

Evaluating Performance Incorporating Multi-Criteria Decision Making and ESG Index: The Case of Taiwanese PCB Industry

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Abstract

The Printed Circuit Board (PCB) industry is known as the "mother of electronic system product" in the high-tech electronics industry. When this industry enters a mature stage, cost control becomes the key to its success. Additionally, as the corporate's awareness of social responsibility like ESG (Environment, Social, & Governance) has risen, the cost control remains a critical indicator for evaluating a company's performance. This study uses the consolidated financial statements of 35 companies in Taiwan's listed PCB industry through collecting data from the Taiwan Stock Exchange from 2022 to 2022. This study chooses 16 key financial indicators through expert opinions and selects 7 input variables and 5 output variables from 5 screening criteria. Then, through the normalization of grey relational data, the degree of influence of each indicator on the performance of PCB manufacturers is analyzed, and which independent variables have better prediction power through the multiple regression model is achieved. The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) analysis in Multi-Criteria Decision-Making (MCDM) is applied to identify the ranking. The relative distance compared with the best manufacturer and the worst manufacturer is used to evaluate and rank the pros and cons of each ranking. VIKOR is then used to analyze ranking further. The results of data analysis have shown slightly different rankings based on TOPSIS and VIKOR. However, it seems the analysis of VIKOR is more accurate. The comparison of Taiwanese PCB manufacturers before and after the ranking is also revealed. Several practical directions for corporate planning or improvement are suggested. The link between ESG indicators and finance is observed not significant.

Keywords: Printed Circuit Board (PCB), Multiple Criteria Decision Making (MCDM), Environment Social Governance (ESG), Grey Relation Analysis, Multiple Regression Analysis, TOPSIS Analysis, VIKOR Method

1. Introduction

1.1 Research Background

In the era of industrial globalization and fierce competition, companies continue to focus on improving their competitiveness in order to achieve the goal of sustainable business operations. Therefore, companies need to innovate and diversify their products or services to differentiate themselves. In doing so, companies not only can enjoy better churn, but also win over more customers from competitors and boost profits (Zhuang Chunling, et, al, 2007). The United Nations Commission on Sustainable Development (CSD) was established in 1992 under the auspices of the Economic and Social Council as a direct result of the United Nations Conference on Environment and Development. Much of its work to date has focused on developing and testing a set of 58 indicators, narrowed from an initial list of 134 indicators, covering social, environmental, economic, and institutional aspects of sustainable development (Parris & Kates, 2003).

The pursuit of progress by human society is never-ending. Today, with the development of economy and society, the world is facing many opportunities as well as challenges. As COVID-19 pandemic spreads, many environmental, social, and governance issues have attracted global attention, such as four breakdowns in the U.S. stock market within two weeks, locust plagues in Africa, and the fraudulent delisting of Luckin Coffee. The topic of sustainable and all-round development has once again become a hot discussion point worldwide. In response

to increasingly severe sustainable development issues such as the environment, society, and financial markets, international organizations and countries around the world have proposed sustainable development action plans such as ESG to build a framework for sustainable and comprehensive development of human society (Li, Wang, Sueyoshi, & Wang, 2021). The Printed Circuit Board (PCB) industry is known as the "mother of electronic system product" in the electronics industry. When this industry enters a mature stage, cost control becomes the key to its success. The rise of Taiwan's PCB industry is closely related to the development of the information industry (Taiwan Circuit Board Association, 2007)

1.2 Research Motivation

ESG is constantly being advocated internationally. It is a concept proposed by the United Nations Global Compact (UN Global Compact) in 2004 and is regarded as an indicator for evaluating a company's operations. From the perspective of end application, the proportion of Taiwan's PCBs used in communication products has been relatively high in the past ten years and has shown an upward trend. The main products include smartphones, base stations, routers, etc. Due to the global trend of working/studying from home impacted by the epidemic, the growth of the personal computer and communication product market has increased new demand for high-value printed circuit boards, which benefits Taiwan's PCB industry (Li Zongyao, Zhang Rongrong, Li Zhenhui, Wen Chunyu, 2023). Every industry is pursuing its own corporate goals. Ultimately, the change of industrial structure is also an important consideration that affects the company's development and performance. How to proceed next for Taiwanese PCB industry is also the motivation of this research.

1.3 Research Purpose

This study uses grey relational data to analyze the influence of various factors on the operating performance of PCB manufacturers. It also uses multiple regression models to understand which independent variables have a greater predictive power on the output variables. The TOPSIS analysis in multi-criteria decision-making is then applied to evaluate the pros and cons of each company using the relative distance between the best manufacturer and the worst manufacturer at the same time. VIKOR is adopted to sort and analyze the data. Finally, conclusions and suggestions are addressed for corporate planning or improvement of Taiwanese PCB manufacturers. This study is helpful for the future development of Taiwan's PCB industry and similar high-tech industry. With the rising awareness of corporate social responsibility like ESG, it has been regarded as an indicator for evaluating a company's operations. Therefore, understanding the correlation between its indicators and the financial statements can help companies respond to the country's future international development trends and the needs of ESG global norms.

1.4 Research Process

This research first proposes the purpose of the overall research based on the background and motivation of the research. The literatures are studied and then the research methods are chosen to construct a research model. Next step is collecting the data and analyze the data. Finally, this study summarizes and discusses the results of the analysis and comparison, and proposes conclusions and suggestions based on the research results.

