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Constructing Climate Justice in Discourse: Australian Logic

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Abstract

This study aims to find out Australian government's logic on climate justice discourse. With Australia's official speeches at the successive sessions of the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) and the climate change-related policy and legal texts issued by the Australian federal government as the corpus, this study explores the logic of generation, organization and function of the discourse under the guidance of Fairclough's idea. It is found that distributive justice and procedural justice are the main dimensions of climate justice in the discourse. And they're organized through judgement, recognition and action. They function with political, economic and social spheres.

Keywords : Climate Justice; Australia; Discourse Study; Frame Analysis

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Introduction

Climate change is a critical issue related to human survival and development, which not only involves the natural environment but also encompasses geopolitics, energy, economy, and development. It is one of the key factors reshaping global politics and development. In recent years, "climate justice," which focuses on the distribution of climate responsibilities, has gained increased international attention. To protect their image and interests, Governments, international organizations, non-governmental organizations, and the media have utilized various discourses on different occasions to convey their positions and demands regarding this issue. However, research on climate justice has predominantly focused on its connotations and implementation from law and ethics. There is still a need for further exploration on the discursive logic, content, and significance of climate justice in different countries.

Australia is the country with the highest per capita carbon emissions (Morton, 2023) and the largest nation in the South Pacific region. In the context of climate change, it not only bears historical responsibility for emissions, but is also directly threatened by rising sea levels. Therefore, it has actively advocated for climate justice in international community, and has introduced domestic climate legislation to construct and maintain climate justice. However, there is still insufficient research on how Australia uses discourse to advocate climate justice and convey its national stance. This study combines critical discourse analysis (CDA) and corpus linguistics (CL) to explore the official discourse on climate issues in Australia. The study aims to interpret the its logic in text, discursive practice and social practice on climate justice, therefore expands the scope of climate justice research, and provide an innovative perspective for Australian studies.

Literature Review

Climate Justice and Its Dimensions

Climate justice extends and expands the concept of "justice" in the context of climate change (Cao Mingde, 2016). It emerged as a response to the significant increase in greenhouse gases emission since the Industrial Revolution, which has led to irreversible climate changes. This concept originated from a report titled Greenhouse Gangsters vs Climate Justice by the NGO Corp Watch in 1999 (Bruno et al., 1999). Subsequently, as environmental movement develops, the term "climate justice" has become widely used in international conferences.

Scholars have different definitions and interpretations of climate justice, depending on their focal points. At the macro level, climate justice refers to the fundamental value norms and moral principles in response to the global climate crisis (Wang Canfa & Chen Yijian, 2013). At the meso level, the focus of climate justice is on how climate change affects people in diverse, uneven, and disproportionate ways, and how to correct these injustices in a fair and just manner (Sultana, 2021). At the micro level, climate justice addresses two key issues: how to drastically reduce global greenhouse gas emissions and how to fairly and reasonably allocate emission quotas among countries (Chen Xiao, 2018).

Due to differences in definitions and demands, the dimensions of climate justice are diverse. For human subjects, the dimensions include distributive justice, compensatory justice, and intergenerational justice. Distributive justice refers to the fair

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allocation of climate resources and environmental obligations between nations. Intergenerational justice aims to protect future generations from harm and hold those responsible for causing such harm accountable. Compensatory justice refers to the responsibility of those who cause harm to repair and compensate the victims. For non-human subjects, including animals and the natural world, the dimension of climate justice is interspecies justice, which focuses on the fairness between humans and other species (Zheng, 2017). Based on the different forms of climate justice, it can be divided into procedural justice and substantive justice. Procedural justice primarily focuses on decision-making processes, which should be fair and inclusive, including access to information and meaningful participation (Newell et al., 2021). Substantive justice addresses the allocations of burdens related to climate change and share of the benefits, with the main form being distributive justice (Yang Bowen, 2023). In line with the categories above, this study will explore the discursive logic of Australia's construction on climate justice through five dimensions: distributive justice, compensatory justice, intergenerational justice, and procedural justice.

Research of Climate Justice

The research framework of climate justice can be categorized into three levels: theoretical construction, dimensional analysis, and practical impact. At the theoretical construction level, early studies focused on the ethical aspects of climate governance. Jamieson (2001) explored the ethical dimensions of climate change policies, while Brown (2002) and Athanaslou and Baer (2002) highlighted the responsibility of developed countries and development rights of developing countries in global governance. Li Chunlin (2010) summarized the concept, the connotation and relationship with climate governance of climate justice. With Vanderheriden's (2008) systematic classification of climate justice, an interdisciplinary research paradigm gradually emerged, which further complemented the construction of climate justice.

In studies related to dimensional analysis, there has been a a diverse landscape. On distributive justice, researchers focused on responsibility-sharing mechanisms, including Polluter Pays Principle, Ability-to-Pay Principle, Beneficiary Pays Principle, Grandfathering Principle, Emissions Egalitarianism (Yang Tongjin, 2022). Subsequently, researchers have improved such principles, and proposed a mixed responsibility model (Wang Yingying, 2023). For Intergenerational justice, studies focused the allocations of limited resources and rights of future generations from the perspectives of ethics, policy-making, economic analysis, and juridic practice (Ohlsson & Skillington, 2023). Compensatory justice constructs a responsibility loop through historical accountability (Caney, 2005) and economic compensation mechanisms (Adelman, 2016). The procedural justice expands within the international legal framework, containing core elements such as transparency, reciprocity and participation (Brandsted & Brüld, 2019), as well as reasonable disagreement and political deadlock, fair process, fair participation, political equality, fair bargaining, and voting (Tomlinson, 2015). In addition, researchers also extend the boundaries of traditional dimensions, advocating interspecies justice based on ecological holism and seeking to coordinate the balance between species (Li Yingchao, 2016).

Research on the practical impact of climate justice presents an interaction between global perspectives and local concerns. Case studies cover industrialized countries sum as the U.S., Germany and Australia, as well as climate-vulnerable regions including small island developing states, Southeast Asia, and Brazil. The research topics include climate politics (Xie Laihui, 2017; Tang Xinhua, 2022); energy issues; communication (Qin Zhe & Zheng Quan, 2020) and discourse study. These studies reflect both the common challenges in global climate governance and the divergent demands of developed and developing countries.

The above research shows that diverse theoretical foundation of climate justice, with dimensional paths entailing various forms such as time, space, and population. Its influence extends beyond multiple countries and regions, affecting various social fields. However, current research emphasizes macro-level political, economic, legal, and ethical issues, while the studies of climate justice at the meso and micro levels, as well as the mechanisms of interaction between climate justice and the social environment, remains insufficient. Notably, the role of discourse, an important form of social practice, has been largely overlooked in the field of climate justice. Discourse can facilitate climate negotiations and discussions through its communicative function, thus promoting procedural justice and influencing distributive and compensatory justice. It can also change people's perceptions and attitudes towards climate through its constructive function, advancing climate education and fostering intergenerational and interspecies justice. Through their competition for the meaning and dominance of discourse in climate debates, different actors can also impact distributive and compensatory justice. Therefore, the introduction of discourse study could provide new perspectives s to explore the mechanisms between discourse and various dimensions of climate justice, the interactions with different actors, and the connection to social power.

Research on Climate Justice and Discourse

Research on climate justice discourse mainly explores aspects such as discourse actors, discourse competition, and discourse impact. Discourse actors include the media (Dreher, 2015) and governments (MacCallum et al., 2014). Discourse competition primarily focuses on comparing the discourse of developed and developing countries at the United Nations Climate Conferences (Audet, 2013; Lefstad & Paavola, 2023) and comparing government and non-governmental actors' discourse frameworks (Shawoo & McDermott, 2020). They counducted their study through comparative study, critical discourse analysis, and corpus-assisted analysis. As for the impacts, researchers tend to exmine countries like Australia, USA and Pakistan on the discourse impacts of policies, social activities, or international affairs. These studies, however, have seldom combined and analyzed of domestic and foreign policy documents to explore how climate justice is expressed, operates, and originates in different contexts.

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Australia is one of the countries with the highest cumulative carbon emissions and is also the largest nation in the South Pacific. In the context of climate change, it not only bears historical responsibility for emissions, but is also directly threatened by rising sea levels. For a long time, Australia has viewed climate change as a critical national security issue, and has worked to uphold climate justice through both domestic policy-making and international participation in climate governance. Currently, research on Australia's climate justice discourse includes critical discourse analysis of local government climate change response strategies (MacCallum et al., 2014) and studies of Australian media coverage of Small Island Developing States (SIDS) on climate justice (Dreher, 2015). There're also studies comparing the discourse differences between news agencies and social media on climate justice movements (Chen Kaiping et al., 2023). These studies provide valuable insights into the official statements, as well as social attitudes toward various entities concerning climate justice. Nevertheless, research on the composition, dissemination, and significance of the Australian federal government's climate justice discourse, both domestically and internationally, remains insufficient. Given that critical discourse analysis can explore the content, causes, and mechanisms of discourse through text description, discourse practices, and social practices, and has already been applied in climate justice discourse research, this study aims to examine the generation, operation, and impact logic of the Australian federal government's climate justice discourse. It will do so using Fairclough's three-dimensional framework and corpus-based techniques.

Research Design

Theoretical Framework

Critical Discourse Analysis (CDA) is a significant method for analyzing language and discourse. It takes langauge as part of the society and views discourse as a social practice (Fairclough, 2015). Under such a paradigm, Fairclough set CDA to interpret the connections and dynamics of discursive practice and social-cultural changes (Chen Jin, 2022: 35). For the analysis procedure of CDA, Fairclough (1992) proposed a three-dimensional analytical framework including textual practice (description), discursive practice (interpretation), and social practice (explanation). The description stage helps understand the "formal propoerties of text „ such as vocabulary, grammar and textual structures (2015). The interpreation stage corresponds to the production and consumption process of the discourse (2022). In the explanation stage, the aim is to figure out the relationship between the discourse practice process and its social context, requiring the incorporation of social structure to show how power and ideology operate (Xin Bin & Gao Xiaoli, 2013).

So far, CDA has been widely applied in studies regarding climate change and government discourse, along with a few studies from the lens of climate justice. However, further attempts in How Australian government contructs climate justice through domestic and international articulation are still in need. In this case, this study introduces frame analysis to interpret the discursive logic. Frame originated from cultural sociology and cognitive psychology, and was elaborated by Erving Goffman. He argued that people's interpretations of events or behavioral sequences are framed by perceptible blueprints surrounding them and the frames that these trigger. This concept was later applied in various research fields, including media studies, cognitive psychology, and linguistics. Based on the functions of framing, Jin Xiaozhe (2022) proposed three dimensions for analyzing the construction of discursive logic: affective focus, cognitive connection, and behavioral transformation, which could be used as the analytical framework of the present study. By integrating CDA and interpretive package, the study could figure out clear how the government's articulaation contributes to the construction of climate justice.

Data Collection

To explore how Australia constructs climate justice in both domestic and foreign affairs, this study selects the speeches made by Australian officials at the United Nations Framework Convention on Climate Change Conference of the Parties (COP) and Australia's Nationally Determined Contributions (NDCs) submitted to the United Nations as the corpus for Australia's climate diplomacy (ACD). Additionally, the study also collects texts including *The Roles and Responsibilities for Climate Change Adaptation in Australia*, *Climate Change Act 2022*, and *Annual Climate Change Statement* as the corpus for Australia's climate policy (ACP). The number of data is shown in Table 1.

Table 1. The Byte Number of Australia Climate Discourse

Name	Byte number
ACD	35,824
ACP	83,028

To dentify dimensions of climate justice witinin Australian government's climate discourse, the study uses a corpus linguistic tool Sketch Engine for texual analysis. This online tool is capable of extracting keywords, collocations and context related to climate justice, thus contributing the comprehensive analysis of the discursive framework surrounding climate justice.

Research Question and Research Steps

Based on Fairclough's three-dimensional framework, the study seeks to explore the following questions:

(1) What climate justice discourses has Australia produced?
(2) How are these climate justice discourses structured?
(3) What are the reasons behind the formation of these discourses?

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To figure out the discoursive construction and logic of Australian government regarding climate justice, the study combines CDA and corpus linguistics (CL) following the three stages: description, interpretation and explanation. At the description stage, the study uses CL to uncover keywords within the ACP and ADP corpora, thus identifying the key concerns held by the government, laying the foundation of linking the government's emphasis to climate justice. At the interpretation stage, the study furthers the investigation over collocations and concordance lines, then frames the government's climate discourse from framing devices and resonning devices guided by the interpretive package. By doing so, the author could link the semiotic features and underlying intentions of the government's dicourve, thus figure out its logic of countructing climate justice. Follwing the two stages, the explanation stage attempts to explore the reasons behind these constructions, connecting discourse on climate justice to broader sociopolitcal factors. The results are presented in the following chapters.

Results

Describing Climate Justice: Distributive and Procedural Justice

In this section, the study identifies the themes Australia outputed on climate issues and their corresponding climate justice dimensions through keywords, lexical choices, and index lines. The study cross-references the ACD corpus with the ACP corpus and extracts the top 10 keywords and terms, as shown in Table 2.

Table 2. Cross-References of ACP and ACD

ACP		ACD	
Keyword	Term	Keyword	Term
NSW	territory government	umbrella	stretch goal
Queensland	critical mineral	assumption	reference indicator
mineral	annual climate change statement	methodological	Kyoto Protocol
Queensland	greenhouse gas emissions reduction	Durban	methodological approach
mineral	annual climate change	Copenhagen	reference point
study	risk management	multi-year	quantifiable information
October	gas emissions reduction	economy-wide	economic stretch
EV	renewable hydrogen	single-year	economic stretch goal
f	energy sector	coverage	natural disturbance
subsection	disaster risk	absolute	clean hydrogen

The data above shows that the Australian federal government emphasized four themes in its publications: emission reduction, international engagement, risk management and internationally responsibility. Firslty, terms such as "critical mineral," "EV," "greenhouse gas emissions reduction," "renewable hydrogen," and "clean hydrogen" suggest a strong emphasis on energy transition and technological innovation. The presence of words like "absolute" (in "absolute economy-wide emissions reduction") reflects Australia's commitment to binding, measurable emission reduction targets. For the theme of international engagement, there is a particular focus on participation in international conferences by the frequent mention of "umbrella", "Durban", "Copenhagen" and the binding nature of international climate agreements like "*Kyoto Protocol*", "Reference Point", "multi-year", "single-year", and "economic stretch goal". Thirdly, Australian government highlighted"risk management", "disaster risk", "natural disturbance" to show its observation and reponse for domestic climate risks and disasters. Finally, it aso used " fund" and "climate finance" to indicate concerns and reponsibility for international climate actions targeting Pacific Island Countries.

Having figured out the government's focus in emission, engagement and response, the study considers its relation to the dimensions of climate justice, and holds the three themes potentially correspond to distributive justice and procedural justice by examining their concordance the lines. In the first place, the emphasis on emission reduction and risk management are set to lower the climate impacts on Australians and improve climate resilience. In doing so, the government promotes "greatest utility" that maximizes the social benefits, mitigating the hits to people, especially those who are vulnerable. Meanwhile, their demandings also align with Polluter Pays Principle, which usually applied to environmental and climate measures to undertake the outcomes of damages and pollutions (De de Vries et al., 2024).

Moreover, the keywords surrounding international engagement reflects Australia's stress on climate diplomacy, adherence to international law and the spirit of agreements, posintioning itself with the reciprocity and inclusiveness of procedural justice.

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However, even though words related to financial aid appeared in the corpora, they're usually linked with "responsibility rather than "history" or "past", suggesting greater inclination on "Capacity to Pay" principle in the distributive justice, but little association on the reflections for historical responsibility in carbon emissions. Meanwhile, the frequency of "compensate" and its derivatives is also low, which indictates the compensatory justice is not consistently underlined compared to the former two dimensions. Finally, to examine if intergenerational justice is concorned by the government, the study searches for words like "future," "children," and "generation" that surrounds future significance, but these words appear infrequently and have weak connections to climate justice in their concordance lines. Such a tendency demonstrates that the Australian federal government has not emphasized intergenerational justice.

These results imply that the government's climate discourse focuses on distributive justice and procedural justice, aligning with its different claims in domestic and international climate adaptation actions and global climate governance participation. Given the frequency and typical cases of these discourses, this study will continue to explore the logic behind the Australian federal government's construction of these two dimensions.

Interpreting Climate Justice: Affective, Cognition and Behavior

This section adopts frame analysis to explore the logic of climate justice discourse. Accoding to this framework, this study combines collocations and intextuality to examine how distributive justice and procedural justice are constructed within Australia's climate discourse. For affection, the study tries to figure out how the government attracts audience attention by searching for evaluative collocations associated with keywords of different climate justice dimensions. For cognition, it identifies the cognitive landscapes generated by related noun phrases associated with keywords. When it comes to behavior, it examines related verbs to determine the practical actions the government calls the audience to take. By extracting the collocations with the highest co-occurrence frequency, the results are shown in Table 3.

Table 3. Frame on the Construction of Climate Justice Discourse

	Distributive justice	**Procedural justice**
Affective Focus	active, strategic, national, renewable, global, Pacific, Asian, long-term, bilateral regional	Global, bold, effective, important
Cognitive connection	Australia, emission, energy, technology, decarbonise, billion, Green Climate Fund	commitment, effort, community, agreement
Behavioral transformation	action, impact, benefit,update, deliver	Agree, work, measure, support

Distributive Justice: Reduction and Promotion

The Australian government emphasises emission reduction and clean energy development as primary strategies for meeting its emission reduction and net-zero goals. The government uses the terms "global," "national," "regional," and "rural" within the affection dimension to highlight that emission reduction actions must be implemented through a top-down strategy, reflecting through various spatial locations. In addition to emission reduction, the government adopts an active approach to renewable energy. The cognition dimension underscores that emission reduction involves not only the limitation of greenhouse gas emissions but also the transition to cleaner, and renewable energy. They believe emission reduction shall not adversely affect the economy, employment, or business, nor should it result in increased energy prices due to higher energy taxes, which would impact people's livelihoods. To achieve such goals, while fostering economic development, the main focus should be on technology rather than taxation (Shi Kun & Cai Jianing, 2022). With sufficient resouses in renewable energy, and support for technologies and project in the clean energy sector, the government wish to make Australia a "renewable energy superpower" (Tang Jie, 2024), thus holding their commitment on the transformation of energy structure.

In addition, the Australian government stresses financial assistance for developing nations via affective focus and cognitive connection, which manifests the "Capacity to Pay" Principle. The discourse points to the Pacific Island countries and Southeast Asian nations in nearby regions of Australia in the affective focus dimension. The location and regional integration of the South Pacific are significant factors in its analysis, with bilateral aid serving as the primary form of assistance from Australia (Jiang, 2018). Using "billion," "update," and "deliver," the government have demonstrated its continuous aid commitments to developing countries. It strengthened its climate finance commitment, expecting to deliver $3 billion towards global efforts over 2020-25, which includes includes $1.3 billion in climate finance for the Pacific Countries (Australian Government Department of Foreign Affair and Trade, 2024). Green Climate Fund was used as a primary mechanism for delivering climate assistance, and the government also indicated supports for the Loss and Damage Fund established at the COP28.

Procedural Justice: Global Participation

On procedural justice.The government values its involvement in international climate matters through the cognitive connection dimension. They supports international climate agreements and make emission reduction promises based on their standing, establishing themsevles as a responsible in fulfilling the duties. At the *Kyoto Protocol*, Copenhagen Climate Conference, and Paris Agreement, the Australian government has shown concern and pledged emission reductions. In 2007, the Rudd government approved the *Kyoto Protocol* and established a target to reduce Australia's greenhouse gas emissions by

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60% from 2000 levels by 2050 (UNFCCC, 2008). During the 2009 Copenhagen Climate Conference, the Rudd government committed to reduce emissions by 5% below 2000 levels by 2020. The Gillard government subsequently submitted its emission reduction plans and targets at the Durban Climate Conference, and signed the second commitment period of the *Kyoto Protocol* at the Doha Climate Conference in 2012. During the Turnbull administration, Australia signed the *Paris Agreement* in 2015, pledging to cut greenhouse gas emissions by 26%–28% below 2005 levels by 2030 and reach net-zero emissions by 2100. To combat climate change, Turnbull proposed to help poor nations and fund clean energy research at the Paris Conference. After the Morrison administration was criticised for its conservative climate policies, the Albanese government reaffirmed Australia's commitment to the Paris Agreement and climate obligations. In signing the newest *Paris Agreement* climate obligations, Australia has boosted several domestic plans and bills in response to international climate agreements. These include the *Carbon Emissions Trading Scheme Bill*, the *Clean Energy Bill*, the Emissions Reduction Fund, the *National Energy Guarantee*, and the 2022 *Climate Change Bill*. They're all aimed at the targets for emission reductions.

Explaining the Discoursive Logic of Climate Justice In Australia

The analysis indicates that the climate justice discourse of the Australian government operates within the frameworks of distributive justice, procedural justice, and compensatory justice. According to the distributive justice dimension, the government sees the development of renewable energy technologies as a means of achieving emission reduction targets. By taking advantage of financial investments and policy support, renewable energy can be applied to promote decarbonization and the energy transition. As for procedural justice, the government underlines its involvement and commitments in international climate affairs, therefore positioning itself as a responsible actor. In the context of compensatory justice, the government focusses on its ongoing climate funding to the South Pacific area. This following section will examine the factors contributing to the emergence of climate justice discourse in Australia from political, economic, and social perspectives.

Political Factors: Global Consensus On Climate Justice

At the political level, the need to adhere to global governance consensus and maintain national image requires the Australian government to comply with climate justice. Climate change is a worldwide problem that affects the world's collective interests and influences the transformation of national and global development models. The collective governance calls for the collaborative efforts of all nations and individuals. The adoption of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and the subsequent *Paris Agreement* in 2015 reflect a significant evolution in the international community's commitment and approaches to climate change mitigation. Despite the inherent contradiction between national interests and the public good of global environmental governance, environmental issues are increasingly critical in shaping international relations and security. Engagement in international issues related to the environment is an essential duty for all nations. Consequently, Australia is required to align with international consensus, making commitments and assuming responsibility in accordance with the principle of Common But Differentiated Responsibilities (CBDR). Furthermore, Australia's position as a significant emitter of fossil fuels and its membership in umbrella countries considerably influences global climate initiatives. Passive actions at international climate conferences or domestic climate measures would weaken Australia's national image and influence in neighboring nations. Australia has received the "Fossil of the Year" award multiple times, reflecting its inadequate performance on climate issues, which has led to a tarnished reputation and criticism from both allies and neighboring nations. Climate issues are a significant focus in Australian elections. The growing public concern regarding these matters, coupled with the emergence of environmental movements, indicates that commitment to climate justice is consistent with public expectations and ethical obligations. Thus, via emission reductions, climate assistance, and other initiatives, Australia attains both primary and secondary compensatory justice, demonstrating its commitment to climate global governance through open and thorough engagement.

