Front. Eng. Manag. 2024, 11(2): 311–325
https://doi.org/10.1007/s42524-024-3069-z

RESEARCH ARTICLE

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Supporting factors model for the sustainable step development of supply chain: An empirical study from China with grounded theory

Abstract The ongoing stability of supply chains faces significant challenges from trade protectionism, anti-globalization trends, and the COVID-19 pandemic. To remain resilient in this dynamic market environment, supply chains must evolve through iterative upgrades and transition to a higher level of sustainability, a process termed "step development." The current literature, however, offers limited insights into achieving such step development in supply chain sustainability and its critical supporting elements. This study, grounded in theory, involved interviews with representatives from eight diverse Chinese enterprises. We introduce a model delineating supporting factors and a roadmap for Sustainable Step Development of Supply Chains (SSDSC). Our findings highlight three pivotal categories of support for SSDSC: institutional, technological, and social factors. Additionally, we observed that external influences in these categories positively modulate their internal counterparts. The study identifies industrial technology, digital intelligence technology, corporate responsibility, and stakeholder needs as key elements in this process. We conclude by offering theoretical and practical recommendations to foster SSDSC.

Keywords supply chain, sustainable development, supporting factors, grounded theory

1 Introduction

With the emergence of a new economic landscape, the role of supply chains in the development of the national economy has gained increasing significance. Nations are progressively elevating their supply chains from a microlevel perspective to a strategic national level. Sustainable supply chain development is being wielded as a strategic instrument to bolster competitiveness and economic prowess, as well as to foster multilateral collaboration. For instance, in August 2020, Japan, India, and Australia launched the "Supply Chain Resilience Plan" aimed at establishing alternative solutions to reduce reliance on China's supply chain in critical domains and enhance supply chain sustainability. In March 2021, the European Union ratified the draft of the European Supply Chain Law, thereby formalizing the responsibilities of enterprises within the supply chain in legal terms. This move seeks to mitigate adverse effects on human rights and the environment, ultimately promoting sustainable supply chain development.

As the concept of sustainable supply chain development has gained momentum, the notion of Sustainable Step Development of Supply Chain (SSDSC) has gradually taken shape. SSDSC represents a transitional process as the sustainable supply chain evolves from one stage to the next. The journey of sustainable supply chain development is dynamic and does not consistently follow a linear upward trajectory; rather, it gradually progresses toward a more mature and stable state through stepwise development (Correia et al., 2017). Various scholars have outlined multiple stages or levels of supply chain sustainability, typically ranging from three to five stages, based on the unique characteristics of different supply chains (Amini and Bienstock, 2014). Drawing from existing

Received Jul. 31, 2023; revised Oct. 24, 2023; accepted Nov. 7, 2023

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This paper is a phased research achievement of the Major Program of the Chinese Academy of Engineering (Grant No. 2022-JB-01). This research is supported by Major Program of the National Social Science Foundation of China (Grant No. 22&ZD139).

research (Gao et al., 2017), we propose that SSDSC exhibits key attributes, including both internal and external influences (SSDSC is subject to the effects of internal and external activities and capabilities), dynamism (in the face of rapidly changing environments and evolving customer needs, SSDSC necessitates dynamic capabilities among all supply chain stakeholders), and a stepwise progression (SSDSC typically advances from incremental changes to substantial transformations). Due to the distinctive features of each supply chain stage, sustainable step development varies, resulting in distinct stepwise processes with unique requirements. For instance, some supply chain sustainable development efforts may prioritize institutional support, while others may emphasize technological or social factors. Thus, it is crucial to investigate the factors influencing SSDSC.

The study of the factors that underpin SSDSC holds considerable significance. First, from a practical standpoint, nations worldwide are turning their attention to sustainable supply chain development due to the considerable pressure on achieving high-quality global economic growth. Taking China as an illustrative example. As a developing nation, its prior development model predominantly relied on natural resources and population. However, with the depletion of various resource advantages, there is a growing recognition of the urgency and importance of sustainable development. Many European countries, faced with the inadequacy of their existing development models in coping with contemporary challenges related to climate, technology, and demographics, have embarked on endeavors to promote sustainable supply chain development through energy and digital transformation, with the ultimate aim of achieving enduring prosperity in future societies.

Second, from a theoretical perspective, while some research has been conducted on the characteristics and phases of sustainable supply chain development (Lee, 2004; Correia et al., 2017), Correia et al. (2017) noted a dearth of comprehensive research from a holistic chain perspective. Existing studies on the sustainability stages of the supply chain predominantly concentrate on specific facets, such as ecological design and product development, leaving a void in the investigation of factors supporting SSDSC. Consequently, it is crucial to accelerate scholarly exploration in this domain. This study centers its attention on the following three research inquiries:

Q1: What factors support SSDSC?

Q2: What are the functional relationships between various supporting factors?

Q3: What supporting factors are the most critical?

This study conducted interviews with eight representative Chinese enterprises across diverse industries and introduced a novel supporting factor model and a roadmap for SSDSC through the application of grounded theory. The research identified three distinct categories of factors that bolster SSDSC: institutional, technological, and social factors. Notably, these three external factors (external institutional, technological, and social factors) exert a positive regulatory influence on the three internal factors (internal institutional, technological, and social factors). Furthermore, the study pinpointed four pivotal supporting elements: industrial technology, digital intelligence technology, corporate responsibility, and stakeholder needs.

The primary contributions and innovations of this study are as follows:

First, it diverges from studies that predominantly concentrate on delineating sustainable stages of the supply chain (i.e., defining the sustainable stage of the supply chain) (Edgeman and Eskildsen, 2014). Instead, this research focuses on the transitional dynamics between these stages (i.e., the process of achieving step development), enriching the discourse on SSDSC and filling a critical gap in this field.

Second, it deviates from studies that explore the quantitative aspects of sustainable development (i.e., quantitative changes in sustainable development) (Chen et al., 2019; Sarkis, 2020). Instead, this study investigates the qualitative aspects of SSDSC (i.e., qualitative changes in sustainable development). It systematically investigates the complex interplay between various factors and demonstrates that internal and external factors assume distinct roles in driving SSDSC, a dimension that previous studies have overlooked.

Last, while there have been prior studies examining the supportive frameworks for systemic, social, and other factors in the sustainable development of supply chains (Kumar and Rahman, 2017; Saeed and Kersten, 2019), many of these studies have not emphasized the importance of these factors. In contrast, this study places a strong emphasis on identifying the most critical supporting factors. Elucidating the differing roles of these factors provides both theoretical guidance and practical recommendations for advancing SSDSC.

The remainder of this paper is structured as follows: Section 2 offers an extensive literature review on sustainable supply chains. Section 3 outlines the research methods and presents case studies. Section 4 details the grounded theory process and introduces the supporting factors for SSDSC. Section 5 expounds upon the relationships and theoretical framework among these supporting factors. Finally, Section 6 offers concluding remarks and prospects for future research.

