

Digital transformation, ESG performance, and management cognitive flexibility of manufacturing industries: Basis for sustainable advantage framework

Ma, Tingting ✉

Graduate School, Lyceum of the Philippines University - Batangas, Philippines (tingtingma503@gmail.com)



ISSN: 2243-7770
Online ISSN: 2243-7789

Received: 28 May 2025

Revised: 20 June 2025

Accepted: 23 June 2025

OPEN ACCESS

Available Online: 25 June 2025

DOI: 10.5861/ijrsm.2025.25074

Abstract

In such a complex and unstable economic environment, digital transformation, ESG performance and management cognitive flexibility are the three key dimensions for manufacturing enterprises in Shanxi Province to achieve sustainable development. Digital transformation provides technology-driven innovation impetus for enterprises, and ESG performance offers long-term measurement standards for enterprises. The management cognitive flexibility provides the capability guarantee for enterprises to achieve strategic adjustments. For manufacturing enterprises, effectively integrating ESG concepts in the wave of digital transformation and examining the role of management cognitive flexibility in this process to achieve a win-win situation of economic and social benefits is the future development direction. This study aims to explore the relationship among digital transformation, ESG performance and management cognitive flexibility of manufacturing enterprises in Shanxi Province, China, which will serve as the basis for formulating a framework for sustainable advantages in the manufacturing industry. This study employs an empirical research method to systematically analyze the relationships between variables and test hypotheses. The target respondents are employees from manufacturing industries in Shanxi Province. Data was collected through questionnaires and analyzed using SPSS. Research results revealed that there is a significant positive correlation between digital transformation, ESG performance and management cognitive flexibility. Digital transformation moderately integrates technology, customer engagement and value creation. In terms of environmental protection, social responsibility and internal governance, ESG performance is average. The management has demonstrated moderate cognitive flexibility, which is reflected in their strategies, operations and learning methods. On this basis, this study constructs a framework for the sustainable advantages of the manufacturing industry, providing theoretical support and practical guidance for the sustainable development of manufacturing enterprises and promoting the green transformation of the economy.

Keywords: digital transformation, ESG performance, management cognitive flexibility, manufacturing industries, sustainable advantage framework

Digital transformation, ESG performance, and management cognitive flexibility of manufacturing industries: Basis for sustainable advantage framework

1. Introduction

In the context of economic globalization and the rapid development of artificial intelligence, digital transformation has become a key factor for manufacturing enterprises to maintain competitiveness. Especially for resource-dependent regions, such as Shanxi Province, China, the upgrading and transformation of the manufacturing industry is particularly important. This paper explores how manufacturing enterprises in Shanxi Province improve their ESG performance in the process of digital transformation and examines the role of management cognitive flexibility in this process, providing theoretical support and practical guidance for the development of a sustainable advantage framework for the manufacturing industry.

In recent years, the emphasis on environmental protection and social responsibility has been increasing around the world, so ESG performance is becoming an important measure of a company's ability to develop sustainably. But for manufacturing enterprises, how to effectively integrate ESG concept into the wave of digital transformation, to achieve both economic and social wins, is still a pressing problem to be solved. Shanxi Province in 2022 year-end released the Implementation Plan on Promoting the Comprehensive Development of Digital Economy in Shanxi Province (2022-2025), explicitly proposing the creation of a new highland for innovation-driven development of digital economy in central and western regions. Manufacturing enterprises in Shanxi Province, as an essential force of regional economic development, the research on the correlation between digital transformation and ESG performance of manufacturing enterprises in Shanxi Province has important theoretical significance, and it is also of great practical significance to promote the green transformation of local economy. As there are many achievements within this study, the empirical research done on certain geographical areas such as in the case of Shanxi, it still remains quite scarce.

Shanxi province, being mainly a region with coal and heavy industries, faces enormous challenges and pressures for transformation and upgrading. The paper focuses on the relation of digital transformation, ESG, management cognitive flexibility and corporate sustainability based on manufacturing companies in Shanxi Province. The variables studied were mainly: digital transformation, ESG performance, and management cognitive flexibility. ESG performance refers to the overall performance of enterprises on environmental protection, social responsibility and governance. Management cognitive flexibility is defined as: The management of an enterprise can flexibly change its own strategies, operations and learning modes when it faces a complex and changeable environment (Mo et. al.,2023). Regarding the dimensions of the research variables, what is mainly looked at with regards to Digital Transformation is technology integration, customer integration and value creation. ESG performance evaluation on environmental protection, social responsibility, and internal governance; Management cognitive flexibility is expressed in terms of strategic flexibility, operational flexibility, and learning flexibility.

There have been some advances in studying digital transformation and ESG performance. But most of the existing studies analyze a single dimension, a certain industry, etc., and the overall research on the specific field of Shanxi's manufacturing industry is still insufficient. Moreover, we need the moderating role of management cognitive flexibility in digital transformation and ESG performance. Thus, based on an in-depth study of real cases of manufacturing enterprises in Shanxi, it reveals the essential impact of management's cognitive flexibility in the process of digital transformation, which affects ESG performance positively.

