

A Study on the Evaluation of Green Production in Manufacturing EnterprisesSang-Bing Tsai^{1,2}¹ University of Electronic Science and Technology of China Zhongshan Institute, Guangdong 528402, China² School of Business, Wuyi University, Wuyishan 354300, China

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Abstract. Green production not only represents the spirit of pollution prevention in the production process, but also aims at pursuing ecological benefits and sustainable development. If high-tech manufacturing enterprises want to break through the dilemma of low-profit competition, they should strengthen their low pollution, low energy consumption, and clean production goals in order to highlight product differences, strengthen their green innovations, and maintain competitiveness. In this study, 20 enterprises in Zhongshan City, Guangdong Province, China are selected as research subjects to understand the dynamics and effects of the green production of enterprises, and based on literature analysis, a study model is established. This study is helpful to guide enterprises and the government to effectively identify the green production level of enterprises and identify the deficiencies and risks in the green production process. This study expects to determine the evaluation index of green production in manufacturing enterprises and analyze the competitive strategies of the enterprises, which can serve as the basis for the improvement of individual companies.

1. Introduction

The UNEP International Organization for Standardization (ISO) published the ISO-14000 series of standards in 1996, which incorporated environmental management into the daily management procedures of enterprises. If export products cannot obtain relevant certification of environmental management, they will be resisted¹⁻³. In 1997, UNEP gave a clear definition for green production, "Green production refers to the continuous application of integrated and preventive environmental strategies in processes, products, and services to increase ecological benefits and reduce hazards to human beings and health". It can be seen that green production mainly covers three aspects: process, products, and services⁴⁻⁵. Regarding process, low-hazard raw materials should be matched with less waste production procedures and high-efficiency production equipment to reduce various hazardous factors and harmful intermediate products in the production process, and reduce the quantity and toxicity of waste to maximize the use of resources. Regarding products, the adverse impact and harm to the ecological environment should be minimized in the product itself, as well as in the process of use. When a product loses its use function, it should be easy to recycle, regenerate, and reuse. At the same time, the entire life cycle of the product should also be considered. Necessary measures should be taken in every process from product development, product planning, product design, raw material processing, product output, and product

use until disposal, in order to minimize the consumption of resources and energy. Regarding services, environmental elements should be incorporated into the design and services provided, and the harm to the environment caused by the services provided should be reduced.

Due to the challenges of increasingly stringent corporate environmental problems, developed countries, such as European countries and the United States, have taken pollution prevention and resource conservation as the development direction of their national environmental policy. Instead of the previous government-led command and control mode and the environmental protection work focusing on the implementation of end-of-pipe pollution control, the government and the business community have become partners to jointly implement pollution prevention and control, and environmental management has become a systematic work.

How to use scientific and quantitative methods to discuss the evaluation index of green production and evaluate the performance of green production is the focus of this study. The purpose of this study is to determine an evaluation index for green production and analyze the competitive strategies of the industry, in order to provide the industry with improvement strategies.

2. Literature Review

Winn and Roome (1993) divided the ways enterprises handle green production into four areas, green quality control, working environment and safety, green marketing, and environmental value and ethics. Among them, the quality approach refers to environmental management with the concept of similar quality control. The health and safety approach refers to the management of work environment, work safety, etc. The product marketing approach refers to the green marketing of enterprises. The value approach refers to the incorporation of the concept of environmental ethics into the content of enterprise environmental management⁶⁻⁷.

Tsai (2015) believed that, from a broad perspective, green production emphasizes the importance of industrial waste reduction, and its main spirit is to reduce the amount of waste at the source and recycle it. The timing of implementation is usually at the stages of process research, mold field testing, production operation, and product use. From a narrow perspective, green production focuses on production and product improvement, emphasizes pollution prevention in industrial manufacturing processes, and includes all possible impacts on ecological environments⁸⁻⁹.

The difference between green production and traditional environmental protection concepts lies in that the traditional environmental protection concept directly considers the treatment of pollutants or wastes when solving environmental problems, while green production first considers the causes of environmental problems and resolves them from the source. Most environmental problems come from the design of products, processes, and management systems. Green production emphasizes that the environmental management of industry should be carried out from managing sources, such as process and product life cycle, while product life cycle should also have the functions or concepts of recyclability, low pollution, resource-saving, etc.

Green production not only represents the spirit of pollution prevention in the production process, it also bears

certain responsibilities for products and the environment. The ultimate goal is to pursue ecological benefits and sustainable development. If high-tech manufacturing enterprises want to break through the competitive dilemma of low profits, they should strengthen their production concepts of low pollution, low energy consumption, clean production, and environmental friendliness. Only by utilizing advanced technologies and strengthening environmental management can they maintain industrial competitiveness, highlight the differences of their products, and increase the high added value of products¹⁰⁻¹³.

Taking green production as the common technical norm for sustainable development is not an accidental case, but a gradual evolution of production and manufacturing management technology. Starting with the initial "end-of-pipe control", how to minimize the impact of manufacturing on the environment? From this we can see that the concept of green production has become an international prerequisite for all "manufacturing" to move towards "sustainable development".

In this study, 10 indicators of green production are proposed to measure the performance and competitive strategies of green production in individual enterprises. Please refer to Table 1 for the details of these 10 indicators.

3. Research method- Simultaneous Importance- Performance Analysis

Burns (1986) proposed the synchronous importance and performance analysis method, which conducts simple analysis according to the three concepts of importance, performance, and competitor's performance¹⁴⁻¹⁸. The basic application of SIPA is to compare the companies to be investigated with competitors¹⁹⁻²³. First, several indicators to be discussed are selected and questionnaires are sent out to the respondents, and the degree of importance attached to the indicators is obtained and classified into High and Low. Then, the respondents are requested to rate the attributes of the company and competitors individually, which are classified into Poor and Good²⁴⁻²⁸. Finally, eight competitive states are obtained, and according to Burns, given corresponding market competitive strategies, respectively, as shown in Table 1.