2 Literature review

Given its pertinence to this study, the subsequent section provides a comprehensive literature review including three critical facets: sustainable supply chain management (SSCM), factors supporting supply chain sustainable development, and the stages of sustainable supply chains.

2.1 Sustainable supply chain management

While a universally agreed-upon definition of SSCM remains elusive, the definition put forth by Carter and Rogers (2008) has gained widespread acceptance: "the strategic, transparent integration and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key interorganizational business processes for improving the long-term economic performance of the individual organization and its supply chains."

Over time, the scholarly community's comprehension of sustainable supply chains has progressively deepened. Lee (2004) underscored that an exemplary supply chain is not solely cost-effective and efficient but also possesses attributes of agility, adaptability, and alignment, often referred to as the "3A supply chain." In recent years, supply chains have witnessed a heightened level of globalization, interconnectivity, and reliance, thanks to advancements in information technology. The importance of sustainability has increased (Wei et al., 2023). Consequently, in the pursuit of crafting a sustainable 3A supply chain, Erhun et al. (2021) reevaluated its definition, incorporating the additional requisites essential for social and environmental sustainability. This clarification of the SSCM definition and its underlying objectives has shifted the research focus toward the means of achieving sustainable supply chains.

2.2 Supporting factors for sustainable development of the supply chain

As SSCM has attracted increased attention from the industry, a growing body of scholarly work has emerged investigating the sustainable development trajectory and supportive factors of supply chains. The Triple Bottom Line theory, which includes balanced economic, environmental, and social considerations, has gained wide recognition and maturity (Gimenez et al., 2012; Shi et al., 2023). This theory serves as a framework for categorizing support factors crucial for the sustainable development of supply chains, including management and product-related factors, as well as internal and external factors (Saeed and Kersten, 2019). In their comprehensive analysis, Saeed and Kersten (2019) identified 40 unique drivers of SSCM drawn from an extensive pool of 217 journal articles, offering valuable insights into the multifaceted nature of this field. Numerous studies have explored these supporting factors individually.

In a separate work, Liu et al. (2023a) asserted that disruptive technologies present a novel paradigm for supply chain risk management, ushering in both opportunities and challenges for enhancing supply chain resilience. In the domain of technological factors, Liu et al. (2023b) conducted a study on the adoption of blockchain technology within a supply chain comprising a core enterprise and a small-sized enterprise, aiming to achieve supply chain coordination.

In the context of institutional factors, Amann et al. (2014) conducted a survey spanning 281 procurement documents across eight product categories and involving four European Union member states from 2007 to 2009. They advocated for the incorporation of environmental and social responsibility goals into public procurement policies by governments. Bhardwaj (2016) illuminated the significance of sustainable policies in bolstering corporate competitiveness, a finding that aligns with the insights of Hamel and Prahalad (1991).

Concerning social factors, multiple studies have affirmed the role of various elements in promoting supply chain transparency and sustainability. These elements include non-governmental organizations (Chen et al., 2019), and the effect of unexpected events, exemplified by the Black Swan incident (Chen et al., 2023).

2.3 Supply chain sustainability stage

Several studies have aimed to furnish enterprise managers with a roadmap for achieving sustainable supply chain development. However, many of these investigations tend to focus on specific facets of sustainability, including knowledge management, ecological design, supply chain networks, and product development. For instance, Robinson et al. (2006) contended that knowledge management strategies constitute the crux of attaining enterprise sustainability. They posited that these strategies empower organizations to harness diverse forms of knowledge or intangible assets, such as intellectual capital, technological capabilities, patents, and goodwill, to cultivate the capacity to implement sustainability principles. In their work, they outlined a maturity roadmap comprising five stages, each representing varying levels of knowledge management maturity. As the maturity level increases, so does the organization's proficiency in implementing sustainability principles.

Srai et al. (2013) proposed a comprehensive five-stage model for sustainable supply networks, offering valuable insights into the progression toward sustainability within supply chains. Edgeman and Eskildsen (2014) advanced a sustainable corporate excellence system that underscores financial stability while also taking into account social and environmental factors. This system employs supply chain sustainability levels to depict corporate performance. However, it is noteworthy that most of these studies categorize the stages of sustainable supply chains from a static perspective, offering limited guidance on how to dynamically achieve SSDSC.

2.4 Summary

A thorough literature review has revealed that existing research has extensively explored the definition,

developmental determinants, and stage demarcation of sustainable supply chains. Nevertheless, two noteworthy theoretical gaps have emerged. First, limited scholarly attention has been devoted to examining the interrelationships among various factors. Second, there is a notable dearth of studies addressing the dynamic progression from lower stages to higher stages in the context of SSDSC. To bridge these gaps, our study employs grounded theory to analyze enterprise experiences in sustainable development. Table 1 highlights the distinctions between our research and previous studies.

3 Research design

3.1 Research methods

This study employed classic grounded theory as its chosen analytical method for several compelling reasons. First, the primary objective of this paper is to explore "what" constitutes the supporting factors of SSDSC, which inherently entails an exploratory research question. Grounded theory aligns well with qualitative research methodologies and is particularly suitable for inquiries of this nature. Second, grounded theory places a strong emphasis on deriving theory from practical observations and experiences. By adopting grounded theory, we can eschew preconceived notions, enhance the scientific rigor and credibility of our research, and align our approach more closely with positivism principles (Glaser and Strauss, 1999; Glaser, 1978). Last, synthesizing insights from multiple cases not only elucidates architectural innovation but also strengthens the theoretical framework's explanatory power, generality, and persuasiveness (Yin, 1994). Utilizing data from a diverse set of enterprises allows for the application of replication logic to analyze the reasons and mechanisms behind specific results (Eisenhardt and Graebner, 2007). This study scrutinized eight representative and distinct enterprises in the logistics and manufacturing sectors, rendering the research findings more robust and applicable across a broader spectrum.

3.2 Case selection

3.2.1 Sampling principles

This study adheres to three key principles of theoretical sampling, as proposed by Eisenhardt and Graebner (2007).

First, the principle of typicality is primary. Given the vast scope of industries within the supply chain, including manufacturing and service sectors, it is unfeasible to comprehensively study all manufacturing industries. To ensure that the sample enterprises represent the manufacturing industry effectively, we initially narrowed down the selection by identifying industries that account for a substantial proportion of the manufacturing sector. To achieve this, we conducted a search for the top ten industries with the highest number of large and medium-sized manufacturing enterprises in 2021 on the official website of the National Bureau of Statistics of China.

In the domain of the service industry, we chose the logistics service sector, which is highly representative, as the initial scope for selecting service enterprises. The logistics industry plays an integral role in the entire supply chain process and holds significant importance. Moreover, its rapid growth has emerged as a critical driver of sustainable supply chain development (Zijm and Klumpp, 2016). The selected sample enterprises needed to possess typical characteristics, a substantial development scale, and a prominent position within their respective industries. Consequently, we conducted a screening process involving Fortune 500 Chinese enterprises.