With the abundant resources, deep cultural heritage and spirit of continuous innovation, Shanxi, manufacturing enterprises in China and even the world's manufacturing enterprises hold an important position. These groups involve many industries including energy, metallurgy, machinery and chemical industry and have

made big contributions to the development of local economy. But under the background of the transformation of digital and sustainable development, these Enterprises are also facing the urgent need for transformation and development. The purpose of the study is to find out how manufacturing firms in Shanxi Province improve their own ESG performance through enhancing management cognitive flexibility during the digital transformation and to develop a sustainable advantage framework for manufacturing industry firms. This study can enrich the theoretical system of digital transformation and ESG performance simultaneously and give practical advice and support for the green transformation of manufacturing companies in Shanxi and even the whole country. After the research, we want to make it for the sustainable development of manufacture enterprises and promote the harmony between economy, society and environment.

Objectives of the Study - The study aims to determine the digital transformation, ESG performance and management cognitive flexibility among manufacturing industries in Shanxi Province, China. Specifically, the study will assess the digital transformation in terms of technology integration, customer integration and value creation; Determine the ESG performance as to environmental protection, social responsibility and internal governance; Describe the management cognitive flexibility in terms of strategic flexibility, operational flexibility and learning flexibility. Test the significant relationship between digital transformation, ESG performance and managerial cognitive flexibility. Develop a sustainable advantage framework for manufacturing industries.

2. Methods

Research Design - Descriptive research design was used in this study for an adequate and precise interpretation of the findings. According to Leiva-Candia et al. (2022), this is a method for gathering information about a topic by observing or surveying a population or phenomenon. It aims to describe the characteristics, frequencies, and patterns of the subject, rather than explaining why things happen.

Participants of the study - The respondents of the study will be 400 employees of manufacturing industries in Shanxi Province covering a variety of fields from heavy industry to light industry, from energy mining to material processing. Each company will have 80 respondents using convenience sampling.

Instrument of the Study - The study used one set of questionnaires as the major mechanism for collecting the necessary data. The items per instrument have been presented as descriptive statements, and respondents indicate the frequency with which each statement applies on a four-point Likert scale as a 3.50 – 4.0 scale means strongly agree, 2.50 – 3.49 rate means agree, 1.50 – 2.49 scale means disagree and, 1.00 – 1.49 rating means strongly disagree. A self-made questionnaire will be used by the researcher in data gathering. The questionnaire was composed of three parts. Part I contains the assessment of Digital Transformation which consists of technology integration, customer integration, and value creation. In part II, the questionnaire is measuring the assessment of ESG performance which consists of environmental protection, social responsibility, and internal governance. In part III, the questionnaire assesses the management cognitive flexibility which consists of strategic flexibility, operational flexibility, and learning flexibility.

Table 1

Reliability Test Result using Cronbach Alpha and its Interpretation

Indicators	No. of Items	Cronbach Alpha	Remarks
Technology Integration	5	0.923	Excellent
Customer Integration	5	0.955	Excellent
Value Creation	5	0.955	Excellent
Environmental Protection	5	0.950	Excellent
Social Responsibility	5	0.946	Excellent
Internal Governance	5	0.953	Excellent
Strategic Flexibility	5	0.963	Excellent
Operational Flexibility	5	0.935	Excellent
Learning Flexibility	5	0.950	Excellent

George and Mallery (2003) provide the following rules of thumb: “_ > .9 – Excellent, _ > .8 – Good, _ > .7 – Acceptable, _ > .6 – Questionable, _ > .5 – Poor, and _ < .5 – Unacceptable”

A pilot test was undertaken to determine the survey questionnaire's efficacy. 30 samples were subjected to a reliability test using Cronbach's alpha via SPSS 28. Table 1 shows the reliability test result for each of the variables used in this research.

Data Gathering Procedure - To obtain necessary data, the researcher used a survey questionnaire and will write a letter of request to the company to conduct the study. The questionnaires will be distributed by the researcher to the participants of the study through sending them hard copy to their company in any available time and using Google forms that will be sent through emails and other communication platforms that the respondents have. The responses to the survey items will be tallied and sent to the university statisticians for statistical analysis.

Data Analysis - Weighted mean and rank were used to assess the digital transformation in terms of technology integration, customer integration and value creation; Determine the ESG performance as to environmental protection, social responsibility and internal governance; Describe the management cognitive flexibility in terms of strategic flexibility, operational flexibility and learning flexibility. The result of Shapiro-Wilk Test showed that p-values of all variables were less than 0.05 which means that the data set was not normally distributed. Therefore, Spearman rho was used as part of the non-parametric tests to determine the significant relationship. All analyses were performed using SPSS version 28.

Ethical Consideration - In conducting this research work, ethical considerations were considered of paramount importance to ensure that the highest standards of integrity and quality are maintained throughout the entire process. It was assured that any information gathered will be used exclusively for research purposes, safeguarding the confidentiality and privacy of all participants. This approach is crucial for upholding the credibility and validity of the research findings.

