

Article

The Quality Evaluation of Environmental Accounting Information Disclosure for the Steel Industry Driven by the “Carbon Peaking and Carbon Neutrality” Goal: An Analytic Hierarchy Process Approach

Jiaojiao Han *, Yan Zhong, Xiaoyun Zhao, Yan Zeng and Ziyang Sun

College of Economics and Management, Baoji University of Arts and Sciences, Baoji 721013, China; 15979811339@163.com (Y.Z.); zhaoxiaoyun@bjwlxy.edu.cn (X.Z.); 15683503225@163.com (Y.Z.); 18762721011@163.com (Z.S.)

* Correspondence: hanjiaojiao@bjwlxy.edu.cn

Abstract

Against the backdrop of China’s “Carbon Peaking and Carbon Neutrality” goal, the steel industry faces mounting pressure to improve its environmental accounting information disclosure as part of its green and low-carbon transition. This study evaluates the quality of environmental accounting disclosure among 30 listed Chinese steel companies from 2019 to 2023, using the analytic hierarchy process (AHP) and content analysis across disclosure channels and content dimensions. Three key findings are revealed: (1) Annual reports remain the dominant disclosure channel, while the share of standalone environmental reports rises from 3.33% to 53.33% but remains low and inconsistent. (2) Disclosure exhibits a pattern of “strong hard indicators but weak soft indicators and excessive positive information but scarce negative information”; environmental liability carries the highest weight (0.3083); and the quantitative disclosure of industrial solid waste and other specific metrics remains below 30%. (3) A weight-driven stratification pattern exists: high-weight hard indicators have improved under policy and market pressure, whereas low-weight soft indicators and negative information remain largely neglected. Based on these findings, this study proposes optimization paths from institutional norms, corporate governance, and external supervision. The conclusions provide practical implications for enhancing disclosure quality and supporting the green transformation of the steel industry under the “Carbon Peaking and Carbon Neutrality” strategy.

Keywords: “Carbon neutrality” goal; steel industry; environmental accounting information disclosure; AHP; analytic hierarchy process; content analysis method

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1. Introduction

The “Carbon Peaking and Carbon Neutrality” goal is driving the deepening of China’s industrial green transformation [1]. As the key industry in terms of its contribution to the energy consumption and carbon emissions of the industrial sector [2], the environmental governance effectiveness of the steel industry will directly affect the realization of the “Carbon Peaking and Carbon Neutrality” goal. Meanwhile, relevant regulations also clearly state that enterprises must disclose environmental information in a legal,

truthful, and complete manner. Industry data shows that in 2024, the carbon emissions of China's steel industry accounted for approximately 19.7% of the country's total industrial emissions [3], which is 8–10% lower than the international advanced level [4]. Even more concerning is that some enterprises produce excessive pollutant emissions [5] and conceal environmental information [6]; such issues not only intensify the pressure on the ecological environment but also seriously restrict the sustainable development of the industry. Under the dual circumstances of increasing pressure for emission reduction and stricter policy supervision in this industry, environmental accounting information disclosure serves as a crucial link connecting the environmental behavior of enterprises with the supervision of stakeholders [7], and the degree of improvement directly affects the environmental governance efficiency of the steel industry [8]. Therefore, there is a pressing need to address the "high-carbon lock-in" predicament of the industry and promote green transformation through standardized information disclosure.

The core value of environmental accounting information disclosure lies in systematically presenting the financial and non-financial effects of an enterprise's environmental activities [9]; this provides a reliable basis for government supervision, investor decision-making, and public oversight and compels enterprises to optimize their production processes and reduce environmental risks [10,11]. From the perspective of international research trends, environmental accounting information disclosure has undergone distinct phases of development. The first stage was the theoretical foundation (beginning in the 1970s), during which early research mainly focused on defining the connotation of environmental accounting and demonstrating its significance [12,13], thus gradually clarifying the accounting logic for environmental costs and benefits. Subsequently, the framework construction stage was entered, with the research focus shifting to the classification and standardization of disclosure contents [14]; beginning to distinguish between monetized and non-monetized information [15]; and systematically exploring core disclosure dimensions such as ecological damage, economic impact, and litigation risks, thus making the framework for environmental accounting disclosure more operational [16,17]. After entering the new media era, research entered a stage of innovation in terms of access. Scholars began to pay attention to the limitations of traditional annual reports. Meanwhile, due to their efficient information transmission and convenient access, online platforms and independent environmental reports have become new research hotspots and practical directions [18–21].

Research on environmental accounting information disclosure in China started relatively late but has always been closely integrated with the country's policy background and industry characteristics. After the proposals of ecological civilization construction and the "Carbon Peaking and Carbon Neutrality" goal were made, the research focus gradually shifted from common issues across the entire industry to the differentiated analysis of heavily polluting industries. Schloesser has generally found problems such as fragmented content and a lack of quantitative data in the environmental information disclosure of heavily polluting enterprises, and due to the differences in production characteristics among different industries [22,23], the pain points of disclosure show significant differentiation. Specifically in the steel industry, existing studies have pointed out that disclosed information mainly focuses on the governance of traditional pollutant emissions [24], while it lacks coverage of new environmental information under the "dual-carbon" background such as carbon emission rights trading [25] and investment in green technology research and development [26]. Disclosure methods mostly rely on the annexes of annual reports [27], and the application rate of independent environmental reports is low [28], thus making it difficult to meet the in-depth information demands of stakeholders. Meanwhile, most existing studies mainly rely on qualitative descriptions or single empirical tests [29], thus lacking a systematic quantitative evaluation of disclosure quality. This

makes it difficult to accurately identify the weight of problems and priority for improvement, thereby limiting the guiding value of research conclusions for steel enterprise practices.

A further critical review of the extant literature reveals that international scholarship grounded in legitimacy theory and stakeholder theory has systematically elaborated the influencing mechanisms of corporate environmental information disclosure (EID) in terms of firms' cost of capital, investor confidence, and market valuation [30,31]. Methodologically, content analysis and disclosure scoring systems have emerged as dominant measurement instruments in this stream of research [15]. The analytic hierarchy process (AHP) has also been progressively adopted in environmental performance assessment, offering a viable approach to weight determination for multi-indicator evaluation frameworks [32]. By contrast, domestic Chinese scholars primarily focus on the driving effects of institutional pressures on corporate environmental disclosure behaviors [33,34] and have accumulated abundant empirical evidence concentrated on heavily polluting industrial sectors [35]. Nevertheless, three conspicuous limitations persist within the aforementioned body of literature. First, most analytical frameworks center on universal environmental disclosure dimensions, while scant scholarly attention has been devoted to emerging environmental information unique to the steel sector under the Carbon Peaking and Carbon Neutrality goals—including carbon emission rights transactions and low-carbon technology investments. Second, prevailing quantitative evaluation schemes predominantly adopt equal-weight assignment or simple frequency statistics, which fail to unpack the hierarchical importance of diverse disclosure dimensions within actual decision-making contexts. Third, prior research lacks a systematic dissection of the interactive institutional–organizational–market mechanisms underlying inadequate disclosure practices, thus resulting in overly generalized optimization proposals with limited practical operability.

Against this backdrop, this study advances the following research questions: 1. Under the institutional constraints imposed by the Carbon Peaking and Carbon Neutrality goals, how should a comprehensive evaluation indicator system for environmental accounting information disclosure (EAID) be constructed for the steel industry, and what hierarchical weighting characteristics characterize the relative importance of each indicator? 2. What systematic quality defects pervade current environmental accounting disclosure practices among listed steel firms, and do significant disparities exist across distinct categories of environmental accounting information? 3. What core barriers hinder high-quality environmental accounting information disclosure, and how can a synergistic optimization framework be established from three interrelated dimensions—institutional design, corporate internal governance, and external market supervision?

Indicators for environmental accounting information disclosure in the steel industry are diverse, with distinct levels of importance, and conventional qualitative or standalone quantitative methods cannot accurately determine indicator priorities and impact weights. Combining qualitative judgment and quantitative calculation, the analytic hierarchy process (AHP) breaks complex decision-making problems into ordered hierarchical frameworks and quantifies the relative importance of indicators through expert scoring and consistency tests. Overcoming the superficial descriptive drawbacks of previous research, this method identifies the hierarchical weight characteristics of disclosure indicators, clarifies the core priorities and governance blind spots of steel firms' environmental accounting disclosure under the "Carbon Peaking and Carbon Neutrality" goal, and provides targeted references for formulating follow-up optimization strategies.