The second principle pertains to content adaptability. Selected enterprises were needed to possess extensive industry experience, a significant business footprint, and a global supply chain presence. This criterion ensured a comprehensive understanding of and practical expertise in SSCM.

Last, convenience and ease of research data acquisition played a pivotal role in the selection process. Considering the practicality of our research, we limited our sample to representative Chinese enterprises. However, it was crucial that these sample enterprises boasted a global

Table 1 Comparison between this study and the most relevant literature in this paper

Paper	Research method	Single factor of sustainable development	Supporting factor framework	Sustainable stage of the supply chain	Mechanism of interaction between factors
Chen et al. (2019)	Mathematical model	√			
Sarkis (2020)	Literature review	√			
Kumar and Rahman (2017)	ISM&AHP		√		
Saeed and Kersten (2019)	Literature review		√		
Srai et al. (2013)	Case study		√	√	
Edgema and Eskildsen (2014)	Case study		√	√	
This paper	Case study		√	√	√

industrial presence, maintained overseas offices, and had management personnel with international experience. This approach guaranteed that our research findings would possess global relevance and applicability.

3.2.2 Case selection

Following the application of these three screening principles, we identified relevant manufacturing and logistics enterprises in China and selected 20 eligible candidates. Research invitations were extended to these entities, resulting in research permits being granted by eight companies. Subsequently, we conducted interviews with 15 managers.

In terms of sample size, there is a range of perspectives in the scholarly community. Some scholars argue that 20 to 30 interviews are ideal for grounded theory research (Boddy, 2016), while others contend that 10 samples suffice for qualitative research, asserting that an excessive number of samples can hinder the refinement of accurate theories (Sandelowski, 1995). To strike a balance between sample sufficiency and the precision of theoretical refinement, we conducted interviews with 15 respondents, generating 15 interview records. Additionally, we collected the latest sustainable development reports from eight enterprises, yielding a total of 23 research samples. We also organized information from the companies' official websites and relevant public opinion comments to support our analysis, thereby employing a triangulation approach to enhance the research's reliability and validity. Similar methodologies have been employed in prior grounded theory research (Fischer-Kreer and Brettel, 2022; Costanza, 2023). Consequently, despite our interviews being limited to eight enterprises, the data obtained can be deemed relatively comprehensive.

To mitigate potential personal biases of managers, interviews were conducted with multiple management personnel from each company. Table 2 provides essential information and the sources of our surveyed enterprises. For confidentiality purposes, we have referred to the companies using letters A to H instead of their actual names.

Regarding the representativeness of the enterprises, it is noteworthy that the six manufacturing enterprises span diverse industries, all of which rank among the top ten industries in terms of enterprise numbers, thereby ensuring their representativeness. Moreover, the selected sample enterprises are leaders in various domestic fields, signifying their prominence and authoritative perspectives within their respective industries. Additionally, considering the global nature of sustainable supply chains, we specifically chose enterprises with a global operational footprint and ensured that overseas managers were included in our interviews, enhancing the study's applicability on a global scale.

Table 2 Interviewed enterprise information and sample sources

No.	Enterprise code	Enterprise scale (billions)	Industry	Industry ranking (number of enterprises)	Ranking of China's Top 500	Sample source
1	A	60.85	Steel	7	99	General manager Business director Sustainability reporting
2	B	2.91	Car	3	58	General manager Business director Sustainability reporting
3	C	11.92	Foodstuff	10	456	General manager Business director Sustainability reporting
4	D	486.90	Chemistry	6	2	General manager Business director Sustainability reporting
5	E	2.44	Electron	1	352	General manager Sustainability reporting
6	F	4.61	Electrical equipment	2	117	General manager Business director Sustainability reporting
7	G	11.70	Integrated logistics	/	111	General manager Business director Sustainability reporting
8	H	11.00	Shipping logistics	/	37	Deputy general manager Business director Sustainability reporting

Note: Sustainability reports refer to the annual sustainability reports released by an enterprise to the public every year.

3.3 Data collection and processing

The research team conducted in-depth interviews with senior managers from eight enterprises through online meetings, employing a combination of personal in-depth interviews and focus group interviews. To ensure the comprehensiveness of the interview materials, we conducted personal in-depth interviews with four of these enterprises, engaging with multiple managers within each organization. These individual interviews had an approximate duration of 90 min. For the remaining four enterprises, we utilized the focus group interview approach, involving simultaneous discussions with multiple managers from each organization, with each interview lasting approximately 150 min. Personal in-depth interviews allow respondents ample room for reflection and expression, facilitating a comprehensive understanding of their inner thoughts. In contrast, focus group interviews encourage dynamic discussions, mutual inspiration, and the exchange of ideas guided by the host, enabling a more comprehensive exploration of the underlying mechanisms of research issues through divergent thinking.

We obtained consent from the interviewees to record the interviews and subsequently organized the recorded materials, resulting in comprehensive interview records and memoranda. In our data analysis process, we randomly selected 3/4 of the interview records and secondary data for coding analysis and model development. Throughout the data analysis, we employed a continuous comparison method, continually refining and revising the theory until it reached theoretical saturation (Glaser, 1978). The remaining 1/4 of the material was reserved for testing theoretical saturation, ensuring the robustness of our findings.

4 Data analysis and SSDSC supporting factors

According to the three-step grounded theory coding program, the data were coded using open, axial, and selective coding.

4.1 Open coding

The primary objective during the open coding stage involved a rigorous examination and analysis of the collected raw case data, scrutinizing every word and sentence. Through this process, we derived initial categories through coding. The study systematically organized and analyzed the original case materials, categorizing each statement and summarizing each original statement. This led to the extraction of 17 initial concepts, including topics such as carbon emissions control, enhanced risk management, the significance of human resources, and the optimization of departmental responsibilities. These initial concepts were subsequently refined theoretically, yielding 17 initial categories, which include energy management, risk management, human resource management, organizational management, supplier management, energy policy, financial policy, industrial policy, industrial technology, standard setting, digital technology, green technology, corporate responsibility, stakeholder needs, stakeholder cooperation, international trade relations, and international organization initiatives, as outlined in Table 3.

4.2 Axial coding

Axial coding represents the process of further elucidating potential logical relationships between the initial categories, building on the foundation laid during open coding. This involves sequentially inducing subcategories and main categories, allowing for a comprehensive exploration of the nuances within each category. When viewed from the perspective of the sources of these factors, the 17 initial categories can be categorized into two overarching groups: internal and external factors. Internal factors are those initiated by the enterprise itself, while external factors are those imposed by external forces. Additionally, the content of these factors can be stratified into three distinct levels: institutional, technological, and social, leading to the emergence of six corresponding subcategories. Finally, we organized the institutional, technological, and social factors into the primary categories, with the classifications and notations presented in Table 4.