The researcher took proactive steps to obtain consent from the participating companies through formal letters and clear communication. This process was designed to ensure that the target respondents were made fully aware of the research objectives and prepared to provide the necessary information. By seeking explicit consent, the researcher aimed to build a foundation of trust and transparency with the participating organizations. To further protect the confidentiality and anonymity of the respondents, the researcher did not seek their names or any personally identifiable information during the questionnaire process. This measure was intended to create a safe and secure environment where participants would feel comfortable sharing their insights and experiences without fear of repercussions. By maintaining anonymity, the researcher encouraged more honest and candid responses, ultimately enhancing the richness and reliability of the data collected. Additionally, the researcher ensured that the respondents voluntarily answered the questionnaires according to their own will. Participation was made entirely voluntary, and respondents were informed that they have the right to withdraw from the study at any time without any negative consequences. This approach respects the autonomy and agency of the participants, ensuring that their contributions are made willingly and in good faith. Lastly, the researcher prioritized the safety and security of all respondents. were ensured that none of the participants would be subjected to any form of harm or distress as a result of their involvement in the study. The researcher took all necessary precautions to protect the well-being of the participants during and after the research process. By placing the highest priority on the safety and security of the respondents, the researcher created a positive and ethical research experience for everyone involved. Overall, these ethical considerations are fundamental to the conduct of this research. By adhering to these principles, the researcher aims to uphold the highest standards of professionalism and integrity, ensuring that the research process is respectful, transparent, and beneficial for all participants.

3. Results and discussion

Table 2 presents the summary Table on Digital Transformation. The composite mean of 3.04 indicates that the respondents agree in general. This implies that the respondents perceive that their companies are

implementing digital transformation initiatives to a moderate degree. This overall "agree" indicates a positive trend towards digitalization, but the mean's proximity to the lower end of the "agree" range suggests that there's potential for more comprehensive and effective implementation. It shows that the respondents are aware of the digital transformations happening within their companies. In the similar study of Wang et al. (2022), this score shows that the companies are implementing digital transformation, but that there is room for improvement. The respondents are generally positive about the digital transformation progress.

Table 2

Summary Table on Digital Transformation

Key Result Areas	Composite Mean	VI	Rank
Technology Integration	3.04	Agree	1.5
Customer Integration	3.03	Agree	3
Value Creation	3.04	Agree	1.5
Grand Composite Mean	3.04	Agree	

Legend: 3.50-4.00=Strongly Agree; 2.50-3.49=Agree; 1.50-2.49=Disagree; 1.00-1.49=Strongly Disagree

Among the items cited, Technology Integration and Value Creation, ranked first with a mean score of 3.04 and verbal interpretation of agree. This implies that: The respondents recognize that technology integration and the resulting value creation are perceived as the strongest aspects of their companies' digital transformation efforts. In the study of Wang et al.(2022), this suggests that the companies have effectively implemented technologies that directly contribute to operational efficiency and tangible benefits. While in the study of (Mann et al.,2022), this indicates that the companies are seeing a return on their investment in technology. It also suggests that the respondents can see the value that technology brings to the company. The alignment of technology integration and value creation suggests the technological implementations are well directed.

Meanwhile, customer Integration, ranked second with a mean score of 3.03 and verbal interpretation of agree. This implies that while still within the "agree" range, the lower mean score for customer integration suggests that this area is perceived as relatively weaker compared to other aspects of digital transformation. This indicates potential challenges in fully integrating digital tools and strategies into customer-facing operations. In the study of Bai et al. (2024), it could also imply that the respondents are less confident in the company's ability to effectively leverage digital channels for customer engagement and relationship management. While in the study of Ai et al. (2024), this lower score suggests that there may be a need for more investment in customer integration strategies. It also shows that the respondents feel that the companies could improve their customer facing digital tools. The companies should look to improve their customer interaction.

In Shanxi Province, heavy industry and manufacturing were traditionally dominant, especially in coal and steel industries. These industries are more traditional and have more legacy processes and systems, so they might pay more attention to using technology to optimize existing production processes during the initial stage of transformation, without considering the management of customer relationships very much. Therefore, the slightly lower score for customer integration is also because such companies still have difficulty in changing from a product perspective to a customer perspective. Many of the skills and resources required for the development and maintenance of customer relationships are not present locally. Shanxi Province is still lacking somewhat in terms of technical talent pools and market resources compared to the coastal economic heavyweights, causing enterprises to hit some snags when it comes to fully implementing customer integration.

Some bigger tech manufacturing companies might spend more on automating assembly lines and connecting internal data systems so they could see faster improvements in making things without spending too much money. These firms will receive substantial benefits for just a short amount of time as they improve their IT infrastructure, when it comes to customer integration, these companies do not have enough experience and data support when moving to a digital customer relationship management system, because they have always paid attention to their products and product quality in the past. and the relatively low level of the local market has made some businesses unenthusiastic about it.

Firms must coordinate their resources and strategy priorities, especially talent, technology. Resource coordination with an emphasis on customer integration is necessary. The use of open cooperation to learn advanced experience and technology at home and abroad, in order to make up for the company's shortcomings in the integration of customers, so as to enhance the competitiveness of the company in the global market. From the results of this study, it can be found that although the manufacturing companies in Shanxi province have made some progress in terms of technology integration and value creation for digitalization, they still have a long way to go in terms of customer integration. Enterprises would be able to improve customer satisfaction and develop more flexible competitive advantages through investments into the creation and effective allocation of CRM resources. By improving the all-around digitalization strategy, Shansui's producing organizations are anticipated to more firmly and powerfully fix and strengthen their situation in the world market.