Based on the aforementioned practical needs and research gaps, considering the background of the "Carbon Peaking and Carbon Neutrality" goal, this study focuses on the issue of environmental accounting information disclosure in the steel industry and

conducts related research. To be more specific, this study first constructs a multi-dimensional evaluation index system comprising disclosure completeness, method appropriateness, and quality reliability using the AHP, clearly defining the weights of each indicator. Secondly, combined with the content analysis method, environmental accounting information from the annual and environmental reports of listed steel companies is systematically sorted and quantitatively scored to comprehensively present the current disclosure situation. Thirdly, on this basis, the core problems in the environmental accounting information disclosure of the steel industry are accurately identified. Finally, based on these problems, a three-dimensional optimization path of “system improvement–enterprise governance–external supervision” is constructed, with the aim of providing theoretical support and practical references for improving the quality of environmental accounting information disclosure in the steel industry and facilitating its green and low-carbon transformation.

2. Sample Enterprises and Data Sources

2.1. Sample Enterprises

The sample selection procedure is outlined as follows. First, all A-share-listed firms categorized under the industry of “Smelting and Pressing of Ferrous Metals” were extracted from the CSMAR database, yielding an initial sample of 45 enterprises. Second, the core business scope of each firm was verified one by one via the Tianyancha platform, and five enterprises whose primary businesses no longer involved steel smelting or processing were eliminated. Third, four firms labeled ST or *ST during the sample period were excluded to avoid disturbances to disclosure behaviors caused by abnormal operating conditions. Finally, to ensure the continuity and comparability of research data spanning 2019 to 2023, six firms that were newly listed or delisted or had less than five full years of observations within this window were eliminated.

Following the above multi-stage screening process, a final sample of 30 listed steel firms was obtained. This sample includes state-controlled and privately owned enterprises of varying sizes, geographically covering major steel-producing regions such as East, North, Northeast, and Southwest China, thereby exhibiting sound industry representativeness. Table 1 presents basic information about the sample enterprises, and to avoid misleading information arising from enterprises changing their names, in the subsequent analysis, the stock code (which is unique) will be used to refer to the corresponding enterprises to facilitate analysis, discussion, and data comparison.

Table 1. Basic information about sample enterprises.

Stock Code	Company Name	Time to Market
000708	Citic Taifutong Steel Group Company Limited	March 1997
000709	Hebei Iron and Steel Company Limited	April 1997
000717	Guangdong Zhongnan Steel Corporation Limited	May 1997
000761	Bengang Steel Plates Corporation Limited	June 1997
000825	Shanxi Taigang Stainless Steel Corporation Limited	October 1998
000898	Angang Steel Corporation Limited	July 1997
000932	Hunan Valin Steel Corporation Limited	August 1999
000959	Beijing Shougangl Corporation Limited	December 1999
002110	Fujian Sansteel Minguangl Corporation Limited	January 2007
002182	Baowu Magnesia Technologyl Corporation Limited	November 2007
600010	Inner Mongolia Baotou Steel Group Co., Ltd.	March 2001
600019	Baoshan Iron and Steel Company Limited	December 2000
600022	Shandong Iron and Steel Company Limited	December 2008
600117	Xining Special Steel Company Limited	March 1997

600126	Hangzhou Iron and Steel Company Limited	March 1998
600231	Lingyuan Iron and Steel Company Limited	May 2000
600282	Nanjing Iron and Steel Company Limited	September 2000
600307	Gansu Jiu'an Group Hongxing Iron and Steel Co., Ltd.	December 2000
600399	Fushun Special Steel Company Limited	December 2000
600408	An Tai Group Co., Ltd. of Shanxi Province	February 2003
600507	Fangda Special Steel Technology Co., Ltd.	September 2003
600569	Anyang Iron and Steel Company Limited	August 2001
600581	Xinjiang Baigang Iron and Steel Co., Ltd.	August 2002
600782	Xin Yu Iron and Steel Company Limited	January 2007
600808	Ma'anshan Iron and Steel Company Limited	November 1993
600961	Zhuzhou Smelting Group Company Limited	August 2004
601003	Liuzhou Iron and Steel Company Limited	February 2007
601005	Chongqing Iron and Steel Company Limited	February 2007
601106	China First Heavy Machinery Co., Ltd.	February 2010
603995	Zhejiang Yongjin Metal Technology Co., Ltd.	December 2019

2.2. Data Sources

Firstly, the names of all listed companies are obtained from the CSMAR database; secondly, the “Search for Enterprises” function of Tianyancha is used to determine the industry of the enterprises; and thirdly, the official website of the enterprises is entered to query information on their environmental accounting disclosure. Finally, the sample enterprises are further screened as follows: ① sample enterprises with missing information are eliminated and ② sample enterprises with ST and *ST labels are eliminated. ③ This study also focuses on the environmental accounting disclosure status of enterprises from 2019 to 2023. To ensure the continuity and reliability of the research data and effectively avoid sample bias caused by differences in the duration of enterprise existence, the research sample is strictly limited to enterprises that have been in existence for the full five-year observation period. Thus, this effectively controls the risk of data fluctuations caused by different enterprise life cycles, thereby enhancing the robustness and persuasiveness of the research conclusions. Regarding the steel industry’s environmental accounting information disclosure, the disclosure situations of 30 enterprises are analyzed to summarize and identify existing problems.

3. Evaluation and Analysis of Quality of Enterprises’ Environmental Accounting Information Disclosure Based on AHP

The quality evaluation of environmental accounting information disclosure mainly includes two core dimensions: the disclosure method and content. The disclosure method determines the efficiency and accessibility of information transmission, while the disclosure content directly reflects the completeness and relevance of information. This study will first summarize the main methods of environmental accounting information disclosure in the steel industry; clarify the carrier and presentation characteristics of information transmission; and then deeply analyze the specific composition of the disclosure content and conduct an evaluation and analysis of the disclosure quality of the steel industry by using the AHP.

3.1. Environmental Accounting Information Disclosure Modes in the Steel Industry

The disclosure of environmental accounting information by enterprises is an important manifestation of their commitment to social responsibility. In the current context of rapid economic transformation and the continuous deterioration of ecological resources and the environment, enterprises should even more promptly and accurately provide

high-quality environmental accounting information. Table 2 shows the ways in which the sample enterprises disclosed environmental accounting information during the past five years (from 2019 to 2023). The symbol “√” indicates that the enterprise disclosed relevant information.

Table 2. The disclosure of environmental information reports by listed companies in the steel industry from 2019 to 2023.

Stock Code	2019			2020			2021			2022			2023		
	AR	SR	ER	AR	SR	ER	AR	SR	ER	AR	SR	ER	AR	SR	ER
000708	√	√		√	√		√	√		√	√		√	√	
000709	√	√		√	√		√	√		√	√	√	√	√	√
000717	√			√			√	√		√	√		√	√	√
000761	√			√			√	√		√	√		√	√	√
000825	√	√		√	√		√	√		√	√		√	√	√
000898	√	√		√	√		√	√	√	√	√		√	√	√
000932	√			√	√		√	√	√	√	√		√	√	√
000959	√	√		√	√		√	√		√	√		√		
002110	√	√		√	√		√	√		√	√		√	√	
002182	√			√			√			√			√	√	
600010	√	√		√	√		√	√		√	√		√		
600019	√			√			√			√			√		
600022	√	√		√	√		√	√		√	√	√	√	√	√
600117	√	√		√	√		√	√		√	√		√	√	
600126	√			√			√			√	√	√	√	√	√
600231	√			√			√			√			√	√	√
600282	√	√		√	√		√			√			√		
600307	√	√		√	√		√	√		√	√		√	√	
600399	√			√			√			√	√		√	√	
600408	√			√			√			√			√		
600507	√	√		√	√		√	√		√			√	√	
600569	√	√		√	√		√	√		√	√		√	√	
600581	√			√			√			√	√	√	√	√	√
600782	√	√		√	√		√	√		√	√	√	√	√	√
600808	√	√		√	√		√	√	√	√	√	√	√	√	√
600961	√			√			√			√	√	√	√	√	√
601003	√	√		√	√		√	√		√	√		√	√	√
601005	√	√	√	√	√		√	√	√	√	√	√	√	√	√
601106	√			√			√			√	√	√	√	√	√
603995	√			√			√			√			√		
Total	30	17	1	30	18	0	30	19	4	30	23	9	30	24	16

Note: AR = Annual Report; SR = Social Responsibility Report; ER = Environmental Report; √ = information has been disclosed.

