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Auxiliary Decision-making of Enterprise Green Innovation under the Background of Environmental Regulation

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Enterprise green innovation often facilitates/accompanies staff training and project operation. Not only does this innovation change the production process, but also it changes product design, adjusts the organization structure and the supply chain, and even leads to renewal of product image as well as influences the company strategy and market competitiveness. So when we make green innovation decision, we should not only take environmental performance as foothold, but also put the long-term company development and competitive as the ultimate goal. Based on the balanced scorecard, this paper aims to help enterprises make choice more effectively and comprehensively to take precedence in the green tide throughout the world, with several factors taken into account, such as evaluation system and method from the perspective of financial and environmental performance perspective, customer perspective, internal process perspective, learning and organizational development .

1. Introduction

In recent years, the whole society is appealing for environmental protection and the government's environmental regulation is stricter. Low carbon, energy saving, clean production and environmental protection will be an inevitable world-beating trend. Under this background, the evaluation and selection of green innovation project will determine the development direction and prospects of enterprises. This paper chose pharmaceutical enterprises as the research object because the pharmaceutical industry has traditionally been referred to the conscience industry, to which market image is crucial. But in recent years, there are some negative events such as chrome overweight capsule events, which have severely damaged the image in the eyes of the public in the industry (Chen and Li, 2014).

2. Literature review and research hypothesis

In the evaluation of green innovation activities, foreign scholars tried to consider the economic performance and environmental performance at the same time, and explored the relationship between them. They emphatically studied the evaluation index system and evaluation method of environmental performance. In general, foreign scholars built evaluation system of environmental performance from the angle of green supply chain, sustainable development, the product life cycle, comparability improvement, risk management and so on. Chinese scholars have carried out many related researches on the basis of fully absorbing foreign advanced experience. For example, (Shen, 2002) proposed set of AHP (C - EPSS) layer calculation model for building enterprise environment evaluation system in the process of evaluating the environmental performance of construction contracting enterprise of mainland and Hong Kong. (Luo and Ye, 2005) designed evaluation index system of green supply chain, established the multi-level fuzzy comprehensive evaluation model and formed a new strategic decision framework model. By analyzing the status quo and pollution characteristics of manufacturing enterprises, (Zhang, 2007) built new evaluation framework and index system.

With the growing environmental awareness, enterprises need to carry out greener innovation activities. The existing theoretical researches can't satisfy the needs of enterprises to carry out the strategy of green because they focus on short-term, local environmental performance evaluation. To conduct a comprehensive and long-term evaluation of green innovation activities, researchers need to construct a complete evaluation system.

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After years of development, the balanced scorecard is now an important tool of enterprise performance evaluation and it has also been used in enterprise environmental performance evaluation, but there are few literatures about the balanced scorecard applied in the auxiliary decision-making of green innovation project. Using the balanced scorecard to make the multi-angle analysis of utility and effect of enterprise green innovation projects can make up for the deficiency in the evaluation of a single financial or environment factor. The factors about the enterprise long-term development and the customer value of enterprise in balanced scorecard make the evaluations more comprehensive and more reflect the value-added aspirations. Therefore, the hypothesis this paper wants to mainly verify is:
H1: Green innovation evaluation results based on the balanced scorecard is different from the traditional single guide decision-making.

3. Construction of evaluation index system of green innovation project

Based on the balanced scorecard, we put forward the evaluation indexes from the perspective of financial and environmental performance, customer, internal process perspective, learning and organizational development to investigate cleaner production options comprehensively.

Table 1: Evaluation index system of Enterprise green innovation

First Grade Index	Second Grade Index	Three-grade Index
Finance U_1	Income index U_{11}	Investment yield rate of environmental protection equipment U_{111}
		Yield rate of comprehensive utilization of "three wastes" U_{112}
	Cost of environment pollution U_{12}	Environmental fines U_{121}
		Pollutant charge U_{122}
Consumer U_2	Evaluation of the government U_{21}	Environmental impact assessment U_{211}
		Observation to “three simultaneous” management system U_{212}
		Mark of environmental products U_{213}
		Number of environmental award received U_{214}
	Evaluation of local residents U_{22}	Number of complaints from local residents U_{221}
		Number of media exposure U_{222}
Internal process U_3	Resource consumption U_{31}	Electricity consumption per unit U_{311}
		Water consumption per unit U_{312}
		Energy consumption per unit(gas) U_{313}
	Pollution index U_{32}	Wastewater discharge per unit U_{321}
		Exhaust emission per unit U_{322}
		Solid waste amount per unit of output U_{323}
	Environmental management index U_{33}	Rate of reaching the standard for Industrial waste water U_{331}
		Rate of reaching the standard for exhaust gas U_{332}
		Solid waste disposal rate U_{333}
		Elimination of backward production capacity U_{334}
	Resources recycling index U_{34}	Cyclic utilization rate of industrial water U_{341}
		Comprehensive utilization rate of solid waste U_{342}
Innovation and Learning U_4	Acquisition of flexible capability U_{41}	Steady-state adjustment according to requirements U_{411}
		Optimization of production methods U_{412}
		Flexibility of integration of external resources U_{413}
		The influence of advertising or promotional measures on consumers U_{414}
	Technology and equipment level U_{42}	Environmental education and training U_{421}
		Investment of environmental technology innovation U_{422}
		Advancement of technology and equipment U_{423}

3.1 Finance

The main financial goal of enterprises is to realize value maximization. But to achieve environmental performance, enterprises inevitably need to invest in environmental management which will reduce the enterprise's profit. So it is reasonable to see that the enterprises' enthusiasm on internal environment management is not high.

