thus, a comprehensive evaluation of the performance of the green supply chain in steel industry attracts great attentions from both industry and academia.

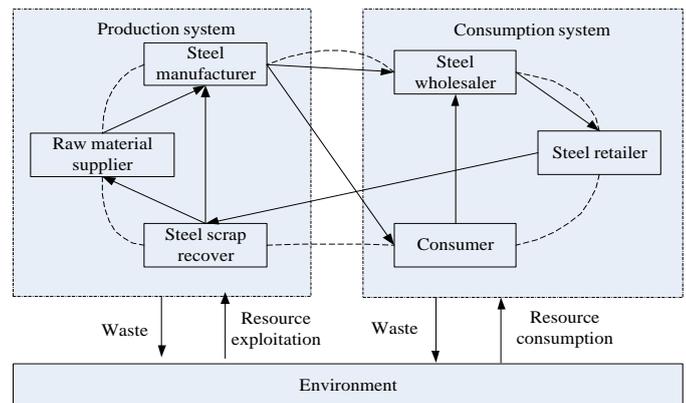


Figure 1. Framework of a green supply chain for the steel industry

In this paper, researchers provide a performance evaluation system for evaluating the performance of green supply chain in steel industry. Researchers first analyze the influencing factors of the performance on green supply chain of Chinese steel enterprises. On the basis of these factors, researchers construct a model for evaluation of performance on green supply chain, which covers not only the financial and operational indicators used for evaluating the performance of the traditional supply chain, but also the impacts on environments. Finally, researchers provide the steel industry with some suggestions about using the green supply chain, which can further benefit the Chinese steel enterprises in adjusting their supply chain.

## II. INFLUENCING FACTORS

In accordance with the basic notion of the green supply chain management and the ISO14000 environmental management certification system [10], researchers evaluate the green supply chain performance of the steel industry in three aspects: financial, operational and environmental.

### A. Financial factors

With the “Performance Evaluation Standards for Enterprises” (issued by Chinese National Bureau of Statistics) and the “Performance Evaluation Index System for State-Owned Capital” (issued by China’s Ministry of Finance, etc.), the financial factors are the most important for evaluating performance of enterprises. For the iron and steel enterprises, their main business purpose is to organize and coordinate their upstream suppliers and downstream distributors and also maximize the economic benefits from

the entire supply chain. The impact of financial factors on the performance of the green supply chain of steel industry mainly focuses on the profitability, asset quality, and cost consuming.

### B. Operational factors

Operating factors are the key factors for maintaining the operation of the green supply chain. They mainly affect business performance in several aspects including the business process, customer service, innovation and development. Here the business process denotes the entire operation process of the steel industry, and it ensures the operation of the entire supply chain so that the business works smoothly to produce the economic benefits. The level of customer service can affect the company's reputation and customer loyalty because only customer service of high-quality can retain customers long and ensure the stable customer source. Innovation and development reflects the development potential, which helps improve the long-term competitiveness of an enterprise.

### C. Environmental factors

An enterprise needs to make a profit, meanwhile takes the corresponding environmental and social responsibilities. One main responsibility is to save energies and reduce environmental pollutions. In addition, a steel enterprise may not only consume many energies and resources, but also emit dusts, greenhouse gases and wastewater pollutants during the production, which can cause serious damage to the environment. Thereafter, the impacts of environmental factors on the green supply chain cannot be ignored, but need to be evaluated. The environmental factors include those for environmental protection and energy consumption and recycling; the environmental protection reflects a degree of the steel industry supply chain to affect the environment; the energy consumption reflects the degree of utilization of the steel industry supply chain to natural resources; recycling of waste materials reflects the degree of the enterprise to conserve resources and reduce costs.

## III. DESIGNING THE INDEX SYSTEM OF GREEN SUPPLY CHAIN IN STEEL INDUSTRY

Since a supply chain management involves a number of factors affecting the performance, it is not easy to evaluate its performance precisely. Especially, as far as researchers know, there does not have any general performance evaluation model for evaluating the performance of green supply chain in steel industry.