4.3 Selective coding

The three primary categories we identified possess guiding and inductive significance. The primary objective during selective coding is to extract core categories based on these primary categories and establish the relationships between each primary category and the core categories, thereby constructing a theoretical framework. Table 5 lists the core categories of supporting factors for SSDSC.

The supporting factors proposed in this study are not specific to a particular sustainable stage but rather represent common supporting factors applicable throughout the step-by-step progression. This approach acknowledges the varying characteristics exhibited by different supply chain sustainability stages across diverse industries. Consequently, presenting generalized supporting factors holds greater universality for enterprise applications and carries practical guidance significance.

4.4 Saturation test

Within the core category of SSDSC, three fundamental factors emerged as pillars of support: institutional, technological, and social. These factors can be categorized as internal and external to the enterprise, offering diverse

Table 3 Open coding

Initial category	Initial concept	Original sentence
Energy management	Control carbon emissions	**H**: The group formulates a carbon peak and carbon neutrality target plan and implements various energy-saving and consumption reduction measures.
Risk management	Strengthen risk Control	**F**: Enterprises conduct annual risk compliance self-inspections and develop internal control manuals.
Human resources management	Outstanding effect	**B**: The company comprehensively stimulates employees' abilities and raises recruitment thresholds through incentive system reform.
Organizational management	Optimize department responsibility	**G**: The company continuously strengthens the collaborative ability of multiple departments through organizational reform.
Supplier management	Ensuring supply Safe and timely	**C**: The company establishes an inventory management system and shares inventory with suppliers.
Energy policy	National Dual Carbon Target	**B**: The Dual Carbon Targets released by the government are indeed a great positive push for us.
Financial policy	Financial support from the government and banks	**C**: The development situation of the country in the international arena, such as the improvement of the international status of the RMB, can significantly improve transaction stability if trade settlement can be directly carried out through the RMB. Financial institutions strengthen their support for the real economy.
Industrial policy	Professional policy support	**G**: The enterprise belongs to the type of comprehensive logistics business, involving many categories, so the change of an industrial policy will not have a significant effect on the enterprise, but the policies of intelligent logistics, platform economy and other aspects will help the enterprise to transform and develop.
Industrial technology	Autonomous knowledge property right	**F**: Maintain technological research and development in core areas, such as 5G wireless, core network, and chips, and ensure that core software and hardware are replaceable.
Standard setting	Set technology standard	**B**: The company ensures technological leadership by developing standard application columns.
Digital technology	Various types intelligent technology	**B**: The application of industrial internet technology to enhance the level and ability of automation and informatization, and achieve digital and intelligent applications; industry level data connectivity.
Green technology	Energy power mode	**B**: The substitutability of technology has a significant effect on the sustainable development of enterprises, such as the trend of replacing fuel vehicles with new energy vehicles and the technological development level of peers.
Corporate responsibility	To do for society contribution	**A**: As a state-owned enterprise, we promote enterprises to become "pioneers of green steel," "leaders of low-carbon technology," and "guardians of a beautiful home" in green and sustainable aspects according to government policies and arrangements.
Stakeholders demand	Customer requirements	**H**: Pay attention to understanding the needs of relevant parties and understand customer concerns. Relevant stakeholders include the government, shareholders, employees, customers, suppliers, associations, organizations, the public, communities, and the media. Fully consider the expectations and needs of stakeholders to update the system, responsibilities, and measures.
Collaborate with stakeholders	Upstream and downstream cooperation	**G**: Strengthen cooperation with peers and leading enterprises in various fields, jointly enhance market recognition, meet the low-carbon requirements of upstream and downstream members, and develop synchronously.
International trade relationship	Trade barrier	**F**: Global trade relations have a significant effect on the sustainable development of enterprises. The industry's core products are still in the hands of foreign countries, and the risk of supply interruption needs to be controllable.
International organization call	Organizational regulations	**H**: The International Maritime Organization has issued a call for sustainable development and formulated multiple international and domestic regulations on marine protection.

perspectives for enterprises to effectively advance SSDSC.

When enterprises focus on optimizing their internal processes, they can emphasize five institutional factors, such as energy management, two technological factors, including industrial technology, and two social factors, exemplified by corporate responsibility. Conversely, when collaborating with external stakeholders, enterprises can shift their focus toward three institutional factors, specifically financial policies, two technological factors, including digital and intelligent technology, and three social factors, including international trade relations.

To verify the saturation of our theoretical framework, we subjected another quarter of the interview records to theoretical saturation testing, following the approach outlined by Berente and Yoo (2012). During this process, we reanalyzed the interview records that had been previously reserved based on grounded theory to assess whether new, significant concepts affecting the existing categories or new structural relationships between categories emerged. The results revealed that the existing categories had undergone substantial development. Regarding the three main categories supporting SSDSC (institutional, technological, and social factors), no new essential categories or relationships were identified, and no new constituent factors surfaced within these three primary categories. Consequently, we can confidently assert that, from a theoretical perspective, the supporting factors for SSDSC have reached a state of saturation.

Table 4 Main categories formed by axial encoding

Main category	Subcategory	Initial category	Connotation
Institutional factor	Internal institutional factors	Energy management	Enterprise's energy consumption management system and "carbon peak and carbon neutrality" plan
		Risk management	Risk management systems, such as internal control management measures and compliance management systems
		Human resource management	Human resource management systems, such as talent introduction and performance incentive optimization
		Organizational management	Organizational management capabilities, such as task division and departmental collaboration in enterprises
		Supplier management	Optimization system for supply-side procurement management, supplier inventory management, etc.
	External institutional factors	Energy policy	The national goal of "Carbon Peak and Carbon Neutrality" and its related policy requirements
		Financial policy	Financial policies launched by the country in areas, such as tax incentives, financial support, and bank loans
		Industrial policy	National support policies for different industries
Technology factor	Internal technological factors	Industrial technology	Enterprises achieve innovation and upgrading of industrial processes, technologies and tools by self-research or collaborative research
		Standard setting	Relevant technological standards extracted by enterprises through their practical operation summary
	External technological factors	Digital technology	Various digital and intelligent technologies represented by modern information technology have undergone iterative upgrades
		Green technology	Including fundamental updates in energy methods, power technology, and other aspects
Social factors	Internal social factors	Corporate responsibility	The sense of responsibility of enterprises to contribute to society is influenced by the characteristics of central enterprises or corporate culture
		Collaborate with stakeholders	Closer cooperation and sharing between enterprises and upstream and downstream stakeholders
	External social factors	International trade relations	The situation of international trade relations is caused by global political, economic and other factors
		International organization call	The call and regulations of domestic and foreign industry organizations on the development trends and basic requirements of this industry
		Stakeholders demand	New demands from various stakeholders, including suppliers, customers, consumers, etc.