Based on how environmental accounting information is disclosed, the samples are divided into annual, social responsibility, and environmental report disclosure. According to the data in Table 2 and the trend chart in Figure 1, the following can be observed: Firstly, in the steel industry, the coverage rate of annual reports reaches 100%, while the ratio of enterprises disclosing environmental information solely in the form of environmental reports has been increasing year by year, but the highest is only half of that for annual reports (53.3%), indicating that in the steel industry, most enterprises tend to disclose their information through annual reports, thus resulting in an imbalance in the ways of disclosing information. Secondly, based on the disclosed data in the table, it can be seen

that Ansteel Co., Ltd.; Huaxiang Steel Co., Ltd.; Shougang Co., Ltd.; Baogang Co., Ltd.; Nangang Steel Co., Ltd.; and Fangda Special Steel Co., Ltd. have all intermittently interrupted the disclosure of information to varying degrees, thus indicating that in the steel industry, some enterprises have unstable disclosure behavior within five years and disclosure can be interrupted.

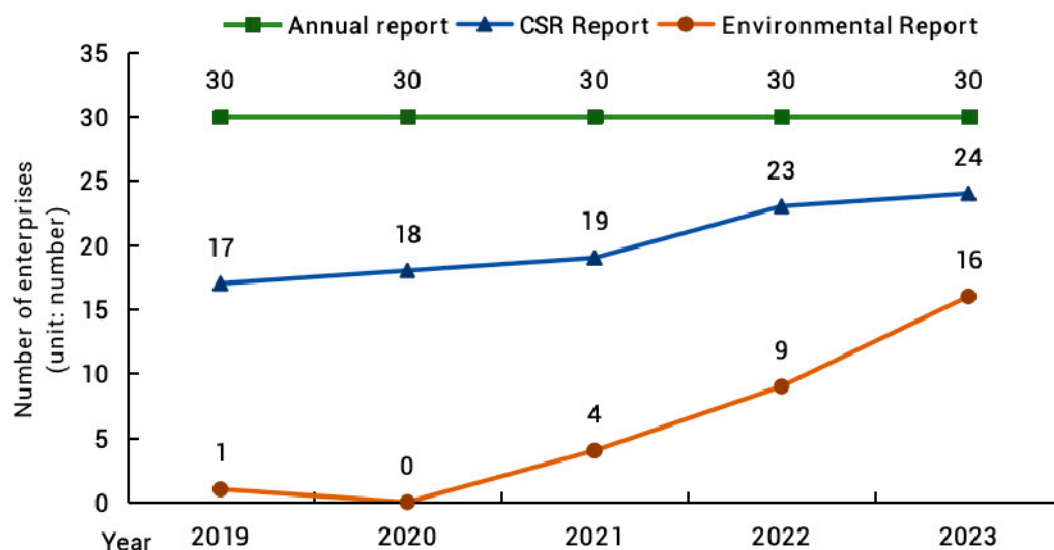


Figure 1. Trend chart of environmental accounting information disclosure modes for sample enterprises from 2019 to 2023.

We then analyze the reasons for the above results: ① At the level of enterprise cognition and motivation, the enterprise merely regards disclosing environmental information as a means for avoiding punishment, without realizing that a separate environmental report has the value of demonstrating environmental performance and accepting public supervision [36]; moreover, compiling an independent environmental report requires investment in human resources and material resources. The enterprise's control over costs [37] leads it to briefly mention environmental accounting information in its annual or social responsibility report, which is the reason why the annual report disclosure rate remains at 100%, while that for environmental reports reaches its highest at only 53.3%. ② From the perspectives of external supervision and the market, the regulatory system for environmental accounting information disclosure lacks mandatory constraints and detailed provisions. Standards governing the format, content, and frequency of environmental accounting information disclosure in the steel industry remain ambiguous, thus resulting in intermittent disclosure among six enterprises including Angang Steel and Valin Steel. Moreover, although a general market-oriented framework has been gradually constructed since the reform and opening-up, supporting reward and punishment mechanisms targeting corporate environmental responsibilities are far from mature. Investors, consumers, and other market participants pay insufficient attention to corporate environmental performance and lack corresponding binding power [38], thus leaving a sound market-driven constraint system incomplete. Consequently, although the environmental report disclosure rate has risen from 3.33% to 53.3%, the overall disclosure foundation has stayed weak, and some enterprises even regressed to zero disclosure in 2020. ③ At the industry characteristic level, the steel industry is a high-energy-consumption and high-pollution sector. Environmental accounting information involves complex data

such as pollution control and carbon emissions. For instance, the quantitative disclosure rate of indicators like the amount of industrial solid waste is less than 30%. Some enterprises may reduce the separate disclosure of environmental reports due to difficulty in data organization and the fear of negative information being exposed, such as non-compliance with emission standards.

3.2. Environmental Accounting Information Disclosure Content in the Steel Industry

Based on the environmental accounting information publicly disclosed by 30 sample enterprises in their annual reports, this study refers to the evaluation table of scholars and the calculation table on the environmental information disclosure index of enterprises and classifies them in detail according to the specific circumstances of the steel industry. To avoid repetition, this study adopts the disclosure of project codes, as shown in Figure 2. The contents of the environmental accounting information disclosed mainly include ① environmental performance and governance; ② environmental liability; ③ environmental management; and ④ environmental supervision and certification. Below, based on the AHP, the quality of the environmental accounting information disclosure of 30 sample enterprises will be evaluated and analyzed, and the reasons for its occurrence will be explored.

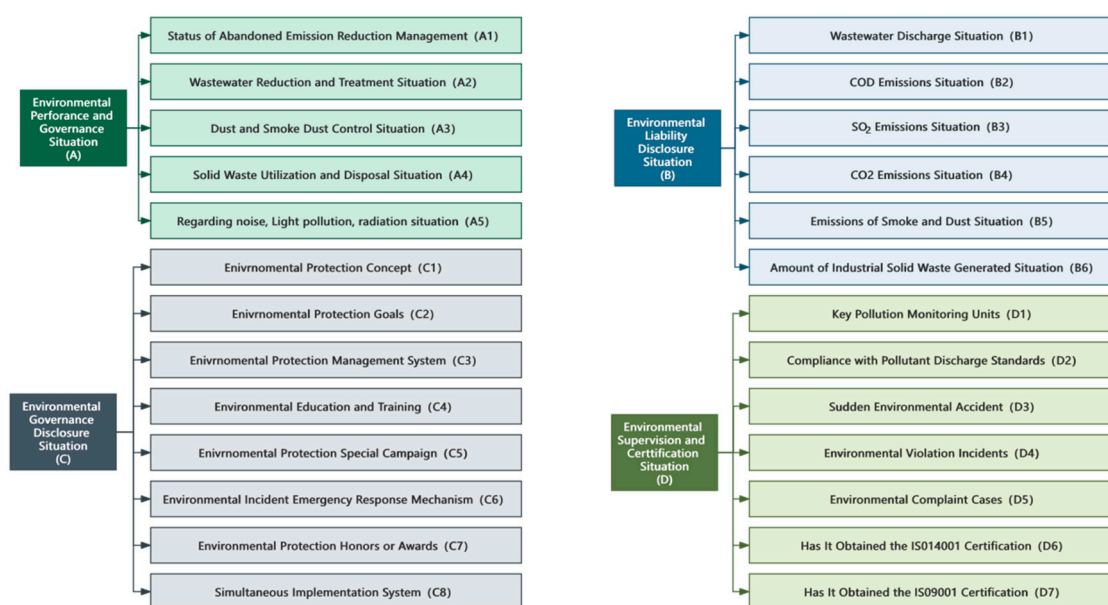


Figure 2. Indicators for enterprises' environmental accounting information disclosure situations.

To identify corporate selective disclosure, this study follows He et al.'s [39] selective disclosure theory and classifies environmental accounting into positive, neutral, and negative information in line with Clarkson et al. [40], GRI Standards [41], Milne & Adler [42], and Deegan & Rankin [43]. Positive items refer to green investments and certifications; neutral ones cover objective emission and resource data; and negative ones include violations and environmental accidents. The classification of all 28 secondary indicators is illustrated in Figure 3.

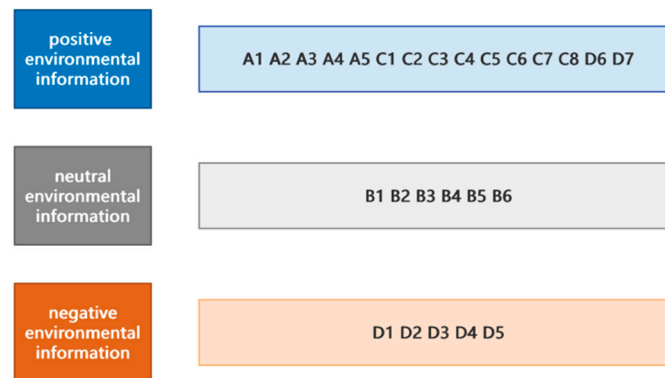


Figure 3. Classification diagram of secondary indicators for environmental accounting information disclosure.

