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# EXPLORATION OF THE EFFICIENCY OF GREEN DESIGN IN INFORMATION TECHNOLOGY INDUSTRY BASED ON DATA ENVELOPMENT ANALYSIS

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**Abstract—Since the Industrial Revolution of 1750, excessive use of natural resources has worsened the global environment and severely consumed resources. More and more advanced countries are paying attention to environmental issues, and more international procurement requires sustainable production. International trade is the main economic lifeline of Taiwan. At the same time, the main source of GDP growth in Taiwan is the Information Technology (IT) industrials. Inevitably, it will be faced with the need to construct green design systems and performance evaluation models. These systems will help strengthen sustainable resource management in industries.**

**Evaluate 13 of the world's TOP100 IT companies based on published industry statistics annual reports. The results show that only one company have a strong efficiency in the green design system. Five of the 13 green design companies can achieve marginal efficiency. The green design systems of the remaining seven companies are inefficient. In addition, recommendations for improving capital investment status are proposed through differential variable analysis. This research will help to enhance the investment management of green design system in the technology industry to meet the requirements of the future international environmental sustainability.**

**Keywords—IT, green design, product design**

## I. INTRODUCTION

With the accumulation of human experience, international environmental awareness has gradually risen in advanced countries, and green design has become increasingly important. In the face of the green design environment, companies can adopt low-level strategies to meet the requirements of international or customer regulations, and can also develop the products with green features (low toxicity/low pollution/low risk, energy-saving, easy to disassemble, recyclable, and reused).

However, it is inevitable that the addition of green design requirements to traditional manufacturing processes and services will increase operating costs. With the increasing emphasis on environmental protection, energy consumption, and environmental protection issues, enterprises from all over the world have faced greater operational pressure. The green design has become a huge cost pressure because many international regulations have been adopted. These regulations may improve the material quality of the products, regulate the collection and recycle the waste, increase the recycle and reuse the abandoned products.

Green design is an indispensable part of future operations. However, it is necessary for companies to keep a balance between developing sustainable ecology and enhance the advantages of the industries in competition. Appropriate strategies and tools become the direction of development. Through the correct strategy application and management, the optimal allocation of limited resources can be achieved.

Taiwan's GDP is largely derived from the international trade of the IT companies and will face more green design requirements from developed countries. The early establishment of the green design management system and the correct evaluation and introduction of technology will help to find the core of the problems and strengthen management capabilities. Therefore, this study is aimed at assessing the green products in the IT companies to help the industry to achieve better efficiency in green design and properly avoid cost risks.

## II. LITERATURE REVIEW

### *A. Green design*

Green design is also known as environmental design. The green design products need to be disassembled, recycled, remanufactured, reassembled and reused (Chen & Chiu, 2016). In the process of development or manufacturing, the green design needs to maintain the standards of products, efficiency, quality and price (Charter, 2017). The environmental damage caused by the final disposal of the product could be reduced

through the designed tools. Thus, the environment will be maintained, the waste of product design resources will be reduced. The material, function, manufacture, packaging, use, transportation and disposal of products need to be considered whether it will affect the environment (Carvalho et al., 2016).

In the study of Aschemann-Witzel & Zielke(2017), the green design was defined as a systematic approach to incorporating environmental considerations into product design processes. Khan & Mohsin(2017) had a similar definition: The way to incorporate environmental, health and safety considerations into all lifecycles of products and processes to consider their design performance. Mantovani(2017) defined the green design as: (1) Raw material management: raw materials should not use harmful substances to reduce the final environmental impact of the products; raw materials should be clearly distinguished(environmentally friendly materials and non-environmental friendly materials) to help to conduct researches. (2) Easy to disassemble: the design structures need to be easily disassembled to facilitate recycling and reusing. The modular design makes the products easier to disassemble and reduce the disassembly time. (3) Recyclability: The possibility of recovery, the value of recycling, and the ease of handling should be considered in the early stage of product design(Yu et al., 2017).

