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System Establishment and Method Application for Quantitatively Evaluating the Green Degree of the Products in Green Public Procurement

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Abstract: The government green purchase is widely considered to be an effective means of promoting sustainable consumption. However, how to identify the greener product is the biggest obstacle of government green purchase and it has not been well solved. A quantitative evaluation method is provided to measure the green degree of different products of the same use function with an indicator system established, which includes fundamental indicators, general indicators, and leading indicators. It can clearly show the products' green extent by rating the scores of different products, which provides the government a tool to compare the green degree of different products and select greener ones. A comprehensive evaluation case of a project purchasing 1635 desk computers in Tianjin government procurement center is conducted using the green degree evaluation system. The environmental performance of the products were assessed quantitatively, and the evaluation price, which was the bid price minus the discount (the discount rate was according to the total scores attained by their environmental performance), and the final evaluation price ranking from low to high in turn is supplier C, D, E, A, and B. The winner, supplier C, was not the lowest bid price or the best environmental performance, but it performed well at both bid price and environmental performance so it deserved the project. It shows that the green extent evaluation system can help classify the different products by evaluating their environment performance including structure and connection technology, selection of materials and marks, prolonged use, hazardous substances, energy consumption, recyclability rate, etc. and price, so that it could help to choose the greener products.

Keywords: green public procurement (GPP); quantitative evaluation method; green product; indicator system; case study

1. Introduction

As an important policy tool, developed countries spend over 10% of gross domestic product on their public procurement [1] and it is widely recognized that laws and regulations can be effective driving force for green public procurement (GPP) practices adoption and Chinese government has enacted a series of GPP policies [2]. In 1984, the US "Government Procurement Law" clearly regulated that the government should procure environmentally sound products and services, which meant that GPP has legal support for the first time. The "Agenda 21 at the United Nations Conference on Environment and Development" indicated that unsustainable production and consumption are the main reasons causing global environmental problems, and the government should control and eliminate these behaviors. Furthermore, GPP is an effective means of sustainable consumption. In 2004, The EU issued a directive on government procurement, in which environmental requirements

need to be considered while procuring and signing a contract. In China, GPP has been attached great importance with the government [3]. In 2006, the "Implementation Opinions on Environmental Labeling Products in Government Procurement" and "Environmental Labeling Products Government Purchasing List" were issued to ensure that the products were green and GPP practices were carried out successfully [1]. The latest relevant policy, for instance, in 2015, "opinions on accelerating the ecological civilization construction" made a proposal to promote energy-conserving and environment-protecting products to boost consumer demands, and established energy efficiency and environmental protection logo certification system to accord with national situations and act on international convention. Then, "guidance on promoting the positive leading role of new consumption to speed up the formation of new supply and new impetus" in 2015 and "guiding opinions on promoting green consumption" in 2016 put forward to lead production mode change by health savings green consumption patterns, to improve the system of GPP, and to expand the scope and scale. "The Thirteen Five-Year Plan" identified five development concepts including green ideas, which indicated that the government should play a guiding role in the green consumption and green procurement. GPP has received international attention because of the influence of its social and economic aspects [4].

Currently, the transformation of green production mode in China has reached a critical stage, and as an important part of demand side, GPP could force supply side to reform, which has been a hot topic in the related document about the development of an ecological civilization. On the other hand, as the government procurement scale grows and products in the list of government procurement keep on increasing, the government green purchase is developing rapidly. However, GPP practice is still too weak to meet the needs of development.

Green procurement could achieve sustainable development goals through the purchasing and supply process, and it should consider at least four themes: moving from an environmental focus to social and economic dimensions; sustainability and innovation; ethical supply; and measurement issues. Above all, measurement issues, especially quantitative evaluation, are urgently in need of research [5]. However, in past studies, product evaluation often centered on a single product; consequently, it is also important to establish a screening system in which most kinds of products can be evaluated. That means we need to found a new general way to weigh the environmental performance of products beyond the scope of "government procurement list". This paper will provide a green product screening system to measure the green degree of different products in "list" by quantitative evaluation method. We established an indicator system, including basic indicators, common indicators, and oriented indicators, to rate different product by scores. It can clearly show the products green extent, so the government can compare products and purchase products by the corresponding strategies. Meanwhile, this paper also introduces a case study, which was the first project to adopt the quantitative evaluation method and indicate that the system can be applied in GPP practices and realize the expected function to identify the greener product. Since the existing research mainly focuses on qualitative evaluation rather than quantitative evaluation, this paper is a useful supplement to the existing research, although the system and method still needs to be constantly improved in the future practice.