3.2.1. Calculation of Indicator Weights and Consistency Test

This study adopts the analytic hierarchy process (AHP) to conduct a quality evaluation of enterprises in the iron and steel industry. The fundamental procedures consist of establishing a hierarchical structural model, constructing pairwise comparison matrices, calculating weight vectors, performing tests, and calculating combined weight vectors.

Based on the constructed index system, the 1–9 scaling method and expert consultation questionnaire survey were adopted. A total of 30 experts in this field were invited to rate the importance of the indicators shown in Figure 2. The sample size of 30 represents a deliberate trade-off between capturing diverse stakeholder perspectives (those of regulators, industry practitioners, academics, and verifiers) and maintaining the cognitive feasibility of pairwise comparison tasks. This scale is consistent with recent AHP studies employing expert panels of comparable size, such as those by Ahmad et al. [44] and Chen et al. [45].

The geometric mean of all scoring results is calculated to obtain the indicator judgment matrix, and the geometric mean formula is expressed as follows:

$$\bar{a}_{ij} = \frac{a_{ij}}{\sum_{i=1}^n a_{ij}} \quad (1)$$

After acquiring the judgment matrix, the square root method is utilized to calculate the relative initial weight W_i of each indicator at every hierarchy. Normalization is then applied to all W_i values within the same hierarchy to derive the weight vector of this hierarchy. The formula for normalized weight W_i is as follows:

$$W_i = \frac{W_i'}{\sum_{i=1}^n W_i'} \quad (2)$$

The calculation formula of initial weight W_i' is as follows:

$$W_i' = \sum_{j=1}^n \bar{a}_{ij} \quad (3)$$

Subsequently, the maximum eigenvalue of the judgment matrix is calculated via the formula below:

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^n \frac{\sum_{j=1}^n \bar{a}_{ij} W_j}{W_i} \quad (4)$$

The consistency index CI is further computed with the following equation:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (5)$$

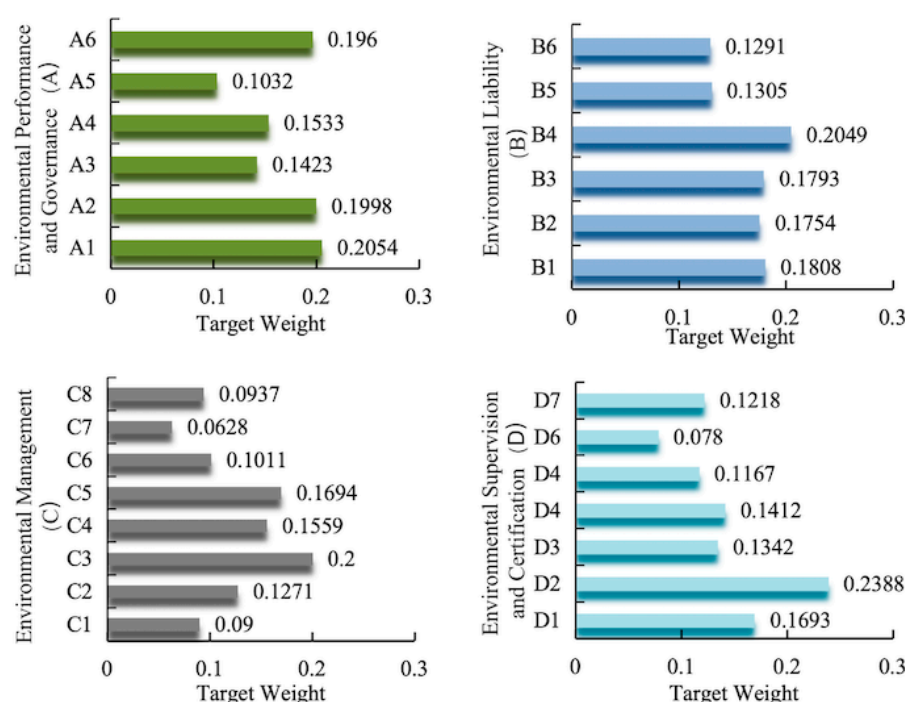
After looking up the corresponding average random consistency index RI (see Table 3), the random consistency ratio CR can be obtained via the following:

$$CR = \frac{CI}{RI} \quad (6)$$

Table 3. The average random consistency index RI value of the judgment matrix.

	<i>n</i>									
	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49

After calculation, all CR values were less than 0.1 (specific data and calculation procedures are shown in the Supplementary Materials), so the construction of the judgment matrix can be considered reasonable. The weight of the first-level indicators multiplied by that of the corresponding second-level ones gives the comprehensive weight, and the final result is shown in Figure 4. A specific analysis based on the four aspects shown in this figure is then conducted.

**Figure 4.** The relative weights of the indicator system.

After calculating the weights via the AHP, this study adopts the content analysis approach to code and quantitatively score environmental accounting information about the 30 sample firms from 2019 to 2023. The detailed scoring criteria are specified as follows. Each secondary indicator illustrated in Figure 2 is coded on a 0–2 scale: a score of 0 refers to the full non-disclosure of the corresponding indicator; a score of 1 denotes a merely qualitative narrative (e.g., “the firm continuously promotes cleaner production”); and a score of 2 indicates the provision of both qualitative descriptions and concrete quantitative data (e.g., “specific volume of waste gas emissions in the current year”). An item is regarded as disclosed if relevant information appears in the annual, corporate social responsibility (CSR), or environmental report. The formula for calculating the environmental accounting information disclosure quality score of each firm in each year is presented below:

$$Disclosure_Score_{it} = \sum (W_j \times Score_{ijt}) \quad (7)$$

3.2.2. Environmental Performance and Governance

Environmental performance information refers to enterprises’ quantifiable data in terms of energy consumption and pollution emissions. Environmental governance is a strategic management system established by enterprises to achieve environmental goals,

thus ensuring the sustainability of environmental performance. The specific disclosure of the environmental performance and governance of the sample enterprises from 2019 to 2023 is shown in Table 4.

Table 4. The specific disclosure of the environmental performance and governance of the sample enterprises (2019–2023).

Disclosure Item	2019		2020		2021		2022		2023	
	N	%	N	%	N	%	N	%	N	%
A1	96.67	53.33	83.33	53.33	90.00	60.00	96.67	90.00	100.00	90.00
A2	93.33	43.33	86.67	36.67	83.33	43.33	93.33	56.67	96.67	63.33
A3	90.00	46.67	80.00	36.67	83.33	56.67	86.67	40.00	90.00	60.00
A4	70.00	43.33	63.33	33.33	38.33	46.67	86.67	60.00	93.33	83.33
A5	63.33	23.33	43.33	13.33	60.00	13.33	60.00	10.00	73.33	6.67
A6	46.67	0.00	46.67	6.67	46.67	3.33	50.55	0.00	53.33	0.00

Note: N = number of enterprises disclosing the item; % = disclosure ratio (%).

Table 4 illustrates that the number of environmental performance and governance indicators of firms, as well as the number of those providing quantitative data on such indicators, generally rose across the five-year period, with substantial disparities across sub-indicators.

For indicators A1 and A2, over 90% of sample firms disclosed them annually. Specifically, the number of firms offering quantitative data for A1 increased from 16 (53.33%) in 2019 to 27 (90%) in 2023, while that for A2 grew from 13 (43.33%) to 19 (63.33%). Combined with the AHP weight scores in Figure 5, both indicators maintained high scores throughout the period (A1: 11.297 in 2023; A2: 9.5904), thus indicating sufficient disclosure breadth and superior performance in importance and disclosure quality.

In contrast, soft environmental indicators A5 and A6 exhibited weak performance. As shown in Table 4, the maximum number of firms disclosing A5 was only 22 (73.33%), and the number of firms with quantitative A5 data remained below 8 (25%) in most years. Fewer than 17 firms (55%) disclosed A6, and zero firms provided quantitative A6 data for multiple years. Their consistently low AHP scores in Figure 5 (A5: 2.4768; A6: 3.136 in 2023) reveal severe shortages in both disclosure scope and quantitative depth for soft environmental indicators.

Further analysis based on Table 4 and Figure 5 reveals the following: Although the quantitative disclosure rates for A1–A6 are generally high and have been increasing year by year, and A1 and A2 achieved a 90% disclosure rate in 2023 due to the mandatory requirements of the “Carbon Emission Trading Management Measures”, the AHP weight scores better reflect the “disclosure quality differences” — A1 and A2 have higher scores.