(1) Neglected Opportunity:

It indicates that the importance of this index is high, and the performances of the company and its competitors are not good. It is a potential opportunity that has been neglected. Whoever grasps this situation first will be able to gain customers by investing resources.

(2) Competitive Disadvantage:

It indicates that the importance of this index is high, and the company's performance lags behind that of its competitors; therefore, it falls into a competitive disadvantage, which may result in significant losses, and should be strengthened and improved immediately.

(3) Competitive Advantage:

It indicates that the importance of this index is high, and the company's performance is better than that of

competitors. This is the competitive comparative advantage, i.e. niche, which requires long-term protection and sustainability.

(4) Head-to-Head Competition

It indicates that the importance of this index is high. The performances of the company and its competitors are both good, thus, the company must continue to perform well without any negligence.

(5) Null Opportunity

It indicates that the importance of this index is low, and the investment performances of the company and competitors are not good, which means that this is a false opportunity, as customers will not become more willing to buy because of the improvement of this index.

(6) False Alarm

It indicates that that the importance of this index is low, and the competitors perform better than the company. This is just a false alarm, as it will not cause the company to lose customers, and no special response is required.

(7) False Advantage

It indicates that that the importance of this index is low, and the company performs better than its competitors. This is only a false competitive advantage, as it cannot bring benefits to the company, and thus, it should consider transferring resource recovery to other aspects.

(8) False Competition

It indicates that the importance of this index is low, but both the company and its competitors have good performance, indicating excessive competition. The company should consider transferring resource recovery to other aspects.

The SIPA method analyses the performance of the company itself, as well as the performance of competitors. In addition to analyzing the indicators that customers attach importance to, it obtains the performance differences between the company and its competitors. According to the comparison conclusions, the company can propose corresponding competition strategies and allocate the investment of company resources.

4. Research Results and Discussion

Company A is the Zhongshan Electronic Materials Company of China. This study takes Company A as the case study subject to evaluate its green production performance, which will then serve as the basis for the improvement of the case company.

This questionnaire uses a Likert scale with a total of 10 questions. The respondents of the questionnaire include 20 industry experts, including 10 professors and 20 senior executives. A total of 30 formal questionnaires were issued, and 30 valid questionnaires were recovered, for an effective recovery rate of 100%.

In this study, according to the questionnaire statistics, the average value of importance (5.80) and the average value of peer performance (5.80) were used as the standard coordinates to determine the performance of each attribute. In addition, the average performance of the industry was taken as a criterion to determine the performance of each company, and assign each competitive attribute as "Good" or "Poor". Please refer to Table 1 for details.

According to the results of SIPA analysis, Company A has “Competitive Advantage” in the 3 criteria of: (4) The compliance rate of air and wastewater discharge, (5) The number of environmental pollution violations, and (7) The utilization rate of recycled wastewater. These are Company A's strengths, which must be maintained to keep its competitive performance and help the company achieve better green production performance.

Company A has “Competitive Disadvantage” in the 2 criteria of: (9) The proportion of green procurement of main raw materials and (10) The degree of product recycling. Company A must concentrate resources to improve the competitiveness of these four criteria in order to reverse the disadvantages and improve its environmental performance.

In addition, Company A outperformed its competitors in the two criteria of: (1) Electricity consumption rate per unit of revenue and (2) Waste rate per unit of revenue; however, these two criteria can only be regarded as the "False Advantages" of Company X. Customers think that this attribute is of low importance, and Company A performs better than its competitors.

Although Company A lags behind its competitors in the two criteria of: (3) The proportion of environmental protection equipment funds to revenue and (7) The utilization rate of recycled waste water, customers think that this attribute is of low importance, and therefore, only belongs to "False Alarm".

Company A performs well with its competitors in the attribute of (8) Product green design, which belongs to "Head-to-Head Competition", and indicates that the attribute is of high importance, the company performs well with its competitors, and must continue to perform well without any negligence. Please refer to Table 1 for details.

Table 1 Competitive Strategy Analysis by SIPA

Item	Index	Importance		X Company's Performance		Competitor's Performance		Market Competitive Strategy
1	Electricity consumption rate per unit of revenue	Low	5.6	Good	5.9	Poor	5.6	False Advantage
2	Waste rate per unit of revenue	Low	5.2	Good	6.0	Poor	5.8	False Advantage
3	Proportion of environmental protection equipment funds to revenue	Low	5.6	Poor	5.4	Good	5.9	False Alarm
4	Compliance rate of air and wastewater discharge	High	5.9	Good	6.2	Poor	5.7	Competitive Advantage
5	Number of environmental pollution violations	High	6.2	Good	6.0	Poor	5.5	Competitive Advantage
6	Utilization rate of main raw materials	Low	5.4	Poor	5.3	Good	5.9	False Alarm
7	Utilization rate of recycled wastewater	High	6.0	Good	5.9	Poor	5.7	Competitive Advantage
8	Product green design	High	5.9	Good	6.2	Good	6.0	Head-to-Head Competition
9	Proportion of green procurement of main raw materials	High	6.1	Poor	5.7	Good	5.9	Competitive Disadvantage
10	Degree of product recycling	High	6.1	Poor	5.6	Good	6.0	Competitive Disadvantage
Average			5.80		5.82		5.80	

5. Conclusion

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