### *B. The performance evaluation*

The performance evaluation system is a reward system. It should be able to control daily operations and correct targets in the short-term. At the same time, it is also a tool for strategic management, strategic planning and strategic achievement in the long run. Le Vigouroux(2017) believed that performance evaluation was a part of management control. The purpose of establishing performance evaluation indicators aimed to achieve business objectives for managers. Yang & Lin (2017) proposed that the effective performance indicators are built to help administrators achieve the business goals and finish future development. Azucar(2018) suggested that performance evaluation indicators can be quantified or non-quantified standards to measure their own operating processes, so as to evaluate whether the business goals or business strategies are correct and make appropriate corrections. Mao(2018) believed that performance evaluation indicators were indicators to achieve goals. Huang(2018) thought it was a method to identify whether enterprise planning goals were achieved. Chen(2016) considered that managers care about the way to optimize the use of limited resources. Zhou(2017) suggested that efficiency evaluation should focus on how resources were effectively used inside the organization. Maximum output and the least input can be achieved by exploring the relationship between resource input and output. The reduction of production costs can also enhance the efficiency of resource use.

### *C. The performance evaluation of green design*

Choe & Kim (2018) found that there is a positive correlation between environmental performance and financial performance. Both enterprises with better environmental performance and those with lower pollution all have better financial performance. Han(2017) proposed that large enterprises in this century began to form multinational companies, and began to develop green design systems. The supply chains of enterprises were adjusted according to environmental efficiency. Barbaro & Pickett (2016) believed that when enterprises consider multiple environmental issues, their business strategies could be affected. Especially when enterprises have to deal with transnational transactions, they must consider the environmental laws and regulations of different countries to maintain their competitiveness. It is necessary to re-examine the impact of enterprise business flow on the environment. Barbaro & Pickett (2016) believed that when the eco-design specifications were clearly defined in the regulations, it usually included six stages of the product life cycle: raw material use or selection, manufacturing, packaging, transportation, sales, assembly, repair, use, and disposal. Kaur(2018) pointed out that the importance of the connection between environmental performance assessment and environmental goals. The Balanced Scorecard (BSC) skills could be used to clarify the causal relationship between corporate strategic goals and four dimensions to create corporate competitive advantages.

## III. RESEARCH METHODOLOGY

In this study, Data were obtained through the Delphi Method. The performance evaluation of green design products was collected through the Data Envelopment Analysis (DEA).

### *A. Evaluation methods*

Delphi Method is a method combining interdisciplinary with future-oriented, which is both qualitative and quantitative. The Delphi Method is also known as expert judgment Method. Shi et al. (2017) defined "expert" as a person who has higher cognition in the field than the average person and possesses (1) knowledge level, (2) credibility and (3) accuracy. Therefore, expert performance evaluation can be more credible than the average person. Delphi method can deal with issues with insufficient data or unknown situation in the research process. It is conducted by an anonymous expert survey, voting, and feedback repeatedly until expert opinions converge.

### *B. Research variables*

The following variables are the four research indicators defined in the study, of which two variables are capital outflow(representing cost) and the others are capital inflow(representing profit).

The outflow variable Vout-OA represents the design cost

- Additional production costs due to green design requirements, such as renewable energy, etc.

The outflow variable Vout-OB represents the back-end processing cost

- Additional production costs in the process of production to elimination due to green design requirements, such as waste disposal, etc.

The inflow variable Vin-IA represents revenue

- Corporate income due to green design

The inflow variable Vin-IB represents circulation revenue

- The ratio of recycling to reuse

### *C. Research objects*

In this study, a total of 13 manufacturers were selected as decision makers (DMUs), all of which entered the top 100 IT companies in Taiwan.According to the annual statistics released by DMU, the Data Envelopment Analysis (DEA) analyzes inflows and outflows as performance indicators.