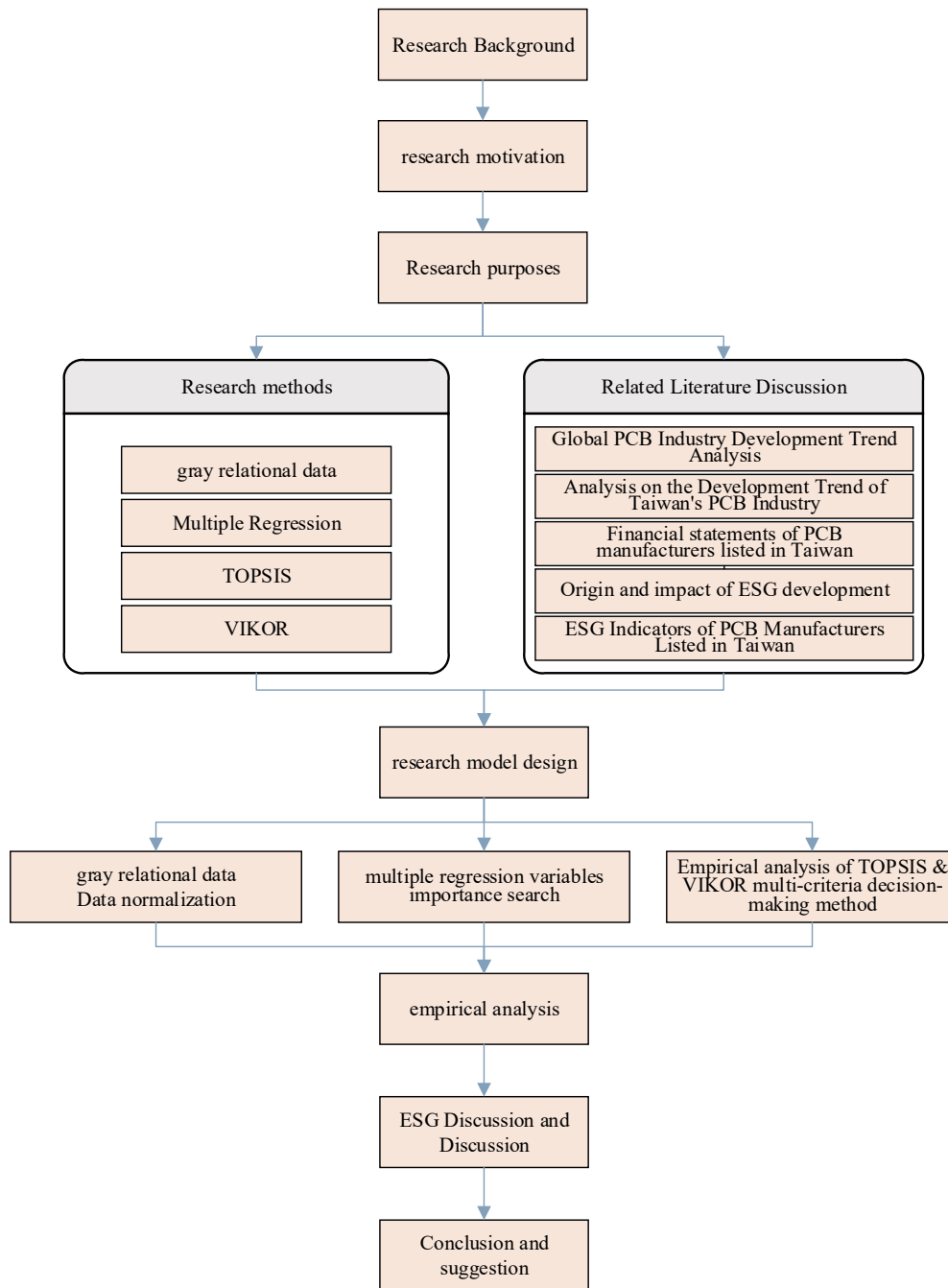


Figure 1. Research flow chart

Source: Compiled by this study

1.5 Research Limitations

The methods used in this study conduct the analysis based on the information obtained. The main data is from the information of the Taiwan Stock Exchange and the public financial statements of various companies. However, some data may appear inaccessible. In this study, the multi-criteria decision-making and ESG performance analysis of the PCB industry may be incomplete such as the time gap between inputs and outputs.

2. Taiwan's Listed PCB Industry from 2020 to 2022

2.1 Global PCB Industry Analysis

The Taiwanese PCB major manufacturers include Zhending, Xinxing, Huatong, and Jianding. The PCB

manufacturers have strong competitiveness in the communication field include Mektron, Sumitomo, Fujikura, Ibiden, TTM, SEMCO, ISU PETASYS, Sanmina, etc. At present, global IC substrate manufacturers are mainly located in mainland China, Japan, South Korea, and Taiwan, and most of them have production bases in China. Taiwan has very complete supply chain and clusters of Integrated Circuit (IC). For example, in terms of upstream, Taiwan has the best design industry second to USA. There is a leading IC manufacturing plant in the middle reaches of the wafer foundry, and the world's largest IC packaging and testing plant in the downstream in Taiwan. These advantages can highlight Taiwan's excellent competitiveness in the IC industry, which benefits Taiwan's PCB manufacturers in developing IC substrates (Wang Xiuchen, 2019).

Shamkhalichenar, Bueche, and Choi (2020) stated that PCB technology has been widely used globally. Besides electronics, this technology is also used to manufacture electrical components, including electrodes for different biological and chemical sensors. The high reproducibility achieved by durable standard processes and the low cost brought by many competitive manufacturing services. It makes this manufacturing method a prime candidate for patterning electrodes and electrical components for biosensors. 2018 was the year of the rise of the next-generation 5G, 2020 was the year of the deployment of the next-generation 5G, and 2021 was a key year for the next-generation 5G to change the history of mankind. Since the beginning of 2020, the outbreak of the new crown pneumonia epidemic has indirectly created business opportunities in the trend of long-distance communication, directly driving the growth of terminal market demand for personal notebook computers, digital communication TVs, and 5G-standard network communication equipment. With the arrival of next generation 5G application technology, related peripheral electronic products have a great demand for printed circuit boards, which promotes the expansion and rapid growth of the market for quota demand in the PCB industry (Huang Shuyuan, 2021).

In 2021, the electronics industry benefited from the vigorous development of terminal applications such as 5G, IoT, and HPC. In addition, the rising cost of raw materials increases the market demand such as PCB industry. According to the Taiwan Circuit Board Association (2023), the global output value of printed circuit boards reached 84 billion US dollars, with an annual growth rate of 20.6%. Among them, the value of printed circuit boards in Taiwan reached 817.8 billion Taiwan dollars, with an annual growth rate of 17.5%. It has had growth rate for five consecutive years. It also reached double-digit growth rate for the first time since 2010 (Guo Shuyan, Chen Zhongren, & Chen Jiefu, 2023). In the printed circuit board industry, IC substrate products are the most eye-catching. Benefiting from the demand for advanced processing products such as high-end computing chips and high-speed memory, IC substrates are almost hard to find. The stock price of substrate stocks has increased by an average of more than 150%, which shows that the operating performance of substrate manufacturers is favored by investors in the electronics industry (Guo Shuyan et al., 2023).