Economical Factors: Opportunities for Renewable Energy

At the economic level, new opportunities for economic development motivate the Australian government to emphasize the application of renewable energy within distributive justice. Currently, Australia's coal-fired power plants are relatively outdated and inefficient, with high coal and natural gas prices and excessively high transmission costs. As a result, its electricity supply has not been adequately secured, leading to consistently high electricity prices (Hou, 2020). The development of renewable energy can reduce energy costs and enhance the diversity of electricity supplies. On the other hand, Australia's geographical environment offers substantial clean energy resources, including wind, solar, and hydro power, and it also holds strengths in the research and development of photovoltaic technology. The advancement of renewable energy corresponds with global energy economic trends and presents an opportunity to enhance Australia's fossil fuel-dependent economic framework, thereby promoting the realization of distributive justice. Furthermore, the increasing global demand for renewable energy provides Australia potentials due to its significant mineral reserves, including cobalt, lithium, and nickel, as well as its photovoltaic products. These factors present growth opportunities for the economy, thereby reinforcing the economic assistance components of compensatory justice.

Social Factors: Climate Risks

As climate risks rise, the Australian government is obliged to advance climate justice to ensure environmental and social stability. The natural environment of Australia is susceptible to and significantly impacted by climate change. In recent years, intensified climate change has further impacted Australia's natural ecosystems through extreme heat, severe weather events, bushfire, floods, sea level rise, and other problems. A wide variety of species face significant existential threats. The declining

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natural environment presents challenges to Australia's agriculture, tourism, infrastructure, international trade, and other sectors, greatly affecting production and the livelihoods of Australians, ultimately enhancing public awareness of climate protection. Advocating for climate justice demonstrates the Australian government's obligation to the environment and its residents, as well as boosting public awareness of climate change and encouraging the adoption of appropriate emission reduction measures. Additionally, the issue of climate refugees arising from the climate impacts on Pacific Island countries (Wang Shiming, 2019) is also significant. As the major aid provider to Pacific Island nations, Australia provides financial aid and technical support through compensatory justice, which not only enhances these nations' capacity to address climate change but also mitigates the uncertainties caused by the large-scale influx of climate refugees.

Conclusion

This study uses official statements by Australia at past United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP) meetings and climate-related policy and legal texts issued by the Australian federal government as the corpus. Guided by Fairclough's three-dimensional analysis framework and incorporating quantitative analysis methods, this research explores the generation logic, organizational logic, and operational logic of Australia's climate justice discourse. The study finds that Australia's climate justice discourse primarily manifests in the dimensions of distributive justice, procedural justice, and compensatory justice. Distributive justice is mainly implemented through emission reduction, the development of renewable energy, and financial aid to neighboring countries. Procedural justice is expressed in Australia's recognition and participation in international climate affairs and climate governance. The construction of climate justice by the Australian government is influenced by political, economic, and social factors. Politically, Australia needs to respond to the international consensus on climate governance and maintain its reputation; economically, it can use the development of renewable energy to implement distributive justice and support compensatory justice; socially, promoting climate justice is essential for mitigating the negative effects of climate change and fostering social stability.

China and Australia are two major energy-producing nations encountering specific climate risks. They are crucial for setting emission reduction targets, advancing clean energy initiatives, and engaging in international environmental policy frameworks. With the rising prominence of ethical and moral issues like climate justice, it is imperative for China to enhance its participation in global climate governance. This includes maintaining the progress achieved in international climate initiatives and strengthening its influence in global discussions, as well as protecting national interests in accordance with procedural justice principles. Promoting its emission reduction initiatives from a variety of views would help China establish a reputation as a responsible major power. It may show its attempts to achieve distributive justice, and use its clean energy advantages as a basis for international discussion and collaboration as well. In addition to climate cooperation and assistance based on CBDR and the idea of "a community with a shared future for mankind", China ought to consider the principle of historical accountability when defining the connotation and position of compensatory justice. Finally, the principles and practices of China should be also reflected in the areas of intergenerational and interspecies justice.

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Conflict of Interest

The authors declare no conflict of interest.

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Navigating the Divide: Balancing AI's Optimal Solution with the Appropriate Solution in Chinese Construction Management

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Abstract

While Artificial Intelligence (AI) offers powerful tools for optimizing construction processes, its effective integration hinges on navigating the gap between algorithmic "optimality" and practical "appropriateness". Focusing on China's construction industry, a critical context for AI deployment, this research explores the managerial decision-making processes involved in balancing these two facets. Through a qualitative methodology involving 15 expert interviews across diverse organizational types (SOEs, private, consultancy) and thematic analysis incorporating constant comparison, this study elucidates the complex interplay between AI recommendations and human judgment. Key findings identify five interconnected themes influencing this balance: Decision Balance & Human Adjustment, Data & Technology Challenges, Human-AI Collaboration and Trust, External Constraints & Contextual Factors, and Sector-Specific Dynamics. The research highlights the proactive role of managers as "adaptive integrators" rather than passive users. Extending existing literature, this study contributes theoretically by challenging simplistic views of optimality, refining human-AI interaction concepts, and proposing an empirically grounded Adaptive Human-AI Interaction Framework that explicitly incorporates contextual modulators and managerial interpretation. The findings hold significant practical implications for developing more effective AI tools, targeted training programs, supportive organizational cultures, and nuanced policy guidelines to foster responsible and productive AI integration in construction and analogous operational fields.

Keywords : Artificial Intelligence (AI); Construction Management; China; Human-AI Interaction; Adaptive Integration

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Introduction

Background and Context

Artificial intelligence (AI) is rapidly transforming industries worldwide, redefining processes in sectors as diverse as healthcare, finance, and manufacturing (Malik et al., 2024). In particular, China's construction industry—fueled by rapid urbanization, massive infrastructure projects, and a national commitment to technological innovation (Wu, 2023; Yu et al., 2024) —has become a key focus area. In recent years, the Chinese government has introduced policies supporting high-tech and digital transformation, encouraging the adoption of AI, big data, and IoT technologies in traditional sectors. As a foundational industry, construction has responded to these policy drivers, beginning to adopt AI for functions like smart construction and safety monitoring. Consequently, the sector is positioned to become a significant adopter of AI technologies like predictive analytics, computer vision, and LLMs, which promise enhanced planning, resource allocation, risk management, and efficiency (Malik et al., 2024). Crucially, however, beneath the surface of these technological advancements lies a critical managerial challenge: reconciling the algorithmically derived "optimal" solutions proposed by AI with the nuanced, context-dependent "appropriate" adjustments required for practical, real-world application. This fundamental tension between algorithmic potential and managerial practice, situated at the intersection of technology adoption, decision-making theory, and organizational practice, remains largely underexplored.

Problem Statement

Despite substantial research demonstrating AI's technical potential to improve design accuracy, forecast delays, and streamline workflows (Kokala, Abhilash, 2024), a significant gap persists. Much of the existing literature centers on the technical performance of AI systems in construction, often overlooking the pivotal role of managerial judgment in mediating their implementation. In practice, managers must interpret AI recommendations—frequently based on idealized assumptions—

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and adapt them to navigate practical constraints such as regulatory requirements, resource limitations, labor dynamics, and stakeholder expectations (Kinney et al., 2024). How managers navigate this critical space between AI's "optimal" outputs and the "appropriate", actionable solutions remains insufficiently understood, particularly within the complex and dynamic environment of China's construction sector. In this study (Ni et al., 2024), an "optimal" solution is defined as the algorithmically derived output based solely on quantitative data and efficiency metrics, while an "appropriate" solution refers to the adaptation of that output through managerial judgment, which incorporates contextual, regulatory, and practical considerations.

Research Objectives and Research Question

This study aims to bridge the gap between AI's technical capabilities and its practical managerial application by examining how managers in China's construction industry interpret and balance AI-driven recommendations with real-world operational constraints. The specific objectives are:

1. To investigate the decision-making processes managers employ when evaluating AI-generated "optimal" solutions.
2. To explore the contextual factors (regulatory, labor, stakeholder pressures) influencing the adaptation of AI recommendations into "appropriate" solutions.
3. To identify best practices and challenges in human-AI collaboration within construction management.
4. To contribute to theoretical discussions on AI, management, and decision-making by illuminating the interplay between algorithms and human judgment.

Accordingly, the research question guiding this study is:

How do managers in China's construction industry interpret and balance AI's optimal solutions with appropriate, practical solutions?

Significance of the Study

This research holds significant implications for theory, practice, and policy. By focusing on the nuanced interplay between AI outputs and managerial discretion, it contributes to a more holistic understanding of AI integration in operational settings. The findings are expected to:

1. Advance academic knowledge by extending literature on human-AI interaction and technology adoption, particularly within the unique constraints of construction management.
2. Inform industry practice by highlighting the indispensable role of human judgment and the need for training and collaborative strategies for effective AI use.
3. Guide policy formulation by illustrating how regulatory and socio-political contexts shape AI adoption, supporting the development of adaptive policies that foster innovation while ensuring safety and sustainability.

Given China's global leadership in both construction and AI deployment, insights from this study may offer valuable lessons for other regions and industries grappling with similar integration challenges.

Structure of the Article

This article proceeds as follows: Chapter 2 reviews the relevant literature on AI in construction and managerial decision-making. Chapter 3 details the research methodology employed. Chapter 4 presents the findings derived from the data analysis. Chapter 5 discusses the implications of these findings in relation to existing literature and theory. Finally, Chapter 6 concludes the study, summarizing key insights and suggesting future research directions.

Literature Review

This chapter critically reviews the existing literature pertinent to the intersection of AI adoption, managerial challenges, and decision-making processes within the construction industry. It synthesizes research across three core areas: (1) the current landscape of AI applications in construction; (2) the identified managerial challenges hindering effective AI integration; and (3) the conceptual tension between algorithmically "optimal" solutions and managerially determined "appropriate" actions. By critically examining these interconnected themes, this review establishes the theoretical foundation for the study and sharpens the focus on the central research gap: understanding how managers navigate the practical realities of balancing AI potential with operational constraints, particularly in the Chinese context.

AI Applications in Construction: Potential and Limitations

The integration of AI into the construction industry has shown considerable promise across various operational phases. Key applications include:

1. **Predictive Analytics:** AI algorithms analyze historical project data to forecast potential risks, cost overruns, and schedule delays (F. Afzal et al., 2019; Gondia et al., 2020). While valuable, such studies often focus on predictive accuracy under controlled data conditions. This research seeks to investigate how managers grapple with AI predictions when data quality is variable in situ, potentially challenging the direct applicability of optimal forecasts derived from idealized data, a nuance often overlooked.
2. **Building Information Modeling (BIM) Enhancement:** AI complements BIM by automating design checks, optimizing layouts, and improving clash detection (Abdulfattah et al., 2023; M. Afzal et al., 2023). However, integrating AI insights

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seamlessly into existing BIM workflows often requires significant technical expertise and process adaptation. Furthermore, the optimistic integration scenarios presented often underplay the socio-technical hurdles (Pan & Zhang, 2023; Tran et al., 2024). By examining managerial resistance documented by Salimimoghadam et al. (2025), this study aims to provide empirical evidence on the specific adaptive strategies managers employ, moving beyond technical potential to explore the practical realities of AI-BIM interaction as mediated by human actors.

3. **Large Language Models (LLMs):** LLMs are emerging as tools for contract analysis, communication streamlining, and knowledge management (Saparamadu et al., 2025; Zafar et al., 2024). Their application is still nascent, and challenges remain regarding domain-specific accuracy and contextual understanding within complex construction projects. Although nascent, their inclusion is relevant as they represent a rapidly emerging category of AI poised to influence communication and knowledge-based decision-making, raising pertinent questions even now about how managers will vet and integrate their potentially opaque outputs into established workflows.
4. **Computer Vision:** AI-powered image recognition is used for site monitoring, safety compliance checks, and progress tracking (Musarat et al., 2024). Deployment can be hindered by variable site conditions (e.g., lighting, weather) and the need for robust data infrastructure.

These applications demonstrate technical potential, the literature often emphasizes technological capabilities over the socio-technical challenges of implementation. A critical gap exists in understanding how managers interact with these tools not just as technical outputs, but as inputs into complex decision-making processes constrained by real-world factors.

Managerial Challenges in AI Implementation

The effective adoption of AI in construction is impeded by several interrelated managerial challenges that directly impact how AI-driven "optimal" solutions are evaluated and adapted:

1. **Data Quality and Availability:** The construction industry notoriously suffers from fragmented, inconsistent, and often incomplete data (Kazmi et al., 2023; Riazi et al., 2020). This directly undermines the reliability of AI predictions and complicates managerial trust in "optimal" outputs, often necessitating significant human oversight and adjustment.
2. **Regulatory and Compliance Hurdles:** Navigating complex building codes, safety regulations, and contractual obligations requires nuanced human judgment (Yazdi et al., 2024). AI solutions, while potentially optimizing for specific parameters, may not fully account for these multifaceted regulatory landscapes, forcing managers to intervene and ensure compliance, thereby modifying the "optimal" suggestion.
3. **Algorithm Aversion and Trust:** Managers may exhibit skepticism or reluctance ("algorithm aversion") towards AI recommendations, especially when they contradict intuition or experience (Turel & Kalhan, 2023). Building trust requires transparency in AI processes and demonstrable reliability, yet the "black box" nature of some algorithms complicates this, leading managers to favor familiar, albeit potentially less "optimal", approaches.
4. **Organizational Culture and Skills Gap:** Successful AI integration requires a supportive organizational culture and a workforce equipped with the necessary digital literacy (Cetindamar et al., 2024; Tursunbayeva & Chalutz-Ben Gal, 2024). Resistance to change and skill deficits can lead managers to underutilize AI or override its suggestions due to a lack of understanding or confidence, impacting the translation from "optimal" potential to "appropriate" action.

These challenges collectively highlight that AI implementation is not merely a technical problem but a complex socio-technical process where managerial interpretation and adaptation are crucial. How managers weigh these challenges against the perceived benefits of AI's "optimal" solutions is central to this study.

The Tension: Optimal vs. Appropriate Solutions

The core theoretical tension explored in this research lies in the divergence between the "optimal" solutions generated by AI algorithms and the "appropriate" solutions deemed necessary by human managers operating within specific contexts. AI often optimizes for quantifiable metrics based on available data (e.g., minimizing cost, maximizing speed) (Surianarayanan et al., 2023). However, managerial decision-making involves balancing these quantifiable metrics against less tangible factors like stakeholder relations, long-term strategic goals, ethical considerations, and unforeseen site-specific issues. This reflects principles of bounded rationality (Hunt et al., 2024), where managers make decisions within cognitive and contextual limits, often relying on heuristics or "satisficing" rather than pure optimization. It also aligns with naturalistic decision-making, which emphasizes how experts operate under time pressure and uncertainty using experience-based intuition (Lawani et al., 2023), factors often contrasting with the data-driven logic of AI.

This necessitates a process of "human adjustment" where managers interpret, validate, and often modify AI outputs (X. Wang et al., 2022). The literature suggests that effective human-AI collaboration involves leveraging AI's analytical power while retaining human oversight for context, ethical judgment, and strategic alignment (Celestin & Vanitha, 2020; Joseph et al., 2024). Yet, *how* this balance is practically struck in the high-stakes environment of construction, particularly when faced with the managerial challenges outlined above, remains inadequately explored. Existing models often focus on either the technology or the human element in isolation, rather than their dynamic interplay in shaping the final "appropriate" decision.

Research Gap and Contextual Focus

Synthesizing the literature reveals a clear gap: while AI's potential in construction and the associated managerial challenges are acknowledged, there is limited empirical research exploring the specific decision-making processes managers use to

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reconcile AI's "optimal" recommendations with the practical need for "appropriate", context-sensitive solutions. This research gap suggests that more research based on field data is needed to explore the actual methods and strategies used by managers when integrating AI decision-making into specific project contexts. Furthermore, much of the existing research originates from Western contexts, understanding this dynamic within Chinese construction firms is crucial for both localized insights and broader comparative understanding. This study directly addresses this gap by investigating the nuanced interplay between AI optimality and managerial judgment within this specific, significant context.

Methodology

This chapter details the methodological approach employed to address the research question: ***How do managers in China's construction industry interpret and balance AI's optimal solutions with appropriate, practical solutions?*** Given the exploratory nature of the inquiry and the need to understand complex managerial decision-making processes within their specific context—considering project background, resource conditions, organizational culture, and on-site realities—a qualitative research design was deemed most appropriate. Because it is necessary to comprehensively consider the specific background, resource conditions and management experience of the project. This balance involves not only quantitative data, but also qualitative factors such as organizational culture, teamwork, experience judgment and actual on-site conditions. Therefore, the use of qualitative research design can better reveal the complex process of managers making decisions in specific situations and help understand how they achieve this balance in theory and practice. This chapter outlines the research philosophy, methodological choices, data collection procedures, analytical strategy, ethical considerations, and methodological limitations.

Research Philosophy and Approach

An interpretivist philosophical stance underpins this research, acknowledging that understanding human actions, like managerial decision-making, requires interpreting the meanings individuals ascribe to their experiences (Cuthbertson et al., 2020). This aligns with the study's focus on the subjective processes managers use to balance objective AI outputs with subjective contextual factors. Consequently, an exploratory qualitative approach was adopted. This approach is particularly suited for investigating phenomena that are not yet fully understood, allowing for in-depth exploration of participants' perspectives and the identification of emergent themes related to the optimal versus appropriate decision-making dynamic (Lim, 2024).

Theoretical Underpinning: Thematic Analysis and Grounded Theory Elements

The primary analytical framework employed is Thematic Analysis (TA), following the steps outlined by (Braun & Clarke, 2023). TA provides a flexible yet rigorous method for identifying, analyzing, and reporting patterns (themes) within qualitative data, making it well-suited to uncovering the core strategies managers use when interacting with AI.

To further enhance the analysis, particularly in understanding the *process* of adaptation and the development of managerial strategies, elements of Grounded Theory (GT) were incorporated, specifically techniques like constant comparison (Timonen et al., 2018). Constant comparison involves continually comparing data segments (e.g., interview transcripts) with emerging codes and themes. This iterative process helps refine thematic definitions and allows for the development of a nuanced understanding of *how* managers actively negotiate between AI recommendations and practical constraints, thereby directly addressing the dynamic nature implied in the research question. This blended approach leverages the structural clarity of TA while incorporating the process-oriented insights facilitated by GT techniques.

Contextual Focus: China's Construction Industry

The study is specifically situated within China's construction industry due to its unique characteristics: rapid AI adoption, significant state influence, large-scale projects, and distinct regulatory and cultural contexts (Yan et al., 2023; Yu et al., 2024). This specific focus allows for a rich, context-dependent understanding of the research problem, acknowledging that managerial practices are deeply embedded within their operational environment.

Data Collection

As shown in Figure 1, we adopted a multifaceted data collection strategy to ensure richness and achieve triangulation. Figure 1 illustrates the iterative flow from purposive sampling to thematic analysis, highlighting the triangulation process that enhances data robustness—a visual aid to the multifaceted strategy described. The flowchart depicts stages including purposive sampling (targeting state-owned enterprises, private firms, consultancies), semi-structured interviews, data familiarization, open coding (using NVivo), axial/thematic coding (using NVivo, Braun & Clarke approach), and validation/triangulation (inter-coder checks, member checking, secondary data), highlighting iterative refinement based on constant comparison.

Primary Data: Expert Interviews:

1. **Sampling:** Purposive sampling targeted 15 experts. This initial range (12-20) was informed by common practices in qualitative exploratory research within management studies aiming for thematic depth. (a final number achieved through iterative recruitment) with direct experience in managing construction projects involving AI applications in China. Participants included senior project managers, technology leads, and department heads.

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2. **Diversity:** Efforts were made to include participants from state-owned enterprises (SOEs), private companies, and consulting firms to capture diverse organizational perspectives.
3. **Protocol:** Semi-structured interviews allowed for flexibility while ensuring key topics were covered, focusing on experiences with AI tools, decision-making processes when evaluating AI outputs, encountered challenges, and strategies for balancing "optimal" versus "appropriate" solutions. Interviews were conducted remotely via secure video conferencing, audio-recorded with consent, and transcribed verbatim. Participants were selected based on criteria including a minimum of 10 years' experience in construction management, direct involvement in AI-supported projects (e.g., predictive analytics or BIM enhancement), and representation across organizational types (SOEs, private firms, consultancies). Recruitment ceased at 15 participants because thematic saturation was demonstrably reached; interviews 14 and 15 yielded no new significant concepts or themes related to the core research question, confirming the adequacy of the sample size for capturing the phenomenon under investigation.

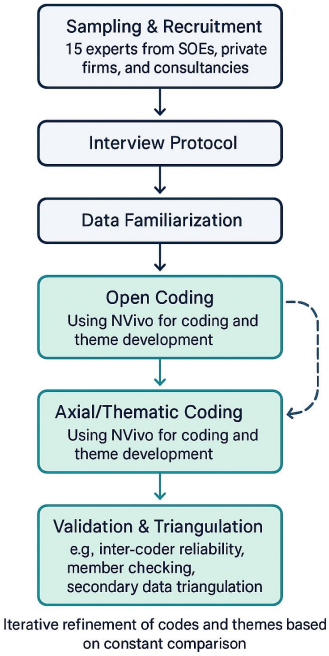

Figure 1 Qualitative Research Methodology Flowchart

Secondary Data:

1. **Sources:** Publicly available data from the National Bureau of Statistics of China, relevant government policy documents (e.g., AI development plans), industry association reports, and company publications were collected.
2. **Purpose:** This data served to contextualize interview findings, triangulate emergent themes (e.g., verifying reported industry trends), and provide a broader backdrop of AI adoption patterns and challenges in the Chinese construction sector.

Data Analysis Process

The analysis followed a systematic process integrating TA and GT elements, facilitated by NVivo software. NVivo was selected for its robust capacity to handle large qualitative datasets and support iterative coding. Specifically, it enabled efficient organization of transcripts, systematic application of open and axial codes, visualization of relationships between codes through mapping features, and execution of complex queries to support the constant comparison technique borrowed from grounded theory, thereby enhancing analytical rigor. Its tagging and query functions enabled efficient theme development across 15 transcripts and secondary sources.

1. **Familiarization:** Repeated reading of transcripts and secondary data to gain deep understanding.
2. **Initial Coding:** Systematically coding interesting features across the entire dataset ("open coding").
3. **Theme Development:** Collating codes into potential themes, examining relationships between codes and themes ("axial coding" inspiration from GT). Constant comparison was used here to refine code definitions and ensure themes accurately reflected the data related to the optimal/appropriate balancing act.
4. **Reviewing Themes:** Checking if themes work in relation to coded extracts and the entire dataset, generating a thematic map.
5. **Defining and Naming Themes:** Ongoing analysis to refine specifics of each theme, generating clear definitions and names.
6. **Validation:** Rigor was enhanced through:

A. Inter-coder reliability: A. Inter-coder reliability: A subset of transcripts (e.g., 20% of the data) was independently coded by a second researcher. Initial agreement yielded a Cohen's Kappa of [Insert Value, e.g., 0.78], indicating substantial agreement. Subsequent discussion resolved discrepancies, leading to consensus on code application and refinement of the codebook.

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B. Member checking: Key findings and interpretations were shared with select participants to verify their resonance with lived experiences.
C. Triangulation: Comparing findings from interviews with secondary data sources.

Ethical Considerations

Ethical conduct was paramount throughout the research process:
1. **Informed Consent:** Participants received detailed information about the study's purpose, procedures, risks, benefits, and their right to withdraw before providing written consent.
2. **Anonymity and Confidentiality:** Participant and organizational identities were anonymized using pseudonyms in transcripts and reports. Data was stored securely on encrypted devices.
3. **Data Security:** Adherence to institutional data protection guidelines was maintained.