Table 5 Typical relationship structure of main categories

Core category	Main category	Connotation
Supporting factors for SSDSC	Institutional factors	Enterprises optimize and upgrade their management systems or rely on government policy support to achieve sustainable leapfrog development of the supply chain
	Technological factors	Enterprises achieve sustainable leapfrog development of their supply chain through technology self-research or relying on industry-related technology iteration and upgrading
	Social factors	Enterprises actively respond to the needs of relevant stakeholders or passively respond to changes in international trade relations to promote sustainable development of the supply chain

5 SSDSC model

5.1 Relationship between supporting factors

To further investigate the relationship between the supporting factors of SSDSC and elucidate the mechanism underlying SSDSC, we conducted an analysis of the material pertaining to the actions of these factors. This analysis aimed to explore the interplay between external and internal factors.

For instance, B, a leading manufacturer of new energy vehicles, acknowledges that the global demand for such vehicles is poised to rise significantly due to policies discouraging the sale of traditional fuel vehicles. However, merely experiencing an upsurge in external demand does not guarantee sustained enterprise sustainability, given the fierce competition in this arena. In this context, the enterprise's cutting-edge technology and effective operational management serve as direct driving forces for achieving sustainable development. When supported by external market conditions, the potency of internal factors becomes more pronounced.

Similarly, D, an energy company, recognizes that carbon reduction policies adopted by various countries have a substantial effect on the sustainability of its supply chain, primarily due to the diminishing use of traditional fossil fuels. Nevertheless, this external factor is not the sole catalyst for the company's sustainability initiatives.

The principal driver is the enterprise's strategic shift from traditional fossil energy to the vigorous pursuit of the new energy sector. However, the backing of external policy factors has further intensified the role of internal factors, catapulting in the enterprise's sustainable development to new heights.

In the case of H, a shipping company, the understanding is that the phasing out of fossil fuels for powering ships is an inexorable trend, driven by government mandates and International Maritime Organization (IMO) requirements. This has prompted major global shipping companies to embark on the construction of new-energy vessels. The true sign of a sustainable leap in the supply chain of shipping enterprises lies not solely in the IMO's regulatory measures but in the completion of the zero-carbon transport capacity network. Enterprises progress toward higher levels of sustainability through internal initiatives such as energy management and technological innovation, with the external impetus provided by the IMO accelerating this process.

Our analysis revealed that most managers believe that the implementation entity of SSDSC is the enterprise itself. In other words, the internal factors within an enterprise exert a direct effect on SSDSC. Nevertheless, external factors compel enterprise managers to recognize the crucial aspects of building a sustainable supply chain, provide the fundamental conditions necessary for implementing sustainable development, and expedite the process of SSDSC. Therefore, external factors play an equally significant positive regulatory role alongside internal factors. Table 6 provides relevant expressions from some enterprise managers illustrating these perspectives.

5.2 Key supporting elements

We have identified 17 supporting elements for SSDSC, but determining which of these elements are the most critical is of primary importance as it guides the focus of efforts for SSDSC. We explored the key supporting elements using the following approach:

First, during the interviews, each company was asked to identify the most critical elements that significantly impact SSDSC. They expressed these factors using phrases such as "what is most important," "what we care about most," and "what is the most critical element among them." We located and screened the relevant statements containing these keywords.

Second, we categorized the relevant statements into one of the 17 initial categories within the model to identify the key supporting elements that each company considered most important.

Finally, to ensure the accuracy of the results, we conducted follow-up discussions with all the interviewees to confirm their recognition of the key supporting elements. We obtained confirmation from all the enterprises.

Table 7 presents the key supporting elements that each enterprise considers crucial, along with the proportion of importance attributed to each element.

Due to the overlap in the key support elements identified by the enterprises, we have distilled four key supporting elements: industrial technology, digital technology, corporate responsibility, and stakeholder demand. As shown in Table 7 three companies consider corporate responsibility as the most critical element, while three

Table 6 Relationship between supporting factors

	Internal factors	External factors
Technological factors	**C**: By using digital means to digitize and make transactions transparent, the entire grain inventory and transportation situation can be digitized and collected, directly promoting the sustainable development of the supply chain. **B**: The core independent intellectual property rights of an enterprise are very important, as they determine your position in the supply chain and directly affect the sustainable development of the supply chain	**C**: Due to the development of digital technology and equipment, including AI cameras, digital lock and seal management machines, and the Internet of Things, it has provided basic conditions for enterprises to promote digital supply chains. **B**: We need to fully integrate industry-leading technology with our scenarios, and it can be said that external technology indirectly affects our supply chain
Institutional factors	**D**: The internal process system of enterprises will have a direct effect on the sustainability of the supply chain, such as the transition from passive procurement to active procurement, and the elimination of traditional high-energy consumption and high-pollution devices. **F**: We have gradually established our leading position in the supply chain through reforms and the construction of business systems, environmental management systems, and inventory management systems, directly promoting the sustainable development of the supply chain.	**D**: The national dual carbon goals and other related policies have put forward clear requirements for the annual carbon reduction of energy enterprises, which makes us constantly innovating and reforming toward this goal. **B**: The national support policies for new energy vehicles have indeed helped us further promote the sustainable development of the supply chain.
Social factors	**A**: As an important national steel enterprise, corporate responsibility directly determines that we must ensure the sustainable development of the supply chain. **H**: The most important domestic shipping enterprise, in addition to economic development, has an important responsibility to ensure the stable operation of the supply chain. For example, during the epidemic, we tried our best to ensure stable freight rates, which directly affects the sustainable development of the supply chain.	**A**: We will update our internal systems, responsibilities, and measures based on the needs of external stakeholders. **G**: We will customize corresponding requirements for social development and ecological environment based on customer needs, and integrate them into the entire supply chain. **H**: To respond to the needs of relevant stakeholders, we can only intensify cooperation with other shipping companies to promote the sustainable development of the entire shipping industry.

Table 7 Key supporting elements for SSDSC

Company	Institutional factors		Technological factors		Social factors	
	Internal	External	Internal	External	Internal	External
A					Corporate responsibility	
B			Industrial technology			
G						Stakeholder demand
H					Corporate responsibility	
C				Digital technology		
D						Stakeholder demand
E					Corporate responsibility	
F						Stakeholder demand
Frequency	None*		1/8 (12.5%)	1/8 (12.5%)	3/8 (37.5%)	3/8 (37.5%)
			1/4 (25%)		3/4 (75%)	
Role	Tertiary role		Secondary role		Primary role	

Note: * None means that all interviewers consider institutional factors as common supporting elements rather than key supprting elements.

companies prioritize stakeholder demand, both of which fall under the category of social factors. Consequently, 75% of the respondents regard social factors as the key supporting factors, indicating that social factors hold the most significant role among the three main categories (primary role). This finding aligns with previous research by Saeed and Kersten (2019). In practice, initiatives related to low-carbon measures, environmental sustainability, employee welfare, and other aspects of sustainable development often do not directly contribute to profitability for enterprises. The primary motivation typically stems from a sense of corporate responsibility or customer requirements. Thus, social factors play a pivotal role in SSDSC.