2. Literature Review

As a procedure, which takes environment impacts into account during confirming requirement, selecting and providing products [6], GPP was put forward, meaning that the government should purchase high-quality, but more environmentally friendly products [7]. GPP are environmentally and ecologically responsible purchases [8]. Therefore, the definition of GPP is considered to be the method by which public authorities integrate environmental criteria into the procurement process, thus encouraging the development of environmentally sound products, services and technologies by seeking and choosing outcomes and solutions that have the least possible impact on the environment throughout their whole life-cycle [4]. GPP represents an increasing trend on sustainable lifestyles of green consumption, which is committed to addressing environmental problems by consumers' co-responsibility [9], and promoting sustainable consumption, eco-production and all together

sustainable development by the enormous purchasing power [10]. Public procurement regulations generate spillover effects that stimulate both the standard adoption of the private-sector and investments [11]. The inclusion of carbon footprint in GPP could play the role of a strong stimulation for eco-innovation in the services sector [12]. The green degree of suppliers is a key factor in the selection because of the demand for intimate connection between contractors and suppliers in green construction [13].

The increasing number of recent academic articles focus on the practice, effect, influence factor and supply chain management of GPP [14]. Buying from small- and medium-sized enterprises (SMEs) can make contributions to local economic development by providing green products and services [15]. Local government in England promote sustainable development through procurement and found the supporting factors, like principle of transparency, organizational culture and strategy as well as leeway in public policy played an important role in sustainable supply chain management (SSCM) in public sector [16]. UNEP along with Wuppertal Institute Collaborating Centre on Sustainable Consumption and Production (CSCP) have analyzed almost all GPP practices in Europe, such as the study of SPP integrated strategy of office supplies in Spain, and a law to promote and support GPP in London [17]. The discussion of GPP practices focused on the site-specific implementation or some particular product, such as green procurement in Asian public sector and the private sector in Hong Kong [18], and a study about GPP of building materials and elements [19]. GPP has developed the ability for green supplies and markets [6], and also stimulated sustainable behaviors of the individuals [18]. Procurement could accumulate the environmental benefits from small to large [20] while GPP is a habit of the purchasers in seven subsidiaries of a Nordic electricity producing company [21]. However, a survey related to eight product categories and four European Union (EU) member states showed that public procurement was more effective in improving social responsibility than environmental protection [22]. The relationships between management, measurement and sustainability performance in supply chains shown varying degrees of alignment so that many enterprises adjust their SSCM and measurement practices to improve their sustainability performance in the supply chain eventually [23]. Firms often engage in responsible supply chain management (RSCM) due to a desire to protect corporate reputation and responsible supply chain practices can enhance reputation and thereby create competitive benefits [24]. Enterprises carried out sustainable supply chain management practices for reasons of reputational risk [25].Furthermore, the key factors increased sustainable procurement behavior may be affective commitment and procedural justice [26].

