

## **2.2. Design of core functional modules**

### **2.2.1. 3D digital twin global perception platform**

Through 1:1 3D modeling technology, it completely restores physical entities such as power plant buildings, equipment, and pipe networks, realizing real-time mapping between the “virtual power plant” and the “physical power plant.” Its core functions include the following.

Plant roaming and concealed facility management: Support gravity roaming and zero-gravity roaming modes. Operators can browse the plant through a first-person perspective or follow perspective, and view real-time data such as underground pipe network coordinates and equipment operation parameters; through three-dimensional and section analysis, it intuitively displays the structure of concealed projects, providing data support for maintenance.

Multi-system integration and linkage monitoring: Connect subsystems such as video surveillance, personnel positioning, and fire alarm. When personnel enter dangerous areas (such as hydrogen stations and oil tank areas), the system automatically triggers electronic fence alarms and simultaneously retrieves nearby camera images, realizing “positioning — monitoring — alarm” linkage.

### **2.2.2. Intelligent public safety prevention and control platform**

Based on the concept of “intelligent security one map”, it realizes rapid deployment of suspicious targets through data correlation analysis.

Personnel and vehicle management: Integrate data from access control, visitors, and vehicle gates, establish personnel/vehicle black and white lists, and automatically warn of unregistered personnel and overtime vehicles; use face recognition technology to real-time compare personnel identities and operation permissions to prevent illegal intrusion.

Low-altitude defense and perimeter protection: Deploy UAV countermeasure systems to real-time track the flight trajectories of unauthorized UAVs, link electronic fences to trigger sound and light alarms, and identify abnormal behaviors such as perimeter wall damage, and through intelligent video analysis, with an alarm response time of no more than 5 seconds.

### **2.2.3. Intelligent operation process supervision platform**

Aiming at the complex operation environment of overseas power plants and the difficult management of outsourced projects, it constructs a full-process control system.

Personnel behavior and health monitoring: Use AI image recognition technology to real-time detect illegal behaviors such as personnel not wearing safety helmets, smoking, and playing with mobile phones, with an identification accuracy of 98%; collect physiological data such as blood oxygen and heart rate through intelligent bracelets to real-time warn of fatigue operation and poisoning risks.

Full-cycle management of high-risk operations: Combine the 3D scene with the “two-ticket management” process. Before operation, delimit electronic fences and mark risk points through the platform; during operation, real-time monitor personnel trajectories and environmental data, automatically suspend operations and notify supervisors in case of abnormalities; establish an outsourced project ledger to record contractor qualifications, operation quality, and safety performance, providing a basis for payment and assessment.

### **2.2.4. Automatic remote AI patrol platform**

Adopt a collaborative patrol mode of “UAV plus Fixed Camera”, replacing more than 60% of manual inspection work.



Multi-dimensional hidden danger identification: Identify hidden dangers such as equipment pipeline leakage (positioning accuracy no more than 5cm), abnormal instrument readings, and fire smoke through video analysis technology; realize early warning of equipment overheating and abnormal noise through infrared thermal imaging and acoustic monitoring.

Closed-loop management process: After discovering hidden dangers, the system automatically generates work orders and pushes them to the responsible persons. The processing results are fed back through mobile terminals, forming a closed loop of “Detection — Order Dispatch — Rectification — Acceptance”, with an average processing time shortened by 40%.

### **2.2.5. Digital support system for safety management**

Risk knowledge base system: Integrate data such as thermal power plant accident cases, safety standards, and operation specifications, establish a structured knowledge base, support intelligent Q&A and risk retrieval, and provide decision-making references for employee training and emergency disposal.

Mobile management terminal: Develop iOS/Android applications to realize functions such as task receipt, knowledge base query, operation approval, and real-time monitoring. Leaders can view the safety situation of the plant through mobile terminals at any time, with decision-making efficiency increased by more than 50%.

## **3. Key technical innovations and applications**

### **3.1. Deep integration of 3d digital twin and physical systems**

Traditional digital twins mostly stay at the visualization level. The Huadian Xigang project connects the underlying device data interface through industrial Internet protocols (such as OPC UA), realizing real-time linkage between the 3D model and PLC and DCS systems. For example, clicking on the steam turbine model in the 3D scene can directly view real-time operation parameters such as vibration and temperature. When abnormalities occur, the model automatically highlights and alarms, improving operation efficiency by 30% compared with the traditional SCADA system<sup>[3]</sup>.