On the other hand, two companies emphasize industrial and digital technologies as key supporting factors, both falling under the category of technological factors. Twenty-five percent of the respondents identify technological factors as key supporting elements, underscoring the significant effect of technology in the current era of technological advancements. Technology provides the necessary conditions for enterprises to undertake green transformations, such as industrial technology optimizing product quality and intelligent technology enhancing production efficiency. However, the role of technological factors is considered secondary to social factors and falls under the secondary role category. In comparison, the importance of institutional factors is less pronounced, classifying them as tertiary role factors.

5.3 Model establishment

In Table 4, we identified 17 supporting elements for SSDSC, categorizing them into three groups based on their distinct connotations: institutional, technological, and social factors. Furthermore, we classified them into two groups based on their origins: internal and external factors. All these factors have an effect on SSDSC. Section 5.1 investigated the relationship between internal and external factors, demonstrating that SSDSC is primarily achieved through the direct involvement of internal factors. External factors lay the groundwork for optimizing internal factors, expediting the process of advancing SSDSC. In essence, external factors serve as positive regulatory influences.

Furthermore, based on the insights from Section 5.2, we have emphasized the four key supporting factors in bold in the figure, alongside the varying levels of importance attributed to social factors (primary role), technological factors (secondary role), and institutional factors (tertiary role). As a result, we constructed a model illustrating the supporting factors for SSDSC, as depicted in Fig. 1.

5.4 Discussion on supporting factors models

The analysis of the model was conducted from the perspective of the role of these three factors in achieving SSDSC. It is worth elucidating why exclusively large and medium-sized enterprises were chosen for interviews, with small enterprises omitted from the selection. This decision stems from two key considerations. First, it is noteworthy that large and medium-sized enterprises have invariably evolved from small enterprises. This evolutionary process contributes to a more comprehensive understanding of SSDSC, including the experiences of small enterprises within its purview. Second, small enterprises, by virtue of their limited scale and relatively weaker competitive position, tend to prioritize profit maximization and market expansion as their primary objectives. Consequently, their inclination toward sustainability considerations is relatively diminished. However, when the need arises for small enterprises to contemplate SSDSC, the model remains applicable.

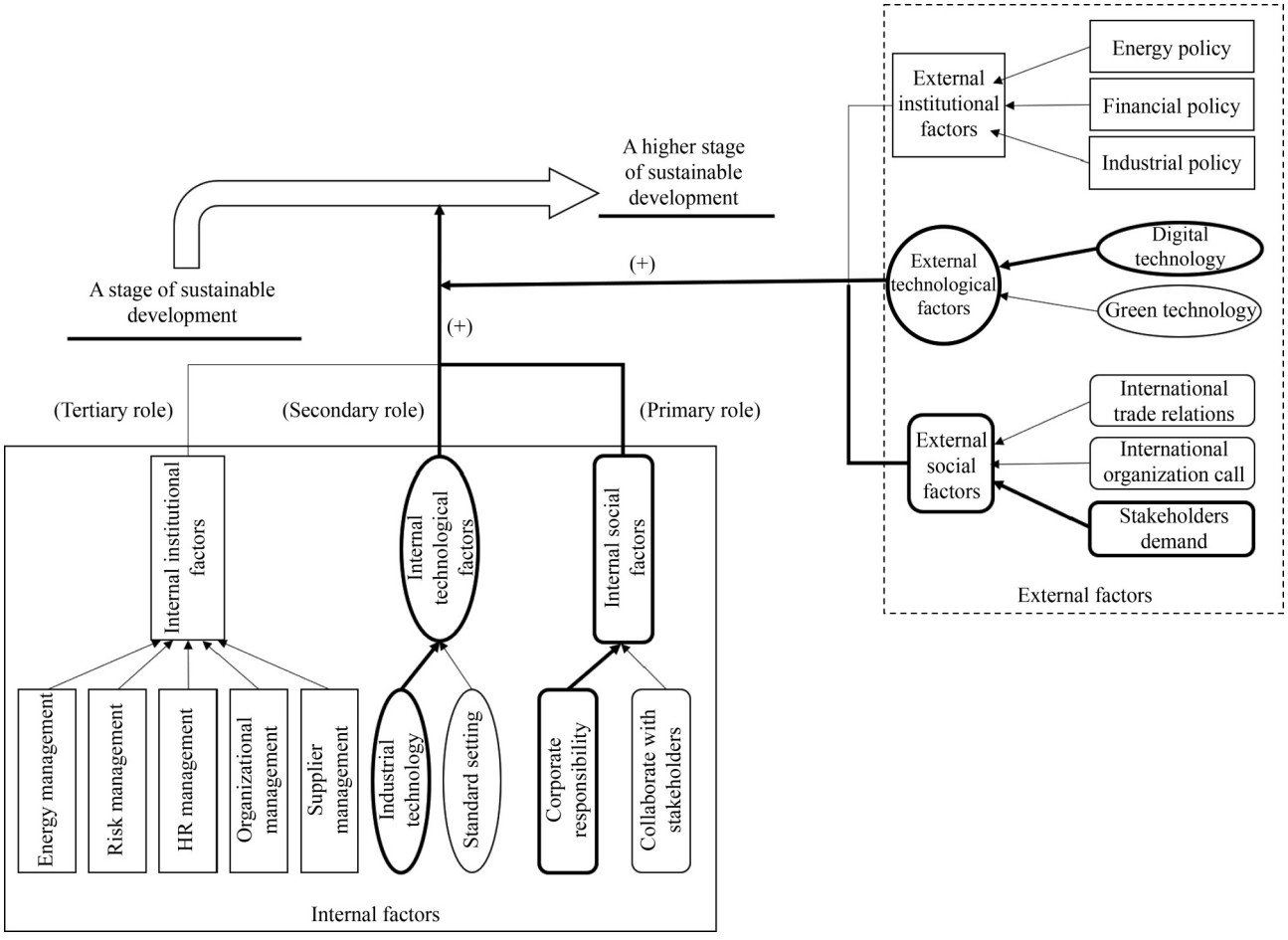

Fig. 1 Model of supporting factors for SSDSC.

5.4.1 Social factors

Social factors play a pivotal role in this process. Internal social factors encompass corporate responsibility, the establishment of corporate culture, and collaboration with stakeholders. External social factors primarily revolve around three key aspects: international trade relationships, engagement with international organizations, and stakeholder demands.

Corporate responsibility or genetic traits are integral to the sustainable development of the supply chain. Corporate culture serves as a fundamental genetic code for a company's growth and largely hinges on the company's goal positioning. Consequently, when a company aligns its responsibility with contributions to the nation and society, its behavioral consciousness directly propels the sustainable advancement of the supply chain, facilitating significant progress. As a state-owned enterprise, A consistently places national interests at the forefront when confronting related issues. In contrast, as a private enterprise, F also underscores its gradual shift toward social responsibility, with evolving focal points each year. For instance, in recent years, the company has directed its attention toward low-carbon planning, health and safety, addressing forced labor concerns, and other related aspects. At present, F has instituted numerous systems, including business continuity and environmental management systems.