Though GPP is getting more and more attention, researches about GPP practices are still insufficient, especially in the evaluation of "the green level" (e.g., energy consumption, resource consumption, healthy ecology, recycled content, biodegradable, renewable, etc.) for a green product, which has remained elusive, while measuring weather the industrial biomass production and use is sustainability or not from the angle of sustainability accounting has been essayed [27] and life cycle assessment (LCA) could take into consideration to measure the impact reduction potential of sourcing strategies [28]. LCA methodology has been used to evaluate the environmental impacts of a road system throughout its whole life cycle on the basis of deeply understanding the technical characteristics of the life cycle phases [29]. The scientific assessment on the green degree of products, currently, is mainly about some special evaluation methods and field. Studies concerning GPP concentrate mainly on products, nevertheless, environmental standards in tender assessment are less common and seldom affect the award decisions [30]. The scientific assessment on the green degree of products, currently, is mainly about some special evaluation methods and some studies of GPP practices. For example, Ruparathna et al. suggest that the knowledge on status-quo of green procurement in Canada is not enough because sustainability has been disregarded in the project life cycle and environmental standards should be given the prominence [31]. Walter Kloepffer provided appropriate and reliable instruments to assess products with life cycle sustainability assessment method [32]. As GPP is playing an increasingly important role in facilitating the consumption of environmentally sound products and services, it is desiderated to analyze which factors drive the inclusion of environmental standards

in public procurement [33]. A total of 164 Italian public procurements were analyzed based on GPP toolkit developed by the European Commission (EC) and the results indicated a limited use of green standards, which were mainly included as technical specifications and award standards [34]. In the process of supplier selection, purchasers could use various types of environmental standards with four approaches to simplify the green supplier selection problem: ignore, incorporate, insist and integrate in different stages of the selection process [35].

3. Methodology

In order to bring environmental factors into the evaluation system of purchasing products on the premise that the products should meet the condition of using function that has been demanded. Thus, it could change the situation where only the economic factors were considered before and encourage the purchase of green environmental friendly products. Different level indicators are set up to reflect different levels of environmental requirements, so most of the suppliers can be evaluated. For instance, fundamental indicators would eliminate backward suppliers as the threshold of GPP; only suppliers who meet all the fundamental indicators could enter the GPP procedures. General indicators evaluate the suppliers by appraisal standards and scoring tables, they reflect the common requirements. Leading indicators evaluate advanced requirements that are scored by the environmental performance of the supplier and products, such as resource consumption, energy consumption, recycle use, etc. Since the quantitative evaluation method is designed to solve the problem how to identify the greener product in GPP, and Tianjin government procurement center have established an expert database including various aspects of the experts (e.g., procurement experts, environmental experts, and industry experts) for bidding evaluation. Besides, not too much research studies about quantitative evaluation of products have been found. Thus, when determining the indicators and weights, we sought expert advice while the experts were selected from the expert database and considered the relevant environmental standards for instance "Technical Requirements for Environment Labeling Products". Finally, the experts general consent the indicators and weights were suitable for the current GPP practices, and of course, the system and method still needs to be constantly improved In the future practice.

This study set up three index levels including fundamental indicators, general indicators and leading indicators to evaluate the green degree of products. Fundamental indicators are the requirements that all suppliers must meet in the process of government green purchase as the basic conditions to participate in bidding. According to the indicators, general indicators are divided into two parts, the plus score part and the minus score part (pluses in the majority), while the range of the score of the general indicators was calculated through analytic hierarchy process (AHP) by the expert scoring. Energy and resource consumption and advanced environmental indicators will be considered in leading indicators in the form of different points as the important supplement of the index system because they have reflected the higher environmental requirements. In the practice of the government green procurement, suppliers who have satisfied all basic indicators will get price subsidies or preferential policies according to the points scored in the general indicators and leading indicators, such as allowance of a certain percentage of the price increase. As a result, a quantitative method for evaluating the green degree of the government sustainable purchasing products is developed.

3.1. Fundamental Indicators

In the government sustainable procurement, we primarily desire that the government procurement suppliers should not be those with backward production facilities, production facilities with overcapacity or production facilities which would be closed soon, so suppliers and production line who are placed on the "Industrial Structure Adjustment Guidance Catalogue of China" are not allowed to bid for government contracts. In addition, when the product categories (e.g., computer, toilet, air condition) have been included in "Government Purchasing List of Energy Saving Products", only the suppliers who have also been included in the list could be alternative suppliers. For specific

products, it must be qualified products obviously, so conformity to the requirements of relevant national quality standards and safety regulations is also essential. In the meantime, pollutant emission of the suppliers should be no more than national and local standards, and cleaner production must be strengthened in the production process. In the aspect of technology, if this kind of products is related to cleaner production standards, the fundamental indicators select level 3 standard of clean production as ordinary technology indicators, which means basic level of cleaner production in a similar industry in China. The fundamental indicators are presented in Table 1.