Methodological Limitations

1. **Generalizability:** As a qualitative study focused on a specific context, findings may not be directly generalizable to all construction sectors or geographic regions. The aim is analytical generalization – contributing theoretical insights applicable elsewhere.
2. **Potential for Bias:** Self-reported data from interviews may be subject to recall bias or social desirability bias. Triangulation with secondary data aimed to mitigate this.
3. **Dynamic Field:** AI technology and its adoption are rapidly evolving, meaning findings reflect a specific point in time.

These limitations were considered during data interpretation and are acknowledged in the discussion of findings.

Results

This chapter presents the findings derived from the thematic analysis of interview data, triangulated with secondary sources, concerning how managers in China's construction industry navigate the balance between AI-driven "optimal" solutions and practically "appropriate" decisions. The analysis involved systematic coding and theme development, including open and axial coding facilitated by NVivo. (Detailed steps, coding examples, and the constant comparison process are provided in Table 1 and Table 2.) Following familiarization with the data, the analysis identified five core themes that illuminate the complexities of this balancing act (shown in Figure 2) : (1) Decision Balance & Human Adjustment; (2) Data & Technology Challenges; (3) Human-AI Collaboration and Trust; (4) External Constraints & Contextual Factors; and (5) Sector-Specific Dynamics. These themes emerged from a systematic analytical process involving deep familiarization with interview and secondary data, rigorous open and axial coding facilitated by NVivo software, and iterative refinement using constant comparison techniques derived from grounded theory. Inter-coder reliability checks and member checking were employed to enhance validation. (Further details on the coding process and preliminary code examples can be found in Appendix A). The following sections elaborate on each of the five core themes identified.

This preliminary analysis reveals that AI integration in construction across SOEs, private enterprises, and consultancies involves a consistent tension between "optimal" AI solutions and "appropriate" real-world adaptations. Key challenges include data quality and integration, regulatory compliance, and the need for human oversight, while strategies differ by organizational type—SOEs emphasize policy-driven validation, private firms focus on cost and innovation, and consultancies prioritize ethical customization. These insights lay the groundwork for deeper thematic analysis in subsequent research phases.

Theme 1: Decision Balance & Human Adjustment

This theme encapsulates the core process observed: managers actively weighing AI recommendations against their own experience and contextual knowledge to arrive at actionable decisions. Participants consistently described AI outputs not as final directives, but as valuable inputs requiring human interpretation and adaptation.

1. Managers emphasized their role in validating AI outputs against practical realities. As Manager[A] (SOE) stated, "***The system might suggest the theoretically fastest schedule [optimal], but it doesn't know about the specific ground conditions we found last week. We have to adjust [appropriate].***" This highlights the need to integrate real-time, site-specific knowledge that AI models might lack.

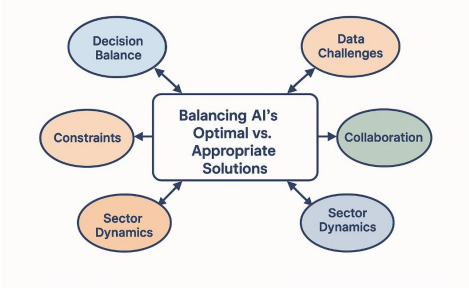

Figure 2 Thematic Map of AI Solution Balancing

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2. Experience and intuition were frequently cited as crucial counterbalances. Manager[B] (Private Firm) explained, "***AI recommended a material allocation based purely on cost [optimal]. But my experience tells me that for this specific application, a slightly costlier but more durable material is better long-term [appropriate]. The algorithm doesn't capture that nuance.***"
3. The "human adjustment" often involved simplifying or modifying AI's complex outputs to make them understandable and implementable for site teams. This iterative process of balancing algorithmic suggestions with practical feasibility was central to decision-making.

Theme 2: Data & Technology Challenges

This theme addresses the significant practical hurdles related to data quality and technological limitations that directly influence managers' ability and willingness to rely on AI's "optimal" solutions. Poor data inputs were seen as directly compromising the reliability of AI outputs.
1. Data fragmentation and inconsistency were major concerns. "***Garbage in, garbage out,***" stated Technology Lead[C] (Consultancy). "***If the initial data from subcontractors isn't standardized or accurate, the AI analysis [optimal] is fundamentally flawed. We spend more time cleaning data than using the insights***." This resonates with industry reports indicating variable levels of data maturity across firms. For instance, while BIM adoption is increasing, its effective integration for data consistency remains a challenge. Studies indicate varied implementation levels; for example, a 2019 study found BIM utilization at ~35% among listed AEC companies over the preceding decade (Babatunde et al., 2020), while others noted low project-level adoption rates and persistent difficulties with data exchange, thereby limiting the quality of data available for AI (Sang et al., 2020).
2. Technological limitations, such as the inability of some AI tools to process unstructured data or adapt to rapidly changing site conditions, also necessitated managerial intervention. This often led managers to favour less "optimal" but more robust traditional methods when AI reliability was questionable.

Theme 3: Human-AI Collaboration and Trust

This theme explores the evolving relationship between managers and AI systems, focusing on the development of trust and the nature of collaboration. Trust was not automatic but had to be earned through consistent performance and transparency.
1. Building trust required AI systems to demonstrate tangible benefits and reliability over time (as shown in Figure 3). Manager[D] (SOE) noted, "***Initially, we were skeptical. But after the scheduling AI correctly predicted several potential delays [demonstrating value], we started trusting its recommendations more, using them as a strong baseline [collaboration].***"
2. Transparency was key. "***If we don't understand why the AI suggests a certain approach [optimal], it's hard to trust it fully,***" said Manager[E] (Private Firm). "***Black box algorithms make it difficult. We prefer systems where we can interrogate the logic.***" This lack of transparency often led managers to default to their own judgment, modifying the AI's suggestion.
3. Effective collaboration was described as synergistic, with AI handling complex data analysis and managers providing strategic oversight and contextual understanding.

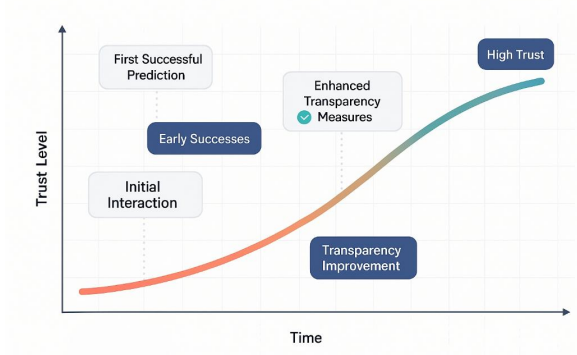

Figure 3 Trust Development in Human-AI Collaboration

Theme 4: External Constraints & Contextual Factors

This theme highlights the significant influence of the broader operational environment, including regulations, client demands, and market pressures, on the adoption and adaptation of AI solutions. These external factors often force deviations from purely "optimal" paths.
1. Regulatory compliance frequently necessitated adjustments to AI-driven plans. "***The AI might propose the most cost-effective site layout [optimal], but it doesn't always align perfectly with local safety regulations or environmental permits. Human oversight is essential to ensure compliance [appropriate],***" explained Manager[F] (SOE).
2. Client expectations and contractual obligations could also override AI recommendations. "***Sometimes the client insists on a specific supplier or method, even if the AI suggests a cheaper alternative [optimal]. We have to balance technical optimization with relationship management [appropriate],***" stated Manager[I] (Private Firm).

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3. The broader economic and policy context in China, emphasizing rapid development and technological advancement, created both pressure to adopt AI and challenges in ensuring its thoughtful, appropriate implementation amidst tight deadlines and competitive pressures.

Theme 5: Sector-Specific Dynamics

This theme acknowledges that the way managers balance optimal and appropriate solutions varies depending on the specific construction sub-sector (e.g., infrastructure, residential, commercial).

1. Large-scale infrastructure projects, often involving SOEs, showed greater propensity for adopting sophisticated AI for planning and risk management due to project complexity and scale, though bureaucratic processes could slow adaptation. As one participant noted, the anticipated productivity gains, often highlighted in government planning documents promoting AI adoption pilots, served as a key incentive for exploring these technologies, despite the complexities of implementation within established protocols (Yigitcanlar et al., 2024).
2. In contrast, smaller residential or commercial projects, often managed by private firms, might use AI more selectively, prioritizing tools with immediate, tangible benefits (e.g., cost estimation) and relying more heavily on managerial experience due to tighter budgets or less complex data environments. Manager[J] (Private Firm, Residential) commented, *"We use some AI for estimates, but for day-to-day site decisions, my gut feeling and direct observation are still primary."*

Sector-Specific Dynamics in Balancing Optimal and Appropriate Solutions

This subsection examines how different organization types in Chinese construction management balance AI's optimal solutions with appropriate, context-sensitive approaches. The following analysis draws from interview data to highlight sector-specific dynamics across SOEs, private firms, and consultancies.

Table 3 Comparison of Organizational Approaches to Balancing Optimal and Appropriate Solutions

Organization Type	Decision-Making Processes	Data Handling	Trust in AI	Response to External Constraints
SOEs	Policy-driven with multi-level approvals	Centralized, governed by strict protocols	Cautious, requiring human oversight	Prioritize regulatory compliance and social goals
Private Firms	Agile, market-oriented decisions	Flexible, cost-focused integration	Pragmatic, tied to return on investment	Adapt quickly to market and client needs
Consultancies	Client-centric, evidence-based customization	Cross-sector data synthesis, secure	Trust via expertise validation	Balance client demands with ethical/regulatory limits

Table 3 summarizes the key differences in organizational approaches, including decision-making processes, data handling, trust in AI, and responses to external constraints.

For example, SOEs emphasized regulatory compliance as a key constraint, while private firms prioritized market agility. Consultancies, meanwhile, focused on integrating client-specific needs into AI solutions. These organizational differences underscore the sector-specific dynamics of AI integration, which are further explored in the Discussion section in relation to existing literature and practical implications

Summary of Findings

The findings indicate that managers in China's construction industry engage in a complex, dynamic process of balancing AI's potential for optimization against practical realities. This involves active "human adjustment" based on experience and context, navigating significant data and technology challenges, building trust through performance and transparency, responding to potent external constraints, and adapting strategies based on sector-specific demands. AI is viewed as a valuable tool, but human judgment remains central in translating its "optimal" outputs into "appropriate" and actionable solutions within the specific operational context.

Discussion

This chapter interprets the findings presented in Chapter 4, discussing their significance in relation to the existing literature and the study's central research question regarding how managers in China's construction industry balance AI's "optimal" solutions with "appropriate" practical applications. Moving beyond a summary of results, this discussion delves into the theoretical contributions, practical implications, limitations, and future research directions stemming from the observed complexities of human-AI interaction in this specific context.

Synthesis of Findings and Connection to Literature

The findings underscore that the integration of AI in construction is not a straightforward process of adopting technically superior solutions, but rather a nuanced negotiation mediated by human judgment. The core finding—that managers actively engage in "Decision Balance & Human Adjustment" (Theme 1)—resonates with, yet significantly extends, existing literature on technology acceptance and human-computer interaction. Furthermore, these themes are interconnected. For instance, the persistent "Data & Technology Challenges" (Theme 2) directly exacerbate the need for "Decision Balance & Human Adjustment" (Theme 1), as managers must compensate for unreliable AI inputs. This unreliability, in turn, hinders the

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development of "Human-AI Collaboration and Trust" (Theme 3), particularly for less transparent systems. Simultaneously, "External Constraints" (Theme 4), such as rigid regulations, often dictate the parameters within which 'human adjustment' must occur, sometimes forcing deviations from AI optima regardless of data quality or trust levels.

This situation is analogous to architectural design, where technologies like Computer-Aided Design (CAD), while offering powerful optimisation capabilities, also function as mediators requiring significant human judgment to align outputs with specific client needs, site conditions, and regulatory contexts. Examining this parallel is valuable because it underscores a fundamental point for AI adoption in construction: the challenge lies not just in the technology itself, but in integrating its logic within the existing complex, socio-technical system of project delivery, which inherently demands negotiation and adaptation by managers. Therefore, much like in architecture, AI in construction does not eliminate the need for human expertise and contextual negotiation; rather, it reshapes how that negotiation occurs, underscoring the manager's critical role as an "adaptive integrator" rather than a passive user of technological outputs.

For this reason, the introduction of technology is actually more like a "negotiation" - in this negotiation, technical suggestions are constantly reconciled with human experience, intuition and ethical judgment to achieve the best design solution. While studies acknowledge managerial oversight (Uusitalo et al., 2024), this research illuminates the proactive and adaptive nature of this oversight in construction. Managers are not just validators; they are active sense-makers and context-weavers, translating abstract AI outputs into grounded actions.

The persistent "Data & Technology Challenges" (Theme 2) confirm known issues in the industry (Sarta et al., 2021), but this study highlights how these challenges directly fuel the need for human adjustment, often forcing managers to prioritize robustness or compliance over theoretical optimality. Similarly, the findings on "Human-AI Collaboration and Trust" (Theme 3) align with literature emphasizing trust as crucial (Shin, 2021), but add nuance by showing how trust is built incrementally through demonstrated value and contingent on transparency, particularly impacting the willingness to adopt less interpretable AI recommendations.

The strong influence of "External Constraints & Contextual Factors" (Theme 4) reinforces the importance of context stressed in socio-technical systems theory (K. Wang et al., 2023) but specifies how regulatory pressures and client demands in the Chinese construction context actively shape the definition of an "appropriate" solution, sometimes diverging significantly from an AI's "optimal" one. Finally, the "Sector-Specific Dynamics" (Theme 5) suggest that the balancing act is not uniform, adding granularity to our understanding of AI adoption patterns across different organizational types and project scales within the industry.

Theoretical Implications: Towards an Adaptive Human-AI Interaction Framework

This study offers several key theoretical contributions:

1. **Refining Human-AI Interaction Models:** Current models often portray humans as either supervisors or collaborators with AI (Sowa et al., 2021). This research suggests a more dynamic role, particularly in operational fields like construction: the manager as an adaptive integrator. This role involves not just using AI outputs but actively synthesizing them with tacit knowledge, contextual intelligence, and foresight – capabilities currently beyond typical AI.
2. **Challenging Notions of "Optimality":** The findings challenge a purely techno-centric view of "optimality". In practice, "optimal" is redefined through the lens of contextual "appropriateness". True optimization in complex environments like construction appears to be a hybrid outcome, emerging from the synergy between algorithmic calculation and situated human judgment. This calls for theoretical frameworks that explicitly incorporate contextual appropriateness alongside algorithmic efficiency.
3. **Extending the Technology Acceptance Model:** The manager as an "adaptive integrator" extends the Technology Acceptance Model by suggesting that perceived usefulness and ease of use are mediated by contextual modulators and managerial interpretation, not just individual attitudes. Similarly, the trust dynamics observed (Theme 3) align with Karhapää (2022) model, where transparency and performance reliability incrementally build trust, though this study highlights the critical role of contextual adaptation absent in their framework. This expanded framework explicitly incorporates: A. Algorithmic Input (the AI's "optimal" suggestions frequently mentioned by participants). B. Contextual Modulators (reflecting Theme 2 findings on data/tech issues and Theme 4 findings on external constraints like regulations). C. Managerial Interpretation Engine (capturing Theme 1's emphasis on experience/intuition and Theme 3 aspects related to trust/skepticism). D. Adaptive Integration Process (representing the iterative balancing and adjustment process described by managers, linking Theme 1 and Theme 5 sector dynamics). E. Appropriate Action (the final, contextually-sound decision resulting from this human-mediated process). This framework
4. **Proposing an Expanded Framework:** Based on the findings, we propose an expansion of existing technology adoption/interaction frameworks for AI in operational settings. This expanded framework should explicitly incorporate (As shown in Figure 4):

A. Algorithmic Input: The "optimal" recommendation from AI.

B. Contextual Modulators: Data reliability, technological limitations, regulatory landscape, client/stakeholder pressures, organizational culture, sector norms.

C. Managerial Interpretation Engine: Experience-based heuristics, risk assessment, ethical judgment, strategic alignment.

D. Adaptive Integration Process: The iterative cycle of evaluating, adjusting, implementing, and learning that leads to the...

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E. Appropriate Action: The final, contextually-sound decision. This framework moves beyond linear models to capture the dynamic, multi-factor negotiation central to effective AI use in practice.

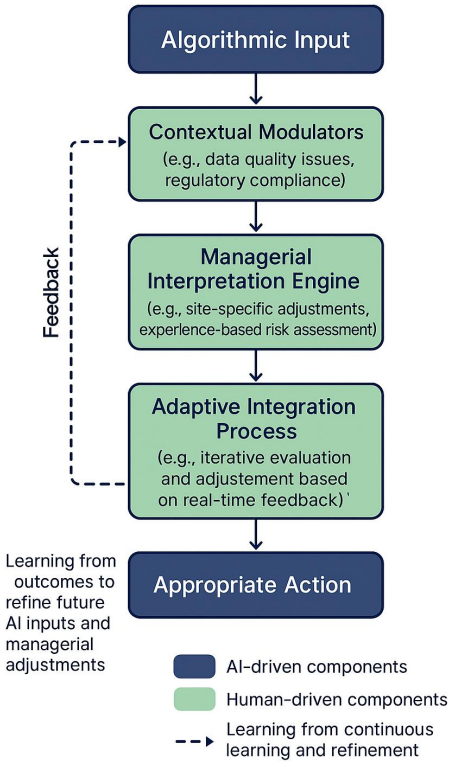

Figure 4 Adaptive Human-AI Interaction Framework

Practical Implications

The findings offer actionable insights for various stakeholders:

1. **For Construction Managers:** Recognize that human judgment is not a barrier to AI but its essential complement. Develop skills in critically evaluating AI outputs and integrating them with contextual knowledge. Foster open communication channels for sharing site-specific insights that AI might miss.
2. **For AI Developers:** Prioritize transparency and interpretability ("explainable AI") alongside predictive accuracy. Design systems that facilitate easy integration of human feedback and contextual overrides. Develop tools that are robust to imperfect data common in construction.
3. **For Organizations:** Invest in data infrastructure and standardization. Promote a culture that values both technological innovation and experiential knowledge. Provide training that focuses not just on using AI tools but on collaborating effectively with them.
4. **For Policymakers:** Develop regulations that encourage AI adoption while ensuring safety, ethical use, and accountability. Support initiatives for workforce training and data standardization within the industry. Recognize that "optimal" technological pathways may need adaptation to meet broader societal or environmental goals.
5. **For Performance Measurement:** Organizations may need to develop or adapt performance metrics. Beyond traditional Key performance indicators (cost, time, quality), new metrics might be needed to evaluate the effectiveness of the "adaptive integration" process itself and the long-term value derived from "appropriate" solutions, which might not always align with short-term "optimal" AI targets.

For managers, training should include workshops on interpreting AI outputs (e.g., understanding predictive analytics dashboards) and scenario-based exercises integrating site-specific variables. AI developers should prioritize features like real-time feedback loops allowing managers to input contextual overrides (e.g., weather disruptions) and visual explainability tools to demystify "black box" outputs. Policymakers could incentivize data standardization through tax credits for firms adopting interoperable BIM platforms.

Limitations and Future Research

While this study provides valuable insights, its limitations, detailed in Chapter 3 (qualitative nature, contextual specificity, potential biases), suggest avenues for future research:

1. **Quantitative Validation:** Complementary studies using large-scale quantitative data could assess the generalizability of these findings and potentially model the factors influencing the optimal/appropriate balance.

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2. **Cross-Cultural Comparison:** Comparative studies in different national contexts could reveal how cultural and regulatory variations shape human-AI interaction in construction.
3. **Longitudinal Studies:** Tracking AI adoption and managerial adaptation over time would provide insights into evolving practices and the long-term impacts on project outcomes and organizational structures.
4. **Exploring New AI Applications:** As new AI tools (e.g., adaptive learning systems, advanced robotics) emerge, research should continue to explore how they reshape managerial roles and decision-making processes.

In conclusion, this study reveals that integrating AI into China's construction industry involves a complex adaptive process led by managers. They actively balance AI's "optimal" suggestions against a web of practical constraints and contextual factors to arrive at "appropriate" solutions. This deepens our understanding of human-AI interaction in demanding operational settings and underscores the enduring value of human judgment in the age of artificial intelligence. The theoretical and practical implications highlighted here provide a foundation for improving AI design, managerial practices, and policy formulation in construction and potentially analogous sectors.

Conclusion

Summary of Key Insights

This study investigated the critical yet underexplored process by which managers in China's construction industry interpret and balance the "optimal" solutions generated by AI with the "appropriate" actions required by practical realities. The research revealed that this is not a passive acceptance of technology but an active, dynamic negotiation. Managers engage in significant "human adjustment", leveraging their experience and contextual understanding to adapt AI recommendations. This process is heavily influenced by persistent data and technology challenges, the necessary cultivation of trust in human-AI collaboration, potent external constraints including regulatory and client pressures, and variations specific to different construction sectors. Ultimately, human judgment remains central in transforming AI's potential into effective, actionable outcomes within the complex operational landscape of construction. A key revelation is the proactive role of managers as "adaptive integrators", actively reshaping AI outputs rather than passively overseeing them, highlighting the primacy of human agency in successful technology integration.

Theoretical Contributions

Theoretically, this study contributes to a more nuanced understanding of human-AI interaction in operational settings. It challenges purely techno-centric views of "optimality" by demonstrating its practical contingency on contextual "appropriateness". By highlighting the manager's role as an "adaptive integrator", the research suggests refinements to existing technology adoption and interaction models, proposing an expanded framework that explicitly accounts for contextual modulators and the managerial interpretation engine in mediating AI use. Crucially, it identifies and emphasizes the manager's role as an "adaptive integrator", offering a more dynamic perspective than traditional supervisor/collaborator models in human-AI interaction literature.

Practical Implications

Practically, the findings offer guidance for managers (emphasizing critical evaluation skills), AI developers (prioritizing transparency and adaptability), organizations (investing in data infrastructure and collaborative culture), and policymakers (developing supportive yet realistic regulatory frameworks). These insights aim to foster more effective and synergistic human-AI collaboration within the construction industry and potentially analogous fields.

Limitations and Future Research Directions

Acknowledging the study's qualitative nature and specific contextual focus, avenues for future research include quantitative validation across broader samples, cross-cultural comparative studies, longitudinal analyses of AI adoption trajectories, and investigation into the impact of emerging AI technologies on managerial practices.

Final Remarks

This research illuminates the vital synergy required between AI's analytical power and human judgment in complex, high-stakes environments like construction. By detailing how managers in China navigate the optimal-appropriate tension, the study underscores that the successful integration of advanced digital tools hinges critically on recognizing and leveraging human expertise. As AI continues its rapid evolution, fostering this human-AI partnership—grounded in transparency, trust, and adaptability—will be paramount for realizing technological potential while ensuring practical efficacy and responsible innovation in the built environment and beyond. The path forward lies not in replacing human insight, but in augmenting it intelligently.

Conflict of Interest

The authors declare no conflict of interest.

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Appendix A: Detailed Data Analysis Procedures

1. Data Preparation

A. Organizing and Archiving: Digitization and Desensitization: All interview recordings and transcripts have been digitized. Sensitive information such as specific project names, financial figures, and personal identifiers has been anonymized to comply with research ethics and confidentiality requirements; Software Readiness: Files are stored in a format compatible with qualitative analysis tools like NVivo or Atlas.ti for subsequent coding and thematic analysis.
B. Ensuring Completeness Verification: Each transcript has been cross-checked for accuracy, including interview date, time, location, and anonymized interviewee details. Background information (e.g., project types, organizational roles) is documented to ensure traceability.