Table 3

Summary Table on ESG Performance

Key Result Areas	Composite Mean	VI	Rank
Environmental Protection	3.05	Agree	3
Social Responsibility	3.08	Agree	1
Internal Governance	3.06	Agree	2
Grand Composite Mean	3.06	Agree	

Legend: 3.50-4.00=Strongly Agree; 2.50-3.49=Agree; 1.50-2.49=Disagree; 1.00-1.49=Strongly Disagree

Table 3 presents the summary table on ESG Performance. The composite mean of 3.06 indicates that the respondents agree in general. This implies that the respondents perceive that their companies are generally committed to ESG principles, but with room for improvement across all areas. The overall "agree" indicates a positive trend, suggesting that ESG considerations are being integrated into company practices. However, with similar study of Liu et al. (2023) the mean's proximity to the lower end of the "agree" range suggests that there's potential for more robust and consistent implementation. It shows that respondents are aware of their companies ESG programs. This score shows that companies are implementing ESG policies, but that those policies could be strengthened (Zeng et al., 2023).

Among the items cited, Social Responsibility, ranked first with a mean score of 3.08 and verbal interpretation of agree. This implies that the respondents recognize that their companies' efforts in social responsibility are perceived as the strongest aspect of their ESG performance. This suggests that the companies have effectively implemented initiatives that positively impact employees, communities, and stakeholders. While in the study of Shrestha et al. (2023), this indicates that the companies are prioritizing social programs. It also suggests that the respondents can see the positive impacts of these programs. The high ranking of social responsibility suggests that this area is a point of strength for the companies involved.

Internal Governance ranked second with a mean of 3.06. This implies that the respondents acknowledge that the companies have established internal governance structures and systems, but with a need for ongoing refinement. In the study of Tang et al. (2024), this indicates a focus on ethical and transparent management practices. The fact that it is close to the composite mean indicates that it is a core part of the companies ESG programs. This score shows that the companies have a good base for internal governance, but that it can be improved Liu et al. (2024). This area is a key part of the ESG programs.

Meanwhile, Environmental Protection, ranked fifth with a mean score of 3.05 and verbal interpretation of agree. This implies that while still within the "agree" range, the lower mean score for environmental protection suggests that this area is perceived as relatively weaker compared to social responsibility and internal governance. From another similar study of Tsang et al. (2024), this indicates potential challenges in fully integrating and implementing effective environmental sustainability initiatives. It could also imply that the respondents are less confident in the company's commitment to environmental stewardship compared to other ESG aspects. While in the study of Chebbi et al. (2024), this lower score suggests that there may be a need for more investment in environmental protection strategies. It also shows that the respondents feel that the

companies could improve their environmental policies. The companies should look to improve their environmental impact.

From the performance data of manufacturing enterprise ESG in Shanxi, even though they have some institutionalization and success in terms of environment, society and governance, there is still a great deal of room for improvement. To improve the company's environmental performance, to further optimize the company's corporate social responsibility strategy, and to strengthen the company's corporate internal control capabilities, these will all be important ways for the company to achieve its own sustainable development. Regarding globalization and digitization, how to use technology to raise overall ESG is what everyone will research and learn.

Table 4

Summary Table on Management Cognitive Flexibility

Key Result Areas	Composite Mean	VI	Rank
Strategic Flexibility	3.05	Agree	2
Operational Flexibility	2.97	Agree	3
Learning Flexibility	3.15	Agree	1
Grand Composite Mean	3.06	Agree	

Legend: 3.50-4.00=Strongly Agree; 2.50-3.49=Agree; 1.50-2.49=Disagree; 1.00-1.49=Strongly Disagree

Table 4 presents the summary table on Management Cognitive Flexibility. The composite mean of 3.06 indicates that the respondents agree in general. This implies that the respondents perceive that their companies' management demonstrates a moderate level of cognitive flexibility across various dimensions. This "agree" indicates a positive trend towards adaptability and responsiveness. However, the mean's proximity to the lower end of the "agree" range suggests that there's potential for further development and enhancement of management's cognitive flexibility. According to the study of Lackner et al. (2022), it shows that the respondents feel that their company's management is flexible. This score shows that the company's management is flexible, but that their flexibility can be improved.

Among the items cited, Learning Flexibility, ranked first with a mean score of 3.15 and verbal interpretation of agree. This implies that the respondents recognize that learning flexibility is the strongest aspect of their companies' management cognitive flexibility. This suggests that the companies prioritize continuous learning, knowledge acquisition, and innovation. This indicates that the companies are prioritizing learning. In the study of Ma et al. (2023), it also suggests that the respondents can see the positive impacts of these learning programs. The high ranking of Learning flexibility suggests that this area is a point of strength for the companies involved.

Strategic Flexibility ranked second with a mean of 3.05. This implies that: The respondents acknowledge that their companies' management demonstrates a degree of strategic flexibility, allowing them to adapt to changing market conditions and uncertainties. This indicates a focus on agility and responsiveness in strategic decision-making. According to the study of Blom et al. (2021), the fact that it is close to the composite mean indicates that it is a core part of the company's management cognitive flexibility. While in the study of Altan-Atalay et al. (2022), this score shows that the companies have a good base for strategic flexibility, but that it can be improved. This area is a key part of the management cognitive flexibility.