Table 1. Fundamental indicators.

Indicators	Description	Meet or Not	
Suppliers	Government forcedly purchasing energy saving products must be in "Government Purchasing List of Energy Saving Products"	☐Yes	☐No
Production Line	Not placed on the "Industrial Structure Adjustment Guidance Catalogue of China"	☐Yes	☐No
Product Quality	Comply with relevant national standards and accordance with the requirements of the procurement	☐Yes	☐No
Energy Efficiency Rate	Comply with relevant national standards	☐Yes	☐No
3C Authentication	Obtained 3C authentication	☐Yes	☐No
Pollutant Emission	Accord with national and local standards and Strengthen cleaner production	☐Yes	☐No

Notes: Suppliers will provide documents to prove its compliance with the relevant requirements.

3.2. General Indicators

General indicators are the main part of the index system, which are expected to evaluate and order the products according to their environmental performance. At present, "technical requirements for environment labeling products" is the most advanced domestic environment demand for all kinds of products, and the preparing process has fully referenced the foreign related standards, so that the availability and sophistication could be ensured. However, at the same time, as the standards in the "Technical Requirements for Environment Labeling Products" seem to be higher for most suppliers, especially for small- and medium-sized suppliers, they are currently only able to reach part of the requirements of "technical requirements for environment labeling products". Furthermore, supporting the development of small- and medium-sized suppliers is the responsibility of government procurement. Some small- and medium-sized suppliers would not have obtained "the China environmental labelling" for small size. Thus, an itemized accounting process is designed in the general indicators to calculate the score by each item of the performance of the supplier. The suppliers who have obtained "the China environmental labelling" could get all of the scores, and the suppliers who have not can also get the scores if they could prove their products satisfy some requirements. Thus, the scope of suppliers to participate in the government green purchase will be expanded to ensure sufficient competition in the government green purchase process.

To comprehensively evaluate their environment performance, each indicator must be weighted to reflect its green degree. Indicators are commonly weighted by their entropy, Delphi method, the analytic hierarchy process (AHP), or principal component analysis (PCA). The present study adopts a mix of qualitative and quantitative methods. The indicator weights of the general indicators and leading indicators were determined by the AHP and Delphi methods on the basis of the attributes of the products such as environmental qualification, manufacturing technique, resources and energy consumption, toxic and harmful substance, cyclic regeneration and so forth by 10 experts

(including five environmental professionals and five government procurement experts). The judgment matrix was constructed as $\mathbf{S} = (u_{ij})_{m\times n}$ (1):

$$\mathbf{S} = \begin{vmatrix} u_{11} & \cdots & u_{1m} \\ \vdots & \ddots & \vdots \\ u_{m1} & \cdots & u_{mm} \end{vmatrix}, \quad (1)$$

where u_{ij} denotes the importance of indicator i to indicator j.

The consistency of the judgment matrix can be tested through calculation. The consistency is acceptable when the consistency proportion <0.1. The feature vector $\mathbf{A} = (w_1, w_2, \ldots, w_n)$ indicates that the largest eigenvalue of the judgment matrix corresponds to the weight distribution [36]. The general indicators and weight distribution results are presented in Table 2.

Table 2. General indicators.