### **3.2. Localized optimization of AI visual analysis technology**

Aiming at problems such as camera lens fogging and image blur caused by the high temperature and humidity environment in Cambodia, adopt an adaptive image enhancement algorithm combined with dynamic background modeling technology to improve the target recognition accuracy in complex scenes. The measured data shows that the recognition accuracy of personnel's illegal behaviors still remains above 95% under conditions such as light changes and dust interference<sup>[5]</sup>.

### **3.3. Multi-system heterogeneous data integration technology**

Overseas power plants often face the problem of incompatible protocols of equipment from different manufacturers. The project uses edge computing gateways to realize protocol conversion of Modbus, MQTT, ONVIF, etc., establishes a unified data middle platform, accesses 15 types of equipment and 876 data points in total, with a data delay of no more than 200ms, providing underlying support for global perception.

## 4. Practical effects and experience summary

### 4.1. Significantly improved safety management efficiency

Reduced labor costs: AI patrol replaces 60% of manual inspection, saving about 2 million RMB in labor costs annually; mobile approval reduces paper process circulation, and the operation permission processing time is shortened from 4 hours to 1 hour<sup>[2]</sup>.

Enhanced risk prevention and control capability: After the electronic fence and intelligent alarm system are put into use, there are zero illegal intrusion incidents; the equipment's hidden danger discovery time is shortened from daily inspection to real-time monitoring, and the defect processing timeliness is increased to 99%<sup>[4]</sup>.

Faster emergency response speed: The safety management command center integrates a large-screen visualization system, which can retrieve accident site videos, personnel distribution, and hazard source data within 30 seconds, shortening the emergency disposal process time by 50%.

### 4.2. Innovation of the localized management model

Compliance guarantee: Embed Cambodian labor safety regulations into the system process, such as mandating foreign employees to wear safety helmets and setting up Thai/English bilingual alarm interfaces to ensure compliance with local regulatory requirements.

Promotion of cultural integration: Through multi-language versions (Chinese/English/Cambodian) of the risk knowledge base and visual safety training modules, improve the safety awareness of local employees, and reduce the incidence of illegal behaviors by 65%.

### 4.3. Replicable technical paradigm

The core value of the Huadian Xigang model lies in the dual-drive of “technical integration plus management innovation.”

Technical level: Form a standardized technical path of “3D modeling — Data Integration — AI Analysis — Closed-Loop Management”, applicable to scenarios such as overseas power plants and chemical parks.

Management level: Construct an active prevention and control system of “Perception — Analysis — Decision-making — Execution”, breaking through the traditional “post-event disposal” model and providing a methodological reference for safety management of overseas enterprises.

## 5. Conclusion

The practice of the intelligent safety prevention and control system for overseas power plants of Huadian Xigang Power Generation Co., Ltd. shows that through the deep integration of global perception technology and digital management means, the safety management problems of overseas energy projects can be effectively solved. The system not only improves the enterprise's own safety performance but also explores a path of “technical localization, management standardization, and intelligent response” for overseas safety governance, providing a reproducible Chinese solution for energy enterprises along the Belt and Road<sup>[1]</sup>.

In the future, the following directions can be further explored: (1) Introduce 5G plus edge computing technology to improve real-time data processing capabilities; (2) Integrate blockchain technology to realize tamper-proof storage of safety data; (3) Develop VR emergency drill modules to enhance the collaborative disposal capabilities of Chinese and foreign employees. With the iteration of new technologies, the intelligent safety prevention and control system will upgrade towards “autonomy, self-adaptation, and self-optimization”,

providing a more solid guarantee for the long-term safety of overseas energy infrastructure<sup>[3–5]</sup>.

## Disclosure statement

The authors declare no conflict of interest.

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# Research on the Refined Path and Strategy of College Students' Ideological and Political Education in the Context of New Media

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**Abstract:** With the continuous improvement of social demand for high-quality talents, the emphasis of higher education on Ideological and political education has gradually increased. The new media environment has brought new development opportunities for college students' ideological and political education, but it also faces severe social challenges. The form of ideological and political education in the traditional higher education system is relatively broad. The transformation from "rough" to "refined" is a new educational concept that fits the current personality characteristics of college students. This paper discusses the related issues of the refined path and strategy of Ideological and political education for college students in the new media environment, analyzes the shortcomings of traditional ideological and political education for college students, the impact of new media on Ideological and political education for college students, and the effective path and strategy of refined ideological and political education for college students, so as to promote the improvement of Ideological and political teaching level for college students.