3.2 Customer

At the customer level, how customer treat enterprise is mainly considered/taken into account. The dimensions of the performance evaluation indicators are government assessment and evaluation of local residents.

3.3 Internal process

Internal process of environmental management is an important aspect of enterprise to improve internal environmental management performance, and it is the foundation of accomplishment of other sectors. This indicator can be considered from the following three aspects: enterprise cost and the current situation of environmental pollution, environmental pollution improvement, and the cyclic utilization of the enterprise for its environmental resources.

3.4 Innovation and Learning

Innovation and learning perspective can be understood as development potential of enterprise, mainly to demonstrate whether we have internal special ability and characteristics of the key strategy.

4. The steps of evaluation method of green innovation activities based on AHP

Using AHP to evaluate environmental performance of enterprises is relatively efficient and effective.
The steps of using AHP to determine the weight of each index are as follows:
Step 1: Construct analytic hierarchy structure
Step 2: Construct judgment matrix
When weighting the index to evaluate environmental performance of pharmaceutical enterprises, we need to judge matrix from three related workers; one is a professor who has been engaged in related research for a long time. The second one is a government official in environmental protection agency, and the third one is an internal worker in the pharmaceutical company. Matlab software is used to deal with the judgment result from the three experts layer by layer to determine the final weights of evaluation indexes.
Step 3: Determine the priorities of various factors
Determine the importance order of various factors by calculating maximum characteristic root and characteristic vector of matrix.
(1)Calculate the product of each line element of priority matrix M_i

$$M_i = \prod_{j=1}^{n} a_{ij},\ i = 1,2,\ \cdots,\ n$$

(2)Calculate n times squaring-roots of M_i

$$\overline{W}_i = \sqrt[n]{M_i},\ i = 1,2,\ldots,n$$

(3)Normalize the vector $\overline{W} = (\overline{W}_1, \overline{W}_2, \ldots \overline{W}_n)^T, \overline{W}_i = \frac{\overline{W}_i}{\sum_{j=1}^{n} \overline{W}_j}$

$W = (w_1, w_2, \ldots, w_n)^T$ is an eigenvector corresponding maximum characteristic root.
(4)Calculate the maximum characteristic root λ_{max} of judgment matrix.

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(A \cdot W)_i}{nW_i}$$

$(A.W)_j$ is ith element of vector AW.

(5)Consistency check
Firstly, consult the mean consistency index RI value table.

Table 2: RI value table

Degree	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.52	0.89	1.12	1.26	1.36	1.41	1.46

Then calculate matrix consistency index CI.

$CI= (\lambda_{max}-n)/ (n-1)$

Finally calculated random consistency ratio CR=CI/RL.
If CR<0.10, the Priority matrix is consistent, or the judgment matrix need to be adjusted.
On the basis of industry application prospect and professional knowledge accumulation, the three experts marked the contribution of each scheme to three-level indexes according to data given by the scheme-proposed personnel. Then the mark is multiplied by the weight to get the score of each program. Thus we can determine the priority of the program, banish bad ones, and determine the priorities.

5. Case application and the result analysis

5.1 Description of the case

Jiangsu ASK pharmaceutical co., LTD. (hereinafter referred to as ASK pharmaceutical) is a national-owned high technology enterprise which is the integration of research and development, production, marketing and sales for pharmaceutical and fine chemical. ASK pharmaceutical has 35 varieties, 64 specifications of injection products of digestion and antitumor.

Table 3: Description of cleaner production plan

Code	Plan name	Plan Instruction	Cost
B1	Improve the packaging technology	Reduce the use of packaging materials, try to choose less environmental hazards, biodegradable and recycled packaging materials.	Low/no fee
C1	Update and modify pac king in cooling tower	Cooling towers have been used 7 years, the packing inside need to be replaced. New added water chillers need to be connected with original cooling towers to increase the service efficiency of the cooling tower.	High cost
C2	Adopt evaporative cond ensation and straight tu be condenser to refrige rating unit	The plan can reduce wastewater discharge and COD emissions, and can save water.	High cost
C3	Add a small oil free air compressor	At night, only a handful of equipments such as lyophilizer need to use compressed air, if still use the current big air compressor, will cause energy waste.	High cost
C4	Energy saving retrofit of cooling water and chill ed water system	By installing frequency conversion device, cooling water pump and chilled water pump can realize automatic frequency conversion.	High cost
M1	Computer aided design storage management s ystem	This scheme can reduce the dosage of raw materials, produce comprehensive benefit of 22000 yuan/y.	Low/no fee
M2	Carry physical balance calculation	This scheme can reduce pollution, save the amount of methanol 0.2 t/a, saving cost 10000 yuan/y.	Low/no fee