	Indicators	Description	Score Ranges
Design phases (7 scores)	Structure and connection technology	Components are easy to separate, remove, and disintegrate, and can complete the disintegration of the whole machine by one person.	0~1
		Supplier should try the collapse, and record the point.	0~1
	Selection of materials and marks	The plastic shell more than 25 g should use single polymer or copolymer of no more than four kinds, easy to collapse, and the tab should be according to the requirements of GB/T16288.	0~2
		The paints for plastic parts should be minimum limit.	0~1
		It has used recycled materials and been tagged correctly.	0~1
	Prolonged use	The CD-ROMs, hard disk and primary storage of desktop microcomputer could be upgraded and have expansion slots.	0~1
Raw material component preparation phases (7 scores)	Hazardous substances	The base material of computer motherboard should not use hexabromocyclododecane (HBCDD).	0~1
		The plastic shell more than 25 g should not use short chain chlorinated paraffins (SCCPs), hexabromocyclododecane (HBCDD) or medium chain chlorinated paraffin (MCCP).	0~2
		The plastic shell more than 25 g should not use phthalate as plasticizer that is listed in the Appendix A of HJ2536-2014.	0~1
		The amount of benzo (a) pyrene should be less than 20 mg/kg and the content of polycyclic aromatic hydrocarbons (PAHs) should be less than 200 mg/kg in the product shell, keyboard, mouse shell and all kinds of buttons, the touchpad and an external power supply cord.	0~2
	Hazardous substances	The content of the heavy metal Hg should be less than 3 mg/kg in the backlight of displayer.	0~1
Production phases (6 scores)	Hazardous substances	Do not use hydrogen CFCS (HCFCs), 1,1,1-trichloroethane ($C_2H_3Cl_3$), trichloroethylene (C_2HCl_3), ethylene dichloride (CH_3CHCl_2), methylene chloride (CH_2Cl_2), chloroform ($CHCl_3$), carbon tetrachloride (CCl_4), and bromine propane (C_3H_7Br) as cleaning solvent.	0~2
		Phosphorus degreasing agent shall not be used in the process of pretreatment about metal case.	0~2
		Do not use hydrogen CFCS (HCFCs) as foaming agent in the Packaging and packaging materials. Furthermore, the total heavy metal content of lead, cadmium, mercury and hexavalent chromium amount shall not exceed 100 mg/kg.	0~2
Service phases	Energy consumption	Be considered in the leading indicators.	
Waste disposal phases	Recyclability rate		

3.3. Leading Indicators

Leading indicators mainly include the resources and energy consumption of products. The suppliers who consume the least amount of energy and resources will be treated as a benchmark to calculate other suppliers' scores through the formula. For the requirements that foreign advanced standards have put forward, while domestic standards have not yet asked for, should also be incorporated into the leading indicators. In the aspect of technology, if this kind of products is related to cleaner production standards, the leading indicators select level 1 standard of clean production as technology indicators, which means advanced level of cleaner production in the similar industry in developed country. Furthermore, if the products are good at prolonged use or have other outstanding environmental performance, we should reward them with points at discretion. The leading indicators are presented in Table 3.

Table 3. Leading indicators.

	Indicators	Description	Score Ranges
Energy consumption	Product energy consumption	The lowest (A) in the rated power scores 30 points, and other rated power (B) will scores the points: $[1 - (B - A)/A] \times 30$.	0–30
	Supplier production energy consumption	The lowest (A) comprehensive energy consume of the supplier scores 5 points, and others (B) will scores the points: $[1 - (B - A)/A] \times 5$.	0–5
Resource consumption	Weight	The lowest (A) weight of the supplier scores 5 points, and others (B) will scores the points: $[1 - (B - A)/A] \times 5$.	0–5
Healthy ecology (discretion assign points)	Hazardous substances	Meet requirements of prohibition on "Certain Hazardous Substances in Consumer Products", SJ/T 11363-2006, GB/T 26572-2011, etc.	0–5
Cyclic regeneration	Recyclability rate	$\geq$90% scores 5 points, $\leq$30% scores 0 points.	0–5
Other outstanding environmental performance		Points will be added to documents suppliers submit.	0–10

4. The Case of Tianjin Government Green Procurement

4.1. General Information for Tianjin Government Procurement Center

As the actuators of municipal centralized purchasing, Tianjin government procurement center was established in April 1999 as a department of Tianjin Finance Bureau. Implementation of centralized purchasing of goods, services, and the project in accordance with the law and policy is one of the duties of the department. A series of measures have been taken to promote GPP in the whole process of purchasing, including purchasing requirements analysis, green supplier selection, green product selection, incentives for green products, and feedback on GPP. Tianjin government procurement center has been committed to promoting government green purchasing in a variety of ways, including carrying out joint research actively with Naikai University, Wuppertal Institute Collaborating Centre on Sustainable Consumption and Production, Beijing University of Civil Engineering and Architecture, etc. This study is completed and applied to practice under the support of Tianjin government procurement center.