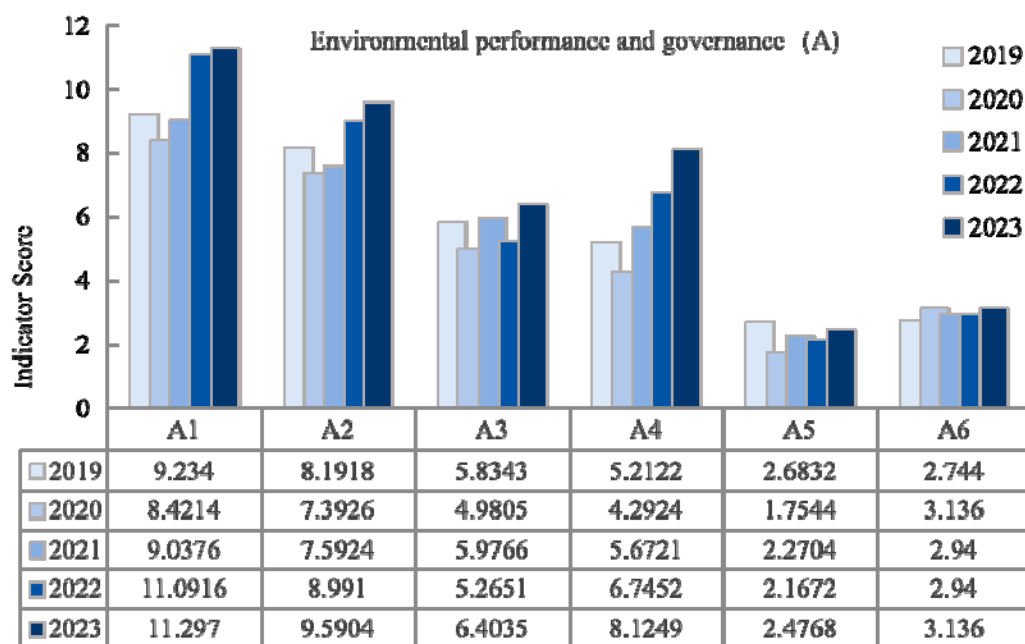


Figure 5. A summary of the A section scores of the sample enterprises from 2019 to 2023.

Further analyses based on Table 4 and Figure 5 reveal that the quantitative disclosure rates of A1 to A6 are generally high and show an upward trend year by year. Mandated by the Administrative Measures for Carbon Emission Trading, the disclosure rates of A1 and A2 reached 90% in 2023. AHP weighting scores can better reflect gaps in disclosure quality, with A1 and A2 recording relatively higher scores. A plausible interpretation for this is that under mandatory policy constraints, firms tend to disclose not only whether carbon governance activities are implemented but also detailed quantitative information such as specific capital inputs and emission reduction volumes, which aligns with the high proportion of quantitative disclosures documented in Table 4. The lower scores of A5 and A6 may be attributable to two potential factors. First, current policies only require firms to report final emission reduction outcomes without unified standards for the base-year [37]; some firms adopt 2019 as the benchmark year, while others use 2020, thus hindering the horizontal comparability of emission reduction performance. Second, Figure 5 illustrates that the score of A6 remains persistently low, and the existing literature confirms that such indicators are not the core concerns of green investors [46], which may reduce firms' incentives to provide high-quality detailed disclosures. In terms of dynamic changes over time, Table 4 shows that the overall disclosure proportion of A4 rose from 70% to 93.33%, and its quantitative disclosure ratio increased from 43.33% to 83.33%, thus corresponding to a growth in its AHP score from 5.2122 to 8.1249, as shown in Figure 5. Prior studies suggest that green investors typically treat A1 and A4 as key references for investment decisions [47,48], thus implying that improving the quantitative disclosure quality of A4 may help firms secure potential green financing advantages. The proportions presented solely in Table 4 only reflect the breadth of disclosure and fail to capture differentiated disclosure quality, whereas the AHP scores in Figure 5 clearly demonstrate a potential progressive relationship spanning disclosure breadth and quality and weighting scores.

3.2.3. Environmental Liability

Environmental liabilities refer to the negative impacts or burdens that an enterprise's economic activities have on the environment [49]. They can transform the hidden environmental risks of enterprises into public financial warnings, thereby avoiding huge

losses in the future. The specific disclosure of the environmental liabilities of the sample enterprises from 2019 to 2023 is shown in Table 5.

Table 5. Disclosure of environmental liabilities by sample enterprises (2019–2023).

Disclosure Item	2019		2020		2021		2022		2023	
	N	%	N	%	N	%	N	%	N	%
B1	93.33	46.67	90.00	40.00	80.00	50.00	96.67	70.00	100.00	90.00
B2	70.00	56.67	63.33	53.33	60.00	53.33	73.33	63.33	80.00	70.00
B3	80.00	73.33	70.00	60.00	70.00	66.67	83.33	76.67	86.67	86.67
B4	20.00	16.67	20.00	13.33	40.00	23.33	93.33	83.33	93.33	76.67
B5	90.00	66.67	73.33	53.33	80.00	63.33	83.33	73.33	90.00	86.67
B6	26.67	3.33	20.00	10.00	13.33	3.33	23.33	6.67	30.00	20.00

Note: N = number of enterprises disclosing the item; % = disclosure ratio (%).

Table 5 shows that in terms of the environmental liability disclosures of 30 steel enterprises from 2019 to 2023, the disclosure performance of different pollution indicators showed significant differentiation: The disclosure proportions of B1 and B5 remained above 80% throughout, and that of B1 even reached 100% in 2023. That of B4 showed a significant phased increase, with long-term values lower than 40% before 2022 and directly rising to 93.33% and remaining stable after 2022, while that of B6 remained in a low range below 30%. Combined with the B section score shown in Figure 6, the scores of B1 and B3 have long been in a high range (in 2023, the B1 score was 9.944, and B3 was 9.3236), B4 soared from 3.8931 to 10.4499 after 2022, and B6 was always below 2, reflecting that not only are the disclosure breadths of different environmental liability indicators significantly different, but also, through the score differences, different indicators can reflect the hierarchical differences in the “information value and actual attention” level.

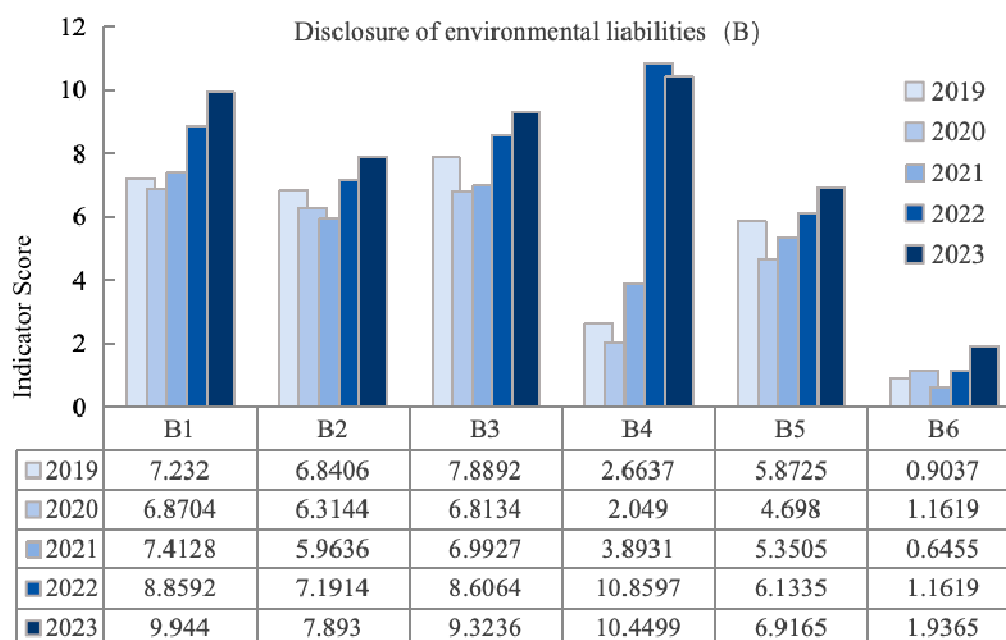


Figure 6. A summary of the B section scores of the sample enterprises from 2019 to 2023.