Sustainable development necessitates the active involvement of stakeholders, encompassing both upstream and downstream members of the supply chain. These stakeholders include the government, shareholders, employees, customers, suppliers, associations, organizations, the public, communities, and the media. Enterprises can better cater to customer demands, ultimately expanding their market share. This serves as a foundational approach to increasing a company's scale and profitability. While continually meeting the expectations of stakeholders, enterprises also strive for continuous improvement in their service capabilities and the sustainability of their supply chain. This, in turn, influences the further integration of sustainability goals into their core responsibilities and missions. Thus, external social factors exert a positive moderating influence on the outcomes of internal social factors. G explicitly states that "the driving force for sustainable development in the supply chain is customer demand," and E also acknowledges that "upstream and downstream members will

drive E to set sustainable indicators, such as environmental protection indicators, social responsibility indicators, environmental requirements indicators, and management indicators such as personnel management."

5.4.2 Technological factors

Technological factors assume a subordinate role in this process. Internal technology primarily emphasizes technology research and development, application, and promotion. This is led by the enterprise itself and stems from the needs of both the enterprise and the industry. Internal technology exhibits notable professionalism and is irreplaceable. In contrast, external technology primarily pertains to the level of development, innovation, iteration, and enhancement of universal technologies such as digital information technology and green energy technology. These technologies have the potential to empower various segments within the manufacturing and logistics industries, thereby fostering SSDSC across various sectors.

Concerning internal technological factors, the key to achieving SSDSC lies in enhancing the independent and controllable capabilities of industrial technology within enterprises. Industrial technology represents the prevailing form of technological evolution at the industrial level. Different enterprises traverse distinct technological evolution pathways, leading to product and service differentiation. Industrial technology constitutes the core of all companies. In our research, many enterprises emphasized that "supply chain security can be achieved only when the core technology is independent and controllable." The fundamental reason behind the "Chinese and American chip event" is the absence of core technologies among Chinese companies.

Digital and intelligent technologies play a significant indirect role in influencing external technological factors. This technological function bears similarity to the transformative changes technology has introduced to social production methods, evolving from the Industrial 1.0 era to the current Industrial 4.0 era. Enterprises must proactively integrate digital intelligence technology with their respective industries, harnessing big data, artificial intelligence, blockchain, and other innovative technologies to construct a dynamic data model for enterprises. This endeavor mitigates business uncertainty. Consequently, enhancing external technology expedites innovation within internal technology, actively moderating the effect of internal technology on SSDSC. In industrial practice, **C** explicitly asserts that the driving force behind the company's promotion of SSDSC primarily stems from digital technology. This digitizes and enhances transaction transparency, elevates overall transaction fulfillment, and ensures supply chain sustainability through the integration of AI cameras, digital lock seal management devices, ERP systems, and other means. **D** represents "technology is the primary productivity, and if the trend of productivity cannot be caught up with, it will directly affect the core competitiveness and sustainable development of the entire supply chain."

5.4.3 Institutional factors

The influence of institutional factors is comparatively less pronounced when juxtaposed with the effect of the other two factors. Internal institutions include the measures, methodologies, and procedures established within an enterprise to interconnect and govern diverse business activities. Conversely, external institutions comprise the economic and social system of the external milieu in which an enterprise operates. A positive and accurate external system serves as a guiding force, spurring the development and reshaping of the internal system.

Internal institutions serve as the bedrock for ensuring SSDSC. Enterprises can further standardize their operations and advance toward the established objectives of sustainable development by nurturing more comprehensive internal institutions. Internal institutions primarily manifest in five key dimensions: the energy management system, risk management system, human resource management system, organizational management system, and supplier management system. For instance, **A** emphasizes that "for the supply chain security problem, the enterprise has provided internal risk management methods, including the coordination of management methods, risk analysis, planning response measures."

External institutions predominantly include energy, financial, and industrial policies. Energy policy comprises a series of directives formulated by a country or international organization pertaining to energy production, supply, and consumption. Effective enterprise energy management necessitates alignment with energy policies. As articulated by **D**, the increasing stringency of low-carbon environmental protection requirements has led to the potential elimination of traditional, high-energy consumption, and high-pollution devices. Financial policy pertains to the monetary and credit policies endorsed by a government or central bank. The implementation of fiscal adjustment tools such as taxes and subsidies can profoundly impact enterprises' enthusiasm for sustainable development. For instance, **B** contends that "the government needs to provide financial and policy support, just as the government provides funds and policies to support the construction of charging stations at the current stage." Industrial policies can steer the economy toward sustainable development by guiding enterprises to allocate resources judiciously and incentivizing or limiting their actions to promote the attainment of developmental objectives. In the course of the research, companies **A**, **B**, and **F** emphasized the crucial role of examining the

dynamics of industrial policy in securing support for the sustainable development of the supply chain.

5.5 Roadmap for SSDSC

Based on the model presented in Section 5.3 and the discussion in Section 5.4, it becomes evident that certain pivotal elements demand early implementation for SSDSC. Consequently, we advocate a roadmap for SSDSC, illustrated in Fig. 2, which revolves around the pillars of "social leadership, technological drive, and institutional assistance."

To commence, enterprises can initiate their SSDSC journey by focusing on the most crucial social factors, heeding the demands of stakeholders, and aligning with the directives of international organizations. Subsequently, enterprises should progressively enhance their level of social responsibility, building upon the foundation laid in the initial phase. Enterprises with a stronger commitment to social responsibility will then adopt digital and green technologies to enhance the sustainability of their operations. Transitioning from technology procurement to in-house research becomes crucial to elevating the technological capabilities of enterprises. Finally, once social and technical factors reach maturity, enterprises can leverage external policies and establish advanced management systems to realize SSDSC.

As elucidated in Section 4.3, the supporting factors outlined in this study are not confined to a specific stage of sustainability; instead, they represent common elements that may be involved throughout the stepwise process. Consequently, Fig. 2 outlines a universal pathway, elucidating how to navigate the interplay between elements and the specific stages of SSDSC.

6 Conclusions and future work

6.1 Conclusions

Initially, this study engages in the coding and analysis of textual materials, leading to the identification of 17 supporting elements integral to SSDSC. These elements originate from three facets: institutional, technological, and social factors.

Subsequently, the study investigates a complex analysis of the functional interplay among the various supporting factors. It elucidates that external institutional, technological, and social factors wield a positive regulatory influence over internal institutional, technological, and social factors. In essence, external factors expedite the process of internal factors propelling SSDSC.