4.2. Purchase Specification of the Case

Tianjin government procurement center was commissioned by Tianjin municipal human resources and social security bureau to provide project procurement services for projects purchasing 1635 desk computers with detailed rules on the technical parameters, after-sale service requirements within the budget of RMB 6 million yuan. The bid evaluation method uses the lowest pricing method in bid evaluation on the basis of price favorable according to the products' environmental performance. The case was selected because it is the first procurement project as the demonstration of the quantitative

evaluation system and an achievement exhibition of "Sustainable Public Procurement in Urban Administration in China" which cooperated with "Wuppertal Institute for Climate, Environment, Energy" and supported by "An Action under Europe Aid's SWITCH-Asia Programme". The data we collected included the basic information of the procurement project and relevant materials provided by the suppliers according to the evaluation indicators, which would determine the suppliers' scores. The case could show the quantitative evaluation system could be applied in GPP practices and realize the expected function to identify the greener product.

5. Evaluation Results

After the review of the bid documents (e.g., qualification documents, relevant evidential document, the necessary product technical parameters, and the readme file on environmental performance) provided by the suppliers according to the evaluation indicators which would determine the suppliers' scores and the judgment according to the basic indicators, five suppliers entered the competition of general indicators and leading indicators. The relevant testimonial material, which was submitted in bid documents, was examined by 10 experts (including five environmental professionals and five government procurement experts). Suppliers' scores are shown in Table 4.

Table 4. Suppliers' scores.

Bidder	A	B	C	D	E
General indicators	25	30	30	17	40
Energy consumption	29.7	28.3	35	32.8	31.6
Resource consumption	4.6	5	4.2	4.7	4.4
healthy ecology (discretion assign points)	4	4	5	5	4
Cyclic regeneration	3	2	5	5	4
Other outstanding environmental performance	3	5	7	6	4
Total scores	69.3	74.3	86.2	70.5	88

The preferential policy in this procurement is that bid price of green products would receive a discount and the discount rate computation formula is as follows:

$$\text{Discount rate} = \text{total scores} \times 10\% \quad (2)$$

Thus, the evaluation price would be calculated as follows:

$$\text{Evaluation price} = \text{bid price} \times (1 - \text{discount rate}) \quad (3)$$

The final evaluation results were shown in Table 5.

Table 5. Final evaluation results.

Bidder	A	B	C	D	E
Bid price	581	588	585	578	592
Discount rate	6.93	7.43	8.62	7.05	8.80
Evaluation price	540.7367	544.3116	534.5730	537.2510	539.9040

6. Discussion

The bid price ranking from low to high in turn is supplier D, A, C, B, and E, and the environmental performance from good to bad in turn is supplier E, C, B, D, and A. To everyone's amazement, the final evaluation result is that the supplier C won the bid, even though C was neither the lowest price nor the best environmental performance. Supplier E, who was the highest price bidder, also scored highest in terms of environmental performance, ranked third in the comprehensive evaluation. The supplier D

who was the lowest price bidder took the second place because of its poor environmental performance, even though it was the lowest price bidder which could not fill the gap in the environmental performance. However, if supplier D could improve environmental performance, it would have competitive advantages in the next project. Furthermore, the itemized accounting process made supplier D score 17 instead of 0 in the general indicators as a small size supplier. The winner, supplier C, performed well at both bid price and environmental performance so it won the project. Supplier A and B came in last two for their poor showing.