In this paper researchers provide an index system for evaluating the green supply chain in steel industry. The index system is given in Table I [7], which combines some performance evaluation criteria provided by the Chinese National Bureau of Statistics and the environmental management standard of ISO14000 series.

The indicators in the system can help analyze the bottlenecks of applying green supply chain as well as provide with advice in optimizing the green supply chain and ultimately improve its performance and decrease the resource usage. Furthermore, researchers apply this model to a practical manufacturer to verify its effectiveness. In order to verify its effectiveness, researchers adopt the AHP

(analytic hierarchy process) and Fuzzy comprehensive evaluation approaches to analyze the results.

TABLE I. INDEX SYSTEM FOR PERFORMANCE EVALUATION

Target level	First-level indicators	Second-level indicators
Performance Evaluation of green supply chain in manufacturing industry A	Financial indicators A1	Growth rate of sale A11
		Growth rate of profit A12
		Capital resale value A13
		Return on equity A14
		Assets liabilities ratio A15
	Operational indicators A2	Market share A21
		Production capacity A22
		Benefits of research project A23
		Average satisfaction A24
		Sales rate of new product A25
	Environmental indicators A3	Energy consumption A31
		Resource consumption A32
		Emissions A33
		Amount of wastewater A34
		Amount of waste A35
		Wastewater recycling rate A36
		Waste recycling rate A37

## IV. IMPROVEMENT STRATEGIES OF GREEN SUPPLY CHAIN IN STEEL INDUSTRY

### A. Using green production technology

The Chinese steel industry has already taken a series of green production technology to improve resource utilization and reduce environmental pollution, but compared with those in developed countries, there still exists a gap. After an investigation of a steel manufacturer, researchers can find that green production techniques can be adopted in order to improve the performance of green supply chain from three aspects:

Improve the degree of gas usage. Steel industry can produce some kind of secondary energy such as coke oven gas, blast furnace gas and converter gas. In Japan, the United States and other developed countries, these gases are recycled and used as the fuel of coke oven, stove and furnace, and the remained gases are fed to the boilers or gas turbines to produce steam or used as fuel for electricity generation. Thus the by-product gases can be recycled during their production. In China the degree of by-product gas usage is relatively low, and a lot of gas is emitted into the atmosphere, which not only wastes energies, but also pollutes the environment. Thus researchers can simply draw a conclusion that the Chinese steel enterprises need to increase the degree of usage of by-product gas.

Save water. Chinese iron and steel industry can consume up to 6.22% of the total industrial water, and produce up to 8.30% of the total industrial wasted water. The rapid development of Chinese steel industry can demand more water and produce more wasted water, which may cause serious contradiction between water supply and demand. In recent years, the Chinese government has promoted the water-saving and sewage treatment engineering, making the water conserved, wastewater treated, and water reused. Meanwhile in 2011, the water recycle rate of Chinese iron and steel enterprises is in average 93%, while that in the steel enterprises in advanced countries can reach 98%. The Chinese steel industry can continue to save water through improving the circulatory system and refactoring the product line.

Reduce SO<sub>2</sub> emissions. At each year, Chinese steel industry consumes about 60 million tons of coal and emits enormous SO<sub>2</sub>. A solution is to take the desulphurization in its production, which can reduce the emissions of about 400 thousand tons of SO<sub>2</sub>.

#### B. *Improving degree of supplier greening*

In order to improve the overall performance of the green supply chain of the steel industry, researchers need to increase the degree of greening of the entire supply chain. Therefore, it is critical for iron and steel enterprises to choose suitable green suppliers. As what researchers have discussed in the previous section, a performance evaluation system for the green supply chain can be constructed for selecting the best suppliers. It is also necessary to evaluate the available suppliers periodically in order to ensure that they are maintaining a long-term green management and taking continuous improvement of degree of greening. Having chosen suppliers, the iron and steel enterprises also guide and support them so that they can achieve a win-win.