2.2 Taiwan PCB Industry Analysis

Taiwan's PCB business began in 1968 when the American company AMPEX (AMPEX) set up a factory in Guishan, Taoyuan. This was the pioneer of Taiwan's printed circuit boards. Later, Japanese companies Taifeng and Hitachi Chemical also entered Taiwan's market. After more than 50 years of expansion, they have cultivated a complete supply chain system in Taiwan's PCB field (Li Zongyao, Zhang Rongrong, Li Zhenhui, Wen Chunyu, 2023). With the rapid development of wireless and broadband information and communication technology, various electronic consumer products with high-speed information processing functions have become an indispensable part of people's daily life, which means that PCBs must be able to handle high-frequency signals, be more precise, and meet higher standards of performance and quality (Wang Xiuchen, 2019). Market players in the PCB industry include Taiwanese manufacturers such as Zhending, Xinxing, Huatong, and Jianding. PCB manufacturers with strong competitiveness in the communication field include Mektron, Sumitomo, Fujikura, Ibiden, TTM, SEMCO, ISU PETASYS, Sanmina, etc. At present, global IC substrate manufacturers are mainly located in Japan, South Korea, Taiwan, and most manufacturers have production bases in China (Wang Xiuchen, 2019). The output value of Taiwan's PCB industry reached US\$18 billion in 2015. Although the growth rate remains flat, it still ranks first in the world. Due to competition and changes in customer demand, manufacturers must continuously improve their process technology to enhance their competitiveness. Facing the competition from manufacturers in Japan, South Korea, and mainland China, Taiwanese companies need to clarify their positioning, grasp industry trends, and seek improvements in process technology and smart manufacturing to keep up with the competitiveness in order to continue to grow and make profits in the future (Yan Qifeng, Yang Kaiwen, & Liao Benzhe, 2019).

In Taiwan's IC substrate production, IC substrate Sanxiong Xinxing, Nandian, and Jingshuo have attracted the most attention. IC substrate Sanxiong has received orders from internationally renowned manufacturers such as Apple, Intel, AMD, Xilinx, Nvidia, and Qualcomm, and has become the driving force behind the success of the

above brands (Guo Shuyan et al., 2023). He Zongnian (2013) researched the competition and cooperation relationship of the IC substrate industry, analyzed the general situation of the IC substrate industry, and the relationship between the upper, middle and downstream suppliers of the industry chain. Ni Weijie (2010) studied the decision-making of IC substrate product mix with the application of constraint theory and determined the optimal product mix based on the key resource utilization rate in the constraint theory. It combined effective output and gross profit margin, and proposed a product mix decision to solve IC substrate manufacturers' price reduction pressure, and found strategies for sustainable profit and growth of substrate manufacturers. Xu Runzhong (2007) used the DEA and MPI model analysis methods to evaluate the business performance of the IC substrate industry. Their research focused on the analysis of the competitiveness within the industry, their level and the annual change. Their research results found that under this research method, the business performance of Nandian, Xinxing, Jingshuo, Quanmao, and Huatong showed a significant positive correlation with stock prices.

2.3 The Financial Statements of Taiwan's Listed PCB Industry

This research uses the consolidated financial statements of 35 companies in Taiwan's listed PCB industry. From the information of the Taiwan Stock Exchange and the financial statements of each company. The main 9 financial performance indicators are: 1) cash and equivalent, 2) inventory, 3) current asset, 4) property, plant and equipment, 5) non-current assets (fixed), 6) total assets, 7) current liabilities, 8) operating costs, and 9) operating expenses (Lee & Pai, 2011). Its average value of cash and equivalent in 2020 was 4.46 billion, the maximum value was 44.22 billion, and the minimum value was 25 million. Its average value of inventory in 2020 was 1.95 billion, the maximum value was 12.99 billion, and the minimum value was 522,000. Its average value of current assets in 2020 was 11.63 billion, the maximum value was 99.31 billion, and the minimum value was 260 million. Its average value of property, plant and equipment in 2020 was 7.64 billion, the maximum value was 68.18 billion, and the minimum value was 15.9 million. Its average value of non-current assets (fixed) in 2020 was 10.06 billion, the maximum value was 81.81 billion, and the minimum value was 29.3 million. Its average value of total assets in 2020 was 21.70 billion, the maximum value was 181.12 billion, and the minimum value was 290 million. Its average cost in 2020 was 12.64 billion, the maximum was 104.69 billion, and the minimum was 350 million. Its average operating expense in 2020 was 1.41 billion, the maximum was 12.44 billion, and the minimum was 22 million.

Table 1. Financial performance indicators of 35 PCB manufacturers in 2020

Company Name/ Indicator	Cash and equivalents	Inventory	Property, plant and equipment	Current assets	Non-current assets (fixed)	total assets	Current liabilities	Operating cost	Operating expenses
Cheer Time	99992	25320	279887	265268	364596	644483	190781	382813	180491
Bor Jyh	1054214	285824	2087387	873029	895168	2982555	1060643	2042644	229602
Subtron	677344	561380	2347033	3746904	4611104	6958137	1176984	3262338	387727
United Recommend	511714	418235	1569549	834717	1248229	2817778	1643540	1528586	571254
Gold Circuit Electronics	4384959	3078980	14726407	5586368	6923089	21649496	9133631	18107743	2172286
Zhen Ding-KY	44222887	12998784	99312005	68177175	81808482	181120487	63423798	104694389	12443932
Tripod	26032815	7431903	52817975	17537643	22431255	75249230	36031188	44397486	4576080
TPT	9991196	2431052	22997341	7524906	8447645	31444986	13138754	19501266	1688874
Song Shang	416990	347161	3142863	578418	748005	3890868	1932949	3370863	402994
Kintech	61655	62606	724939	374076	390750	1115689	179331	491199	112528
Plotech	887950	314895	2825812	2009498	2223204	5049016	2180369	2601885	348958
Aurora	415068	406782	1246184	991589	1096134	2342318	916706	962189	167095
Dynamic	998567	1598097	7281248	5240292	5904058	13185306	6593878	10910451	1164875
Lasertek	534060	225991	2306912	698700	1389110	3696022	1783860	857670	266160
Yufu	684750	187940	1474751	340525	763326	2238077	300267	1205722	80721
Unimicron	24194463	8926459	53731376	57980739	70978848	124710224	42368800	75064455	8859473
HannStar	11364576	10108623	40859515	11072315	34569383	75428898	24207230	36110210	4230478
Ichia	1868780	957653	5960814	2783419	3499420	9460234	3599329	4758407	548748
APCB	2820836	973113	6792755	2643008	2931124	9723879	5718140	7321298	753771