Meanwhile, Operational Flexibility, ranked fifth with a mean score of 2.97 and verbal interpretation of agree. This implies that while still within the "agree" range, the lower mean score for operational flexibility suggests that this area is perceived as relatively weaker compared to learning and strategic flexibility. In the study of Ma et al. (2023), this indicates potential challenges in adapting operational processes to fluctuating demands and emergencies. It could also imply that the respondents are less confident in the company's ability to quickly adjust resource allocation and operational procedures. This lower score suggests that there may be a need for more investment in operational flexibility strategies. While in the study of van Hooijdonk et al. (2022), it also shows that the respondents feel that the companies could improve their operational flexibility. The companies should

look to improve their operational agility.

Although enterprises have a positive attitude towards learning flexibility and strategic agile, many enterprises will face practical resistance to operational agility because of the limitations of traditional management model. SMEs enhance its operational flexibility, it's hard to improve its day-to-day management operation because of resources and technology. thanks to the continuous advancements in technology, newly emerging technologies like AI and big data offer fresh tools which could augment operational versatility for companies. There are more government policies on digitalization and greening transformation, giving enterprise strategic planning and operations external motivation. Shanxi province manufacturing enterprises have a more positive attitude towards management cognitive flexibility, especially learning flexibility, they are key driving forces of enterprise sustainable development, though it is rated with a slightly lower operational agility rate, buy-in to strategy and learning has a strong base for managing overall agility. The companies in Shanxi can further improve their operational flexibility through better allocation of resources, enhancing technology application skills and deepening the degree of policy implementation to comprehensively improve their overall management cognitive flexibility.

Table 5

Relationship Between Digital Transformation and ESG Performance

Variables	rho	p-value	Interpretation
Technology Integration			
Environmental Protection	0.769**	<.001	Highly Significant
Social Responsibility	0.753**	<.001	Highly Significant
Internal Governance	0.757**	<.001	Highly Significant
Customer Integration			
Environmental Protection	0.734**	<.001	Highly Significant
Social Responsibility	0.707**	<.001	Highly Significant
Internal Governance	0.757**	<.001	Highly Significant
Value Creation			
Environmental Protection	0.780**	<.001	Highly Significant
Social Responsibility	0.775**	<.001	Highly Significant
Internal Governance	0.756**	<.001	Highly Significant

** Correlation is significant at the 0.01 level

Table 5 shows the relationship between digital transformation variables—Technology Integration, Customer Integration, and Value Creation—and Environmental, Social, and Governance (ESG) performance metrics. The rho values indicate a highly significant positive correlation ($p < 0.001$) across all ESG dimensions, including Environmental Protection, Social Responsibility, and Internal Governance. Technology Integration, for example, shows strong correlations with Environmental Protection ($\rho = 0.769$), Social Responsibility ($\rho = 0.753$), and Internal Governance ($\rho = 0.757$). Similarly, Customer Integration and Value Creation also demonstrate robust correlations with all ESG aspects, consistently surpassing a rho of 0.700.

The consistent and highly significant positive correlations underscore a strong interdependency between digital transformation initiatives and ESG performance. This indicates that companies leveraging digital technologies for integration, customer engagement, and value creation are also more likely to achieve superior ESG outcomes. Specifically, the strong correlations suggest that digital tools and strategies facilitate improved environmental management, enhance social responsibility practices, and strengthen internal governance structures. According to the study of Anwer et al. (2023), the fact that Value Creation shows the strongest correlation with Environmental Protection and Social Responsibility implies that companies that are effectively using digital transformation to create value are also the most likely to be implementing strong ESG practices. In the similar study of Zeng et al. (2023), the data strongly suggests that digital transformation is not only a driver of operational efficiency and customer engagement but also a critical enabler of sustainable and responsible business practices. The high correlation values across all variables emphasize that integrating digital transformation with ESG strategies can lead to synergistic benefits, where improvements in one area reinforce positive outcomes in the other.

When combined with the context of Shanxi province, manufacturing companies in Shanxi province must face environmental pressures from both the government and growing consumers and social groups. In this sense, ESG performance is becoming more and more important for companies. The government's support of the digital transformation of companies creates both opportunities and obstacles for manufacturing enterprise. It is driven by this policy backdrop toward digital technology to be competitively advantaged and reach Sustainable development Goals.

In short, this is because the strong ESG performance in the process of digital transformation is mainly because the technology and customer integration and value creation have a major impact on the internal and external operating environment of Shanxi Province. these factors not only help with how well the company runs and makes money but also means the company is trying to help their community and the world around them and then they can stay good at what they do even after a long time has passed Due to policies and markets, digital transformation has become an important way to realize the sustainable development goals.

Table 6 presents the relationship between digital transformation and management cognitive technology. It reveals a highly significant positive relationship between digital transformation variables—Technology Integration, Customer Integration, and Value Creation—and different aspects of management cognitive flexibility, including Strategic, Operational, and Learning Flexibility.

Table 6

Relationship Between Digital Transformation and Management Cognitive Flexibility

Variables	rho	p-value	Interpretation
Technology Integration			
Strategic Flexibility	0.737**	<.001	Highly Significant
Operational Flexibility	0.738**	<.001	Highly Significant
Learning Flexibility	0.758**	<.001	Highly Significant
Customer Integration			
Strategic Flexibility	0.725**	<.001	Highly Significant
Operational Flexibility	0.734**	<.001	Highly Significant
Learning Flexibility	0.751**	<.001	Highly Significant
Value Creation			
Strategic Flexibility	0.767**	<.001	Highly Significant
Operational Flexibility	0.754**	<.001	Highly Significant
Learning Flexibility	0.750**	<.001	Highly Significant

** . Correlation is significant at the 0.01 level

The rho values consistently exceed 0.700, indicating strong correlations with p-values less than 0.001. For example, Technology Integration is strongly correlated with Strategic Flexibility (rho=0.737), Operational Flexibility (rho=0.738), and Learning Flexibility (rho=0.758). Similarly, Customer Integration and Value Creation are also highly associated with all three flexibility dimensions, with Value Creation showing the strongest link to Strategic Flexibility (rho=0.767).