#### C. *Adopting the green equipments*

Chinese iron and steel enterprises should discard the equipment of high resource consuming, with high pollution, of poor product quality and low productivity, such as open-hearth steelmaking converter, etc. And they also need to adopt the equipment having energy-saving techniques, with measures of reducing pollutant emissions and increasing recycling of resources. For example, a using of the CDQ waste heat recovery to produce power can reduce up to 21kg energy consuming when produce a ton of steel; a using of the sintering heat recycling can reduce about 10kg energy per ton of steel; a using of the blast furnace gas-fired turbine generator can help reduce about 21kg energy per ton of steel, and the furnace gas emitted is close to zero.

#### D. *Researching on green products*

Green products are different from other products in that they are not only of good quality but also satisfy the requirements of environmental protection. It is necessary for the Chinese iron and steel enterprises to invest in this field, because the research and development of the green products can be a driving force for them to take sustainable development. Since the requirements for producing the green products are high, the extra values of the products are also high. The iron and steel enterprises in developed countries invest even up to 40% of their net proceeds on the R&D of green products. Compared with them, the Chinese enterprises need to improve the competitiveness of enterprises through researching and developing on green products.

#### E. *Establishing the green image of steel enterprises*

The iron and steel enterprises establishing a green image can help them obtain the reputation and trustiness from the public and reduce the losses caused by the market risk. It helps the enterprises to increase the competitiveness, reduce the threats to be substituted, and obtain a high market share rate. It also helps the enterprises be financed and attract talents, because the green products can be easily accepted by the investors and employees. The advantages

will eventually be transformed to high productivity, which further improves the performance of the supply chain.

#### F. *Improving the environmental management system*

The ISO 14000 environmental management standards developed by the International Organization for Standardization (ISO) are used for establishing, implementing and auditing the environmental management system, which require enterprises adopt standardized management as well adopt environmental protection measures in their production. The ISO14000 certification is also required for enterprises to enter the international market and break through the green barriers. Some large and medium-sized iron and steel enterprises in China, such as Baogang, Shougang, Anshan Iron and Steel Corp. have passed the certification, but many others still face problems to get certified. It is believed that a Chinese iron and steel enterprise should establish some strict environmental management system on the basis of the ISO14000 certification, and incorporate the ISO14000 standards into its managements, and thus the standards can be accepted and adopted qualitatively and quantitatively by each member in the enterprise.

#### G. *Establishing an efficient reverse logistics system*

The reverse logistics of the steel industry refers to a production phase of using the scrap and energy recycled, and thus it improves resource utilization, reduces the consumption of natural resources, and helps the development of circular economy, and finally reduces the operation costs. Energy recycle can be taken through adopting some energy-saving techniques so as to reuse the energy, e.g., to recycle the scrap. Since the scrap recycles only requires a simple processing including sorting, collection, and transportation, the scrap price is usually lower than that of raw iron. Furthermore, a replacement of iron ore using scrap can reduce up to 86% of gas pollution, 46% of water pollution, 70% of water consumption, and reduce up to 97% of mining wastes.

At present, the Chinese scrap reverse logistics have not yet formed an effective system. The scrap recycling points of small-scale and poor equipment disperse around the society, and the specialized large-scale recycling centers are still rare, which results in the poor quality of the recycled scraps and the difficulty of reusing them. It wastes many resources and increases the cost of the iron and steel enterprises. Thus, the large-scale specialized recycling centers need to be established so that the iron and steel enterprises can recycle waste steels in an active manner.

## V. CONCLUSIONS

In this paper, researchers construct a performance evaluation system of green supply chain, and the system is applied to a study on a steel enterprise where the performance of green supply chain is evaluated. At first, the paper analyzes the influencing factors of the performance on green supply chain of Chinese steel enterprises. On the basis of these factors, researchers construct a model for evaluation of performance on green supply chain, which covers the important indices in the economy, operation, and environment aspects. Finally, this paper provides the steel industry with some suggestions in

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