Company Name/ Indicator	Cash and equivalents	and inventory	Property, current assets plant equipment	and Non-current assets (fixed)	total assets	Current liabilities	Operating cost	Operating expenses	
Career	4376759	1786904	12407895	17948625	19869755	32277650	9526159	14171347	1454285
Unitech	1065212	1957815	7663415	13277793	16170882	23834297	7760319	14390500	2306610
Lin Horn	1378536	206478	2455982	695472	1015062	3471044	2072620	1088914	72183
Yuhuan	397994	117686	836055	639070	1166120	2002175	1110869	1293636	73855
Howteh	768992	162151	1988239	113658	336938	2325177	1203140	2869282	187035
Chin-Poon	4110135	2941555	11981325	7331156	10495993	22477318	6261915	14443453	993603
First Hi-tec	473101	435083	1705728	917728	960389	2666117	862452	1947217	158044
Uniflex	210702	190542	1278438	960961	1070582	2349020	812690	1792548	287514
Tong Hsing Electronic	3791174	1519181	7962533	7825277	17474640	25437173	3801650	7282206	890349
Apex-KY	821682	2227880	6925804	7516542	8342558	15268362	5244657	9325012	1313390
Nan Ya	5573154	4988765	23256467	19710121	21299770	44556237	8253037	32760832	1644370
Shun On	823008	188728	1847963	454706	1725801	3573764	914764	1493569	366005
Trust-Search	177012	522	269666	15883	29294	298960	29035	346197	22476
New Era	702298	103384	2409002	339504	477903	2886905	318143	622327	97528
Sunflex	152380	128346	1529461	210759	321922	1851383	830596	655548	123823
Ecocera	25164	77134	257361	213694	274043	531404	305153	407822	54753

2.4 Summary

Taiwan's PCB output value exceeded one trillion yuan in 2022, which is the foundation for the development of other types of electronics industries and has made outstanding contributions to Taiwan's economy. A search of domestic and foreign literatures related to the PCB industry found that few scholars have explored the competitive position of PCB companies' business performance and the direction of business strategies through objective financial index information and the degree of ESG introduction by companies. Therefore, this study analyzes and evaluates the comprehensive operating performance of 35 listed PCB companies in Taiwan. It is expected that each PCB industry can review the pros and cons of its own operating performance and learn from the benchmark companies in the PCB industry to improve. The results of this study can be helpful for Taiwanese PCB companies to improve their operating performance, formulate sustainable growth strategies, and introduce ESG performance analysis.

3. Introduction to the Development of Environment Social Governance (ESG)

3.1 The Origin of ESG Development

When a company's influence on society is great, people start to examine its sense of existence. Corporate social responsibility emerges in academic dialogues, and there are more discussions in different theoretical fields. The definition of corporate social responsibility is most recognized by scholars like Friedman (2007) who believes that the social responsibility of a company is to increase profits. However, the discussion of corporate social responsibility so far has also waved away the view that the company's only responsibility is to make profits. It does not violate the company's pursuit of profit goals, and at the same time, it is affirmed that the company shall review its influence on society and choose to participate in non-profit activities (Cai Yingxin, 2019).

According to the United Nations Development Program, UNDP (2023), the sustainable development goals are also known as the Global Goals. There are 17 comprehensive goals that affect each other and balance social, economic and environmental development. Countries are suggested to commit to sustainable development and use creativity, knowledge tools and financial resources to promote the sustainable development of the whole society (Li Siwei, 2023).

3.2 The Role of ESG in Economic Development

ESG indicators can measure the performance of a country or a company considering the external environment. Many studies focus on events at the company level, but few studies focus on the country level. For example, some scholars have studied how the formulation and adoption of ESG at the company level affects the national macroeconomic performance of developed and emerging economies (Guillermo, Vicente, & Torres, 2019; Zhou, Caldecott, Harnett, & Schumacher, 2020).

The relationship between natural resources and economic development has become an eternal mystery in the

scientific community. Especially in sustainable economies, many people understand that wealth from natural resources can contribute to increased national income, better development of financial institutions, or improved human capital (Naomi & Akbar, 2021). Many scholars have also used the SDGs to analyze and improve environmental public policy (Cisneros-Montemayor et al., 2020; Kynčlová, Upadhyaya, & Nice, 2020; Mulligan et al., 2020).

3.3 The Impact of ESG on Listed Companies

Greenpeace Foundation (2022) pointed out that after the concept of ESG is proposed, investors begin to pay attention to various non-financial factors that affect the company's future development. For example, the carbon emissions of enterprises, the efficiency of energy use, the impact of production lines of supply chain manufacturers on the environment, the working conditions of employees, and the rights and interests of stakeholders, etc. It makes ESG an important indicator for investors to evaluate the sustainable operation and risk response ability of enterprises today, and it is also one of the important decisions that affect investors. Tsai et al. (2015) applied the Fuzzy-DEMATEL model to examine the environmental performance of Taiwan's PCB industry. Fuzzy theory was used to examine manufacturers' environmental performance standards and analyze fuzzy linguistics. They then adopted the fuzzy DEMATEL model to evaluate the direction and level of interaction between environmental performance standards, and determined the core environmental performance standards that are crucial to improving the environmental performance of Taiwan's PCB industry.