The data presented in Table 6 demonstrates a compelling and statistically significant positive relationship between digital transformation initiatives and management cognitive flexibility. This signifies that companies that effectively implement digital transformation strategies also tend to exhibit greater strategic, operational, and learning flexibility. According to the study of Shrestha et al. (2023), the consistently high rho values across all digital transformation and management flexibility dimensions emphasize that digital technologies are not merely tools for operational improvement, but also catalysts for enhancing management's ability to adapt and innovate. Specifically, the strong correlations suggest that leveraging digital tools for technology integration, customer engagement, and value creation fosters a culture of agility and responsiveness within the organization. While in the study of Bekele et al. (2024), the high association between Value Creation and Strategic Flexibility indicates that companies that are successful in using digital transformation to create value are also those who are the most adaptable in their strategic thinking. The consistent significance across all flexibility dimensions suggests that digital transformation is a holistic driver of management's cognitive capabilities, enabling companies to thrive in

dynamic and unpredictable environments.

Shanxi Province's industrial structure is mainly heavy industry, and the digital transformation of such industries often needs technology to be integrated comprehensively. Take mining and steel manufacturing for example, they need advanced automation plus data processing technologies to help make things more effective and do less harm to nature. Technology is complicated and the change must be quick due to this complex nature thus management has to be more cognitive flexible with regards to embracing uncertainty and a constantly changing environment. Second, as a resource-consuming area, Shanxi is currently going through an economic structural change, thus it has put forward higher requirements for the customer integration capability and market flexibility of enterprises. In order for companies to adapt the shift in the economy from resource-based to innovation-based, the companies must be much more customer-focused when it comes to defining the value of a product or service, which provides more opportunity for fast changes as well as fast iterations.

Table 7 illustrates a strong, highly significant positive relationship between ESG (Environmental, Social, and Governance) performance and management cognitive flexibility, with rho values consistently above 0.74 and p-values below 0.001. Environmental Protection shows strong correlations with Strategic Flexibility (rho=0.751), Operational Flexibility (rho=0.764), and Learning Flexibility (rho=0.781). Similarly, Social Responsibility is significantly linked to Strategic Flexibility (rho=0.760), Operational Flexibility (rho=0.778), and Learning Flexibility (rho=0.749). Internal Governance also correlates strongly with all three cognitive flexibility dimensions.

Table 7

Relationship Between ESG Performance and Management Cognitive Flexibility

Variables	rho	p-value	Interpretation
Environmental Protection			
Strategic Flexibility	0.751**	<.001	Highly Significant
Operational Flexibility	0.764**	<.001	Highly Significant
Learning Flexibility	0.781**	<.001	Highly Significant
Social Responsibility			
Strategic Flexibility	0.760**	<.001	Highly Significant
Operational Flexibility	0.778**	<.001	Highly Significant
Learning Flexibility	0.749**	<.001	Highly Significant
Internal Governance			
Strategic Flexibility	0.756**	<.001	Highly Significant
Operational Flexibility	0.755**	<.001	Highly Significant
Learning Flexibility	0.764**	<.001	Highly Significant

****.** Correlation is significant at the 0.01 level

Table 7 demonstrates that companies with strong ESG performance also exhibit high levels of management cognitive flexibility. This indicates that organizations that prioritize environmental sustainability, social responsibility, and sound governance are also more adept at adapting strategically, operationally, and through continuous learning. According to the study of Drobetz et al. (2024), the consistently high correlation values across all ESG and flexibility dimensions highlight that a proactive and adaptable management approach is crucial for achieving and maintaining strong ESG performance. Specifically, the strong correlation between Environmental Protection and Learning Flexibility (rho=0.781) suggests that companies that excel in environmental sustainability are also those that prioritize knowledge acquisition and innovation. Similarly, the high correlation between Social Responsibility and Operational Flexibility (rho=0.778) indicates that companies that are responsive and agile in their operations are also more effective in addressing social issues. While in the study of Liu et al. (2023), the general trend shows that companies that are flexible and willing to learn are also those that are the most successful in implementing strong ESG practices. This data strongly suggests that a synergistic relationship exists where a flexible, learning-oriented management fosters an environment conducive to strong ESG outcomes, and vice versa.

Shanxi is changing from old industries into service and tech industries; local governments wish enterprises

to step up social responsibility activity to create economic harmony. In this process, it is also an organization that must be constantly changing its internal structure and management methods, etc. for corporate responsibility efforts. In this sense, social responsibility performance improves relations with employees and the community, promoting strategic agility and operational agility.