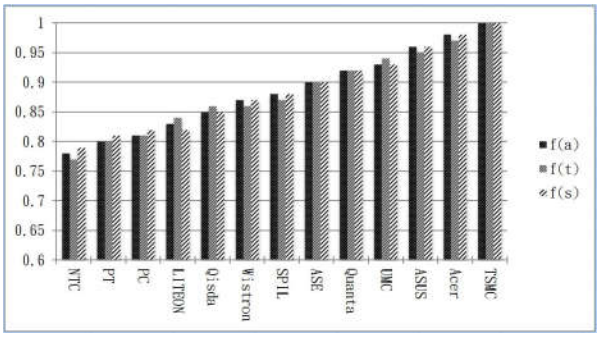


Fig 1: The relative efficiency values of different enterprises. f(a) is the overall efficiency, f(t) is the technical efficiency, and f(s) is the scale efficiency. The horizontal axis is the 13 target manufacturers, and the vertical axis is the efficiency value.

## IV. RESULTS

In order to understand the efficiency situation of green design, the efficiency of the thirteen target decision-making units was evaluated through the Data Envelopment Analysis (DEA). If the efficiency value is greater than 1, it means it has positive efficiency. If the efficiency value is less than 1, it means that the efficiency result is not good enough.

The research results are shown in figure 1. f(a) is the overall efficiency, f(t) is the technical efficiency, and f(s) is the scale efficiency. The overall efficiency comes from the overlap of technical efficiency and scale efficiency.

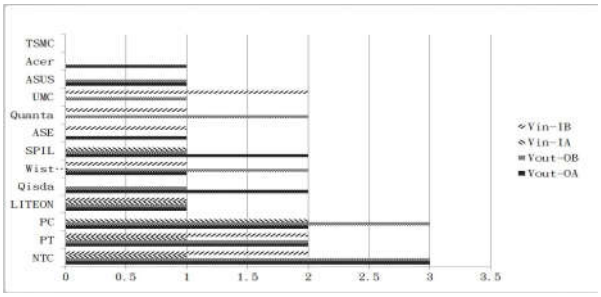


Fig 2: The efficiency values of the relative efficiency of high-tech enterprises. Vout-OA is the design cost, Vout-OB is back-end processing cost, Vin-IA is revenue and Vin-IB is circulation revenue.

Figure 1 shows a DMU reach the efficiency value of 1, which accounts for only 8% of the total. The green product design efficiency value of 5 DMU is between 0.9 and 1, which is the edge efficiency (3.8% of the total). The edge efficiency represents that the efficiency of such enterprises still has space for improvement. These enterprises are easy to improve. There are 7 DMU green products efficiency were lower than 0.9, which represents significant inefficiency (54% of all). Among them, NTC's green product design efficiency is low, only 0.78.

It can be found from the data that only one IT companies has operating efficiency in green design, and the other 12 enterprises all suffer from low efficiency(the input of resources exceeds the profit). It can be seen that only one enterprise's green design efficiency has reached the optimal level by analyzing the scale efficiency of each enterprise, while the other 12 enterprises are increasing in scale, indicating that they can improve efficiency through industrial scale.

In addition, the difference variable analysis can help companies to correct the investment direction. The analysis results of the study are shown in figure 2. Vout-OA is the design cost. Vout-OB is the back-end processing cost. The variable Vin-IA is the revenue, and Vin-IB is the circulation revenue. The green operating efficiency of enterprises could be improved by reducing investment in excessive projects or adding investment in insufficient projects.

## V. DISCUSSION

Based on the results of the research and analysis, the following suggestions for improving the efficiency of green design of enterprises are collected:

### *A. Good corporate social responsibility does not mean that costs will inevitably rise.*

It can be seen from the research results that different companies will have different cost benefits when introducing green designs. Enterprises can fulfill their social responsibilities through reasonable green design management and obtain higher profits.

*B. The systematic tools can help to effectively control the cost of green design.*

In the process of introducing green design, the company not only needs to plan indicators, but also recommend system analysis tools. These tools can help build key metrics and increase green design efficiency.

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