Pizzi, Principale, and de Nuccio (2022) conducted research using a quantitative approach with a sample of 2,046 U.S. listed companies during the period 2017-2020. The analysis found that the materiality of finance and sustainability is driven by different purposes. The combination has the advantage of sustainability importance. The Financial Regulatory Commission (2023b) has promoted the 2013 Blueprint for Strengthening Corporate Governance in China since 2013, the New Corporate Governance Blueprint (2018-2020) in 2018, and the Corporate Governance 3.0-Sustainable Development Blueprint in 2020. It has just been 10 years, and has completed a number of important measures, including setting up independent directors, audit committees and corporate governance directors in listed companies, and adopting electronic voting. The election of directors adopts a candidate nomination system. The institutional investors sign the due diligence governance code and evaluation mechanism. All listed companies with a capital of more than 10 billion yuan and foreign-owned shares of more than 30% need to upload shareholder meeting manuals and annual reports in advance. All listed companies with a capital of more than 2 billion yuan need to prepare sustainability reports, etc. (Financial Regulatory Commission, 2023b).

3.4 The Direction of ESG Operational Reform for Listed Companies

In order to comply with the world's Kyoto Protocol and the United Nations Convention on Climate Change, there is a need to achieve the ultimate goal of significantly improving climate change and reducing the risk and impact of climate change. Both governments and industries in the world have begun to formulate corporate solutions for issues related to environmental risks and fulfill their corporate social responsibilities. ESG data is cited from the data published by companies in the Public Information Observatory of the Taiwan Stock Exchange, and is divided into environmental aspects, social aspects and governance aspects. Among them, no data at all is 0; 0.33 for only one item of information and 0.66 for only two items; the content of all three information is 1, which is explained in the table below.

Table 2. The 2022 sustainability reports of 35 PCB listed companies table

Company Name/ Indicator	Introduction degree	ESG	GRI	SASB	TCFD
Cheer Time	1.5		V	Δ	Δ
Bor Jyh	2		V	V	V
Subtron	0		X	X	X
United Recommend	2		V	V	V
Gold Circuit Electronics	1		V	Δ	Δ
Zhen Ding-KY	2		V	V	V
Tripod	2		V	V	V
TPT	2		V	V	V
Song Shang	1.5		V	Δ	Δ
Kintech	1.16		V	Δ	Δ
Plotech	1.5		V	Δ	Δ
Aurona	2		V	V	V
Dynamic	0		X	X	X
Lasertek	2		V	V	V
Yufo	1.16		V	Δ	Δ
Unimicron	2		V	V	V
HannStar	1.5		V	Δ	Δ
Ichia	1.5		V	Δ	Δ
APCB	2		V	V	V
Career	2		V	V	V
Unitech	2		V	V	V
Lin Horn	1.16		V	Δ	Δ
Yuhuan	1.5		V	Δ	Δ
Howteh	1.16		V	Δ	Δ
Chin-Poon	2		V	V	V
First Hi-tec	1.5		V	Δ	Δ
Uniflex	1.5		V	Δ	Δ
Tong Hsing Electronic	1.5		V	Δ	Δ
Apex-KY	2		V	V	V
Nan Ya	2		V	V	V
Shun On	1.16		V	Δ	Δ
Trust-Search	1.16		V	Δ	Δ
New Era	1.16		V	Δ	Δ
Sunflex	1.16		V	Δ	Δ
Ecocera	0		X	X	X

Source: Taiwan Financial Supervisory Commission, compiled by this study.

4. Research Methods

4.1 Grey Relational Analysis (GRA)

Grey relational analysis refers to the quantitative description and comparison method of a system's development and changing situation. Its basic idea is to determine whether the connection is close determined by the geometric similarity between the reference data column and several comparison data columns. It reflects the degree of correlation between the factors. In the process of system development, if the changing trends of the two factors are consistent, then the degree of synchronous change is high. In other words, the degree of correlation between the two is high, otherwise it is low. Therefore, the grey relational analysis method is based on the degree of similarity or difference between the development trends of factors, that is, grey relational degree, as a method to measure the degree of correlation between factors (Xu Fengyin, Zhu Xingshan, Yan Qibin, & Li Shilun, 1994).

Usually, this method can be used to analyze the degree of influence of various factors on the results, and it can also be used to solve comprehensive evaluation problems that change over time. The core is to establish a parent sequence that changes over time according to certain rules and use the changes of each evaluation object over

time as a sub-sequence to find the degree of correlation between each sub-sequence and the parent sequence, and draw conclusions based on the magnitude of the correlation. The correlation degree can be divided into absolute correlation degree and relative correlation degree. The absolute correlation degree is initialized by the initial point zeroing method. When the factors to be analyzed are quite different, due to the inconsistency of the dimensions between the variables, the analysis is often affected, and it is difficult to obtain a reasonable result. The relative correlation degree is analyzed by relative quantity, and the calculation result is only related to the change rate of the sequence relative to the initial point and is irrelevant with the size of each observation data, which makes up for the defect of the absolute correlation degree to a certain extent (Li Chunliang, Tang Zhenling, Ma Yiru, & Chang Jincai, 2019). GRA is a measurement method that applies quantification to measure the degree of correlation between discrete sequences. Its advantages are mainly to effectively deal with the uncertainty of factors, multi-variable input, discrete data and data incompleteness. It does not need to demand a large amount of data. The distribution of data is not necessarily a typical normal distribution. It helps to make decisions in different environments (Wu & Chen, 1999).

4.2 Multiple Regression

Wen Chunyu, Jiang Qixian, and Zeng Aihui (2021) stated that if only one independent variable is discussed in the linear regression analysis, the impact on a dependent variable is called simple linear regression analysis. The coefficient of determination (R^2) of simple linear regression is equal to the square of the correlation coefficient between the independent variable and the dependent variable. The independent variable in regression analysis is also called predictor variable or explanatory variable. The dependent variable is also called criterion variable or response variable. If there are more than two independent variables in regression analysis, it is called multiple regression analysis or multiple linear regression analysis.

The multiple regression analysis prediction method is to explore the relationship between the independent and dependent variables. If there are more than two or more independent variables in the regression program, which belongs to the multiple regression analysis or multiple regression analysis. Multiple regression analysis is one of the most common data analysis methods in social science empirical research. When researchers attempt to explore the influence of a group of independent variables on a dependent variable, multiple regression analysis is a commonly used data analysis method for researchers (Xie Yusheng & Zheng Yizhong, 1998).