**Keywords:** New media; College students; Ideological and political education; Refinement

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## 1. Introduction

The demand for high-quality talent is increasing with the in-depth development of the social economy. Higher education needs to further strengthen the functional role of Ideological and political education and moral education content, so as to realize the guiding role of students' ideology and values, and promote the development and improvement of students' comprehensive quality. Under the new media environment, college students' thinking consciousness has changed greatly, and the ideological and political education and daily management work are also facing higher requirements. How to carry out effective ideological and political education has become a key issue for higher education. The refined ideological and political education helps to reflect the pertinence and effectiveness of Ideological and political education. It is of practical significance to explore the refined path of Ideological and political education in the new media environment for achieving the goal of talent training in higher education.



## **2. Deficiencies of traditional ideological and political education for college students**

The ideological and political education course of higher education is an important way to cultivate and improve college students' Ideological and moral awareness. The ideological and political education course needs to integrate the cultivation concept of socialist core values and guide students to establish a correct concept of life development and values. As a required course in colleges and universities, the ideological and political education course plays an important role in value guidance. With the development and progress of the social economy, changes are taking place at all levels of society, and students' thinking consciousness is also changing under the influence of the social environment. The ideological and political education in colleges and universities is also facing the new requirements of educational development and the realistic demands of mode adjustment. The ideological and political education in colleges and universities needs to abandon the traditional teaching mode and ideological and political education mode, and further improve the effectiveness of education and the pertinence of Ideological and political education.

In the current social and cultural environment, college students are in a state of diversified thinking consciousness, and the consistency between the professionalism and effectiveness of ideological and political education and students' thoughts is gradually reduced. The didactic and indoctrinated teaching mode and daily management mode will also make students resist ideological and political education, and then affect the daily moral education and curriculum teaching efficiency. The improvement of college students' self-demand has put forward higher requirements for moral education and ideological and political work in the new era. It is urgent to integrate some mainstream social thoughts and humanistic ideas into the connotation of moral education, so as to enrich and improve the connotation of moral education <sup>[1]</sup>. From a macro perspective, contemporary college students do not neglect the development of their own thinking consciousness, but the current open network environment and media communication pattern in the new media era have gradually improved the students' listening taste, monotonously and boring to instill truth into students, which makes it difficult for ideological and political education theory to be transformed into students' own quality, and the learning process of ideological and political courses has also become a rote process to cope with examinations. This cycle makes it difficult to implement the spirit of ideological and political education, and gradually reduces the effectiveness of ideological and political education. In the ideological and political class, the common phenomenon of "bow head group" among college students has caused us to think deeply — are they using mobile phones to independently acquire knowledge, or using the free classroom atmosphere as an excuse to indulge themselves? Some students do turn mobile phones into learning tools, such as completing online question answering, taking handouts, AI intelligent search, etc. However, many students are unable to resist the temptation of the Internet because of their weak self-control and lack of clear learning objectives. They spend their precious youth on mobile phones in a short class of dozens of minutes. In the future, the ideological and political education in colleges and universities must reasonably introduce new media technology and give full play to the role of media in ideological and political education. How to guide college students to use new media correctly and enhance the acceptance effect of ideological and political education in colleges and universities is an important part of the current ideological and political education work <sup>[2]</sup>.

## **3. The influence of new media on college students' ideological and political education**

### **3.1. It is conducive to cultivating students' democratic consciousness**

Under the new media environment, it is more convenient for college students to obtain social information and

various resources through network channels. Students can choose information content independently according to their own needs, reflecting the autonomy and randomness of students' network information application. At the same time, the efficient and fast network information replacement speed and transmission path make college students' thinking consciousness relatively open and active, and students' innovative thinking is more easily stimulated. The relatively closed education mode and method in the traditional education system have been unable to meet the development needs and practical requirements of modern education. The new media environment has built an open communication platform and social network media for college students. Students can express their thoughts and self-awareness through the network environment, reduce their ideological concerns about communication and exchange in the real situation, and make their own voice in the public platform, so as to spread the demands of contemporary college students through new media channels, and promote the development of students' democratic thinking consciousness and the realization of self-identity value in one way or another.