By combining Table 5 and Figure 6 for further analysis, a plausible logic underlying such discrepancies is proposed: disclosure ratios merely capture “whether relevant information is disclosed”, while the AHP score is more capable of reflecting “the value weight of the disclosed contents”. The relatively high disclosure ratios of traditional pollutants

(such as B1 and B5) may be due to the mandatory requirements of long-term environmental protection supervision and well-established technologies [50], and their elevated scores could correspond to the guaranteed information quality shaped by regulatory-driven disclosure frameworks [51]. Both the disclosure ratio and score of B4 have climbed synchronously post-2022, which may be linked to tightened carbon accounting oversight rolled out alongside the “Carbon Peaking and Carbon Neutrality” goal. Firms appear to have expanded their disclosure coverage while supplementing granular high-quality information including carbon emission volumes and abatement measures. Such progressive improvement from broad disclosure coverage to refined information quality can be clearly observed via the AHP score. By contrast, the low disclosure ratios and scores of B6 could be attributed to multiple intertwined factors: unstandardized procedural data used for industrial solid waste accounting, the limited corporate awareness of related disclosure rules, and disclosure’s status as a non-core focus of existing regulatory oversight and green investment screening. These factors may weaken firms’ incentives to produce comprehensive, high-quality disclosures. The AHP scores plotted in Figure 6 illustrate visible quality stratification within environmental liability disclosures and lend suggestive support to the documented pattern that disclosure quality disparities among heavily polluting industries are jointly shaped by regulatory pressures and economic incentives [52].

3.2.4. Environmental Management Disclosure

Environmental management information serves as the foundation for enterprises to implement refined management and achieve sustainable development, and it can effectively transform environmental risks into development opportunities. The specific disclosure of environmental management information about the sample enterprises from 2019 to 2023 is shown in Table 6.

Table 6. Disclosure of environmental management information by sample enterprises (2019–2023).

Disclosure Item	2019		2020		2021		2022		2023	
	N	%	N	%	N	%	N	%	N	%
C1	25	83.33	25	83.33	23	76.67	27	90.00	28	93.33
C2	13	43.33	11	36.67	17	56.67	17	56.67	21	70.00
C3	23	76.67	14	46.67	21	70.00	22	73.33	27	90.00
C4	8	26.67	6	20.00	10	33.33	15	50.00	23	76.67
C5	12	40.00	7	23.33	12	40.00	17	56.67	23	76.67
C6	25	83.33	24	80.00	26	86.67	27	90.00	27	90.00
C7	14	46.67	8	26.67	14	46.67	14	46.67	20	66.67
C8	15	50.00	12	40.00	16	53.33	18	60.00	20	66.67

Note: N = number of enterprises disclosing the item; % = disclosure ratio (%).

As shown in Table 6, the disclosure performance regarding environmental management information about the sample enterprises from 2019 to 2023 presented the characteristic of the “basic category being stable, with the expansion category improving”. C1 and C6 consistently maintained a high disclosure ratio (above 80%), as only two and three enterprises failed to make disclosures, respectively, in 2023; the disclosure ratios of C4 and C5 increased the most, rising from 26.67% and 40% in 2019 to 76.67% in 2023; that of C3 fluctuated and then rebounded to 90%; and those of C2, C7, and C8 showed a gradually increasing trend. Considering the scores shown in Figure 7, from 2019 to 2023, the scores of C3, C4, and C5 increased from 4.4 to 5.2, 1.2472 to 3.4298, and 2.0328 to 3.7268, respectively, while those of C1 and C6 remained in a relatively stable range.

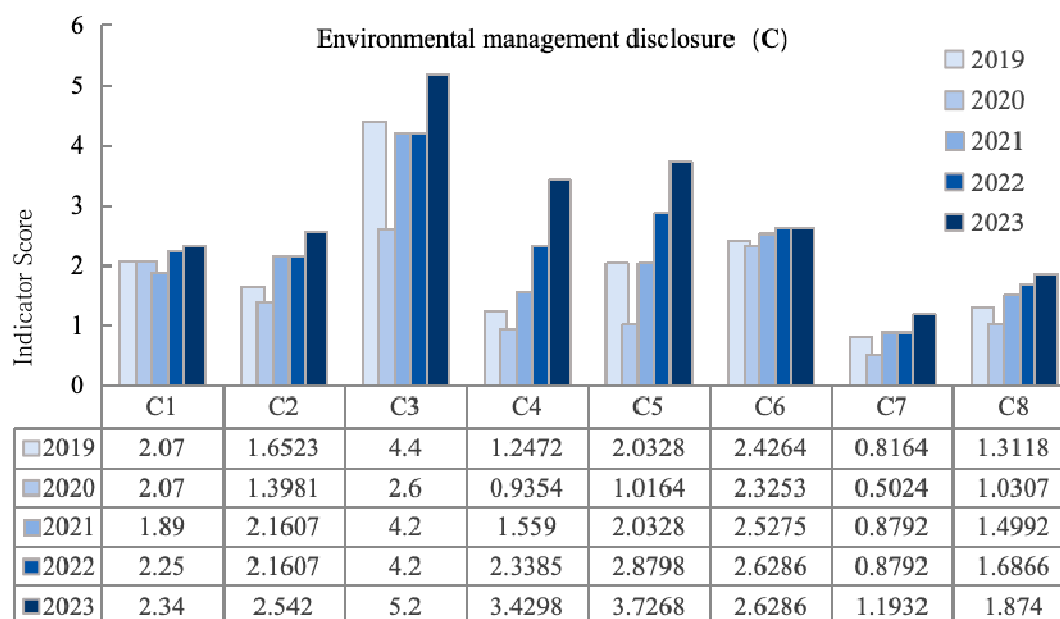


Figure 7. A summary of the C section scores of the sample enterprises from 2019 to 2023.

The plausible logic behind such disparities can be elaborated as follows: The disclosure ratios shown in Table 6 merely reflect the “coverage of management measures”, while the scores plotted in Figure 7 are more indicative of the “practical implementation depth of management measures”. The high disclosure ratios of C1 and C6 may derive from fundamental compliance rules set by environmental supervision authorities [53], yet their stagnant scores hint that the practical implementation intensity of such “framework-based management” might not have been markedly elevated. Both the ratios and scores of C4 and C5 rose in tandem, which is a pattern coinciding with tightened environmental governance regulations for the steel sector post-2021. It is speculated that firms gradually shifted from “passive compliance” to the “active strengthening of internal management” [54]; they not only expanded their disclosure coverage but also allocated tangible resources to environmental training and targeted mitigation initiatives, and the upward trend in their scores arguably mirrors the “deepened implementation of environmental management”. The consistent growth observed in C3’s scores is suggestive of the transition of environmental management systems from a “formal institutional setup” toward “systematic operational practice” [55], which implies that environmental management disclosures may be evolving from a framework-focused format toward a more refined, implementation-oriented configuration.

3.2.5. Environmental Supervision and Certification

Environmental supervision and certification ensure the effectiveness of enterprises’ environmental governance from dynamic and static perspectives, respectively. In the context of China’s “Carbon Peaking and Carbon Neutrality” goal, environmental supervision and certification are important methods for enterprises for managing their environmental risks. The specific disclosure of environmental supervision and certification for sample enterprises from 2019 to 2023 is shown in Table 7.

Table 7. Environmental supervision and certification disclosure of sample enterprises.

Disclosure Item	2019		2020		2021		2022		2023	
	N	%	N	%	N	%	N	%	N	%
D1	22	73.33	15	50.00	26	86.67	28	93.33	29	96.67

D2	30	100.0	30	100.0	30	100.0	30	100.0	30	100.0
D3	1	3.33	0	0	0	0	0	0	0	0
D4	2	6.67	1	3.33	1	3.33	3	10.00	2	6.67
D5	0	0	0	0	0	0	0	0	0	0
D6	12	40.00	11	36.67	13	43.33	13	43.33	19	63.33
D7	10	33.33	9	30.00	13	43.33	15	50.00	15	50.00

Note: N = number of enterprises disclosing the item; % = disclosure ratio (%).

As can be seen from Table 7, the disclosure rate of environmental supervision and certification indicators for the sample enterprises from 2019 to 2023 exhibited the characteristic of “compliance indicators being saturated, while risk/certification indicators were differentiated”. D2 maintained a 100% disclosure rate throughout, being the most fully covered indicator; the number of enterprises disclosing D1 rose from 22 to 29, with the proportion fluctuating from 73.33% to 96.67%; the disclosure rates of D3 and D5 remained at 0 for a long time; and that of D4 only briefly reached 100% in 2022 before decreasing again. Among the certification indicators, the disclosure rates of D6 and D7 showed a slow upward trend. Considering the scores shown in Figure 8, from 2019 to 2023, the scores of D2 and D1 increased from 4.7404 to 6.9252 and 3.386 to 4.5711, respectively; those of D3 and D5 remained at 0; and that of D4 fluctuated at a low level for a long time.