4.3 TOPSIS

The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method is a multi-attribute evaluation method developed by Hwang et al, (1981), which is used to improve the concept that the Displaced Ideal should be the closest to the ideal solution. The TOPSIS evaluation method is a multi-attribute decision-making method applied in a certain situation. It uses the relative distance compared with the best company and the worst company at the same time to evaluate the pros and cons of the companies. The basic concept of this method is that the decision-maker finds out the ideal solution composed of the best values of these criteria and the negative ideal solution composed of the worst values of these criteria according to the various criteria of feasible companies for evaluation.

TOPSIS is an order selection technique for the similarity of ideal goals, and it is a very effective method in multi-objective decision analysis. Through the normalized data and matrix, it finds out the optimal target and the worst target among multiple targets represented by ideal solution and anti-ideal solution respectively. It calculates the distance between each evaluation target and the ideal solution and anti-ideal solution. It also obtains the closeness of each target to the ideal solution, sorts according to the closeness of the ideal solution, and uses this as the basis for evaluating the quality of the target. The value of closeness is between 0 and 1. The closer the value is to 1, the closer the corresponding evaluation target is to the optimal level. On the contrary, the closer the value is to 0, the closer the evaluation target is to the worst level. This method has been successfully applied in many fields such as land use planning, material selection evaluation, project investment, medical care and health, which has significantly improved the accuracy and operability of multi-objective decision analysis (Li Hao, Luo Guofu, & Xie Qingsheng, 2007).

4.4 VIKOR

The VIKOR research method (Vlsekriterijumska Optimizacija I Kompromisno Resenje) was proposed by Serafim (Serafim Opricovic, 1998; Serafim Opricovic & Tzeng, 2004; Yu, 1973). Zeleny in 1982 also mentioned that Lp-metric was used to produce the VIKOR method using related eclectic planning models, (Serafim Opricovic & Tzeng, 2004). VIKOR method uses criteria and evaluation units to calculate the values of S_i (the sum of the distance ratios between the i -th industry and the real ideal solution under weighted conditions) and R_i (the i -th industry's distance from the real ideal solution under the weighted conditions) of the relevant schemes.

It then finds the compromise solution identified by experts under the eclectic correlation planning method. At the same time, the compromise solution must provide the maximum group utility and the minimum individual disagreement. It is cultivated and produced under the conditions of individual disagreement.

The so-called ideal solution refers to the best value that the evaluated company can obtain in each evaluation standard. While the negative ideal solution refers to the worst value that the evaluated company can obtain in each evaluation standard. When the evaluated company has the shortest sum of distances from the positive ideal value and the farthest distance from the negative ideal value in each evaluation criterion, the evaluated company is the best. If the total distance of each evaluated company is sorted, the priority order of comprehensive performance can be formed (S Opricovic, 1994; Serafim Opricovic, 1998; Serafim Opricovic & Tzeng, 2004; Serafim Opricovic & Tzeng, 2002). Multicriteria Optimization and Compromise Solution method was proposed by Opricovic, and it is one of the optimization methods (Compromise Programming) in Multi-Criteria Decision Making (MCDM). The analysis procedure firstly normalizes the data, determines the ideal value and the negative ideal value, calculates the distance and the comprehensive index, and sets the larger the value of the v parameter (usually equal to 0.5), the more the obtained index is biased towards the Majority Rule. The acceptance and reliability of the prioritization Q_j are verified. Q represents the comprehensive performance, and j represents the j th company.

4.5 Summary

Through grey relational data analysis, we can understand the degree of influence of various financial indicators on the operating performance of PCB manufacturers. Multiple regression model analysis is to find out the degree of correlation between each input item and output item of the manufacturer, and to understand which independent variables have a greater predictive power on the standard variable. We then calculate the relative distance between the best manufacturer and the worst manufacturer through TOPSIS to evaluate the pros and cons of the rankings. Finally, the overall distance of each evaluated company is sorted by VIKOR to form a priority order for comprehensive performance.

5. Research model

5.1 Establishing Research Model and Analysis

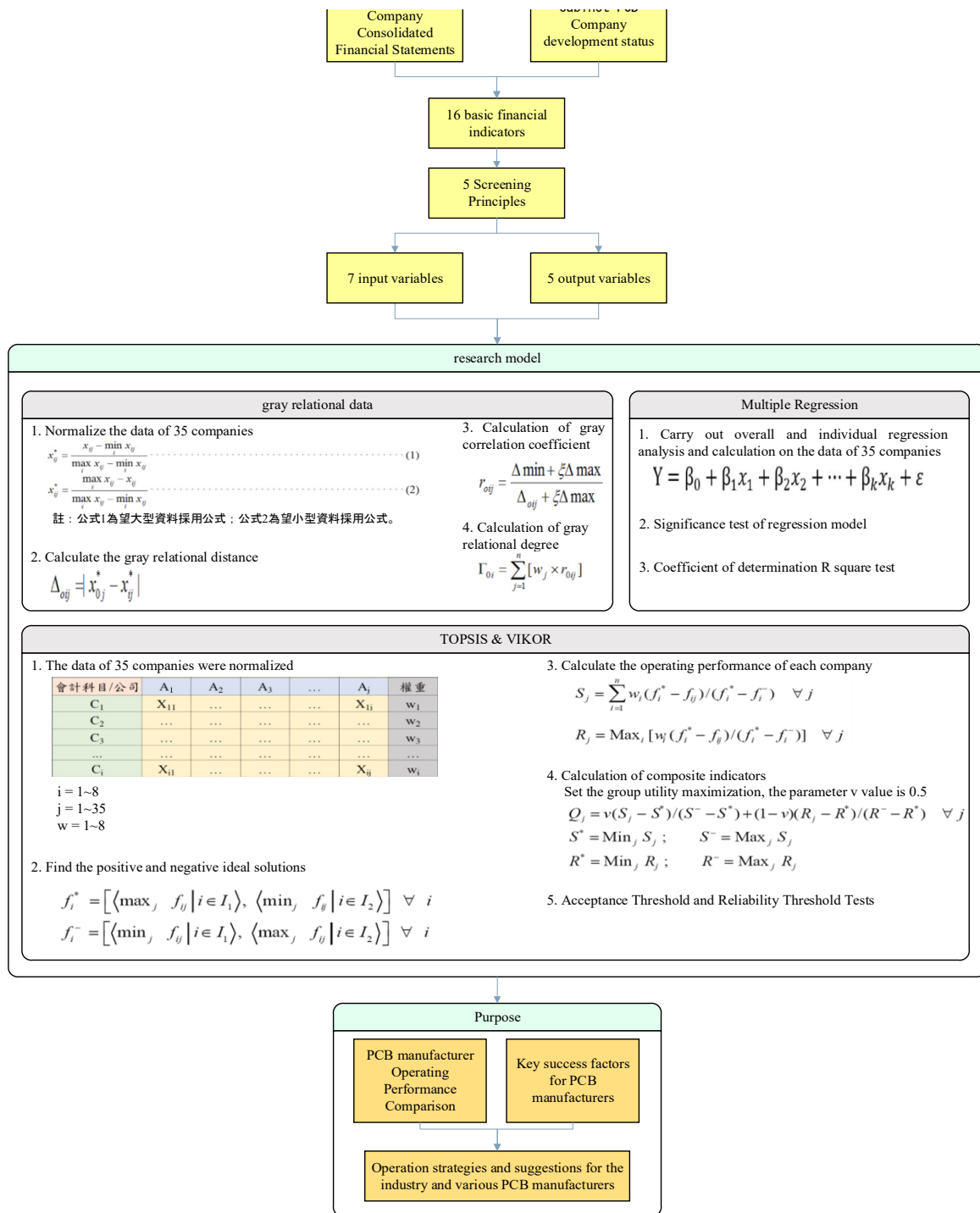
This study first collects the balance sheets and profit and loss statements of listed PCB companies in Taiwan from 2020 to 2022. Next step is to analyze the influence of various factors on the operating performance results of PCB manufacturers through grey-linked data, as shown in the figure below.