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C. Data Security: A secure storage scheme using encrypted cloud servers has been established, adhering to ethical standards and confidentiality protocols outlined in the informed consent agreements signed by interviewees.

2. Familiarization

A. Initial Observations: Recurring Keywords: “Optimal vs. appropriate solutions”, “data quality”, “human-machine collaboration”, “policy constraints”, “cost control”, “ethical considerations”.
B. Phenomena: Frequent adjustments of AI-generated “optimal” solutions to “appropriate” ones due to real-world constraints; challenges in data integration across platforms; emphasis on human oversight in decision-making.

3. Initial Coding (Open Coding)

Linear coding: For each interview, identify and mark key concepts and phenomena line by line. Table 1 shows the initial codes generated:

Table 1 Initial Coding Codes from Interview Analysis

Category	Codes
AI Recommendations and Adjustments	"AI optimal solution", "appropriate solution adjustment", "continuous operation vs. single shift", "model output vs. site conditions", "human intervention", "human-machine responsibility"
Data Issues	"insufficient data quality", "data integration difficulties", "BIM model conversion losses", "lag in real-time data updates", "data desensitization", "multi-source data integration"
Technology and Implementation	"predictive analytics", "multimodal AI", "laser radar scanning", "UWB positioning", "intelligent scheduling", "algorithm ethics", "four-dimensional validation"
Management and Decision-Making	"policy compliance review", "economic and social risks", "human experience and judgment", "approval processes", "cost-benefit trade-off"
Enterprise and Industry Characteristics	"state-owned vs. private enterprise differences", "consultancy strategies", "cross-border regulation", "industry innovation and risks"
Background Condition Codes	"prefabricated residential project", "labor shortage", "environmental pressure", "political mandate"
Technical Practice Codes	"component hoisting path optimization", "concrete curing decisions", "GPS to UWB technology transition"
Decision Trade-Off Codes	"conflict between optimal and appropriate solutions", "policy, economic, social considerations"

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4. Axial Coding

Group similar codes: Aggregate preliminary codes into higher-level categories to provide a structured framework for analysis. The categories include Table 2:

Table 2 Axial Coding Categories and Codes

Axial Coding Category	Codes / Themes
Decision Balance & Human Adjustment	"optimal solution", "appropriate solution", "human adjustment", "four-dimensional validation", "policy-economic trade-off"
Data & Technology Challenges	"data quality", "multi-platform data integration", "real-time issues", "technology implementation barriers", "model limitations"
Human-AI Collaboration and Trust	"human-machine interaction", "experience supplementing AI", "technology reliance vs. human wisdom", "training and cultural acceptance"
External Constraints & Contextual Factors	"regulatory requirements", "policy compliance", "environmental conditions", "social factors", "market demand"
Sector-Specific Dynamics	"state-owned vs. private enterprise differences", "consultancy strategies", "cross-border regulation challenges", "industry innovation and risks"

5. Constant Comparison Method

1. **Similar Scenarios**: Across interviews, AI's "continuous operation" suggestions are adjusted for feasibility, showing a shared need for practical adaptation.
2. **Data and Tech Limitations**: SOEs and private firms both note data scarcity, but private firms use riskier acquisition methods.
3. **Differences by Context**: SOEs face stricter policy constraints, while private firms prioritize cost and brand, and consultancies navigate ethical data use.

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Four-dimensional model analysis of the hidden barriers to the first promotion of college graduates and their breakthroughs

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Abstract

The first career promotion of college graduates is the most important step in the early stage of their career development. In order to help graduates break through the hidden barriers to initial promotion, this paper uses Porter and Shepherd's endogenous and exogenous barriers theory and David McClan's competency model to analyze the hidden barriers to graduates' initial promotion, constructs a four-dimensional model to solve the problem, and conducts statistical analysis of 1315 questionnaires in 12 provinces, autonomous regions and municipalities directly under the central government. The quality of micro-leaders and the ability to deal with on-site incidents are significant factors affecting the initial promotion of graduates, and learning and proficient in the content of four-dimensional models are important ways for graduates to break through hidden barriers.

Keywords : University graduates; Initial promotion; implicit barriers; Four-dimensional model

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Background

According to the latest data released by the Ministry of Education, the class of 2025 is expected to be 12.22 million college graduates, and there is no doubt that 2025 will still be a "difficult year for employment". Most of the graduates do not know what abilities or skills they need to prepare when they are first promoted to the post, and they have already understood the competitive pressure of the business society and the complexity of real life in the early stage of employment, and they are no longer enthusiastic about career development. Obviously, there are hidden barriers to first-time promotion. The so-called implicit barriers refer to the hidden, invisible and unexplicit barriers set up for relevant subjects to enter new fields, and the implicit barriers are difficult to find out and break through. Based on the experience of guiding graduates for the first promotion of enterprises in 32 sub-industries as an expert in enterprise management, this paper analyzes the phenomenon and influencing factors of the initial promotion of college graduates, and tries to construct a model through investigation and theoretical analysis to reveal the dimensions and main contents of the hidden barriers to the initial promotion of graduates.

Theoretical analysis framework and model construction

Analysis of the hidden barriers to the first promotion of college graduates

The term implicit barriers comes from the field of international trade, so the current research on implicit barriers is mainly reflected in the implicit trade barriers. Porter pointed out that market barriers are barriers that prevent other competitors from entering a market, and Shepherd divides such barriers into endogenous barriers and exogenous barriers, and Karakaya and Stah (1989) believe that endogenous barriers are barriers that are set up by the original market actors according to the reaction expectations of new market entrants to discourage later entrants. Gableeta (1995) found that different types of barriers are different in importance for different markets. Hidden barriers are invisible barriers, and in reality, most graduates feel that it is difficult to get promoted but cannot clearly explain what the obstacles are. Crites and Swanson believe that occupational barriers are all the factors related to career development that hinder the achievement of career goals, and can be divided into two dimensions: individual internal factors and external environmental factors that hinder career development. In the face of corporate promotion opportunities, the obstacles to the success of graduates' first promotion competition are first of all their own internal factors, that is, the endogenous quality and ability barriers that can be grown mainly in school education, and secondly, the technical process and management skills that can be accumulated mainly in the working environment and post "learning by doing" are regarded as exogenous double skill barriers.

In the early 80s of the 20th century, David McCland put forward the theory of competency, he believes that the potential deep-seated characteristics of employees can distinguish the excellent people in the work from the average, such characteristics include attitudes, values and self-image, motivation and traits and other competencies, the deep-seated characteristics are

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difficult to judge and identify through traditional testing methods, it can be seen that the individual's qualities and abilities are endogenous, not easy to observe from the individual but will affect personal development, and belong to the internal factors of the individual that promote or hinder career development. That is, endogenous implicit barriers. Yu Hao, Lu Huajing, Wenwu, Wei Huanchun and others respectively elaborated on the quality ability model, believing that quality ability is an intrinsic characteristic element of a person, and the cultivation of quality ability plays an important role in individuals and enterprises. Li Jin (2004) proposed that the quality of team leaders includes knowledge quality, personnel processing ability, operation research ability, excellent quality, and learning ability, and believed that team leadership quality can improve the efficiency of team operation. This paper defines the team leadership quality emphasized by many parties as the micro-leader quality, which refers to the character of dedication, advocating professional ethics, adhering to principles and leading by example, the craftsman spirit of pursuing excellence, self-discipline, positive and responsible, and following professional ethics to shape physical and mental quality, which can help graduates show their personal charm and create a good image in the process of work. On the basis of the quality and ability cultivated by the school, it is expected that graduates who win the competition for promotion for the first time should quickly accumulate the energy to break through the endogenous hidden barriers, enhance the ability to deal with on-site problems and events, improve the quality of micro-leaders, and further consolidate the foundation of personal competitiveness.

David McCland also pointed out that personal knowledge and skills are shallow, easy to judge through various professional tests, and can be obtained through external environments such as corporate training, which are external environmental factors that hinder the career development of graduates, that is, exogenous hidden barriers. Exogenous hidden barriers are usually reflected in the work technology process and on-site management skills, and better dual skills can be directly tested by superiors and colleagues at work to get praise and become the driving force for promotion. Yu Jing (2015) believes that the work process has a good role in promoting the production and operation activities of the enterprise, and graduates can prepare for the first promotion by learning and mastering all the work technical processes on the site. Sun Yingfei (2018) believes that the work technology process can effectively improve the work efficiency and quality, and Zhang Zheng Guo Qian (2021) believes that without procrastination, graduates can improve their personal performance through proficiency in the work technology process, and gradually build prestige and enhance their competitiveness in promotion. In terms of on-site management skills, Jin Xiaoya et al. (2009, 2016) expounded the importance of graduates' job skills and the development, cultivation and improvement of their skills from the perspective of employability skills of college graduates, which is even more important for graduates who want to be promoted to on-site managers (Bu Jingwen, 2018).

Domestic research on career development barriers also includes occupational barriers and hierarchical barriers. Guo Ruowei and Wang Hongkui (2008) discussed modern occupational barriers from the perspective of labor property rights, and believed that it was necessary to break through such occupational barriers. In addition to endogenous and exogenous career barriers, graduates should break through hierarchical barriers and achieve their first promotion. Li Xiaohua and Jin Jiuren (2010) conducted a study on the class barriers in the employment equity of college students, and believed that promotion is a leap in the hierarchy, and graduates need to break through the first level barrier when they are promoted from grassroots personnel to on-site managers.

Based on the theory of job promotion and the construction of the "individual ability model" of on-site managers to break through hierarchical barriers

For the analysis of the factors affecting promotion, Miao Wenli (2020) emphasized the need to examine from a multi-dimensional perspective, and created a job promotion probability model, which mainly believes that the potential job promotion opportunity is determined by the unobservable "individual ability", and when it reaches or exceeds the promotion threshold, Wei Xuhua et al. (2021) believe that if the impact of the team level gap can be understood and properly handled, the individual may get the promotion opportunity. The theory of job promotion is mainly studied from three aspects: the perspective of distribution, the perspective of providing incentives and the contradiction between the two. Restricted by the acquisition of internal information for enterprise promotion, the existing job promotion theory mainly discusses the influencing factors of individual promotion from the external environment such as distribution and incentive, and the author is to design the promotion mechanism for the enterprise as an enterprise human resource management expert and participate in the promotion evaluation and decision-making, and the internal information is the work data that the enterprise must provide, which provides a favorable opportunity for exploring the unobservable "individual ability". The "individual ability" of graduates is the core content of the promotion examination of enterprises, and the author intends to model the "individual ability" that college graduates need to break through the hierarchical barriers but cannot be observed, that is, to explicitly explain what kind of hidden barriers college graduates need to break through for the first promotion.

The development of things is the result of the combined action of internal and external causes, and external causes must act through internal causes. The hidden barriers to graduates' initial promotion are also caused by endogenous and exogenous barriers. If graduates want to be promoted to become qualified on-site managers, they first need to have the quality of micro-leaders, convince people with morality and character, and also have the ability to deal with on-site emergencies and convince people with ability. The ability to deal with events and the quality of micro-leaders in the ability of college graduates are not easy to be directly observed from individuals, that is, the internal influencing factors of individual promotion can only be observed through the performance of incident handling, and indirect observation of thinking and understanding is required. The endogenous barriers that hinder individual promotions are the barriers that graduates need to break through when they are first promoted. The breakthrough of exogenous barriers is based on the breakthrough of endogenous barriers, the work

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technical process and on-site management skills need to be accumulated in the enterprise working environment, and the graduates who want to be promoted not only need to be familiar with the work technology process, cultivate others with professional technology, but also need to master on-site management skills to serve others with management skills. Therefore, if graduates want to be promoted to become qualified on-site managers, they need to first improve their quality, enhance their ability to break through endogenous barriers, and then train dual skills to break through exogenous barriers and become the driving force for their first promotion. In practice, depending on the individual's situation, there may be cross-breakthroughs.

After breaking through the endogenous barriers, it is also necessary to break through the hierarchical barriers to achieve a higher level of jumping, that is, after the graduates fully grasp the key points of the work process, they will also be able to judge the work flow of all operators in the job site platform; Learn on-site management skills and be able to train subordinates; After improving your work ability, you also need to learn to reduce the work pressure of colleagues and supervisors, improve your self-image and be able to supervise the team through on-site management skills. The breakthrough direction of the hidden barriers for graduates to be promoted for the first time is as follows:

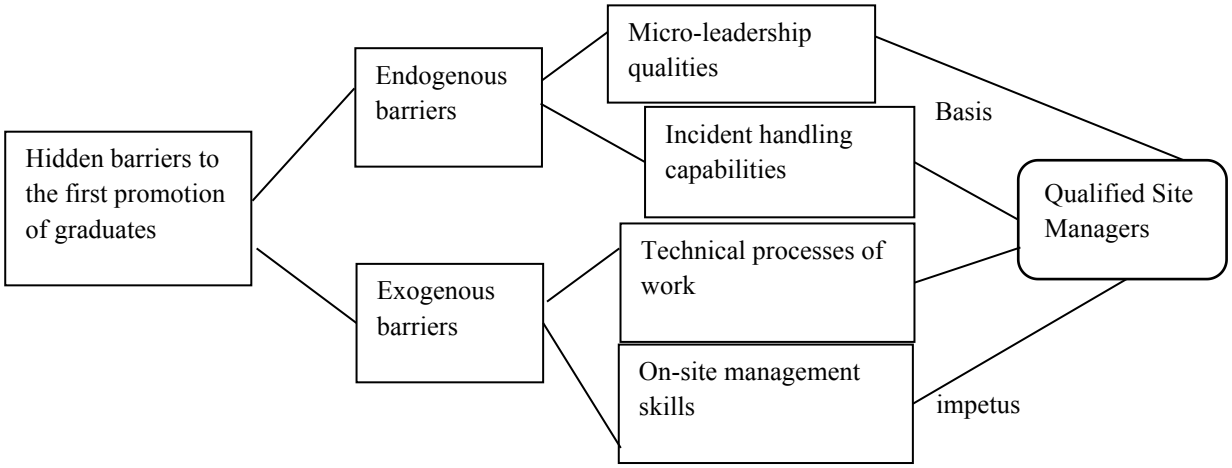

Figure 1 Classification and breakthrough direction of hidden barriers for graduates to be promoted for the first time

Because of the implementation of all rules and regulations and work processes, changes in various technical routes and technological processes, various material transfers, changes in on-site personnel and changes in customer needs, all these abnormal changes will directly affect the operation site, so that the operation site faces various emergencies and difficulties, which may affect the achievement of work goals. The task of the on-site manager is to deal with various emergencies and ensure that the work goal is achieved, so in the face of relatively complex job site changes in the enterprise, graduates need to quickly accumulate experience to make themselves have the corresponding on-site incident handling ability. The main content of on-site incident handling ability is to promote the achievement of work goals, learn to control emotions and humor in the face of emergencies, coordinate the disharmony and conceptualization of employees to express the main problems, be good at collecting credit and analyzing the causes of problems, observe and think and solve problems, and ultimately ensure that the work goals are achieved. In more complex cases, it is possible to let the boss and the human resources department know that the graduates have the trust of on-site management and achieve a breakthrough in endogenous barriers through the demonstration of micro-leadership qualities.

The work technology process refers to the sequence of activities of work items, and the work process includes the links, steps and procedures in the actual work process; At present, there are many primary management skills training such as team leaders, store managers, foremen, etc., and the implicit assumption is that the work technology process of the participants in the primary management skills training has been proficient, and only those who can do things will come to participate in the management training of managers and managers. If graduates in the early stage of employment want to be promoted to become on-site managers, they should first learn to do things, that is, they must understand all the technical processes of the site and be proficient in the key processes in the process, so as to improve their professional competitiveness. Quickly learn and master the five-level 10-step method of the work technology process: the first level of key steps, step 1, clarify the key steps, step 2, understand the key steps, the second level understand the whole process, step 3, clarify the whole process, step 4, understand the whole process, the third level of proficiency in the whole process, the fifth step of proficiency, the key steps, the 6th step of proficiency in the whole process, the fourth level of comparison of advantages and disadvantages, the 7th step to obtain the comparison process, the 8th step to compare and analyze the advantages and disadvantages of the process, the fifth level of optimization and innovation, the 9th step of optimizing the process or process, and the 10th step of micro innovation process or process. After practical experiments, the five-level 10-step method is effective in 31 sub-industries, 28 majors, or migrant workers who have not received professional training from universities. In order to be promoted to become on-site managers, graduates must improve the ten skills of implementing the best resource management on site: on-site manager role-playing, on-site management technology, supervision and management, work plan and material management, team equipment and tool management, communication and coordination inside and outside the team, team personnel education and training, standardized operation and quality assurance, team economic accounting and performance incentives, self-growth and improvement goal management, etc. The basic requirements of on-site management are that employees self-manage to develop

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industrial and commercial civilization habits, and make their daily work actions work efficiency meets the requirements, work quality assurance qualified, for graduates who want to strive for promotion, literacy, ability and technical process degree must meet higher requirements, always show high efficiency and quality fully qualified, so graduates should highlight on-site management skills when preparing for promotion. On-site management skills are mainly the main content of the graduates' first promotion to break through the barriers to exogenous employment. The above four aspects can be comprehensively summarized as the hidden barriers to initial promotion, and the following individual ability model can be constructed through the analysis of these four dimensions:

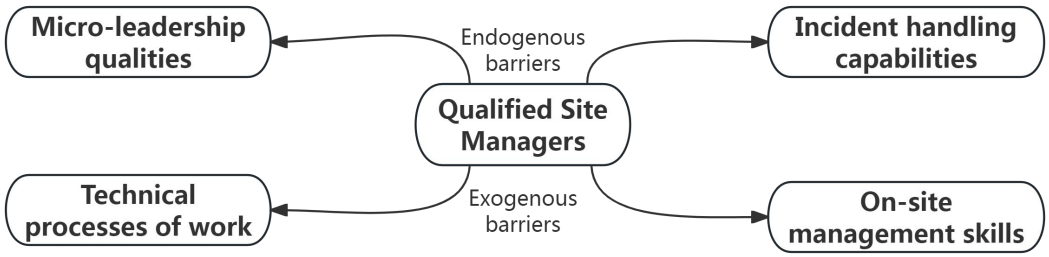

Figure 2 A four-dimensional model of the individual competence of qualified site managers

To sum up, in order to break through the hidden barriers of initial promotion and become qualified on-site managers, graduates must not only be proficient in professional work technology processes, but also need to have on-site management skills, excellent micro-leadership qualities, and strong on-site incident handling capabilities. In practice, the four-dimensional model of individual ability using quality, ability, technology and skills is used for targeted counseling, and the success rate is extremely high.

Empirical analysis

Description of the sample data

The data for this study were obtained from questionnaires and interviews. The survey subjects are college graduates and enterprise workers who deal with graduates, and the service industries such as logistics, catering, finance, film and television culture, and IT are the main service industries, and the manufacturing industries are mainly electronics, machinery, automation, robots, auto parts, etc.; The survey of the Pearl River Delta (Guangdong), the Yangtze River Delta (Shanghai, Zhejiang), the eastern coast, Hunan, Hubei and Guangxi and other 12 provinces, autonomous regions and municipalities directly under the central government and other densely populated areas, the data have a good representative of career development. The survey adopts statistical sampling methods, basically according to the province to find more than 3 regions, a region to find 3-4 enterprises, each enterprise to distribute 15-20 questionnaires.

The questionnaire survey was conducted from May to October. Form of questionnaire distribution: on-site distribution is used for those that are convenient for face-to-face distribution, and electronic questionnaires are distributed for those who are far away. After complete statistics, a total of 1423 questionnaires were received, 1315 valid questionnaires were received, and the effective rate of the questionnaire was 92.4%. The following is a brief analysis of the results of each survey of 1,315 valid questionnaires.

Basic characteristics of the sample

The main purpose of the questionnaire survey was to understand the current situation and expectations of college graduates who are promoted for the first time after they have secured employment, and to summarize the hidden barriers to the first promotion through their current situation and expectations for the first promotion. Questionnaires 1-8 are asked about the basic information of the respondents, i.e., gender, age, city of work, major, education and length of service. The main content of the questionnaire is the opinion of the influencing factors of college graduates' initial promotion from the perspective of the respondents, that is, by asking graduates about their quality, ability, technology and skills in the company's work, we can understand the situation of graduates' initial promotion after stable employment.

55.4% of women filled out the questionnaire, 10.8% more than men.

56.3% of the respondents were under the age of 25; followed by 26~30 years old 18%; while 31~35 years old and over 36 years old were 12.4% and 12.8% respectively; The results show that the respondents under the age of 25 believe that graduates have a strong expectation of a first promotion after a stable employment, and they themselves have strong expectations.

53.9% of the respondents majored in science and engineering, and 31.9% majored in liberal arts. 63.6% have a bachelor's degree or above, and 20.7% have a junior college degree; and 15.6% of those with high school, technical secondary school or vocational high school or below. 43% in the manufacturing sector and 29.4% in the service sector, while 26.8% chose other industries – with a lack of clarity about their industry.

45.6% worked within 12 months during the internship period and after obtaining the graduation certificate, and the proportions of the group who worked for 1-2 years and 3-5 years were similar, 13.2% and 13.4%, respectively. 27.5% have

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worked for more than 5 years. The results of the survey and interviews show that most of the survey groups with more than 5 years of service are graduates with teachers or team leaders, and the success of the graduates for the first time is also their success, and some enterprises also have incentive systems, and their interests are closely related. The group that has been working for about a year has just entered the social work, and all work is under the command of the boss, and the feeling is stronger.

Statistical analysis of the influencing factors of graduates' initial promotion

The influencing factors of this study do not have an obvious order in which factor A is stronger than factor B and stronger than factor C, so the option of our questionnaire design is a number of disordered categorical variables, which meets the conditions of chi-square test, so we use Stata statistical software to statistically analyze the influencing factors of graduates' initial promotion.

The results of the person chi-square test were carried out on the data of each option, and the results showed that different people believed that there were significant differences in the management skills, micro-leadership qualities, on-site incident handling ability and work technology process that affected the graduates' initial promotion (the chi-square value was high, P <0.001 for all items), that is, management skills, micro-leadership qualities, on-site incident handling ability and work technology process were all important factors affecting the success of different graduates' initial promotion.

The following is a chi-square value table of the relationship between the influencing factors such as management skills, micro-leadership quality, on-site incident handling ability and work technical process and the success of graduates' initial promotion after stable employment:

Table 1 Statistical analysis of chi-square value tables

category	Management skills	Micro-leadership quality of managers	On-site incident handling ability	Work technology process
Chi-square value	2945.90	2061.80	1809.30	1228.60
p-value	< 0.001	< 0.001	< 0.001	< 0.001

The chi-square values of the four factors in the table are arranged in descending order, that is, relatively speaking, the degree of success of graduates' initial promotion, management skills> managerial quality> on-site incident handling ability> work technology process. In the interview, it was found that familiarity with the work technology process is the basic requirement, and if you are not familiar with the work technology process, it is impossible to train as a manager, so it is weak in the "individual ability" influencing factors of promotion success. In addition, the relationship between workers and co-workers is harmonious, and it is also a basic requirement for the boss to know himself and remember his strengths.