Research Output

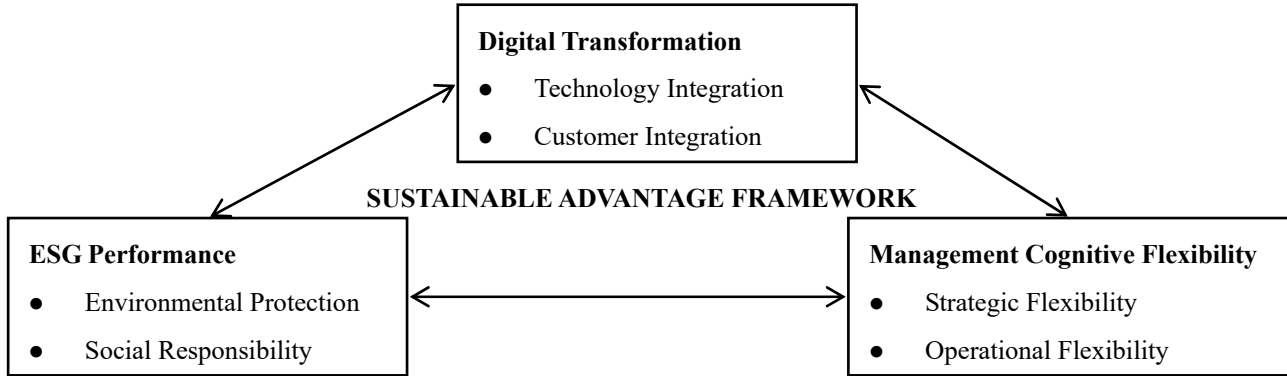


Figure 1. Sustainable Advantage Framework

The proposed Sustainable Advantage Framework shown in the figure 1 presents a holistic approach for manufacturing companies aiming to integrate sustainability into their core operations. By recognizing the inter-connectedness of Digital Transformation, ESG Performance, and Management Cognitive Flexibility, this framework offers a pathway to achieve a competitive edge while minimizing environmental impact and fostering social responsibility. Digital Transformation acts as the catalyst, enabling companies to optimize resource utilization, enhance transparency, and improve customer engagement through technological integration, data-driven decision-making, and value creation. Simultaneously, strong ESG Performance, encompassing environmental protection, social responsibility, and internal governance, ensures that the company's operations are aligned with ethical and sustainable practices. This not only mitigates risks but also enhances brand reputation and stakeholder trust.

To effectively utilize this framework, manufacturing companies should begin by assessing their current standing in each of the three dimensions. This involves evaluating the level of digital technology adoption, analyzing existing ESG practices, and gauging the organization's capacity for strategic, operational, and learning flexibility. Based on this assessment, companies can develop targeted strategies to enhance their performance in each area. For instance, implementing IoT solutions for real-time monitoring of energy consumption can improve both digital transformation and environmental protection. Similarly, fostering a culture of continuous learning and cross-functional collaboration can enhance management's cognitive flexibility, enabling quicker adaptation to market changes and better integration of ESG considerations into strategic planning. Ultimately, the framework underscores the importance of a synergistic approach, where improvements in one area positively influence the others, creating a virtuous cycle that drives sustainable growth and competitive advantage.

4. Conclusion and recommendation

The digital transformation is moderately integrated across technology, customer engagement, and value creation. A moderate ESG performance in terms of environmental protection, social responsibility, and internal governance is observed. The management demonstrates a moderate degree of cognitive flexibility, as reflected in their strategic, operational, and learning approaches. There is a highly significant relationship between digital transformation, ESG performance and managerial cognitive flexibility. A proposed sustainable advantage framework was developed for manufacturing industries. To accelerate digital transformation, the company may prioritize data-driven decision-making and invest in scalable technologies that enhance operational efficiency and customer experience. To elevate ESG performance, the management may integrate ESG metrics into core

business strategies and performance evaluations, ensuring transparency and accountability at all levels of the organization. To cultivate management cognitive flexibility, the companies may implement regular cross-functional workshops and training programs focused on strategic thinking, scenario planning, and adaptive leadership, fostering a culture that embraces change and continuous learning. The different manufacturing companies may evaluate and assess the applicability of the proposed framework to improve the sustainable advantage. The future researchers may validate the results of this study by looking into other business sectors in the Shanxi Province, China.