Furthermore, the study scrutinizes the pivotal elements within the initial category of these 17 supporting factors. It discerns that industrial technology, digital technology, corporate responsibility, and stakeholder demand emerge as the four pivotal supporting elements.

In conclusion, through the construction of a model including these supporting factors and the delineation of a comprehensive roadmap for SSDSC, the study pinpoints a strategic direction for enterprises to advance

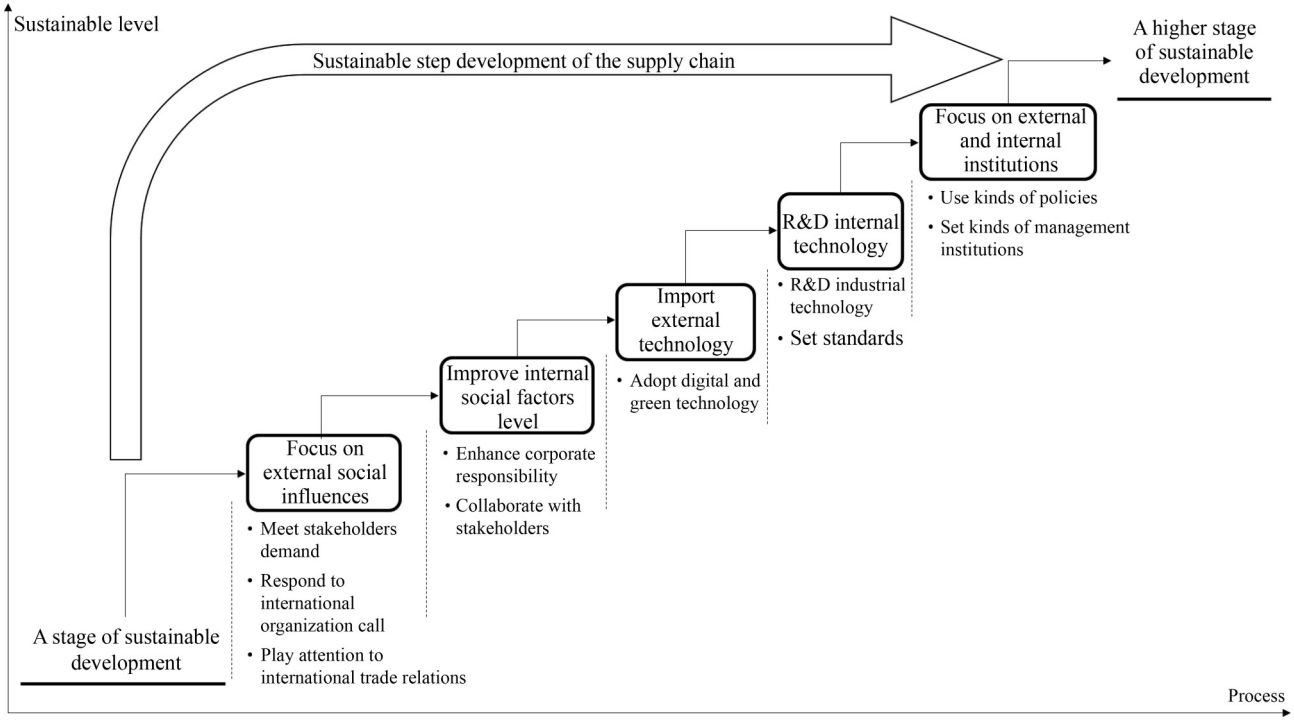

Fig. 2 Roadmap for SSDSC.

SSDSC. It also proffers practical recommendations for governmental authorities to enact incentivizing policies.

6.2 Management insights

Through the conclusions of this study, insights can be provided for enterprise management and regulators.

6.2.1 Management insights for enterprises

There are three distinct approaches to consider:

The first approach centers on 17 supporting elements, including institutions, technology, and society. Attaining SSDSC demands more than a singular focus on economic growth and environmental protection by enterprises. Instead, a multifaceted approach is crucial, incorporating dimensions such as enterprise management, technological innovation, corporate responsibility, and policy application. These 17 elements, as outlined in this study, should serve as the foundational starting point for effectively embedding sustainable development across all facets of enterprise operations.

The second approach emphasizes the catalytic role of external factors. While enterprises cultivate their internal capabilities, it is essential to judiciously harness external forces, a pivotal measure in achieving SSDSC. In the domain of institutions, enterprises should respond comprehensively to policy directives, leverage policy advantages, and institute a responsive sustainable management framework within the enterprise. Additionally, enterprises should amalgamate digital and industrial technologies, harnessing the value-added potential of various emerging technologies to expedite industrial advancements and erect technological barriers. Regarding society, enterprises must vigilantly attend to stakeholder needs, concurrently elevating their competitiveness while addressing personalized customer demands.

The third approach involves adopting a developmental trajectory characterized by "social leadership, technological drive, and institutional assistance." Enterprises must discern their position within the spectrum of sustainable development stages. When enterprises require specific impetuses to propel them forward, they should respond to stakeholder demands for sustainable transformation to enhance managerial social responsibility, thereby achieving SSDSC. Simultaneously, enterprises can enhance their research and development efforts to enhance product quality, thereby bolstering their competitive position in the market. Gradual progress toward carbon neutrality can be realized by establishing distributed energy power plants and implementing smart energy management systems, in alignment with government mandates for carbon emission reduction. Finally, enterprises should maximize the supportive role of policies and optimize their internal systems to realize SSDSC.

6.2.2 Management insights for regulators

On the one hand, in addition to traditional economic and environmental regulations, the government can implement policies derived from 17 supporting elements, including society, technology, and institutions, to foster SSDSC. This proactive approach establishes a stronger foundation for the sustainable development of enterprises. For instance, supporting the advancement of information technology and green technology also contributes to SSDSC.

Concurrently, the government, as a key stakeholder in enterprises, assumes a pivotal role as the most critical supporting element in achieving SSDSC. Many enterprises place greater emphasis on supply chain sustainability due to government policies. Therefore, the government should fulfill its responsibilities and function as a regulator for enterprises through external initiatives to promote and realize SSDSC.

6.3 Future research directions

This study introduces a model outlining the supporting factors crucial for SSDSC based on diverse enterprise samples characterized by richness and differentiation. Consequently, this model exhibits versatility and applicability across a spectrum of scenarios, affording strategic assistance and guiding pathways for enterprises embarking on sustainable supply chain development. However, there remains scope for further enhancement in the following aspects of this paper.

First, this study confines its analysis of the supporting factors of SSDSC to qualitative examination through the grounded theory method. In the future, it is advisable to incorporate quantitative analysis methodologies to gauge the influence of various factors on SSDSC more rigorously. Additionally, for future research, there is an opportunity to refine theoretical models by broadening the spectrum of samples. This expansion should include perspectives from both manufacturing and service industries, with the objective of determining the presence of additional supporting factors for SSDSC beyond the current model.

Conflicts of Interest The authors declare that they have no conflicts of interest.

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