Conclusions of the survey analysis

In order to successfully achieve the first promotion after the initial employment is stable, the graduate group who has worked for half a year to two years has a strong feeling about the influencing factors of "individual ability", and the feeling is even more profound to successfully achieve the first promotion to achieve the rigid needs, because there is pressure to win, and the loser of the competition may leave. Most of the groups with more than 5 years of service are graduates with teachers or group leaders, who have rich experience, and the success or failure of the graduates' first promotion is related to the interests, and they are more able to appreciate the importance of the influencing factors of "individual ability".

The first promotion of college graduates is certainly not only related to a certain factor or a certain aspect, but many factors and many aspects, and it will not be a success when an independent thing happens, but should be the final result of the accumulation of a series of related events and mutual influence. This process needs to pay attention to management skills training, improve the quality of micro-leaders and on-site incident handling capabilities on the basis of familiar work technology and process, and have a series of good performances in four aspects, and successfully break through the hidden barriers step by step to achieve results.

Conclusions and Recommendations

Conclusions

Based on the theory of job promotion, this paper constructs a four-dimensional "individual ability model" for college graduates who break through hierarchical barriers to become qualified on-site managers, and the empirical analysis results show that the work technology process, on-site management skills, micro-leadership quality and incident handling ability are important factors affecting the initial promotion of graduates in the four-dimensional model.

Recommendations

Graduates can take the four-dimensional "individual ability model" of qualified on-site managers as a way to break through

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the hidden barriers for the first promotion, one is to learn the main content of the four-dimensional "individual ability model" of qualified on-site managers, the influencing factors of the first promotion of graduates summarized in this paper are the hidden barriers for the first promotion, graduates want to break through the hidden barriers to become on-site managers, first need to be familiar with the framework of the four-dimensional model of on-site managers, and learn its detailed rules, that is, the work technical process, on-site management skills, Micro-leadership quality and incident handling ability are four dimensions to think and complete the training of corresponding items. In the process of learning, graduates can learn relevant knowledge and training methods by formulating targeted plans; On the other hand, those who have a harmonious relationship with workers and their superiors can remember their strengths can consult their superiors and colleagues for advice and master relevant direct and effective training methods. After graduates are familiar with and learn the four-dimensional model framework of on-site managers, they should know how to prepare the detailed rules in place one by one according to the plan every month, that is, they should immediately prepare for the first promotion after the job is stable, and should draw up a self-training plan every month half a year in advance, find mentors to guide work skills training, cultivate the quality of managers and improve their work ability. Familiar with the work technology process, be able to fully grasp the key points of the work process, and be able to judge the work flow of all operators in the job site platform; After learning on-site management skills, you also need to know ten management skills and be able to train others; On the basis of completing their own work tasks, take the initiative to help colleagues and superiors and reduce their work pressure; Enhance self-image and be able to inspire, lead, care, affirm, veto and supervise the team. In this way, after preparing the relevant details of the four-dimensional model one by one and showing the bright spots, it is possible to become a qualified on-site manager by seizing the opportunity for career development. Not to be squeezed out by elite migrant workers, it is necessary to break the iceberg and achieve a harmonious relationship with workers through top-post learning, especially to correctly perceive the trust of masters and superiors to leave a good impression in the eyes of superiors.

Colleges and universities can incorporate the four-dimensional model of qualified on-site managers into the career guidance course, and graduates can learn the content of this model in advance and prepare for knowledge one by one; Colleges and universities can also set up career guidance seminars, inviting college graduates who have already experienced first-time promotions to share their work experience, so that graduates can understand the current situation of future work in advance and make future career development plans.

Enterprises can use the four-dimensional model of qualified on-site managers to understand the characteristics of college graduates when they are first promoted, and organize college graduates to learn and train the relevant rules of the model, so as to formulate talent training programs and cultivate a new generation of talents.

Acknowledgment

All contributions of the third parties can be acknowledged in this section.

Conflict of Interest

The authors declare no conflict of interest.

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Attribution of Liability in Transboundary Water Pollution Incidents

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Abstract

The issue of attribution of liability for transboundary water resource pollution involves a large number of stakeholders. It is necessary to analyse the ambiguities in the liability in the light of the legal basis and the practical orientation, and to find a way forward to improve clarity and enforceability. It is crucial to clarify the liability and compensation mechanism, which not only needs to follow the basic principles of international environmental law, such as common but differentiated responsibilities and sustainable development, but also draws on international treaties and judicial practice. Besides, At the same time, it is also important to pay attention to the fact that China has already gained some influence in the international community in the area of liability determination for transboundary water pollution, including the management of transboundary water resources based on sovereignty and co-operation, the construction of a legal system using a combination of soft and hard law, and the establishment of an ecological compensation mechanism. In order to enhance the clarity and operability of international liability norms in line with the international process, China can refer to international practices and achieve its goals by promoting transboundary water resources cooperation, strengthening legal enforcement and cross-border accountability, and improving emergency preparedness and liability implementation.

Keywords : International water law; Transboundary water resources; Transboundary environmental damage; State responsibility

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Introduction

Necessity for protection based on the legal attributes of transboundary water resources

Transboundary water resources, in the form of rivers, lakes and groundwater systems, cross national borders and have a global impact on ecosystems, economic conditions and public health and safety. Such water bodies, such as the Nile, the Amazon and the Mekong, are rich in political, economic and socio-cultural values, and are indispensable for agricultural and industrial production and daily life, as well as for the preservation of biodiversity.

However, transboundary water resources involve various fields, including politics, society, jurisdiction, physical, ecological, and biochemistry, which determines the particular complexity of the issues of allocation, supply, demand and utilization management of transboundary water resources. (Yifei Zhang, et al., 2024). The 1992 "Convention on the Protection and Use of Transboundary Watercourses and International Lakes" explains the regulation of transboundary impacts, which emphasizes preventing, controlling, and ensuring the fair and reasonable use of transboundary water resources. Concerning transboundary pollution, the high mobility of water resources, their wide distribution, and their shared nature pose even greater risks to the public health and ecological balance of affected countries. Pollution from industries, agriculture, and domestic activities entering a shared watershed does not respect national boundaries, creating a more complex situation for managing water pollution. These pollutants can degrade water quality, threaten aquatic ecosystems, affect human health, and cause long-term ecological damage. Moreover, the economic and technological disparities between countries mean that the consequences of pollution are unevenly distributed, with downstream countries often bearing a greater burden due to upstream pollution activities.

Significance of clarifying liability and compensation mechanisms

The relationship between human rights and sovereignty is inseparable, and protecting human rights does not limit the essence of national sovereignty (it limits the dynamic attributes of sovereignty)(Canling Lin, 2019). Transboundary water resources possess a multilevel tenure system. From the perspective of international water law, this requires recognizing the sovereignty issues of transboundary water resources and defining ownership, usage, and distributive rights at different levels among the sovereign states sharing the river basin(Zhixuan Zhao, 2018).

Sovereignty is not only a nation's right but also a concept of national responsibility. Since pollution often spans multiple borders and involves various actors, clarifying state responsibility is essential to ensuring fair treatment for affected countries at different levels of rights. On the one hand, this avoids long-term disputes caused by unclear or deflected responsibility; on

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the other, it provides legal protection to affected parties and promotes timely corrective actions. Pollution incidents not only cause environmental damage but also economic losses and social impacts, potentially triggering cross-border agricultural production, fisheries crises, and public health issues. Therefore, constructing a clear compensation mechanism to ensure that affected parties receive economic compensation and ecological restoration is vital for achieving environmental justice and restoring ecological damage.

The Legal Basis and Practical Orientation for Determining Liability in Transboundary Water Pollution

Definition of Liability for Transboundary Water Pollution

Transboundary water bodies often span multiple national political boundaries and have shared and public characteristics. Their management and protection face complex legal challenges, particularly concerning pollution, over-exploitation, and ecological destruction. Defining liability for environmental damage to transboundary waters has become a key issue in international law. This requires a solid foundation in international environmental law's fundamental principles, exploring feasibility and general trends through international treaties and judicial practices.

Liability for transboundary water pollution refers to the responsibility for pollution that occurs as a result of the actions of one or more countries in the use, management, and protection of transboundary waters. This includes state liability and corporate responsibility. For example, when activities within a state's jurisdiction, such as pollution or exploitation, lead to cross-border damage to the water resources and ecosystems of neighboring states, the responsible party must bear compensation and restoration duties.

In general customary international law, the liability of a State for transboundary water pollution depends mainly on the failure to fulfill the duty of care and diligence, the existence of objective fault, and the violation of treaties. For example, Japan, as a State party, has signed a series of international treaties, including the "United Nations Convention on the Law of the Sea" and the "Convention on Nuclear Safety". On the issue of nuclear sewage discharge, its decision is suspected of violating the core obligations to protect and preserve the marine environment and to prevent the spread of pollution under the "United Nations Convention on the Law of the Sea" , etc. If Japan's nuclear sewage discharge into the sea poses a great danger to all mankind as well as to the marine environment, the international community is justified in believing that Japan may be in breach of the customary international law "Obligation Erga Omnes" obligations (Huanxin Luo, 2021). The "Obligation Erga Omnes" relates to the common interests of the international community as a whole or of members of a collective. Rather, the concept of community interest, which reflects the common or fundamental values of the international community, is a key element of the "Obligation Erga Omnes"(Yuanyuan Li & Yan Zhang, 2023). This is because such behavior not only affects the specific interests of the neighboring countries, such as the marine environment, fishery resources, and public health, but also poses a potential threat to the global ecological balance, the common environmental interests of mankind, and the rights and interests of future generations, and involves significant interests of concern to the international community as a whole.

Scope of Liability for Transboundary Water Pollution

Transboundary water pollution involves various types of pollution sources, including industrial wastewater discharges, agricultural runoff, domestic sewage, chemical substance spills, etc., which may lead to water quality degradation, destruction of aquatic ecosystems and public health crises when they enter other basins. According to the principles of international law, the source country of pollution should bear the "preventive responsibility" and "remedial responsibility" for the transboundary water pollution caused by it, and the so-called "preventive responsibility" means that the source country of pollution needs to proactively take all kinds of preventive and control measures before pollution occurs, so as to reduce the possibility of pollution occurring. In the field of ecological and environmental governance, the concepts and systems of damage prevention and risk prevention have never been lacking. It can be said that ecological environment legislation is inherent with damage prevention and risk prevention"gene"(Xianjing Wu, 2024) ; whereas "remedial liability" requires the source country of pollution to assume the corresponding liability and the obligation to repair the damaged ecology after the pollution has occurred, which belongs to the remedial measures after the fact.

Pollution not only adversely affects the natural functions of water bodies, but also causes long-term and incalculable economic losses to communities and countries that depend on water resources for their survival and development. In view of the cumulative and long-term nature of the pollution problem, countries in the development and utilization of water resources, should strictly adhere to the rational use and fair distribution of the basic norms, to effectively avoid over-exploitation or irrational development of a country's neighboring ecological environment suffered irreparable damage results.

With regard to the determination of specific liability, it is generally necessary to make a comprehensive judgment based on causality, with the main factors of consideration including whether the pollution or damage was triggered by the specific acts of a country, the actual extent of the damage and the scope of its impact, as well as the obligation of the responsible country to prevent pollution, etc.; and the establishment of a mechanism for compensation, including economic compensation, ecological restoration, and compensation for communities in the affected areas, etc.

Basic Principles in International Environmental Law

Since there are differences in economic development, political systems and technical resources among countries, the allocation of responsibilities needs to be considered equitable. Developed countries, with their strong economic and

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technological foundations, have greater capacity and resources to deal with transboundary water pollution. Developing countries, on the other hand, often rely on resource development and industrial development paths in their development process, and face the dual problems of technological bottlenecks and lack of financial resources in the field of environmental monitoring and pollution control. Adopting a uniform standard of liability may be too harsh for developing countries.

Instead, the principle of common but differentiated responsibility allows for the allocation of responsibility in accordance with the actual capacity of each country, and the concept of "common responsibility" proclaimed by the Stockholm Conference on the Human Environment in 1972 is a preliminary form of the principle of common but differentiated responsibility; "differentiated responsibility" allows countries to allocate responsibility in accordance with their own practical and developmental needs. The concept of "differentiated responsibilities" allows countries to define specific tasks in accordance with their national realities and development capacities, so as to avoid shirking responsibilities and imbalances in international cooperation and to work for the common good. As early as the 1992 Framework Convention, the original purpose of the principle of common areas manifested the spirit of the value of equity. Whether the principle can continue to gain universal acceptance and adoption, and achieve environmentally effective implementation depends on whether the basis of responsibility is established fairly and equitably while responding to the dynamically changing international situation (Chen Zhou, 2023). Transboundary water resources should have the legal attribute of "shared natural resources" in addition to the natural attributes of mobility, wholeness and circularity (Lili Shao, 2017). Based on common natural resources or interest claims, the theory of community of interest of riparian/basin states, or common resource/interest theory, has emerged in international water law (Yanmei He, 2007). For transboundary water, if justice is to be distributed among basin countries, the first step is to regard the basin as a common resource, and then to distribute the benefits of basin utilization in accordance with the procedure of justice, therefore, the theory of justice, which is the most original theory of jurisprudence, constitutes the jurisprudence theoretical foundation of the community of interest theory (Desheng Hu, 2018). The 1997 "Convention on the Law of the Non-navigational Uses of International Watercourses", on the other hand, supported by the theory of common interests, tries to resolve disputes through the management of common property and the sharing of revenues by downplaying the sovereignty and failing to clarify the nature of the transboundary water resources belonging to the situation, and these provisions have been utilized in practice, and the reason why it can resolve the disputes essentially lies in the fact that the sovereignty of the transboundary water resources, a common property, is clarified in the respective riparian countries to clarify (Lili Shao, 2017). The principle of sustainable development has been implemented in the context of environmental protection and economic development, and the common interests focusing on the rational exploitation and protection of multiple interests in water resources.

The principle of sustainable development is consistent throughout the entire process of environmental protection and economic development, with the key to achieving synergistic development of the economy, society and the environment, maintaining intergenerational equity, and ensuring that future generations will have clean and abundant water resources. In the process of national economic development, the environmental and socio-economic impacts of transboundary water pollution on other countries must not be overlooked, and enterprises should not sacrifice the environment for short-term profit gains in their overseas investment and trade activities. In the determination of liability for transboundary water pollution, countries need to weigh the relationship between economic development, social stability and environmental protection, rationally allocate responsibility, and actively encourage the adoption of comprehensive programs that can reduce water pollution, promote economic development and social progress.

Liability Determination in International Practice

The Polluter Pays Principle of the EU legal system for water pollution control is gradually being extended to many areas of environmental management in Europe. The Polluter Pays Principle advocates that after an accident occurs, the polluter should pay for the control, removal and protection measures of the pollution in order to promote the internalization of economic costs (Canling Lin, 2019). The original intention of this principle is to let the polluting enterprises bear the cost of pollution control due to production activities, which not only fits the public's call for the burden of pollution control costs, but also the state, through the environmental tax levied on enterprises, on the one hand, clarifies the responsibility of enterprises for the control of pollution, and on the other hand, mobilizes a large amount of funds for environmental protection and control(Cunfan Ding, 2020). Clearly define the "polluter" definition standard covers enterprises, investors, traders and other multiple subjects, and each subject in different pollution scenarios bear differentiated responsibilities. In the face of complex situations such as intertwined multiple sources of pollution or long-term cumulative pollution, it is possible to combine the causation criteria, including direct and indirect causation determination. Direct causation means that a certain behavior directly leads to water resource pollution; indirect causation needs to integrate a variety of factors to accurately judge the responsible subject, such as the contribution of different pollution sources, time sequence, spatial diffusion path, etc.

At the practical level, in typical incidents such as oil spills and radioactive waste discharges, liability is usually attributed to the operator. For example, in the general principles of nuclear liability set out in the "Vienna Convention on Civil Liability for Nuclear Damage", it is stated that the basic principles on which the special nuclear liability regime is based include references to "absolute" liability, i.e., no-fault liability, and the exclusive liability of the operator of the nuclear installation, which reflects a regime of strict liability that shifts the responsibility to the operator who has caused the contamination. The liability is shifted to the operator who caused the pollution. By analogy with the production activities of enterprises, enterprises that pollute water resources by discharging wastewater in the course of production should bear the corresponding costs of remediation on the basis of the polluter pays principle.

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However, due to the extended and holistic nature of cross-border pollution, which cannot be characterized in time and space within a short period of time, most of the tangible and intangible damages caused by cross-border pollution are not instantaneous, but need to be accumulated year by year before they can be fully released. Relying solely on such strict liability may extend the liability of the polluter indefinitely, and therefore, in the case of bilateral and multilateral transboundary pollution, it is also necessary to consider the synergy between joint liability and payer compensation mechanisms.

According to the principle of prevention of damage, even in the absence of scientific certainty, effective and costly precautionary measures should be taken to prevent the risk of environmental damage, scientific uncertainty cannot justify the failure to take measures (Weichun Chen, 2018). In developing and utilizing its indigenous natural resources, a state should consider its existing or future impacts on the environment outside its jurisdiction within its sovereign jurisdiction, while taking appropriate measures to prevent transboundary pollution while formulating substantive and procedural rules for environmental protection (Lili Shao, 2017). As the Pulp Mills on the River Uruguay judgment had shown, the Court had gone a long way towards clarifying the nature and scope of the obligations relating to the prevention of transboundary harm, in particular the duty of due diligence owed by watercourse States. The Court held that the duty of prevention could be divided into procedural and substantive due diligence requirements, the procedural requirements being based on early notification and consultation, and the substantive requirements being the development and effective implementation of appropriate domestic legal controls over the extraction, pollution and protection of shared watercourses and their associated ecosystems, which imposed a full range of pre- and post-commitment requirements on the perpetrator to proactively prevent and respond to pollution and to minimize harm.

Legal Norms in International Treaties

Bilateral agreements based on treaties can significantly curb unilateral actions. By clearly defining the responsibilities, obligations, and corresponding measures of both parties, these agreements help establish unified governance rules, which have a positive effect on addressing environmental pollution at the borders (Xuyu Hu, 2013). The 1997 "Convention on the Law of Non-Navigational Uses of International Watercourses" is one of the cornerstones of transboundary water resource management. It emphasizes that when states develop or use transboundary water resources, they must consider the interests of all the countries involved, avoid over-exploitation or misuse, and ensure the sustainable use of shared resources. The dual principles of "equitable and reasonable utilization" and "no significant harm" have been established.

In regional agreements, such as the "Convention on the Protection of the MarineEnvironmentin the Baltic Sea Area of 1992" in Europe and the "Agreement concerning the Niger River Commission and the navigation and transport on the River Niger" in Africa, member countries cooperate and coordinate the management of shared water resources. These agreements, particularly in terms of pollution prevention and emergency response, provide clear legal guidelines for informing affected parties, cooperation mechanisms, and liability for compensation. The "Uruguay River Pulp Mills Case" demonstrated that regional treaties, such as the "Statute of the River Uruguay (1975)", could serve as the basis for the International Court of Justice to determine the Uruguay River's management responsibilities and whether Uruguay met its notification obligations (Shicun Wu, 2020). These international documents emphasize the prevention and control of transboundary water pollution through international cooperation, which, together with State practice and the development of international environmental law, has contributed to the formation of the law on transboundary water pollution prevention and control and has become an important part of international water law, facilitating the establishment of bilateral or multilateral specialized pollution prevention and control management regimes in many transboundary basins.(Yanmei He, 2007).

Ambiguities in Determining Liability for Transboundary Water Pollution

Differences in Legal Interpretation and Application

While international practice provides a standard framework for liability determination, there are numerous challenges in enforcing international agreements due to differences in national laws, policies, and interests. These challenges become particularly evident when regional and global environmental agreements have differing provisions. Coordinating these differences is one of the central difficulties in determining responsibility, as achieving consensus through international cooperation is a complex and time-consuming process. It not only requires legal and diplomatic efforts but also involves political and economic considerations. The many uncertainties that arise in the process often slow the progress of state responsibility determination, leaving room for states to shift or avoid responsibility.

Although core principles of international water law, such as "equitable and reasonable use" and "no significant harm", are widely recognized, their legal connotations and implementation guidelines lack clear and specific definitions, which exacerbates distrust between nations. This is because countries differ in their standards and enforcement mechanisms, which can lead to inconsistent applications and interpretations of international norms. Additionally, the emphasis placed on the two principles varies, with upstream countries often favoring the "equitable and reasonable use" principle to support their development activities, while downstream countries may rely on the "no significant harm" principle to oppose development. As a result, there has been ongoing debate about whether one principle is subordinate to the other and which principle should take precedence (Qian Wu, 2021).

In the enforcement of international water law, many countries, deeply concerned about national sovereignty, tend to reject international jurisdiction, fearing that following international environmental law or accepting international rulings could undermine their autonomy over natural resource management and policy-making (Philpot D. & Wei Yi, 2018). This resistance

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is particularly strong when international environmental regulations might negatively impact a country's economy. For example, some countries may be concerned that adhering to international environmental laws would severely impact their mining industries, increasing costs and reducing production, thereby affecting national income and employment (Agaraj X., 2011).

Force Majeure and Multi-Entity Responsibility Factors

If an event is proven to have been caused by unforeseeable, unavoidable, and insurmountable external factors, an argument of force majeure can be accepted as a defense (Saul R., et al., 2016). However, if the force majeure event is fully or partially caused by the state invoking this defense, the force majeure argument cannot be invoked. Determining the specific impact of force majeure events on water pollution often requires rigorous scientific analysis and substantial factual evidence (Jinpeng Wang, Lulu Jiang, 2023). This makes it particularly difficult to establish causality, as it is necessary to distinguish the environmental impact of human activities from that of force majeure factors. Moreover, water pollution cases often involve multiple parties and numerous contributing actions, which complicates the distribution of liability. It is not only necessary to assess the relative responsibility of each party but also to consider the direct consequences of their actions. This complexity makes liability determination extremely challenging, as many interconnected factors increase the difficulty of resolving the issue.

Although international environmental law has established broad principles for preventing, reducing, and controlling pollution, as well as ensuring the sustainable use of water resources, it often lacks specific guidance on addressing complex pollution situations involving multiple factors. This lack of clarity leads to uncertainty in enforcement and compliance. When multiple parties are involved in pollution incidents, it becomes difficult to pinpoint the specific impact of each source, further complicating the determination of legal responsibility and the implementation of remediation measures(McIntyre O., 2017).

Conflicts in International Jurisdiction and Applicable Law

In cross-border water pollution cases, jurisdictional conflicts are inevitable due to the involvement of multiple countries, each with its own legal system and environmental regulations. International practice tends to address conflicts by harmonizing substantive laws, rather than resolving jurisdictional and applicable law conflicts. For instance, Principle 22 of the Stockholm Declaration (1972) states", States shall co-operate to develop further international law regarding liability and compensation for the victims of pollution and other environmental damage caused by activities within the jurisdiction or control of such States to areas beyond their jurisdiction".