According to the balance sheets and profit and loss statements of PCB companies listed in Taiwan from 2020 to 2022, the data is analyzed and calculated through the multiple regression model for overall and individual regression analysis. It helps to understand which independent variables have a greater predictive power on the standard variables, and find out the influence relationship between the PCB industry as a whole and the financial indicators of individual companies. It can be seen as the figure below.

TOPSIS analysis is then applied to use the relative distance compared with the best manufacturer and the worst manufacturer at the same time, to evaluate the pros and cons of rankings. VIKOR is used to perform sorting analysis to find out the positive ideal solution and negative ideal solution, as shown in the figure below.

5.2 Combined Research Model

This combined research model is based on the consolidated financial statements and development status of PCB companies listed in Taiwan. There are 16 financial indicators are obtained through expert opinion. Finally, 7 input variables and 5 output variables are obtained through 5 screening principles. Grey correlation data is used for data processing, and then the data of 35 companies are calculated as a whole and individually through multiple regression models. Then, TOPSIS & VIKOR in the multi-criteria decision-making method is used to find positive ideal solutions and negative ideal solutions and obtain the operating performance of each company. Finally, compare the operating performance among PCB manufacturers and analyze the key success factors of operation, and put forward the operating strategies and suggestions for the industry and each PCB manufacturer.



Purpose

PCB manufacturer
Operating
Performance
Comparison

Key success factors
for PCB
manufacturers

↓

Operation strategies and suggestions for the
industry and various PCB manufacturers

Figure 2. The combined model diagram of this study

5.3 Data Sources

The data collection is from the public information of the Taiwan Stock Exchange, the financial statements of 35 listed companies in the PCB industry, as well as the ESG information published by each company. The main financial indicators include cash and equivalent, inventory, current assets, property, plant and equipment, non-current assets (fixed), total assets, current liabilities, operating costs, operating expenses, operating income, net operating profit, operating profit, non-operating income and expenses, net profit before tax, earnings per share, and the ESG level.

5.4 Empirical Analysis Procedures

The first step is to select decision-making indicators, input and output indicators from various PCB industry information. We then perform overall and individual regression analysis calculations based on their correlations, as well as normalized processing and grey correlation data analysis. Then, TOPSIS analysis is used to compare the relative distance between the best manufacturer and the worst manufacturer to evaluate and rank the pros and cons of rankings. VIKOR is employed for sorting analysis. We finally analyze and compare the advantages and disadvantages of the two methods of TOPSIS and VIKOR and summarize and discuss the results and insights.

6. Empirical Analysis

6.1 Data Collection and Processing

This study uses the consolidated financial statements of 35 companies in Taiwan's listed PCB industry, namely Shengtai, Bozhi, Xude, Meierkuai, Jinxiangdian, Zhending-KY, Jianding, Zhichao, Songshang, Qingsheng, Baicheng, Giant Oak, Dynamic, Leike, Yufu, Xinxing, Hanyubo, Yijia, Jingguo, Jialianyi, Yaohua, Linhong, Yuhuan, Haode, Jingpeng, Gaoji, Tongtai, Tongxindian, Taiding-KY, Nandian, Chunan, Baodaoji, Xinfuxing, Xuruan, and Licheng, from the public information of the Taiwan Stock Exchange and the financial statements of each company. In order to make the importance of each evaluation factor have the same weight distribution, this study first normalizes the original manufacturer's data, so that the values of each evaluation factor can be converted into a value ranging from 0 to 1 according to the ratio of the original data. In this way, the absolute value of different evaluation factors is not too different, and the larger value can affect the evaluation factor with a smaller value. We use multiple regression analysis to find out financial indicators with multiple inputs and outputs, and to calculate the data related to the impact value. We filter a total of 16 original data and ESG indicators into 7 input indicators and 5 output indicators. Among them, the input indicators include cash and equivalent, inventory, non-current assets (fixed), total assets, current liabilities, operating costs, and operating expenses. The Taiwan Financial Supervisory Commission does not have a login system for ESG indicators in 2020. Therefore, this study only searched for ESG comprehensive indicators of manufacturers in 2021 and 2022. The comprehensive indicators are divided into four categories. Among them, no information is 0; three items are only 0.33, and only two items are 0.66; all three items are 1. There is no absolute standard for ESG. Only individual companies set their own standards. Compared with the data of the company in the previous year, if there is improvement data, it means that the company has made progress and improvement in this indicator.