GPP means environmental and ecological responsible purchasing [8] that the government should purchase the high-quality, but more environmentally friendly products [7], and the evaluation results have confirmed that. Supply chain management of GPP considered many factors like corporate-social-responsibility [22–25], supporting the development of small- and medium-sized enterprises (SMEs) [15] and so on, but GPP pay more attention to the environment influence of the purchasing behavior. As a theme of GPP [5], measurement is the inevitable matter to promote GPP while the existing discussion focused on qualitative evaluation [17–21]. Furthermore, the lack of standardization of the quantitative evaluation system hindered the development of GPP, because government procurement practitioners are not environmental experts who find it difficult to evaluate which product is greener. In addition, the subjectivity of the bid evaluation experts will affect the evaluation result.

This method is based on the need for the product green degree evaluation in GPP practice. It has been used in purchasing practices in Tianjin government procurement center, and to a certain extent, achieved the expected goal about quantitative evaluation green degree of product. We tentatively put forward a mix of qualitative and quantitative method, since the existing research mainly focused on the practice, effect, influence factor and supply chain management of GPP [14] or the qualitative evaluation rather than quantitative evaluation, while other studies about product evaluation often focus on a single product [18,19]. This is probably the first comprehensive evaluation of their green degree from the perspective of environmental performance and a quantitative method applicable to a variety of products has been developed and it could be truly applied in GPP practices. Therefore, this paper is a useful supplement to the existing research although the system and method still needs to be constantly improved in the future practice.

However, as a method proposed for the first time, certainly, it also has many deficiencies. The choice of evaluation indexes consulted many suggestions from experts, environmental mark, etc. The influence on environment and optimizing usage of resource have been considered from very beginning of a product design to final lifecycle in these requirements. However, even so, the choice of indicator still possesses definite subjectivity inevitably. Constant revision and perfection is required in the future application. Secondly, government procurement staff would be required to reserve a lot of knowledge about environmental protection. There was a need for staff with higher profiles and qualifications working on government procurement to ensure the effect. Moreover, the evaluation method requires suppliers to provide a large number of documents to prove that they meet the relevant requirements, which may increase the supplier's burden. Finally, due to the development of technology, environmental requirements will also unceasingly be enhanced. Thus, the quantitative evaluation system also needs to be constantly upgraded.

7. Conclusions

This study established a method for evaluating the environmental performance of the products in the government procurement. To this end, the relevant documents about manufacturing technique, resources and energy consumption, toxic and harmful substance and so forth were presented and estimated. Moreover, the bid price and environmental performance were synthetically considered in government procurement. The main contributions of the study are summarized below.

(1) To evaluate the green degree of products, three index levels including fundamental indicators, general indicators and leading indicators, were set up. Fundamental indicators are perceived as

the basic conditions of suppliers to participate in bidding, while general indicators are considered to be the main body of the index system, and leading indicators are expected to reflect the higher environmental requirements.

(2) The study adopted a mix of qualitative and quantitative methods. The indicator weights of the general indicators and leading indicators were determined by the AHP and Delphi methods on the basis of environmental qualification, manufacturing technique, resources and energy consumption, toxic and harmful substance, cyclic regeneration and so forth by 10 experts (including five environmental professionals and five government procurement experts).

(3) A comprehensive evaluation of the project purchasing 1635 desk computers was conducted using the indicator system. By this method, the price and environmental performance of the products were assessed quantitatively. The evaluation result has shown that the indicator system can indeed sort out products according to their environment performance and choose the more suitable products.

(4) For government procurement practitioners, this study established an objective quantitative evaluation system which do not ask them to have rich knowledge of the environment like environmental experts and could avoid the subjectivity due to the different bid evaluation experts for similar procurement projects.

Overall, this study is a good practice to evaluate the green degree of products on the basis of environmental performance and basically achieve the desired function. It could be very beneficial to solve the higher price problem of green products for their higher environmental costs and this study could balance between economy and environment. Without doubt, there have some deficiencies of course that need to improve in future studies such as indicator set and weight distribution, which need to constantly adapt to the latest situation of government procurement. Furthermore, environmental benefit assessment about the implementation of the evaluation system could be another research emphasis.

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