Current international practice designates the modalities that may be used to resolve certain specific types of transboundary pollution disputes, such as the "Paris Convention", which in the case of nuclear pollution allows actions to be brought only in a Contracting State or in the State where the accident took place; and in the case of oil pollution, the "Brussels Convention", which limits the action to the territorial limits of the Contracting State or Contracting States in which the damage occurred. In the field of international water law, there was a lack of guidelines that could be used to resolve conflicts of jurisdiction. Conflicts could arise when different States asserted jurisdiction on different legal bases, such as the place of pollution, the nationality of the polluter or the location of the source of pollution. Diverse jurisdictional claims complicate the overall legal environment, leading to disputes over applicable law and jurisdiction, which in turn leads to inconsistencies in adjudication and enforcement. Even when jurisdiction is successfully established, its enforceability may face many limitations. This is mainly due to the fact that States have incorporated environmental law into their domestic legal systems in different ways and that agreements often do not provide for the proper resolution of conflicts between different legal systems, leaving room for interpretation and application.

Owing to the inadequacy of formal legal avenues, many transboundary environmental issues may also be resolved through diplomatic rather than legal channels. Diplomatic solutions have the advantage of taking into account the amity of countries and the interests of all parties, but the disadvantage is that it is difficult to determine the applicable rules, and if only negotiated between the two parties, it is difficult to avoid the strong countries overpowering the weak ones, or even making the results biased in favour of the interests of the strong countries, which is unfair.(Hong Zhao, 2023).This may lead to a tendency to politicize environmental issues and deviate from the scientific track, which is not conducive to the proper handling and effective management of transnational water pollution problems.

China's Approach to Determining Liability for Transboundary Water Pollution

The Legal Foundation of Sovereignty and Cooperation in Transboundary Water Resources

China's legal regulations and practices regarding liability determination for transboundary water pollution cover several aspects, including international river management, state sovereignty protection, liability for industrial water pollution, and the application of soft law in water resource management. However, a single nation cannot independently address the challenges posed by transboundary water resources. Therefore, China actively advocates for extensive cooperation and consultation with neighboring countries to ensure the efficient and sustainable use of transboundary water resources. In managing transnational river basins, China consistently prioritizes cooperation and consultation, striving to achieve equitable distribution of resources and balance the interests of both bilateral and multilateral stakeholders.

"Sovereign ownership" and "common interest theory" are central to the legal framework governing transboundary water resources. In the process of managing and utilizing transboundary water resources, each state must respect the sovereignty of others and rely on cooperation to achieve shared interests. The Lancang-Mekong cooperation mechanism, for instance, serves

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as a platform for China and downstream countries to jointly manage and utilize the Mekong River's water resources. This framework comprehensively regulates the rights and obligations of riparian states, balancing the rights and obligations of upstream and downstream countries, thereby creating a more orderly system for water resource development and utilization to protect the ecological and environmental interests of the Lancang-Mekong Basin (Yongmei Chen, Youfang Guo, 2023). The common interest theory must emphasize the rightful interests of each riparian state based on the clarified nature of sovereign ownership of transboundary water resources to achieve justice in water resource distribution (Lili Shao, 2017). The theory requires that, in allocating responsibilities, we do not rely solely on one factor but instead comprehensively consider the roles and capacities of all parties involved in the utilization of water resources. This approach ensures that responsibility allocation is fair, reasonable, and practically implementable. In this process, not only the responsibility of polluters must be considered, but also the responsibility of affected countries in pollution prevention, implementing response measures, and maintaining regional interests.

Application of soft law in the determination of liability for transboundary water pollution

International soft law primarily manifests in non-binding legal documents adopted by international organizations and multilateral diplomatic meetings, including declarations, resolutions, guidelines, or codes of conduct (Wei Shen, Shuo Feng, 2022). Examples include the "Agenda 21" from the United Nations, draft convention proposals from expert groups, and bilateral and multilateral agreements signed between states and regions, along with cooperation mechanisms. These soft law documents are non-binding but are flexible enough to be adjusted in response to the dynamic changes in regional water resource management needs. The flexibility and guidance of soft law help facilitate intergovernmental cooperation, creating a more orderly framework for regional cooperation (Youqi Shi, Weiwen Zheng, 2022).

For example, within the Lancang-Mekong cooperation mechanism, the soft law documents developed by participating countries, though non-binding, establish a common framework that promotes information sharing, technical exchange, and policy coordination. This has significantly reduced barriers to cooperation and increased the efficiency of addressing transboundary water pollution. However, in matters of determining compensation liability and enforcing legal responsibility, soft law's non-binding and ambiguous nature cannot provide precise or authoritative grounds. In such cases, hard law, with its clear legal provisions, rigorous responsibility standards, and state enforcement, offers a solid legal foundation and institutional framework for implementing soft law. China's hard law system, such as the "Water Pollution Prevention Law" (2017 amendment) and the "Environmental Protection Tax Law" (2018 amendment), reflects the"polluter pays"principle, specifying that polluters must bear responsibility for the damage caused to water resources. This includes taking effective measures to control and eliminate pollution and compensating for all direct and indirect losses caused by pollution, ensuring authoritative legal determination and enforcement of liability through national authority.

Ultimately, soft law provides practical experience and theoretical foundation for hard law, and its standards and guidelines, once tested in practice, can be integrated into hard law systems. Simultaneously, hard law provides the legal basis and institutional security for the application of soft law. Together, they complement each other, building a comprehensive legal system for determining liability for transboundary water pollution. The simultaneous use of both soft and hard law and cooperative governance will be the future path for regional intergovernmental cooperation (Youqi Shi, Zhikun Yang, 2018). This will ensure the necessary legal support and institutional guarantee for the reasonable protection and sustainable use of transboundary water resources.

Ecological Compensation in the Construction of State Responsibility

In addressing transboundary water pollution, China supports a state-led compensation responsibility system, which not only compensates for damages caused by polluters but also includes mutual compensation between affected countries. The core principle of the ecological compensation model is"beneficiary pays,"which is an extension of the"polluter pays"principle. This principle requires that countries benefiting from the development, utilization, and ecological conservation of transboundary river resources must compensate the countries that carry out conservation and environmental protection efforts for these shared water resources (Tianbao Qin, 2021). The determination of compensation responsibility for transboundary water pollution highlights both state responsibility and shared responsibility, advocating for international cooperation to strengthen preventive and compensatory measures. As a member of the international community, China must also shoulder certain compensation responsibilities in transnational river basin management and global issues such as climate change (Qingjun Wang, 2023). Currently, China and some neighboring countries have engaged in water resource cooperation, establishing dialogue platforms and execution agencies in most transboundary river basins to support ecological compensation mechanisms for water distribution.

Enhancing the Clarity and Operability of International Liability Norms

Promoting Regional Cooperation and Diplomatic Negotiation on Transboundary Water Resources

In the context of transboundary water pollution, the international legal system provides an effective framework for resolving disputes over the use, management, and protection of shared water resources. The International Court of Justice plays a crucial role in resolving legal disputes between states, offering important legal foundations for preventing environmental damage, defining state responsibility, and determining compensation for pollution. Although decisions by international courts do not always lead directly to economic compensation, they advance the development of international environmental law by

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establishing fundamental principles of state responsibility, prevention measures, and international cooperation. As global environmental issues continue to evolve, the role of the International Court of Justice in ensuring state accountability for transboundary pollution will remain a core element of the international environmental governance system, and its precedents should be referenced by states when determining responsibility.

Early transboundary water pollution management systems focused on passive control or "case-by-case" solutions, which were ineffective until the influence of ecological science and international environmental law spurred the adoption of ecosystem-based approaches (Yanmei He, 2020). For example, the Montara oil spill and the Danube cyanide leak cases highlighted the importance of cooperative management in shared water resources, stressing the obligation of states to work together in managing and protecting these resources.

China can promote effective management by establishing robust cross-border environmental cooperation mechanisms, conducting joint monitoring and environmental impact assessments, and ensuring that pollution issues are effectively prevented during transboundary water resource development (Zewei Yang, 2023). China could consider exploring cooperation mechanisms or pathways with ASEAN countries in areas related to marine environmental protection under the "Declaration on the Conduct of Parties in the South China Sea (DOC)" and other marine environmental fields . Specific measures could include establishing evidence collection teams of experts to conduct real-time monitoring of marine environments, expanding water quality sample selection, and maintaining evidence and testing data for future legal action (Bangda Hu, 2024). In addition to technical measures, diplomatic negotiation should be incorporated as a conflict resolution tool. It is the most advantageous approach for resolving disputes while respecting the sovereignty of all parties and avoiding conflicts (Hang Zeng, 2019). When countries have disagreements over responsibility and interests, negotiation offers a platform for dispute resolution, saving costs and preventing escalation(Qingjun Wang, 2024).

Strengthening Legal Enforcement and Cross-Border Accountability

The decision of the International Court of Justice emphasized the obligation of States to prevent significant harm to the water resources of neighbouring States. In the Pulp Mills on the River Uruguay case, the Court ruled that Uruguay had violated its obligation to prevent transboundary harm under international law by failing to effectively assess the potential environmental impacts of its project on shared water bodies. When addressing transboundary water pollution, China should clearly define the responsible parties and vigorously strengthen the legal scrutiny and supervision of enterprises and projects that may cause transboundary pollution. For example, when water resources development activities in upstream countries pose a potential risk of contamination of water bodies in downstream countries, it is important to clarify liability through legal means and actively implement preventive measures to prevent pollution.

In handling transboundary water pollution incidents, the scope of compensation should not be limited to the costs of environmental restoration, but should also include the economic losses and ecological restoration costs arising from pollution. At the same time, the relevant compensation mechanism should be flexible and operable, so as to ensure that the compensation can be provided in a timely manner, and to prevent the delay of compensation from triggering negative social sentiments and even conflicts between countries. By effectively increasing the strength of the implementation of domestic environmental laws and regulations, to ensure that in various types of cross-border pollution cases can be effectively held accountable. Therefore, when dealing with cross-border water pollution cases, we should not only rely on the framework of the international legal system, but also give full play to the functions of domestic law enforcement departments, so as to promote the strict compliance of domestic enterprises and government agencies with environmental protection standards, and to effectively fulfill their international responsibilities and obligations.

Improving Emergency Preparedness and Responsibility Implementation

In the construction of the mechanism for recognizing and managing transboundary water pollution liability, international water law has demonstrated its comprehensive and systematic character. It not only covers the core aspects of preventive measures, emergency response and liability, but also accurately clarifies the legal responsibilities and action guidelines of various countries. For example, in the Montara oil spill incident, the Montara Commission of Inquiry report pointed out that there were major deficiencies in the company's procedures, and the failure to comply with reasonable oilfield operational practices was the main cause of the blowout. There was also negligence on the part of the regulator, as in the case of the Northern Territory Department of Resources, which made significant errors in approving drilling procedures and failed to ensure that the company's procedures complied with statutory standards of good oilfield practice. As far as preventive measures are concerned, the core lies in the effective control of industrial discharges, agricultural runoff and other sources of pollution through scientific and rational planning and rigorous and efficient management, so as to prevent the growth and spread of transboundary water pollution from the source. As for the emergency response mechanism, in the event of an environmental incident that may have a serious impact on the waters of other countries, the responsible country is obliged by law to immediately notify the affected country and to take urgent measures in cooperation with the affected country to minimize the scope and extent of environmental damage.

For China, the Montara incident offers critical insights into enhancing transboundary water pollution governance. In constructing monitoring systems, it is imperative to establish a comprehensive and efficient framework to ensure timely and precise detection of pollution, thereby providing a robust scientific basis for accountability. When implementing mitigation measures, cross-border impacts must be rigorously evaluated through scientific data analysis to inform evidence-based decision-making. Concurrently, real-time monitoring of intervention efficacy should be prioritized to enable agile strategy

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adjustments in response to evolving scenarios. Strengthening emergency preparedness is equally vital. This involves developing standardized contingency plans and institutionalizing emergency response protocols to address sudden pollution events. Upon an incident, immediate preventive measures must be activated, coupled with coordinated communication among stakeholders. Predictive modeling of pollution trajectories—including spatial extent, temporal progression, and contamination severity—should guide downstream nations in preemptive risk mitigation, ensuring systematic crisis management.(Guanwen, Tan, Tingting, Wei, 2024). On the issue of compensation for cross-border water resource pollution, the standards and methods of loss assessment should be clarified, the burden of proof should be reasonably distributed, and the assessment of potential losses such as ecological damage should be strengthened to ensure that the victims can obtain reasonable compensation, and thus promote the effective development of cross-border water resource pollution control.

Conclusion

The attribution of liability for pollution of transboundary water resources is multidimensional in character. Transboundary water resources, by virtue of their wide distribution and shared nature, have a profound and lasting impact on the ecosystems, economic development and social well-being of many countries. Clarifying the attribution of responsibility and constructing a scientific and reasonable compensation mechanism are the core of realizing the sustainable use of transboundary water resources and guaranteeing environmental justice. From the legal basis and practice-oriented point of view, the current definition of liability for transboundary water pollution is hindered at the level of legal interpretation, multi-entity and jurisdiction. However, the basic principles of international environmental law have always provided the fundamental basis for the allocation of liability, while the principles of polluter pays and damage prevention have played a key guiding role in defining liability in practice. Numerous international treaties and organizations played an active and irreplaceable role in regulating the determination of liability and promoting international cooperation.

China has been active in the area of liability determination for transboundary water pollution, carrying out transboundary water resource management on the basis of the legal principles of sovereignty and cooperation, and constructing a legal system for liability determination by means of a combination of soft and hard laws, which has given a strong impetus to regional inter-governmental cooperation. At the same time, China has actively advocated a state-led ecological compensation mechanism, which has achieved certain milestones, but still faces challenges in technical support and other aspects. In order to enhance the clarity and enforceability of international liability norms, China should proactively promote cross-border water resources cooperation and diplomatic negotiations, strengthen joint monitoring and environmental impact assessment, and flexibly and skillfully use negotiation means to resolve disputes; strengthen the enforcement of laws, strictly pursue cross-border liability, clarify the main body of responsibility, and improve the compensation mechanism, so as to ensure that the responsibility can be effectively and efficiently carried out; and improve the emergency preparedness and liability implementation mechanism, and build an efficient and sensitive mechanism for the implementation of emergency preparedness. implementation mechanism, build an efficient and sensitive monitoring system, formulate scientific and reasonable coping strategies, and strengthen the construction of contingency plans and response systems, so as to ensure that transboundary water resources pollution problems can be properly and effectively managed, and ultimately realize the sustainable use of water resources and the goal of international environmental justice.

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Conflict of Interest

The authors declare no conflict of interest.

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A Review of Adolescents' Digital Self-Efficacy: Conceptualization, Measurement, Impacts, Influencing Factors, and Future Directions

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Abstract

With the deep penetration of digital technology in life and education, the cultivation of digital literacy among adolescents has become a focus. As a key component of digital literacy, digital self-efficacy profoundly affects adolescents' use of digital systems and the development of digital competence. In this paper, we systematically review the current status of research on adolescents' digital self-efficacy at home and abroad, elaborating on the evolution of its concept, the development of measurement tools, and analyzing its role in the use of digital systems and learning, as well as the influencing factors at the environmental and individual levels. At the same time, we point out the shortcomings of the current research in terms of conceptual connotation and structure, local characteristics, systematicity of influencing factors, formation and mechanism of action, and interventions, etc., and provide directions for the subsequent in-depth research, aiming to promote the development of the research on adolescents' digital self-efficacy, and help to improve adolescents' digital literacy.

Keywords : Adolescents; digital self-efficacy; digital literacy; research review

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Introduction

General Secretary Xi Jinping pointed out in the thirty-fourth collective study of the Political Bureau of the Central Committee that "it is necessary to improve the digital literacy and skills of all people and society as a whole, and to strengthen the social foundation for the development of China's digital economy". Along with the rapid updating of digital technology, digital products are more convenient to operate and the tasks that can be accomplished are becoming more and more complex (Vrontis et al., 2021; Jiang, 2021), and the use of digital products is increasingly becoming an important part of daily life (Parker & Grote, 2020; Jiang et al., 2023). This also makes it even more important to be digitally competent in order to adapt to modern life (Larson & DeChurch, 2020; van Kessel et al., 2022; Wang et al., 2022). Especially in the field of education, learning and living effectively with the help of digital products has become an important skill for contemporary primary and secondary school students (Zhang et al., 2021).

Enhancing the digital literacy of adolescents has been a critical concern closely monitored by the Chinese government. As early as 2016, the Opinions on Strengthening Cybersecurity Discipline Development and Talent Cultivation jointly issued by six departments including the Office of the Central Leading Group for Cybersecurity and Informatization emphasized that "cybersecurity education should start with children, and adolescent digital literacy education must be prioritized" (Office of the Central Leading Group for Cybersecurity and Informatization et al., 2016). In subsequent years, policy documents released by the Central Committee of the Communist Party of China, the State Council, the Ministry of Education, and other departments repeatedly underscored the importance of digital literacy (e.g., State Council Information Office of China, 2017; General Office of the Central Committee of the Communist Party of China and General Office of the State Council, 2017; National Development and Reform Commission of China, 2018; Central Committee of the Communist Party of China and State Council, 2019; General Office of the Ministry of Education and General Office of the Ministry of Finance, 2020; Cyberspace Administration of China, 2021, 2022).

Similarly in 2016, the Organisation for Economic Co-operation and Development (OECD) identified the knowledge and skills related to operating digital devices (e.g., computers, smartphones, tablets), applications, and digital environments as essential 21st-century competencies (OECD, 2016). The European Union further refined this digital competence framework into five dimensions: information and data literacy, digital communication and collaboration, digital content creation, digital security, and digital problem-solving (Carretero et al., 2017).

Empirical studies have revealed that not only objective skills but also subjective ability beliefs influence the effective use of digital systems (Peiffer et al., 2020). Notably, self-efficacy related to digital system usage serves as a critical determinant of its

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effective utilization (Ulfert-Blank et al., 2022). Furthermore, competence and competence beliefs often exert independent effects on learning, motivation, and performance (Hughes et al., 2011; Marsh et al., 2017; Pajares & Schunk, 2002). Extensive research indicates that internet- and computer-related competence beliefs significantly predict individuals' capacity (Eastin & LaRose, 2000) and willingness (Venkatesh & Bala, 2008) to adopt digital technologies. Among subjective beliefs, digital self-efficacy—defined as an individual's perceived confidence in performing tasks involving digital systems—emerges as the strongest predictor of digital system engagement (Ulfert-Blank & Schmidt, 2022). Scholars globally and domestically argue that digital self-efficacy constitutes a core component of digital literacy (Ulfert-Blank & Schmidt, 2022; Wang et al., 2013).

A comprehensive understanding of the conceptual structure, cultural specificity, influencing factors, and mechanisms of adolescents' digital self-efficacy is fundamental to its scientific enhancement. Such findings are crucial for achieving the goals outlined in the 14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives Through 2035 of the People's Republic of China and advancing citizens' digital literacy.

Analysis of research status and development dynamics

Conceptual Development of Digital Self-Efficacy

Empirical studies have revealed that not only objective skills but also subjective ability beliefs influence the effective use of digital systems (Peiffer et al., 2020). Notably, self-efficacy related to digital system usage serves as a critical determinant of its effective utilization (Ulfert-Blank et al., 2022). Furthermore, competence and competence beliefs often exert independent effects on learning, motivation, and performance (Hughes et al., 2011; Marsh et al., 2017; Pajares & Schunk, 2002). Extensive research indicates that internet- and computer-related competence beliefs significantly predict individuals' capacity (Eastin & LaRose, 2000) and willingness (Venkatesh & Bala, 2008) to adopt digital technologies. Among subjective beliefs, digital self-efficacy—defined as an individual's perceived confidence in performing tasks involving digital systems—emerges as the strongest predictor of digital system engagement (Ulfert-Blank & Schmidt, 2022). Scholars globally and domestically argue that digital self-efficacy constitutes a core component of digital literacy (Ulfert-Blank & Schmidt, 2022; Wang et al., 2013).

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Measurement of Digital Self-Efficacy

Social cognitive theory emphasizes that self-efficacy measurements should focus on specific domains or tasks and reflect judgments of individual capabilities rather than social comparisons (Bandura, 2006; Marsh et al., 2017). Although the study of digital self-efficacy is relatively recent, its measurement tools have undergone several iterations. Early instruments focused on computer self-efficacy, assessing individuals' confidence in general or specific computer-related tasks. General computer self-efficacy measured confidence across diverse computing applications (Bao et al., 2013; Compeau & Higgins, 1995; Marakas et al., 1998; Weigel & Hazen, 2014), while specific computer self-efficacy targeted task-specific judgments (Marakas et al., 1998). However, these scales often fail to account for the dynamic nature of digital systems, leading to rapid obsolescence of their items (Weigel & Hazen, 2014).

With the rise of internet and communication technologies, measurement tools for internet self-efficacy (Eastin & LaRose, 2000) and ICT self-efficacy (Aesaert et al., 2017; Rohatgi et al., 2016) emerged. While these tools incorporated broader digital competencies compared to earlier computer-focused scales, they often adopted unidimensional structures, overlooking the multifaceted nature of digital literacy (Ulfert-Blank & Schmidt, 2022).

Rapid technological advancements have further complicated human-digital system interactions (Ulfert-Blank et al., 2022), exposing limitations in early measurement approaches. First, these tools neglected emerging digital competencies, such as digital security and online problem-solving. Second, their unidimensional or superficial dimensional frameworks inadequately captured the multidimensional essence of digital literacy, risking misinterpretation of scores.

Currently, the most comprehensive instrument is the Digital Self-Efficacy Scale developed by Ulfert-Blank and Schmidt (2022), based on the EU Digital Competence Framework. This 25-item scale comprises five dimensions:

1.Information and data literacy self-efficacy: Confidence in collecting, evaluating, and managing digital information.
2.Online communication and collaboration self-efficacy: Confidence in interpersonal interaction, information sharing, collaborative activities, digital etiquette, and identity management.
3.Digital content creation self-efficacy: Confidence in developing, integrating, and remixing content, handling copyrights, and programming.
4.Digital security self-efficacy: Confidence in protecting devices, personal data, privacy, health, well-being, and environmental sustainability.
5.Digital problem-solving self-efficacy: Confidence in troubleshooting technical issues, identifying needs and solutions, creatively applying digital tools, and addressing competency gaps.
While validated in European contexts, the scale's cross-cultural applicability, particularly within China's sociocultural environment, remains untested.

The Role of Digital Self-Efficacy

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A synthesis of existing research reveals that studies on digital self-efficacy primarily focus on two domains: (1) digital system usage and digital competence development, and (2) learning behaviors and outcomes.

1. Digital Systems and Competence Development

Empirical evidence identifies digital self-efficacy as a critical factor in shaping individuals' digital competence (Peiffer et al., 2020) and driving motivational processes (Eccles & Wigfield, 2002). Studies demonstrate that digital self-efficacy serves as a core predictor of both digital competence and subsequent digital system engagement (Deng et al., 2004; Hatlevik, 2017; Hatlevik et al., 2018; Odaci, 2013), influencing individuals' adoption of new technologies (Xie Youru et al., 2011; Ertmer et al., 1994; Hatlevik et al., 2018; Wartella & Jennings, 2000). Individuals with low digital self-efficacy exhibit reluctance and reduced likelihood of using digital systems, even when their objective digital competence is high (Hsia et al., 2014). Additionally, digital self-efficacy fosters the development of digital interaction skills (Ertmer et al., 1994; Hatlevik et al., 2018; Wartella & Jennings, 2000).