5. Reference

- Ai, M., Zhang, W., Du, S., Yu, X., & Bu, Y. (2024). The impact of digitalization on the green transformation of China's industrial sectors: The mediating role of green technology innovation and technological transformation. *International Review of Economics & Finance*, 96, 103736. <https://doi.org/10.1016/J.IREF.2024.103736>
- Altan-Atalay, A., Kaya-Kızıllöz, B., İlkmen, Y. S., & Kozol, E. (2022). Impact of abstract vs. concrete processing on state rumination: An exploration of the role of cognitive flexibility. *Journal of Behavior Therapy and Experimental Psychiatry*, 74, 101691. <https://doi.org/10.1016/J.JBTEP.2021.101691>
- Anwer, Z., Goodell, J. W., Migliavacca, M., & Paltrinieri, A. (2023). Does ESG impact systemic risk? Evidencing an inverted U-shape relationship for major energy firms. *Journal of Economic Behavior & Organization*, 216, 10–25. <https://doi.org/10.1016/J.JEBO.2023.10.011>
- Bai, Y., Song, Y., & Cui, S. (2024). Professions need professional talents: Executives with internet experience and digital transformation of manufacturing companies. *Finance Research Letters*, 70, 106264. <https://doi.org/10.1016/J.FRL.2024.106264>
- Bekele, H., Raj, S., Singh, A., Joshi, M., & Kajla, T. (2024). Digital transformation and environmental sustainability in the hospitality industry: A three-wave time-lagged examination. *Journal of Cleaner Production*, 484, 144263. <https://doi.org/10.1016/J.JCLEPRO.2024.144263>
- Blom, E., Berke, R., Shaya, N., & Adi-Japha, E. (2021). Cognitive flexibility in children with Developmental Language Disorder: Drawing of nonexistent objects. *Journal of Communication Disorders*, 93, 106137. <https://doi.org/10.1016/J.JCOMDIS.2021.106137>
- Chebbi, K., Ammari, A., Athari, S. A., & Ben Arfa, N. (2024). The impact of firm-level political risk on ESG practices: Does CEO Duality Matter? *Journal of Cleaner Production*, 480, 144096. <https://doi.org/10.1016/J.JCLEPRO.2024.144096>
- Drobetz, W., El Ghoul, S., Guedhami, O., Hackmann, J. P., & Momtaz, P. P. (2024). Entrepreneurial finance and sustainability: Do institutional investors impact the ESG performance of SMEs? *Journal of Business Venturing Insights*, 22, e00498. <https://doi.org/10.1016/J.JBVI.2024.E00498>
- Lackner, J. M., Gudleski, G. D., Radziwon, C. D., Krasner, S. S., Firth, R. S., Naliboff, B. D., Vargovich, A. M., Borden, A. B., & Mayer, E. A. (2022). Cognitive flexibility improves in cognitive behavioral therapy for irritable bowel syndrome but not nonspecific education/support. *Behaviour Research and Therapy*, 154, 104033. <https://doi.org/10.1016/J.BRAT.2022.104033>
- Leiva-Candia, D. E., García, I. L., Lopez, I., Serrano-Herrador, J. A., & Dorado, M. P. (2022). Descriptive and inferential statistics as an exhaust emission comparative tool between different engine operating conditions and fuels. Application to highly oxidized biodiesel blended with primary alcohols. *Fuel*, 324, 124453. <https://doi.org/10.1016/J.FUEL.2022.124453>
- Liu, T., Abdelbaky, A., Elamer, A. A., & Elmahgoub, M. (2023). Real earnings management and ESG disclosure in emerging markets: The moderating effect of managerial ownership from a social norm perspective. *Heliyon*, 9(12), e22832. <https://doi.org/10.1016/J.HELİYON.2023.E22832>
- Liu, X., Liu, J., Liu, J., & Zhai, Q. (2024). Can investor-firm interactions mitigate ESG rating divergence? Evidence from China. *International Review of Financial Analysis*, 96, 103612. <https://doi.org/10.1016/J.IRFA.2024.103612>
- Ma, J., & Li, F. (Sam). (2023). How does self-construal shape tourists' image perceptions of paradox destinations?

- The mediating roles of cognitive flexibility and destination involvement. *Tourism Management*, 95, 104664. <https://doi.org/10.1016/J.TOURMAN.2022.104664>
- Mann, G., Karanasios, S., & Breidbach, C. F. (2022). Orchestrating the digital transformation of a business ecosystem. *The Journal of Strategic Information Systems*, 31(3), 101733. <https://doi.org/10.1016/J.JSIS.2022.101733>
- Mo, F., & Wang, D. D. (2023). Emerging ESG reporting of higher education institutions in China. *Heliyon*, 9(11), e22527. <https://doi.org/10.1016/J.HELIYON.2023.E22527>
- Shrestha, K., & Naysary, B. (2023). ESG and economic policy uncertainty: A wavelet application. *Finance Research Letters*, 58, 104645. <https://doi.org/10.1016/J.FRL.2023.104645>
- Tang, N., Xu, X., Hsu, Y. T., & Lin, C. Y. (2024). The impact of ESG distance on mergers and acquisitions. *International Review of Financial Analysis*, 96, 103677. <https://doi.org/10.1016/J.IRFA.2024.103677>
- Tsang, A., Wang, Y., Xiang, Y., & Yu, L. (2024). The rise of ESG rating agencies and management of corporate ESG violations. *Journal of Banking & Finance*, 169, 107312. <https://doi.org/10.1016/J.JBANKFIN.2024.107312>
- van Hooijdonk, M., Ritter, S. M., Linka, M., & Kroesbergen, E. (2022). Creativity and change of context: The influence of object-context (in)congruency on cognitive flexibility. *Thinking Skills and Creativity*, 45, 101044. <https://doi.org/10.1016/J.TSC.2022.101044>
- Wang, Q., & Du, Z. Y. (2022). Changing the impact of banking concentration on corporate innovation: The moderating effect of digital transformation. *Technology in Society*, 71, 102124. <https://doi.org/10.1016/J.TECHSOC.2022.102124>
- Wang, Q., Hu, A., & Tian, Z. (2022). Digital transformation and electricity consumption: Evidence from the Broadband China pilot policy. *Energy Economics*, 115, 106346. <https://doi.org/10.1016/J.ENERCO.2022.106346>
- Zeng, Y., Zhao, X., & Zhu, Y. (2023). Equity incentives and ESG performance: Evidence from China. *Finance Research Letters*, 58, 104592. <https://doi.org/10.1016/J.FRL.2023.104592>