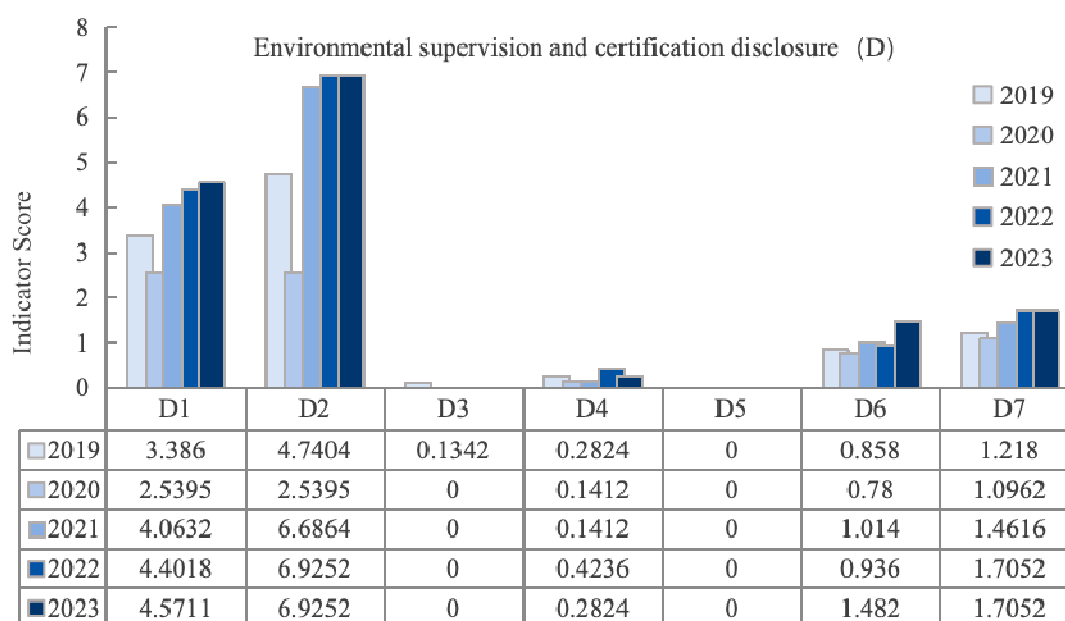


Figure 8. A summary of the D section scores of the sample enterprises from 2019 to 2023.

A plausible interpretation of such discrepancies is as follows: the disclosure proportions listed in Table 7 merely capture firms’ basic “willingness to disclose information”, whereas the weighted scores illustrated in Figure 8 are more likely to mirror the intrinsic value of disclosed information, as well as the extent of corporate attention allocated to each indicator. The rising disclosure share and score of D2 may be linked to the strict mandatory compliance rules on pollutant discharge imposed by environmental regulators. Firms are required to not only make relevant disclosures but also provide quantitative data to verify their regulatory compliance. The score climbed from 4.7404 in 2019 to 6.9252 in 2023, which is a trend that arguably aligns with the improved quality of compliance-related disclosures [56]. The disclosure ratio of D1 fluctuated from 73.33% to 96.67%, which was accompanied by a score increase from 3.386 to 4.5711, which may signal a

gradual shift among key polluters from passive public reporting to the voluntary disclosure of targeted regulatory response measures. The persistently low disclosure proportions and zero scores recorded for D3, D4, and D5 could suggest a tendency for firms to selectively withhold information associated with negative operational risks. Since regulators do not mandate the disclosure of such content and its publication may exert adverse impacts on corporate reputation, firms might possess limited incentives to produce thorough, high-quality disclosures on these items [57]. Turning to certification-related indicators, D6 and D7 maintained relatively stable weighted scores, with D6's disclosure rate growing from 40.00% to 63.33% and D7's from 33.33% to 50.00%. This pattern implies that while firms increasingly release certification information, they may not treat such disclosures as a core management priority. Most released content is limited to basic binary statements on certification status, with scarce granular details regarding practical implementation outcomes [58]. This tiered characteristic—prioritizing detailed compliance disclosures, evading negative risk-related information, and providing superficial certification content—can hardly be fully captured by disclosure proportions alone. It further offers suggestive evidence of the balancing dynamic between regulatory enforcement and firms' voluntary disclosure incentives within environmental certification reporting frameworks.

4. Discussion

The findings of this study reveal several phenomena worthy of in-depth exploration regarding environmental accounting information disclosure in the steel industry. The following discussion proceeds along three dimensions.

4.1. Path Dependence in Disclosure Channels

Our finding that annual reports remain the dominant disclosure channel—with standalone environmental report rates reaching only 53.33% and some firms exhibiting intermittent disclosure—is consistent with Mwelasi-B et al. [30] and Li et al. [31], who documented similar “institutional inertia” in emerging economies in which firms embed environmental information within existing financial reporting frameworks to avoid additional costs. Wang et al. [59] further confirmed that disclosure continuity depends heavily on regulatory certainty, thus explaining the interruptions observed in our sample.

However, divergent evidence exists. Frost [19] found that Australia's mandatory environmental reporting legislation significantly increased standalone report adoption, while Huang et al. [60] documented a rapid rise from below 20% to over 75% in India following stock exchange mandates. These contrasting outcomes suggest that the strength of institutional compulsion—rather than voluntary motivation—is the critical determinant of overcoming path dependence in disclosure channels. The persistent “annual report dependence” in China's steel industry thus inversely demonstrates the insufficiency of current regulatory force.

4.2. Divergence Between Hard and Soft Indicators

Our AHP analysis reveals that hard indicators (environmental liability weight = 0.3083) dominate the information value hierarchy, while soft ones (environmental management weight = 0.1779) remain marginalized—a pattern mirrored in disclosure practices in which the quantification of CO₂ emissions rose to 76.67%, while that of cleaner production and environmental training indicators fell to near zero.

This finding aligns with those of Zhang et al. [61], who found disclosure improvements concentrated in policy-constrained indicators, and of Huang and Huang [62], who documented the persistently low disclosure of soft management indicators despite their importance for sustained environmental performance. Liu et al. [63] similarly warned that

excessive focus on compliance information while neglecting management information may reduce disclosure to a “window-dressing exercise.”

However, divergent findings exist. Abbasi et al. [64] found soft indicator weights rapidly approaching hard indicator levels in Indonesian manufacturing, which was attributed to a stakeholder shift toward “whole-process management” evaluation. Cormier and Magnan [65] documented insignificant soft–hard indicator value gaps in more mature European markets. These divergences suggest that industry characteristics—steel’s end-of-pipe emission risks versus manufacturing’s process-oriented concerns—and market maturity moderate the information value assigned to different indicator types.

4.3. The “Selective Silence” on Negative Information

The near-zero disclosure of environmental violations and accidents in our sample is consistent with González et al. [66], who documented systematic “good-news-only” tendencies, particularly pronounced in weaker institutional environments. Long et al. [67] further found that selective disclosure significantly exacerbates stock price crash risk, thus indicating investors’ awareness of information gaps. Ying et al. [68] attributed this phenomenon to institutional environments lacking either mandatory requirements or incentive mechanisms for negative disclosure, making “selective silence” the dominant strategy, while Pinar et al. [69] demonstrated that investors overestimate environmental risk management in the absence of negative information, thereby leading to capital misallocation.

However, Tian et al. [70] documented significant increases in violation disclosure after China’s 2010 mandatory policy, and Wang et al. [71] found that international supply chain pressures (e.g., EU importer requirements) drove higher negative disclosure among export-oriented Pakistani firms. Three reasons may explain the persistent absence in our sample: (1) steel violations involve severe economic consequences (large fines and production suspensions), thus intensifying concealment incentives; (2) the sample period coincides with accelerated “Carbon Peaking” implementation, increasing pressure to maintain “green images”; and (3) current regulations require quantitative emission disclosure but lack specific operational standards for negative events, thereby aligning with Li et al.’s [31] argument that institutional specificity is key to disclosure quality improvement.

4.4. Robustness of the Hierarchical Pattern

Although a full quantitative sensitivity analysis under alternative weighting schemes is beyond the scope of the current study, the core finding—“hard indicators outweigh soft indicators”—is structurally robust. The weight gap between Environmental Liability (0.3083) and Environmental Management (0.1779) exceeds 0.13, which is substantially larger than typical fluctuations observed in AHP sensitivity tests. Moreover, the near-zero disclosure rates of negative information and soft indicators are not statistical artifacts but extreme empirical observations. Therefore, even under reasonable weight variations, our main conclusions remain qualitatively unchanged.