2. Learning Behaviors and Outcomes

Research indicates that digital self-efficacy predicts preferences for digital learning methods (Sun Xianhong, 2016) and correlates with learning motivation and academic performance (Chang et al., 2014; Chen, 2017; Joo et al., 2000). Teachers' digital self-efficacy also impacts their attitudes toward technology-integrated pedagogy (Yesilyurt et al., 2016) and students' information literacy (Chen, 2022). Furthermore, studies highlight its role in enhancing knowledge sharing (Shao et al., 2015; Teh et al., 2010), promoting individual agility (Maran et al., 2022), and increasing online altruistic behaviors (Liu, 2015).

Factors Influencing Digital Self-Efficacy

Digital self-efficacy is influenced by both environmental and individual factors. Environmental determinants include familial, educational, and peer-related aspects. Family factors such as household computer availability, internet access, and socioeconomic status positively correlate with digital self-efficacy (Liao et al., 2016). In educational settings, teacher support enhances digital self-efficacy (Chen, 2022), while peer support similarly contributes to its development (Hsiao et al., 2012). At the individual level, personality traits, cognitive abilities, and emotional states play significant roles. Openness to experience (Maran et al., 2022) and computational thinking skills (Liao et al., 2022) are positively associated with digital self-efficacy. Emotionally, higher emotional stability correlates with stronger digital self-efficacy (Maran et al., 2022), whereas computer anxiety negatively impacts computer-related self-efficacy (Sun Xianhong, 2017). Conversely, enjoyment of programming fosters digital self-efficacy (Liao et al., 2022). These findings collectively highlight the multifaceted interplay of contextual and personal elements in shaping individuals' confidence in navigating digital environments.

Current Research Gaps

While digital self-efficacy and digital competence independently influence the effective use of digital systems, research on digital self-efficacy remains underexplored compared to digital competence. Key gaps include:

Conceptual Ambiguity and Structural Underdevelopment

The conceptualization of digital self-efficacy lags behind advances in digital competence frameworks. Digital competence has evolved from narrow definitions (e.g., information retrieval and content creation; Jin et al., 2020; Siddiq et al., 2016) to multidimensional constructs, notably the European Commission's framework encompassing five dimensions: information and data literacy, communication and collaboration, digital content creation, digital security, and problem-solving (Carretero et al., 2017; Ulfert-Blank & Schmidt, 2022). This framework has gained cross-cultural validation (Law et al., 2018). In contrast, digital self-efficacy research predominantly employs oversimplified unidimensional measures (e.g., Guo et al., 2019; Hatlevik & Bjarnø, 2021; Kuo & Belland, 2019; Spears & Zheng, 2020; Zhang et al., 2020). Even multidimensional studies often lack theoretical depth, relying on superficial distinctions like "basic vs. advanced" computer self-efficacy (Kim & Glassman, 2013; Liang et al., 2011). The recent multidimensional framework by Ulfert-Blank and Schmidt (2022), mirroring the EU's digital competence model, remains understudied in its structural logic and untested in non-Western contexts, including China.

Cultural and Measurement Limitations

Despite early contributions from mainland Chinese scholars (e.g., Li, 2004; Tang & Yan, 2004; Wang, 2010; Yang & Li, 2010; Zhong & Liu, 2007), current research in China continues to rely on outdated constructs like computer self-efficacy or ICT self-efficacy (e.g., Sun, 2017; Wu & Wu, 2017; Li et al., 2019). No studies explicitly addressing digital self-efficacy exist in the Web of Science Core Collection (see Table 3). The absence of a culturally adapted measurement tool and a clear conceptual framework impedes progress in understanding the mechanisms of digital self-efficacy in Chinese populations, hindering efforts to enhance positive digital behaviors and mitigate negative usage patterns.

Unclear Cultural Specificity of Digital Self-Efficacy

The indigenous characteristics of digital self-efficacy remain underexplored. Current studies predominantly employ oversimplified (e.g., Guo et al., 2019; Hatlevik & Bjarnø, 2021) or superficial dimensional frameworks (e.g., Kim & Glassman,

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2013; Liang et al., 2011), leaving latent typologies of digital self-efficacy unexamined. Identifying such typologies is critical for comparing influencing factors and mechanisms across subgroups and tailoring interventions to enhance digital literacy. Developmental trajectories are also poorly understood. Existing studies focus on homogeneous samples (e.g., elementary students: Li et al., 2022; Aesaert et al., 2017; college students: Kuo & Belland, 2019) or short-term longitudinal designs (<1 year; Nelissen, 2019). While cross-sectional studies suggest age positively correlates with digital self-efficacy (Kuo & Belland, 2019; Wu & Tsai, 2006), longitudinal evidence is insufficient to infer developmental patterns or critical periods. Cultural heterogeneity in age-related effects (Peterson, 1993; Li et al., 2016) further underscores the need for context-specific investigations into Chinese adolescents' digital self-efficacy trajectories.

Fragmented Understanding of Influencing Factors

Despite identifying environmental (e.g., family resources, teacher support) and individual (e.g., personality, cognitive skills) predictors, research lacks a systemic framework to integrate these factors. Theoretical models are needed to elucidate hierarchical or interactive relationships among determinants.

Underexplored Formation and Impact Mechanisms

Research on digital self-efficacy formation faces four key limitations. First, conceptual oversimplification persists, with most studies treating the construct as unidimensional (e.g., Kuo & Belland, 2019), thereby masking dimension-specific mechanisms. Second, reliance on legacy constructs like computer or internet self-efficacy (e.g., Choi et al., 2022; Hong et al., 2021) limits generalizability to modern multidimensional frameworks. Third, environmental influences remain narrowly focused, neglecting macro-level factors (e.g., cultural norms) and peripheral contexts (e.g., community networks). Fourth, methodological constraints dominate, as cross-sectional designs (e.g., Hammer et al., 2021) hinder causal inference, while longitudinal and experimental approaches are rare.

Regarding impact mechanisms, studies predominantly emphasize generic digital system usage and academic outcomes, overlooking critical domains such as online prosociality, cyberbullying prevention, and victimization resilience—areas theoretically linked to digital self-efficacy through frameworks like Bronfenbrenner's ecosystem theory and bystander intervention models (Levine et al., 2005; Knauf, 2018). Additionally, developmental research disproportionately targets teachers (Sun, 2017; Wu & Wu, 2017) and college students (Huang et al., 2013; Wang, 2010), neglecting adolescents, a pivotal group for advancing national digital literacy. Global studies exhibit similar biases, underscoring the urgency of broadening both thematic and demographic scopes in future investigations.

Insufficient Empirical Research on Interventions

Randomized controlled trials (RCTs) are essential for evaluating interventions targeting digital self-efficacy. While correlational and longitudinal studies on digital self-efficacy abound, empirical intervention research remains scarce, with limited rigorous assessments of efficacy. Although studies on general self-efficacy interventions (e.g., Bresó et al., 2011; Siegel et al., 2022) have identified effective strategies, their applicability to digital self-efficacy—including operational adaptations and outcome generalizability—requires further empirical validation.

Conclusion

In summary, while research on digital self-efficacy in China commenced early, current domestic studies employ outdated conceptual frameworks, structural models, and measurement tools that fail to align with global advancements. The applicability of recent international findings to China's cultural specificity remains unverified. Existing research also neglects the indigenous and developmental characteristics of Chinese adolescents' digital self-efficacy. Both domestic and international studies lack systematic exploration of its formation mechanisms and exhibit limitations in understanding its impacts. To address these gaps, this project proposes a comprehensive investigation grounded in ecological systems theory, focusing on (1) the conceptual structure and internal logic of adolescents' digital self-efficacy in China, (2) its cultural distinctiveness and influencing factors, (3) developmental continuity and critical phases, (4) formation and impact mechanisms, and (5) the efficacy of educational interventions. These findings will advance efforts to achieve the goals outlined in the 14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives Through 2035 of the People's Republic of China and enhance citizens' digital literacy.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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Mirror, Reflection, and Prospect: South Korea's Integration into Economic Globalization—Process, Experiences, and Implications for China

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Abstract

From the 1960s to the present, South Korea has risen from the ashes of war, rapidly and comprehensively undergoing a modernization process that transitioned from an agrarian economy to one led by light industry, then heavy and chemical industries, followed by the tertiary sector, and finally a knowledge-based economy. This trajectory mirrors the path China is currently on and will continue to pursue. A key factor in South Korea's successful economic and national transformation has been its adept utilization of opportunities afforded by economic globalization. Its valuable experiences offer important lessons for China.

Keywords : economic globalization, South Korea's economic miracle, implications for China

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Introduction

The renowned historian Wallerstein[i] once outlined three development strategies for Third World countries: first, integrating into the world economic system; second, seizing opportunities to pursue import-substitution industrialization; and third, completely decoupling from the capitalist world system to focus on self-sufficient production. Many Latin American countries adopted the second approach, which proved effective in boosting economic development to some extent temporarily, but unsustainable in the long run. During the Cold War, socialist countries insisted on establishing a "parallel market," isolating themselves to focus on internal development, resulting in evident economic backwardness.

In contrast, South Korea chose the first path and emerged as one of the "Four Asian Tigers." The key to its success lies in adeptly leveraging the opportunities presented by economic globalization, consistently aligning its economic development with the global market. In particular, it capitalized on the gaps created by industrial restructuring in developed countries, utilized its comparative advantages, and achieved industrial upgrading. By adapting domestic reforms to meet the demands of the international economic system and proactively integrating into the wave of globalization, South Korea achieved rapid economic growth—a major factor behind its economic miracle.

Next, the author will focus on South Korea's historical process of actively integrating into economic globalization and its implications for China.

Seizing the Historic Opportunity Presented by Industrial Upgrading in Western Developed Countries

During its first Five-Year Economic Development Plan, South Korea adopted an "import substitution" strategy as its overarching guiding principle. The rationale was to rely on domestic resources, technology, and labor to produce the machinery, equipment, and consumer goods needed for economic development, thereby minimizing imports and alleviating the government's balance of payments pressures. Accordingly, the South Korean government implemented various measures to restrict foreign imports and protect domestic industries.

In its first Five-Year Economic Development Plan, South Korea adopted an "import substitution" strategy as its overall guiding principle. The intention behind this strategy was to rely on the country's own resources, technology, and labor to produce the machinery, equipment, and daily necessities required for economic development, thereby minimizing imports and easing the government's strained balance of payments. As a result, the South Korean government implemented numerous measures to restrict the importation of foreign goods and to protect domestic industries.

On the surface, this kind of trade protectionism appeared to effectively safeguard the fledgling national industries in the short term, gaining the support and endorsement of certain national capitalists. However, from a long-term perspective, this

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strategy was not well-suited for South Korea's development. Due to South Korea's small land area, high population density, and limited natural resources, its domestic market was constrained, which in turn became a bottleneck for further economic growth. Moreover, prolonged warfare and political instability weakened the purchasing power of the population and led to insufficient capital accumulation among enterprises.

As one scholar remarked, "The 'import substitution' policy implemented by South Korea during this period was, in fact, a policy of 'self-imposed isolation.' The fatal flaw of such a policy lies in placing the foundation of economic development solely on the country's limited human, material, and financial resources, failing to participate in international economic activities actively and to leverage external conditions for domestic economic development fully" [ii].

The historical development opportunity brought about by industrial upgrading in developed countries such as the United States happened to resolve this developmental dilemma for South Korea. After President Park Chung-hee came to power in 1961, in response to the reality of a limited domestic market, scarce resources, and a relatively abundant labor force, he seized the once-in-a-lifetime opportunity presented by the industrial restructuring taking place in the United States. He proposed the slogan "building the nation through trade, exports first," and began to implement an export-led outward-oriented development strategy. By 1964, South Korea had established a relatively sound export-oriented management mechanism, which in turn spurred rapid national economic growth.

Broadly speaking, South Korea's outward-oriented development strategy can be divided into two phases. The first phase, in the 1960s, was an export-oriented strategy centered on light and textile industrial products. The second phase, beginning in the 1970s, shifted to an export-oriented strategy focused on heavy and chemical industrial products. The adoption of these two strategies was, in the broader context of international development, a timely response to the restructuring of industries in developed countries led by the United States, which effectively made room in the global market.

The first phase emerged in the context of rising technological standards and increasing labor costs, which rendered labor-intensive industries—such as light and textile manufacturing—less profitable in developed countries. Starting in 1964, the South Korean government officially began to use export volume as a key indicator of national strength and placed particular emphasis on the development of labor-intensive industries, especially those based on light and textile manufacturing. The government took the initiative to implement a series of supportive measures.

This strategy achieved significant results in a remarkably short period of time, as it capitalized on favorable international opportunities while maximizing South Korea's domestic advantages—playing to its strengths and avoiding its weaknesses. The South Korean economy experienced rapid growth, and export volume soared—from $65 million in 1962 to $835 million in 1970. Throughout the 1960s, the average annual export growth rate reached 38.1%, a pace rarely seen worldwide. The surge in export volume also led to a significant shift in the overall product structure, with the proportion of industrial manufactured goods continuously increasing, thereby promoting healthy development in both the industrial sector and the national economy.

Entering the 1970s, South Korea's export-oriented development strategy faced significant challenges. With more and more developing countries joining the ranks of export processing zones, South Korea's previous advantage of cheap labor gradually diminished. Moreover, in producing these low-tech, low value-added goods, intense international competition led to rapidly shrinking profit margins, leaving little room for further development. At the same time, this development strategy inherently required the large-scale import of raw materials and machinery from abroad. The terms of trade between primary goods and high-tech machinery continued to deteriorate, making further expansion of exports nearly impossible. Additionally, the appreciation of imported goods combined with relatively declining exports began to create a trade deficit. In response to these evolving realities, South Korea began to continuously upgrade its outward-oriented development strategy.

During this period, developed countries, pressured by energy crises and the need to adjust their own industrial structures, began relocating energy- and resource-intensive, low-technology, and environmentally harmful heavy and chemical industries to other countries. This shift created a favorable opportunity for South Korea to upgrade and transform its industrial structure. Compared to light and textile industries, these heavy and chemical industries had advantages such as higher value-added production, broader markets, and more significant returns. Therefore, beginning in 1972, the South Korean government began tilting its support toward heavy and chemical industries. In 1973, the government issued the Heavy and Chemical Industry Declaration. The declaration stated, first, that the economic strategy centered on light industry in the 1960s had encountered barriers that hindered export growth and had become increasingly unsustainable. Therefore, it was necessary to concentrate national efforts on developing industries with higher value than light industry—such as shipbuilding, machinery, electronics, steel, and chemicals—with the world market as the target, striving to increase exports. Second, in order to reverse the worsening balance of payments, it was essential to upgrade and sophisticate the industries that had previously substituted for imports, starting with the development of heavy and chemical industries.[iii]To this end, in 1979, the South Korean government established the "Committee for the Promotion of Heavy and Chemical Industry," headed by the Prime Minister. A series of effective measures were taken to implement this strategy: key industries were identified for focused development and received strong support in terms of credit and taxation; special export bases were created specifically for heavy and chemical industrial production; more than 60% of government investment was directed toward infrastructure development to eliminate future obstacles to industrial growth; large enterprises were cultivated, and the development of small and medium-sized enterprises was also supported.

The successful implementation of this strategic decision enabled South Korea's industrial structure to rapidly shift toward a more advanced configuration. Within a short period of time, the country established a relatively complete national economic system and improved its technological capabilities, thereby significantly accelerating the industrialization process.

Overall, South Korea's rapid modernization from the 1950s to the 1970s was closely tied to the broader international economic environment of the time, particularly the postwar "golden age" of prosperity in major capitalist countries. South

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Korea fully leveraged the favorable global market conditions characterized by the "three lows" phenomenon—low growth, low inflation, and low interest rates—and seized the historic opportunity presented by the industrial restructuring of developed nations. Facing difficulties with determination and maintaining an independent approach, South Korea formulated its own development strategy and achieved a qualitative breakthrough in industrialization. With strong support from the United States and Japan, South Korea actively absorbed foreign capital and technology, and boldly integrated itself into the global economic system. As a result, it realized the miracle of rapid economic takeoff. It can be said that the key to South Korea's modernization process lies in its adoption of a correct internationalization strategy.

Advancing Internationalization Through APEC[iv]

South Korea's economy exhibits a high degree of external dependency and follows an export-led, outward-oriented structure. In the past, South Korea relied on free trade with the Western industrialized countries—led by the United States—pursuing an export-oriented development strategy to transform its impoverished and underdeveloped conditions, ultimately emerging as a newly industrialized nation. However, as the international situation changed, the Western developed countries not only began to adopt trade protectionism and regionalism based on their own national economic interests, but also demanded that South Korea compete on equal footing with developed countries in the global market. As a result, South Korea had to choose to join global economic cooperation organizations, seeking new paths for survival under their protection and coordination mechanisms. Especially since the late 1980s, the rapid emergence and development of economic regionalization and bloc formation, as well as the growing severity of regional trade protectionism, posed significant threats to South Korea's economic development. In response, the South Korean government once again adjusted its external economic development strategy, actively seeking ways to break through these difficulties.

South Korea chose to join APEC. Leveraging its national strength and international reputation, it sought to play a guiding—not leading—role in the Asia-Pacific region to stimulate its own economic growth while simultaneously counterbalancing Japan and the United States. Maintaining a centrist and neutral stance within Asia-Pacific regional economic cooperation was one of South Korea's key strategies[v]. Given its position within regional cooperation frameworks, South Korea aimed to strike a balance between developed and developing countries, drawing benefits from both sides. It adopted a strategy of alignment with the developed countries, especially the United States, to secure funding and access to advanced technologies, while showing sympathy and support toward developing countries to gain goodwill. This dual approach enabled South Korea to attract foreign investment, safeguard its access to the American and Japanese markets, reduce pressure from the U.S. to fully open its domestic market, and curb the rise of superpower dominance (particularly Japan). It also sought to expand its foreign trade and investment markets and reduce excessive dependence on the U.S. and Japan by positioning itself as a mediator between developed and developing nations.

For this reason, South Korea—along with Australia—was among the first to propose the establishment of the Asia-Pacific Economic Cooperation (APEC) forum. Since the founding of APEC in 1989, South Korea has actively participated in regional cooperation as one of its founding members (along with the United States, Canada, Japan, Australia, and New Zealand), as well as a host of trade and investment discussions. South Korea has worked to expand economic exchanges with other countries in the region and has sought to play a "core," "pioneering," "bridging," and "mediating" role in order to enhance its political and economic standing and influence both in the Asia-Pacific and globally. Throughout its engagement in APEC, South Korea has maintained a neutral stance, acting as a mediator in conflicts, and proposing flexible solutions that are more likely to be accepted by all parties. This approach has helped South Korea maintain harmonious cooperative relations with APEC member states and strengthen its international influence.

Implementing a Globalization Strategy: Fully Embracing the World

After World War II, and particularly following the major global shifts between 1989 and 1991, the process of economic globalization entered a new phase of development. However, true integration into the global economy remained largely limited to 20 to 30 industrialized countries. For the vast number of developing nations—especially the newly industrialized economies—this situation posed both serious challenges and significant opportunities.

Alongside globalization, another parallel trend emerged: the increasing regionalization of the world economy. Over the past decade, this regionalization has become markedly more pronounced. The establishment of the North American Free Trade Agreement (NAFTA) and the Asia-Pacific Economic Cooperation (APEC) has accelerated economic integration among countries within these regions and promoted close interactions and cooperation among them. These forms of cooperation, beyond offering regional advantages, are also closely linked to the global trend of nations adopting market-oriented economies. Given South Korea's unique geographic position and its advantageous standing within both global and regional economic groupings, the pursuit of a globalization strategy proved to be a wise and timely decision. Facing a century marked by both challenges and opportunities, South Korea began formulating its own "Globalization Strategy" in 1995[vi]. The main goals of this strategy were to reform its domestic political and economic systems in alignment with the emerging international economic order and to further enhance its international competitiveness so that all sectors of national development could integrate more fully into the global landscape. To this end, South Korea adopted a series of measures aimed at comprehensively implementing its globalization strategy, introducing effective reforms in both domestic governance and international relations.

Actively Promoting Enterprise Management and Operational System Reforms

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The South Korean government has made efforts to steer its enterprises toward globalization. It has engaged in dialogues with the North American Free Trade Area, strengthened cooperation with Western Europe, particularly the European Union, and actively developed new markets in third-world countries. Regarding changes in enterprise dynamics, the government has encouraged businesses to implement flexible production systems, reduce dependence on the government, expand interactions between domestic and international enterprises, enhance internal development, and actively introduce advanced foreign technologies. Guided by this principle, the government has introduced a series of measures to promote reforms in enterprise management and operational systems.

Actively Engaging in the Global Integration Trend

By the 1990s, South Korea gradually realized that, based on the achievements attained during the "industrialization" phase and its existing capabilities, it could accelerate the process of global and Asia-Pacific integration, occupying a relatively favorable international strategic position. Consequently, South Korea actively advocated for advancing global integration and the integration process of the Asia-Pacific region. To achieve this, South Korea sought to shift its foreign strategy, engage in comprehensive diplomatic activities, and actively participate in international organizations. Particularly during the Uruguay Round of negotiations, despite strong opposition from domestic farmers, South Korea accepted the terms and actively participated in the World Trade Organization (WTO). At the same time, South Korea recognized the importance of regional and national cooperation within "small circles." Not only did it actively engage in regional organizations, but it also made efforts to "bind" the countries of the Asia-Pacific region together, aiming to play a "core role" in the development of the Asia-Pacific Economic Cooperation (APEC) and compete with other nations.

Actively Promoting the Liberalization of International Trade

South Korea is an important member of the Asia-Pacific Economic Cooperation (APEC) and is keen to play a core role within the organization. It advocates that APEC should serve as a tool for promoting trade liberalization and eliminating trade barriers in the Asia-Pacific region. To advance the liberalization of international trade, South Korea plans to reduce the number of imported goods subject to restrictions by 50 each year, gradually achieving unrestricted and multilateral imports, thereby fully integrating the domestic and international markets and aligning the country’s economic development with global trends. While relaxing import restrictions, South Korea also strengthened support for exports and worked to improve the international competitiveness of its export products. To this end, South Korea established the "International Competitiveness Enhancement Committee," abolished more than 100 regulations that hindered competitiveness, and focused on protecting key export products. In early 1995, South Korea also put forward the slogan, "Consolidate and develop the Western European market, and develop the markets of third-world countries."

Relying on External Forces for Internal Reforms to Adapt to the Demands of Economic Globalization

After the Asian financial crisis, the cooperation between the South Korean government and the International Monetary Fund (IMF) exemplified South Korea's ability to seize opportunities, proactively integrate into the global economic system, and utilize the power of international organizations to carry out internal reforms. This enabled the country's economic system to align with the requirements of economic globalization.