6.2 TOPSIS Analysis

The TOPSIS results aggregate the performance of 35 PCB manufacturers from 2020 to 2022. Due to the time gap in the financial data, the three-year summation is more accurate. Therefore, the development of several manufacturers is relatively stable. The larger the value of this empirical analysis, the better. The top five manufacturers are Dynamic, Xude, Licheng, Jinxiangdian and Haode, as shown in the table below. This study observes their financial index data and finds that although the input data of Dynamic and Jinxiang Electronics are not high, the output data is much higher than the average; while Xude, Licheng and Haode are all higher than the average in the input data, but lower than the average in the output data.

6.3 VIKOR Analysis

VIKOR's empirical analysis comprehensively sums up the performance of 35 PCB manufacturers from 2020 to 2022. Due to the problem of time gap in financial data, it is more accurate from the three-year summation. Therefore, the development of several manufacturers is relatively stable. This study observes its financial index data and finds that Zhending-KY has the minimum value in all input and output items; while Xinxing, Jianding, Nandian and Hannstar are also lower than the overall average value in input and output items. The VIKOR method of multi-criteria decision-making method and discussion are the ideas of this study, which can avoid the shortcomings of individual minority and the accuracy of evaluation is relatively stable.

traditional method. This evaluation method is a multi-attribute decision-making method applied in a certain situation. It uses the relative distance between the best selection target and the worst selection target at the same time to evaluate the pros and cons of the ranking scheme. TOPSIS can present the analysis results in a simple way, allowing ordinary readers understand it intuitively. The VIKOR summation method is developed using the Lp-metric of the eclectic programming method. It provides the minimum individual disagreement and the maximum group benefits. It allows all decision-making experts can accept the calculated compromise solution and use the aggregation function to express the distance between a solution and the fastest solution. The ranking index is to aggregate all attributes, the relative importance of attributes, and the balance between overall and individual satisfaction. Therefore, VIKOR is more capable of considering the real performance of a comparison unit and is not distorted by data conversion.

6.5 Discussion

The smaller the value calculated by VIKOR, the better, and the larger the TOPSIS ranking, the better. Both methods are performance evaluation. Following the information of financial indicators and the new ESG indicators recognized around the world, we find that the link between ESG indicators and financial indicators is not realistic enough. Future changes must be linked to the company's financial reports or IFAR accounting standards. In this study, VIKOR is more accurate, and the major factors are considered rather than a single consideration. A comprehensive review is achieved in this study which can provide reference for enterprises. The ESG discussion of the three systems and our analysis are connected in terms of performance. It is possible to predict how to revise at the initial stage of implementation, and how to link with company indicators in the future, so that the company's financial indicators can be reflected.

7. Conclusions and Suggestions

7.1 Conclusion

Taiwan's PCB output value exceeded one trillion yuan in 2022, which is the foundation for the development of other types of electronics industries and has made outstanding contributions to Taiwan's economy. Changes in Taiwan's PCB industry structure also affects important considerations in company development and performance. Environmental protection such as ESG is regarded as an indicator for evaluating a company's operations. TOPSIS is relatively simple and belongs to the traditional method. This evaluation method is a multi-attribute decision-making method applied in a certain situation. It uses the relative distance compared with the best selection target and the worst selection target at the same time to evaluate the pros and cons of the ranking scheme. TOPSIS can present the analysis results in a simple way, allowing ordinary readers understand it intuitively. The VIKOR summation method is developed using the Lp-metric of the eclectic programming method. The biggest feature of it is to provide the largest group benefit and the smallest individual disagreement, so that all decision-making experts can accept it. The calculated compromise solution uses an aggregation function to express the distance between a solution and the fastest solution. The ranking index is to aggregate all attributes, the relative importance of attributes, and the balance between overall and individual satisfaction. Therefore, VIKOR is more capable of considering the real performance of a comparison unit and is not distorted by data conversion. Judging from the results and data analyzed in this research, the analysis of VIKOR is more accurate, and the top five manufacturers from 2020 to 2022 are Jianding, Zhending-KY, Nandian, HannStar, Jinxiangdian and Xinxing. We find that the characteristics of these 6 manufacturers in terms of the operating income, operating gross profit, operating profit and pre-tax net profit of the output items are mostly higher than the overall average, although the input items are not high. The TOPSIS empirical analysis of comprehensive summation performance is based on 35 PCB manufacturers from 2020 to 2022. The top five manufacturers are Dynamic, Xude, Licheng, Jinxiangdian and Haode. The comprehensive performance VIKOR empirical analysis of 35 PCB manufacturers from 2020 to 2022, the top five manufacturers are Zhending-KY, Xinxing, Jianding, Nandian and HannStar.

ESG disclosure requirements also have differences in culture, human capital, and social responsibility. This also means that it is difficult to obtain ESG performance information for companies. However, in order to comply with the policies of the Financial Supervisory Commission of Taiwan and address issues related to environmental risks, companies have begun to formulate related solutions for companies and fulfill their corporate social responsibilities. Therefore, it is an important issue for Taiwanese PCB companies to improve operating performance, formulate sustainable growth strategies, and introduce ESG performance analysis. Finally, having the Taiwan PCB manufacturers comparison of the differences before and after the ranking, practical suggestions for business planning or improvement and the reference direction for future business operations are addressed. Although they all meet the international reporting ESG norms, these three reports have

different emphases. Most of Taiwan's listed companies mainly adopt GRI norms for reporting.

7.2 Suggestions

Taiwan's listed PCB manufacturer rankings may change every year. Therefore, individual manufacturer needs to understand the changes in the market environment and change their own business models and strategies in order to maintain their advantages in this field. This study is based on the multi-criteria decision-making and ESG performance analysis results of manufacturers from 2020 to 2022. We find that the link between ESG indicators and finance is not enough for actual needs. Therefore, ESG performance indicators in the future must be linked with the company's financial reports and IFRS accounting standards.

7.3 Suggestions for Future Research

If other researchers prefer to use multi-criteria decision-making and ESG performance to analyze the influence degree of PCB manufacturers' operating performance results, it is recommended to add sensitivity analysis and increase or decrease factors successively to strengthen the validity of the evaluation results. In addition, this study only analyzes financial indicator data from 2020 to 2022, and ESG performance data is relatively new, thus only manufacturers in 2021 are published in corporate information. Therefore, it is recommended that researchers can add future corporate ESG performance based on this and observe whether it is related to financial indicators.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal and publisher adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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