The energy and resource used by ASK pharmaceutical in its production process are mainly electric power, water and steam, at the same time discharging waste water, solid waste, waste gas and noise. Cleaner production audit group holds an activity with prize to encourage all staff to put forward rational proposal, and collects 23 optimization proposals about technology and devices. There are 5 high cost plans and 18 Low/no fee schemes among them. The high cost plans are the schemes that are determined to invest 50000 Yuan or above. Low/no fee schemes are those plans whose investment cost is below 50000 Yuan or no investment at all. This paper chooses seven representative schemes as the research objects, as shown in table2.

5.2 Green innovation decision-making evaluation based on factors evaluation method

Clean production audit team of ASK pharmaceutical screened the clean production options and evaluated them from four aspects as below.

Table 4: Plan Scoring and sorting table

Factor	Weight W(1-10)	Score R(1-10)						
		B1	C1	C2	C3	C4	M1	M2
Environmental benefits	10	7	6	7	9	9	5	5
Economic feasibility	9	7	8	7	9	8	9	9
Technical feasibility	7	7	6	7	7	7	7	7
Exploitativeness	6	6	6	6	6	6	6	6
Aggregate score(W×R)		218	210	218	256	247	216	216
Priority		5	4	3	1	2	6	6

5.3 Evaluations of green innovation activities based on the balanced scorecard and AHP decision

Calculate the average of the weight of the three experts (w) and score (s) of every solution, take several aggregation after two averages multiplication get expectancy value for each scheme, comparing expectations and that is the prioritization of scheme.

Table 5: Weight of index of environmental performance evaluation for clean production project

Index	Weight	Score (s)						
		B_1	C_1	C_2	C_3	C_4	M_1	M_2
U_{111}	0.0821	90	85	85	90	90	100	100
U_{112}	0.0575							90
U_{121}	0.0710			70				80
U_{122}	0.0317			70				70
U_{211}	0.0316	70		100				70
U_{212}	0.0286	0						
U_{213}	0.0205	80		85				80
U_{214}	0.0244	80		85				80
U_{221}	0.0600			70				70
U_{222}	0.0709	70		70				
U_{311}	0.0362		90		90	90		
U_{312}	0.0160		90	86		90		
U_{313}	0.0321							
U_{321}	0.0382			85				70
U_{322}	0.0327			85				70
U_{323}	0.0333							70
U_{331}	0.0255							70
U_{332}	0.0212							70
U_{333}	0.0159							70
U_{334}	0.0244							
U_{341}	0.0408							
U_{342}	0.0245	90						
U_{411}	0.0093		90		90	90	95	
U_{412}	0.0203	90						85
U_{413}	0.0396						95	
U_{414}	0.0898	90		90				
U_{421}	0.0048							90
U_{422}	0.0111	90						
U_{423}	0.0058		90	90	90	90		
ΣW*S		31.2783	13.0312	46.3100	12.0018	13.4415	12.8544	45.1263
Priority		3	5	1	7	4	6	2

5.4 analysis and discussion

Adding new facilities in C3 scheme (add small oil free air compressor) can reduce energy consumption by changing the situation in the evening when only a few devices such as the lyophilizer requiring air compressor. The company used a large air compressor which has caused the waste. According to the traditional evaluation method, the basic indexes are environmental benefit, economic feasibility, technical feasibility and exploitativeness, and C3 scheme is ranked first. But in comprehensive consideration of the contribution values of the scheme from financial perspective, customer perspective, internal process perspective, enterprise learning and growth perspective, C3 scheme is ranked the bottom. This is because of its features of locality, mechanical, end-of-pipe treatment. And B1 (improve the packing process), M2 (physical balance) which used to get low rank in traditional evaluation method is mentioned highly in the new framework of comprehensive evaluation. It is clear that new evaluation system pays more attention to the effect of ductility, integrity, and the ability to solve problem from the source.

6. Conclusion

On the one hand, by paying attention to green innovation, companies can reduce energy consumption, reduce pollution, meet the requirements of relevant environmental laws and regulations, improve the corporate image; on the other hand, enterprises can use the "green" opportunity to review and combine product design, process, organization structure, etc., and use advanced technology and ideas to improve and reform the existing business. Through injection of environmental design and optimization of product process, companies can obtain innovation value and environmental benefits, gain market competitive advantages at the same time, and truly realize "from green to gold". Therefore comparing with management after pollution, by solving problem from the source up to value chain, enterprise can obtain greater opportunities to grow up. So for the purpose of combination of enterprise's long-term interests and short-term interests, local interests and overall interests, this paper put forward the value-added oriented enterprise evaluation system based on AHP and balanced scorecard method to give in-depth evaluation of potential of green innovation behaviour and plan from different aspects.

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