Following the outbreak of the East Asian financial crisis, the IMF implemented its reform prescription for the countries in crisis. After winning the presidential election, Kim Dae-jung engaged in discussions with the IMF to devise strategies for resolving the crisis. The IMF urgently formulated an unprecedented aid plan, offering South Korea a loan of $57 billion, but with very stringent conditions. South Korea was required to undertake thorough economic reforms, significantly change its past development model, and move closer to a free-market economic model akin to those of the U.S. and the UK. In response to this challenge, Kim Dae-jung clearly stated that his new government "would fully implement the agreement with the IMF."[vii] However, Kim Dae-jung's acceptance of the IMF’s demands was not entirely out of necessity. Reform had long been his political goal. He believed that although the IMF’s reform demands seemed disastrous at first, they actually offered a significant opportunity. Kim Dae-jung sought to use the IMF’s prescriptions to reform South Korea’s economic system, with the aim of revitalizing the economy. Therefore, he made it clear that eliminating deep-rooted issues and addressing the "Korea disease" would be his top priority, with reforms driving the economic resurgence. After his election, he did not hesitate to cooperate with the IMF. In his inaugural speech, Kim reiterated his commitment to reforms, promising to revitalize the national economy, eradicate corruption, and end centralized authoritarian rule. He also pledged to establish a smaller government that better reflected the people's will, focusing on economic development while advancing democracy, and eliminating unnecessary government restrictions and privileges as quickly as possible, rooting out the sources of bureaucratic control over the economy.

South Korea’s acceptance of the reform conditions set by the International Monetary Fund (IMF) aimed at positioning the country within the international economic system and adapting to the demands of economic globalization. This was not only a crucial factor in South Korea’s swift recovery from the economic crisis but also one of the key reasons behind its successful modernization.

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From the above analysis, it is evident that every step of South Korea's modernization has been closely related to international contexts and the global economy. South Korea has been adept at seizing every opportunity and international condition available to serve its economic development, actively participating in international cooperation and competition, and proactively integrating itself into the wave of economic globalization. Moreover, South Korea has boldly used the demands of international organizations and the operating rules of the international economy to carry out internal reforms and align itself with the requirements of global economic development. It can be said that economic globalization created the opportunity for South Korea's economic rise, while South Korea's active engagement in the global economic wave is the true reason behind its economic success.

Implications for China

Every economy in the world is unique, with varying scales, histories, and cultural backgrounds. However, this does not diminish the fact that there are certain regularities and lessons from the development of some early industrialized economies that can be beneficial for others. From South Korea's active integration into the globalized economy, there are several aspects worth considering for China.

Chinese-style modernization must proceed under conditions of openness, making rational use of international division of labor and industrial transfer trends, and adapt to the changing global landscape.

In the current context of global economic integration, although there is still varying degrees of trade protectionism, openness and globalization remain the mainstream. When formulating industrial policies, China should not attempt to build "full industrial chains" and achieve self-sufficiency on its own. Instead, it should make reasonable use of international industrial division, industrial transfer, and factor flows, striving to make breakthroughs in key sectors and participate in international competition.

Take advantage of the demands of international organizations and the rules of international economic operation to carry out internal reforms, adapting to the requirements of global economic development.

South Korea has emphasized the importance of utilizing international industrial transfer under open conditions, combining industrialization, urbanization, and internationalization, and actively participating in international division of labor and industrial competition. The industrial policies during South Korea's authoritarian era led to the first stage of the "Miracle on the Han River," transforming the country from a backward, impoverished agricultural nation into an industrial powerhouse, but they also created serious problems, known as the "Korea Disease." South Korea used the East Asian financial crisis as an opportunity to reform its economic system, adopting the IMF's prescription. By decisively abandoning old industrial policy models, replacing them with competition policies and technology policies, South Korea eradicated the "Korea Disease" and achieved a profound transformation, enabling the second phase of the "Han River Miracle" and propelling high-quality development.

Managing the Relationship Between the Broader Government (Administrative, Legislative, and Judicial) and the Broader Market (State-Owned Enterprises, Private Enterprises, Entrepreneurs, and Entrepreneurial Spirit)

A crucial aspect of South Korea's integration into economic globalization and its modernization process is its emphasis on government leadership, while never denying the importance of the market. South Korea respects and adheres to market principles, balancing the roles of the government, market, enterprises, and entrepreneurs. During this process, a large group of entrepreneurs, such as Chung Ju-yung, Suh Seung-hwan, Lee Byung-chul, Lee Kun-hee, Choi Jong-hyun, and Koo Ja-kyung, emerged. These entrepreneurs had strong nationalist sentiments and exemplary entrepreneurial spirit. South Korea's government leadership does not mean the government handles everything; rather, the government provides public goods, encourages private sector participation, and maintains clear boundaries between the public and private sectors.

Conclusion

Korean's experience offers valuable insights for China, which is currently undergoing comprehensive reforms. Government decision-making should broadly incorporate diverse opinions, ensure procedures are legal and compliant, and avoid closed decision-making and "small circle" benefits. The central government's focus should be on providing public goods, optimizing the market environment, and, to prevent market failure, allowing, guiding, or encouraging private capital to flow into certain specific sectors. It is important to fully harness the creativity, exploration, and innovation of entrepreneurs, as well as the role of market-driven financial instruments in incubating, nurturing, and accelerating development. For state-owned enterprises involved in market competition, reforms should be carried out in terms of ownership structure, incentive mechanisms, and constraints in accordance with market rules.

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All contributions of the third parties can be acknowledged in this section.

Conflict of Interest

The authors declare no conflict of interest.

References

[1] Immanuel Maurice Wallerstein (September 28, 1930 – August 31, 2019) was born in New York City, USA. He served as a Senior Research Scholar at Yale University and previously taught in the Department of Sociology at Binghamton University, State University of New York. A renowned historian, sociologist, and international political economist, Wallerstein was a key figure in Neo-Marxist thought and the principal founder of World-Systems Theory. His scholarly output was prolific, with his most influential work being *The Modern World-System* (4 volumes), a magnum opus to which he devoted over three decades of research.

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A Multidimensional Perspective on Language Planning and Policy in Singapore: Theory, Practice and Challenges

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Abstract

As a model of a multilingual country, Singapore's language policy has always aimed to balance linguistic diversity and social integration. Through the synergy of status planning, corpus planning, prestige planning and education planning, Singapore has successfully shaped a multilingual society with English as the lingua franca while preserving the cultural identity of the community. However, the new challenges posed by globalization and intergenerational linguistic change have prompted Singapore to continuously adjust its policy framework. Taking Singapore as an example, this paper explores the practical paths, effectiveness and inherent tensions of its language policy from the definitions of language planning and language policy, as well as from the perspectives of functionalism, social constructivism and critical theory.

Keywords : Singapore; language planning; language policy; language prestige; international cases

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Introduction

Singapore's language policy and language planning, as a model for the management of a multilingual society, have long attracted extensive attention in the international academic and policy research fields. Since its independence in 1965, the Singaporean government has established a pragmatism-oriented language governance framework. Rooted in its multiracial society (Chinese, Malay, Indian, and other ethnic groups) and national security needs, this framework designates English as the administrative lingua franca while retaining Malay (the national language), Mandarin, and Tamil as official languages. This policy not only serves the country's economic construction (through the integration of English into the globalization system), but also assumes the political functions of balancing ethnic identities, maintaining cultural traditions and shaping the national identity.

Definition of Language Planning and Policy

Language Planning (LP) refers to the systematic and prolonged intervention in language selection, standardization and promotion, usually at the national or regional level. The process involves the collaboration of government agencies, educational systems, and other social forces.[1]Fishman, one of the leading scholars in the field of language planning, emphasizes that the core of language planning lies in promoting the social functions of language, especially in enhancing social cohesion in multilingual societies.

Language Policy, on the other hand, is regarded as a superordinate concept of language planning, and its connotation is diversified according to the different perspectives of scholars. From the instrumental perspective of language, Robert B. Kaplan & Richard B. Baldauf (1997) emphasize language policy as a state-led normative framework covering language choice, education system design and standardization measures.[2] From the dimension of power and authority, Bernard Spolsky (2004) points out that language policy is an institutional arrangement of language use by an authority[3]; Tove Skutnabb-Kangas(2000) combines it with social justice, and advocates that language policy should protect the language rights of ethnic minorities.[4]From the perspective of dynamic construction, Thomas Ricento(2006) holds that language policy involves decisive measures for the role and position of language in the public sphere, and points out that it is not only the result of government decision-making, but also influenced by social forces and historical background.[5] Michael Heller(2007) believes that language policy is not only a question of language selection and standardization, but also reflects social structure, identity, cultural identity and power inequality, so it involves complex political and social forces.[6]

Theoretical basis of language planning and policy

Functionalism theory

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Functionalism theory emphasizes the social function of language and its close relationship with social, economic and political needs. According to this theory, the choice and promotion of language is usually to meet the needs of a social group in communication, cultural identity and education.[7] The Singapore government has positioned English as a strategic choice of economic language and successfully built a competitive advantage in the context of globalization. Through the implementation of English-oriented bilingual education system (English+mother tongue), Singapore has cultivated a highly internationalized labor market, and its English proficiency has ranked first in Asia among non-native English-speaking countries for eight consecutive years (EffEnglish Proficiency Index, 2022).[8]This language advantage has helped Singapore attract more than 42,000 multinational companies to set up regional headquarters, forming a cluster effect in knowledge-intensive industries such as finance and science and technology, and promoting the average annual GDP growth rate to remain stable at 3.2% in the past decade (World Bank, 2023).More profoundly, English, as the common language of all ethnic groups, has effectively reduced the communication cost of a pluralistic society, making Singapore one of the top indicators of social cohesion in the global urban competitiveness index all the year round.

However, the excessive strengthening of language instrumental rationality is causing a structural crisis of cultural inheritance. According to a survey conducted by the Ministry of Education, the proportion of households using only English at home has soared from 32% in 2010 to 48% in 2020, while less than 15% of teenagers are fluent in their ancestral dialects (Khoa Vlt, 2024).[9]This intergenerational language gap has led to a dilution of cultural awareness - about 63 percent of the Post-95s are unable to recognize dialectal phrases in traditional operas, and the loss of clan ritual phrases is particularly noticeable in the Chinese community. Despite the government's attempts to remedy the situation through policies such as the Speak Mandarin Campaign, most young people view their mother tongue as a test-taking tool rather than a cultural vehicle, and the trend of abstracting the historical memory of the community continues to intensify. This inherent tension between economic rationality and cultural values reflects the universal dilemma faced by post-colonial societies in the process of modernization.

Social Constructionist Theory

The social constructivist perspective, on the other hand, argues that the formulation and implementation of language policy is not only a product of social needs, but also a reflection of social power, cultural identity and historical context. [10]This perspective focuses on the relationship between language and power, and argues that political and social power plays are often hidden behind language policies. The formulation of certain language policies may help to maximize the interests of one social group while ignoring the language needs of others. The formulation of language policy in Singapore, a multicultural island nation, is a stark example of this. Singapore's language planning not only reflects respect for multiculturalism, but also has a profound impact on the country's governance and social cohesion. Singapore has implemented a multilingual system where Malay is the de jure national language, while English, Mandarin, Malay and Tamil are all recognized as official languages. Such a language policy aims to reconcile the differences in the use of mother tongues by various ethnic groups and to promote communication and integration among different ethnic groups, reflecting the response of language policy to social needs from a social constructivist perspective.

However, when analyzed in depth from the perspective of social constructivism, the formulation of Singapore's language policy also reflects the game of social power and cultural identity. The fact that Malay is used as the national language reflects the respect for the indigenous Malay culture, while English is used as the administrative language and the main tool for international communication, which to a certain extent reflects the importance Singapore attaches to international communication as an internationalized metropolis. At the same time, the extensive use of English in administration and business also ensures administrative efficiency and smooth international communication, which is implicitly based on considerations of economic and political power.

In addition, the Singapore government has vigorously promoted Chinese language education, both in response to the language needs of the Chinese community and in recognition of the importance of Chinese culture. As China's international status continues to rise, the status of the Chinese language in Singapore has also become increasingly prominent. By promoting Chinese language education, the government not only meets the language needs of the Chinese community, but also strengthens the cultural ties with mainland China, which to a certain extent reflects the pursuit of maximizing the benefits of the social groups by the language policy.

Critical Language Policy Theory

Critical language policy theory is based on the framework of critical theory, with special emphasis on the close connection between language policy and the issues of social inequality, class and ethnicity.[11]The theory holds that language is not just a tool for communication; it contains behind it a struggle between cultural and political forces. In a multilingual society, the promotion of certain languages may strengthen the cultural hegemony of the dominant group and weaken the language rights of marginalized groups. This theory pays special attention to the social justice dimension of language policy, emphasizing that language planning should protect the linguistic rights of minority languages and disadvantaged groups.

Although Singapore's language policy formally advocates multilingual coexistence, it essentially constructs an implicit hierarchical order in which “English is the dominant language and the mother tongue is the secondary language”. This order is not only embodied in the design of the system, but also permeates the deep logic of social operation. In the legal field, for example, although the government requires public documents to be published in the four official languages (English, Mandarin, Malay and Tamil), the English version always has the highest legal effect. For example, in the revised Employment Act 2021,

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in the event of ambiguity between the different language versions of the provisions, the English version shall prevail in the final interpretation. This provision ostensibly safeguards multilingual services, but in fact reinforces the authoritative status of English through institutional arrangements, leaving non-English-speaking groups in a passive position when it comes to understanding legal rights and interests. As sociolinguist Tan (2021) points out, "Singapore's language policy masks the hegemonic nature of English as a 'meta-language' through the rhetoric of 'multilingualism', a symbolic inclusion that essentially is an instrumentalization of linguistic diversity that serves the efficiency needs of state governance."[12]

Types of language planning

Language Status Planning

Language status planning refers to the determination of social status for the languages in a language bank, which mainly involves language selection and is developed by the government or a policy-making body. Heinz Kloss, a famous German linguist, proposed a dichotomy of language planning research in 1969, namely status planning and corpus planning.[13]Language status planning, also known as language function allocation, language status policy, etc., is more related to the external social environment of language, including activities such as language choice (e.g., national language, official language) and dissemination.

Singapore's language planning and language policy is an exemplary case of global language status planning, and its characteristics are highly compatible with Heinz Kloss's theoretical framework. As a microstate with a multiracial and multilingual society, the Singaporean government has achieved the dual goals of social integration and economic development through systematic language status planning.

At the level of language status planning, Singapore has adopted the strategy of functional multilingual stratification. First of all, the four official languages (English, Chinese, Malay and Tamil) were established through the Constitution, among which Malay was positioned as a symbolic national language, which not only respected the historical status of indigenous people, but also avoided political disputes caused by a single national language. English has been given the status of the actual administrative language. As the common language of cross-ethnic communication, this choice has profound political and economic considerations: maintaining connections with western economies while avoiding strengthening the cultural hegemony of any native ethnic group. In terms of language function distribution, the government has built a fine language hierarchy system. As the top language, English dominates government affairs, judicial system, higher education and business; Each mother tongue (Chinese, Malay, Tamil), as a second language, undertakes the functions of cultural heritage and ethnic identity, and implements a mandatory mother tongue policyin school education; At the same time, language communication projects such as Speaking Mandarin Campaign are introduced to integrate dialect groups into standard Chinese. This bilingual structure of English + mother tonguenot only maintains multiculturalism, but also creates a unified foundation of national identity. Singapore's experience has also successfully verified the practical value of Kloss theory.

Language corpus planning

Language corpus planning generally refers to the standardization and standardization activities of language itself. The concept of corpus planning was first put forward by the famous German linguist Heinz Kloss in 1969. Together with status planning, it constitutes a dichotomy of language planning research classification. Language corpus planning mainly involves literalization, standardization and modernization. Literalization involves the creation and improvement of characters, such as the design of pinyin characters for ethnic minorities in China and the adoption of new Latinized alphabets in Turkey. Standardization aims to unify the orthography, grammar, vocabulary, etc. of the language, and is achieved by compiling dictionaries and formulating norms. In terms of writing, the Singapore government has implemented a differentiated strategy for different ethnic groups: Chinese adopts simplified characters and Chinese Pinyin, Malay follows the Rumi system, and Tamil uses Grantha characters, which promotes written communication. In terms of standardization, language management organizations, such as the Chinese Language Council for the Promotion of Chinese Language, should be set up to standardize vocabulary and flexibly standardize Singapore English. In the process of modernization, Singapore has innovated language planning, such as translating scientific and technological terms, creating new words, and digitizing multilingual teaching resources.

Discussing the sequence between language status planning and language corpus planning has always been one of the core topics to study the relationship between them. In this regard, Joshua Fishman pointed out that there are the following three situations: one is that status planning is carried out before corpus planning; The other is that corpus planning is carried out before status planning; There is also a situation where the two go hand in hand and at the same time.[14]The three forms of interaction proposed by Fishman are all reflected in Singapore's language ecology:

1. Parallel promotion: While establishing English as the administrative language (status planning) in the early years of the nation's existence, the standardization of the scripts of the official languages (corpus planning) was simultaneously promoted, forming a dual-track system in which "English is the language of use and the mother tongue is the language of the body".

2. Status-led: After Malay is designated as the national language (status planning), its ontological planning will be gradually improved through standardized texts such as the Malay Grammar Guide to strengthen the function of national identity symbols.

3. Ontology-forced: Singlish (Singaporean English) grows spontaneously in the private sector (implicit corpus planning), prompting the government to introduce the Guidelines on Language Use in Public Places (explicit status planning), forming a reverse regulation.

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Language Prestige Planning

The term “prestige” was first proposed by Uriel Weinreich in 1968, who pointed out that the value of language in the process of social development can be called prestige. [15]Haarmann introduced the term prestige into the field of language planning in 1984 and suggested that prestige planning should be considered as a new dimension of language planning, involving different levels such as governments, organizations, groups and individuals.Prestige planning is divided into prestige related to the production of language planning (e.g., prestige of planners and policies) and prestige related to reception (value judgments of the audience about planning activities). It is not dependent on status or ontological planning, but can influence its process and determine the success or failure of planning.

The Singaporean government builds the prestige of planners through policy authority and implementation effectiveness, such as the 1979 “Speak Mandarin Campaign”, which combined with the country's modernization strategy to build a positive reputation for the Mandarin language and create a cycle of policy legitimacy. In terms of audience acceptance, English as an economic language has gained instrumental prestige through the education system and the demands of the workplace, while the mother tongue maintains emotional prestige through cultural heritage policies. Prestige planning interacts with status/corpus planning, e.g. the “Speak Chinese Campaign” to enhance the prestige of the Chinese language. Singapore has developed a “multi-layered prestige” model, with Malay reinforcing symbolic prestige and Tamil maintaining communal prestige. The rise of prestige planning in the digital realm, such as the TikTok dialect project, which reconfigures the prestige of dialects, demonstrates a shift towards multi-actor negotiation in prestige planning. Singapore's experience shows that effective prestige planning requires balancing institutional authority and audience perceptions, and maintaining a dynamic balance between linguistic tools and cultural values.

Language Education Planning

Language education planning is a kind of conscious intervention in the process of language education and language learning, which is also called “(language) acquisition planning” or “language planning in education”. Language education planning is the specific practice of language planning in the field of education, which is consistent with the goals of national or local language planning, and involves schools, universities, primary and secondary schools, as well as family education, with the main body being the education authorities, as well as nongovernmental organizations and individuals. Its responsibilities include determining the language of instruction, teacher training, community participation, the selection of teaching materials and curricula, the establishment of testing systems, the determination of financial inputs, and the selection or modification of teaching methods.

Singapore's language education planning is a key part of the national language policy, showing the systematic nature of multilingual governance. As one of the few countries whose constitution guarantees multilingual education, Singapore has established a bilingual system of English + mother tongue through careful planning, respecting multiculturalism and adapting to the needs of globalization. The implementation characteristics include: 1. The selection of instructional language has political and economic considerations, English is the administrative language and teaching medium, and mother tongue is a compulsory subject to ensure international competitiveness and ethnic cultural identity. In 2022, 15% of the education budget will be used for bilingual teacher training and teaching materials development. Second, planning and policy coordination, such as the 2011 Mother Tongue Education Review Plan, to refine the Chinese curriculum and improve the Chinese passing rate of secondary school students. Third, the embedded characteristics of society, the deep participation of non-governmental organizations, such as the Speak Chinese Campaign and the family language learning program, have increased the bilingual usage rate of families to 71%. In terms of technology empowerment, the Ministry of Education has developed the Yulin AI auxiliary system to provide personalized learning solutions and improve learning efficiency. Singapore's practice shows that successful language policy requires institutional flexibility, coordination of multiple subjects, and intelligent technical means, which provides a model for language planning with national strategic orientation, educational innovation, and social participation.

The four types of language planning (status planning, corpus planning, prestige planning and educational planning) do not operate in isolation in practice, but form an organic whole with dynamic linkage. As the cornerstone of the policy framework, status planning needs to standardize the language system through corpus planning, and rely on prestige planning to enhance the social identity of the target language, and finally penetrate into intergenerational inheritance through educational planning. Taking Singapore as an example, the success of its language policy benefits from the coordinated advancement of four types of plans:

In Singapore's language planning, the government first established English, Mandarin, Malay and Tamil as the official languages from the status planning level, in which English serves as the administrative lingua franca to promote cross-ethnic communication, while the mother tongue assumes the function of cultural heritage. Then, at the level of corpus planning, the Ministry of Education set up the Chinese Curriculum and Teaching Method Review Committee to simplify grammar (such as reducing the use of traditional characters) and promote the localization of vocabulary (such as incorporating local concepts such as HDB—Housing and Development Board and hawker center) by revising Chinese textbooks and formulating Singapore Chinese Curriculum Standards, so as to enhance the practicality of the language. To further enhance the social prestige of the mother tongue, the government launched the Speak Mandarin Campaign and the Mother Tongue Fortnight campaign, using celebrity endorsements and social media challenges (such as # MyMotherTongue #) to enhance the emotional identity of the younger generation with the mother tongue. However, at the level of educational planning, despite the implementation of the bilingual education policy, which requires all students to use English as their first language and take their mother tongue,

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excessive emphasis on English leads to the weakening of their mother tongue ability. This contradiction reveals the internal tension in language planning: if corpus planning fails to match the resource allocation of educational planning, or prestige planning lacks continuity, the long-term effect of language policy will be compromised.

Conclusion

Singapore's language planning and policy, as a model for the management of a multilingual society, demonstrates its unique wisdom in balancing linguistic diversity with social integration. Through the synergy of status planning, corpus planning, prestige planning and education planning, Singapore has successfully built a multilingual framework with English as the lingua franca, while retaining Malay (national language), Mandarin (Putonghua) and Tamil as official languages. This policy system has not only facilitated the country's economic development and international exchanges, but has also effectively preserved the cultural identity of the ethnic groups and strengthened social cohesion.

However, with the acceleration of globalization and the intensification of intergenerational linguistic change, Singapore's language policy is facing new challenges. On the one hand, the over-enforcement of the instrumental rationality of English has triggered a structural crisis in the cultural heritage, leading to the weakening of mother-tongue competence and the dilution of cultural cognition; on the other hand, the process of formulating and implementing language policy has also mapped out the complex game of social power and cultural identity. Therefore, Singapore needs to continuously adjust its policy framework to cope with these emerging challenges.

In the future, Singapore's language planning and policy should pay more attention to the dynamic balance between language tools and cultural values, strengthen the status of mother tongue education, and enhance the public's sense of identity and frequency of use of the mother tongue. At the same time, the government should also strengthen communication and collaboration with all sectors of the community to ensure that language policies are formulated in a more scientific and rational manner, and are more in line with the actual needs of the public. Through these efforts, Singapore is expected to continue to maintain its unique charm of linguistic diversity amidst the wave of globalization, and to make positive contributions to the building of a more harmonious and inclusive multilingual society.

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