5. Optimization Strategies and Conclusions

5.1. Optimization Strategies

5.1.1. Institutional Aspect

Based on the AHP weights as the core basis, the system norms can be improved in terms of three aspects: ① High-weighted fields, such as environmental liabilities (weight 0.3083), environmental supervision and certification (weight 0.2415), and environmental performance and governance (weight 0.2723), should be listed as mandatory disclosure categories. The quantitative disclosure standards for detailed indicators should be clearly defined, such as the amount of industrial solid waste generated and CO₂ emissions, and

enterprises should be required to disclose core data, such as the carbon emission intensity per unit output and the completion degree of emission reduction targets in accordance with the progress of the “Carbon Peaking and Carbon Neutrality” goal, thus filling the current gap in quantitative information. ② In response to the insufficient disclosure of soft indicators in the environmental management category (weight 0.1779) in the AHP weights, special guidelines should be issued; the disclosure framework for indicators should be clearly defined, such as the implementation effect of clean production and environmental education and training investment; the benchmark year accounting standards should be unified (such as using 2020 as the benchmark); it should be ensured that emission reduction effects can be compared horizontally; and enterprises should be urged to attach importance to the implementation and public disclosure of soft indicators. ③ Through mandatory institutional requirements, enterprises are required to disclose negative information, such as sudden environmental accidents and environmental violation events; link the completeness of disclosure with the environmental credit rating; solve the “selective disclosure” dilemma; and, at the same time, combine the importance of environmental risk indicators in the AHP weights and build a full-chain disclosure system covering “problem–rectification–effectiveness”.

5.1.2. Enterprise Aspect

By using the AHP indicator weights as the guiding principle for allocating disclosure resources, enterprises can promote the coordinated optimization of environmental accounting information disclosure in terms of three aspects: ① High-weighted environmental liabilities and carbon emission-related information should be incorporated into the financial accounting system, thus achieving the coordinated disclosure of environmental costs, emission reduction investments, and financial data; allowing stakeholders to perceive the financial impact of environmental behavior; and enhancing the value of information for decision-making. ② In response to the core pain point of insufficient quantitative disclosure in the AHP analysis, enterprises need to establish a full-process environmental data monitoring system, covering various indicators from the production process to the end-of-pipe treatment, especially strengthening the data accumulation of weak indicators such as the generation volume of industrial solid waste and investment in environmental education. At the same time, third-party institutions should be introduced to verify the data of high-weighted indicators, thus improving the reliability of information. ③ While maintaining a 100% coverage rate of annual reports for information disclosure, the promotion of independent environmental reports should be accelerated. The evaluation logic of the AHP should be drawn on in terms of the adaptability of disclosure methods; multi-dimensional information such as environmental performance, liabilities, and management should be integrated; and “data charts + text explanations + target comparisons” should be adopted to clearly present the phased progress and future plans under the “Carbon Peaking and Carbon Neutrality” goal, thus enhancing the readability and systematic nature of the information.

5.1.3. External Aspect

Regulatory authorities, the market, and the public can utilize the AHP weight system to establish a multi-party co-governance supervision framework: ① Regulatory authorities use the AHP weight system as a tool to establish an environmental accounting information disclosure quality rating system for the steel industry. They implement differentiated supervision for enterprises that fail to meet the standards for high-weight indicators, link the rating results with environmental protection subsidies and carbon emission quota allocation, and strengthen policy constraints. At the same time, they conduct regular spe-

cial inspections, focusing on verifying the authenticity of quantitative data and the completeness of negative information. ② Investors should be guided to incorporate environmental indicators with higher AHP weights into their investment decision-making models, the linkage between green financial products and disclosure quality should be promoted, and high-quality disclosing enterprises should be allowed to obtain lower financing costs. Third-party institutions should be encouraged to release industry disclosure quality rankings based on the AHP evaluation logic, thus forming a market reputation incentive mechanism and compelling enterprises to improve their disclosure quality. ③ An open and transparent information query platform should be built, through which enterprise environmental accounting information can be displayed according to the priority of AHP weights, thus highlighting high-weight core indicators and negative information and lowering the threshold for public supervision. At the same time, a public feedback channel should be established, and public reports should be linked with enterprises' environmental credit ratings, thus forming a virtuous cycle of "disclosure–supervision–rectification" and facilitating the implementation of the "Carbon Peaking and Carbon Neutrality" goal.

5.2. Conclusions and Future Research Directions

5.2.1. Main Conclusions

Based on the AHP method and combined with the data of 30 listed steel industry companies from 2019 to 2023, the core conclusions are as follows: (1) The disclosure channels exhibit an unbalanced pattern characterized by an over-reliance on annual reports and insufficient growth in standalone environmental reports. Environmental information disclosure through annual reports achieves full coverage with a 100% disclosure rate, yet relevant environmental contents are mostly scattered in appendices, suffering from poor integration and a systematic nature. Although the disclosure ratio of independent environmental reports gradually rose from 3.33% in 2019 to 53.33% in 2023, its overall base remains low. Moreover, several steel enterprises including Angang Steel Co., Ltd. and Valin Steel Co., Ltd. show intermittent disclosure behaviors without sustainable and stable disclosure mechanisms in place. (2) In terms of disclosure content, there is a structural imbalance of "hard indicators being sufficient while soft indicators are insufficient" and "positive information being redundant while negative information is absent". Specifically, the following observations are made: ① The environmental liability indicator with the highest AHP weight (weight 0.3083) is the core disclosure dimension, but the quantitative disclosure of sub-indicators varies significantly. The quantitative disclosure of indicators such as industrial solid waste generation volume is less than 30%, while indicators such as CO₂ emissions, which are driven by the "Carbon Peaking and Carbon Neutrality" policy, show a rapid increase in the quantitative disclosure rate to above 76.67% after 2022. ② In the indicators related to environmental performance and governance, management, supervision and certification, etc., the quantitative data of soft indicators such as clean production and environmental education are seriously lacking, and the quantitative disclosure rate of some indicators is always 0. The disclosure rate of sudden environmental accidents and environmental petition cases is nearly 0, thus showing a significant "selective disclosure" tendency. (3) In terms of quality differences, the quality of disclosure shows a hierarchical feature guided by AHP weights. Under the dual drive of policy mandatory constraints and market attention, hard indicators with high AHP weights such as exhaust gas reduction and pollutant emission compliance have not only high coverage rates of disclosure but also a simultaneously improved completeness of quantitative data and information depth. Meanwhile, low-weight soft indicators such as clean production and environmental training, as well as negative information such as environmental violations and sudden accidents, due to the lack of clear regulatory requirements and market

incentives, display insufficient enterprise disclosure motivation, thus presenting a “formal coverage, light quality deepening” governance blind spot, and the overall disclosure quality is not in line with the adaptability of multiple information demands such as carbon accounting, green investment, and public supervision under the “Carbon Peaking and Carbon Neutrality” goal.

5.2.2. Future Research Directions

In terms of the robustness test of the multi-index evaluation framework constructed in this study, follow-up research can further carry out targeted sensitivity analysis to examine how indicator rankings change with adjusted criteria weights and varied stakeholder assumptions. Three representative weighting schemes widely adopted in energy economics research can be adopted for comparative calculation, namely equal, experience-, and familiarity-based weighting, as summarized in the prior literature, including research on emerging energy economics and policy research priorities for supporting the electric vehicle sector. By collecting supplementary expert scoring data and comparing the weighted evaluation results under different weighting rules, subsequent research can more sufficiently verify the stability of environmental disclosure quality stratification conclusions and strengthen the generalizability of relevant research implications. Limited by the survey cycle and data acquisition conditions of the current study, this multi-scheme sensitivity test is not implemented in this manuscript. Therefore, we take this quantitative robustness examination based on multiple weighting schemes as a key direction for our subsequent in-depth research. In addition, future research can expand the sample scope to cover more industrial sectors, compare the differences in environmental information disclosure logic among heavy- and low-polluting enterprises, and further enrich the theoretical research on corporate environmental disclosure quality evaluation.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su18157596/s1>, Table S1: Target system; Table S2: Standards for Relative Importance Ratios; Table S3: Random Consistency Index (RI); Table S4: Judgment Matrix for the Four Dimensions of Primary Indicators; Table S5: Weightings of Primary Indicators; Table S6: Judgment Matrix for Environmental Performance and Governance; Table S7: Weighting Table for Secondary Indicators (Dimension A); Table S8: Judgment Matrix for Disclosure of Environmental Liabilities (Dimension B); Table S9: Secondary Indicator Weighting Table (Dimension B); Table S10: Judgment Matrix for Environmental Management Disclosure Status (Dimension C); Table S11: Secondary Indicator Weighting Table (Dimension C); Table S12: Judgment Matrix for Environmental Regulation and Certification Status (Dimension D); Table S13: Secondary Indicator Weighting Table (Dimension D); Table S14: Comprehensive Weights of the Indicator System.

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