### **3.2. It helps to promote the reform of the concept of talent cultivation in colleges and universities**

The new media environment is based on the high-speed popularization of mobile Internet technology. Various mobile devices and terminals have become a necessity of college students' lives, and have also become an important carrier for students to apply the new media platform. In the current social environment, colleges and universities will also promote the transformation and expansion of their own educational philosophy and teaching objectives, which are limited to the ideological and political education and moral education forms in the classroom, and it is difficult to achieve the ideal teaching effect and educational purpose. Colleges and universities can use microblogging, WeChat and other new media to carry out characteristic ideological and political education and theme education activities, take new media technology as the catalyst of traditional ideological and political education, and highly integrate with information technology, so as to form the normalization and specialization of online ideological and political education, and realize the overall goal of ideological and political education and moral education. Colleges and universities should strengthen the production and dissemination of innovative campus cultural content, organically integrate social hot spots, maps, real-time interaction, propaganda titles and contents, strengthen the cultivation of brand awareness, and strengthen the ideological education of college students <sup>[3]</sup>.

### **3.3. Conducive to improving the timeliness of ideological and political education**

Morality cultivation is the fundamental task of colleges and universities and the central link and key work of talent cultivation <sup>[4]</sup>. The traditional ideological and political education activities are mainly in the form of lectures, preaching, and theoretical indoctrination. The content and form of ideological and political education are relatively boring and single. There are differences in each student's acceptance of Ideological and political education and the way of thinking and cognition, and the overall effect of Ideological and political education will also be seriously affected. Under the new media environment, colleges and universities should have timely insight into the development characteristics of social and cultural forms, timely adjust and optimize the form and content of Ideological and political education, and quickly transmit network information and media resources information to the educated groups. The implementation of ideological and political education in colleges and universities can also take advantage of the application advantages of Internet technology, timely insight into the physical and mental development of college students and related interest demands, and understand students' psychological state, emotional state and ideological and political awareness concerns through students' interactive behavior and language characteristics in the network platform, so as to enhance the pertinence and effectiveness of Ideological

and political education. The ideological and political education of college students in the new media environment can change the constraints of the classroom on Ideological and political education, make the teaching activities of Ideological and political education go deep into college students' learning life, and become a favorite learning and lifestyle of college students.

#### **4. The importance of refined ideological and political education for college students**

Ideological and political education is an effective way and an important path to improve the comprehensive quality of college students. Ideological and political education activities are also the main method to guide students to establish a correct world outlook and life values. The traditional concept of higher education attaches importance to the cultivation of students' professional quality and moral education spirit. In view of the current rapid development of new media and network social platforms, colleges and universities actively innovate the working mode of Ideological and political education for college students, advocate the integration of refined education concept, fine arrange the content of ideological and political education, and formulate corresponding refined education plans and programs, so that the ideological and political education for college students can meet the development needs of students' thinking consciousness, and reflect the diversification of Ideological and political education content and teaching forms. Refined ideological and political education changes the "big pot" phenomenon existing in the traditional ideological and political education field, improves the attention to students' learning and life needs, considers the teaching effect of ideological and political education, timely adjusts the teaching plan and teaching content according to the effect of Ideological and political education, and takes the development of overall students' thinking consciousness as the educational goal, so as to ensure the applicability and teaching effect of the ideological and political education plan to the greatest extent, and improve the quality of Ideological and political education. Ideological and political education is a process to help students correct their thoughts and cultivate their morality. The ideological and political education work in colleges and universities is complex and greatly affected by external factors, which requires the construction of an all-around and collaborative education system and mechanism <sup>[5]</sup>.

#### **5. Effective paths and strategies for the refinement of college students' ideological and political education in the new media environment**

##### **5.1. Ensuring the refinement of the concept of ideological and political education for college students**

The work concept is an important basis for guiding work behavior. In order to implement the ideological and political education of college students, educators need to take the refined work concept as the direction guidance. To carry out refined ideological and political education in colleges and universities can not only be regarded as a slogan, but also need to determine the refined benchmarking role from the heart of the educator, give full play to the guiding role of ideological and political education for students' values, and root the ideological and political education required by students in their minds and in their actions. In essence, ideological and political education activities are not the interaction of educational information between teachers and students, but the emotional interaction between teachers and students. Teachers can timely capture students' emotional dynamics and psychological demands, analyze students' psychological changes and emotional support from emotional dynamics, make full use of new media and network resources to obtain students' actual requirements, capture students'

psychological dynamics through media resources, so as to ensure that ideological and political education can meet students' comprehensive demands, and strengthen the integration of ideological and political education through excellent traditional culture education. As an important part of the youth group, college students themselves have a sacred responsibility in inheriting Chinese traditional culture. An in-depth understanding of the connotation of traditional culture can enable students to have higher respect for traditional culture and help students establish a sense of cultural confidence and national pride <sup>[6]</sup>.

## **5.2. The practice of paying attention to the refinement of ideological and political education**

To carry out refined ideological and political education, educators need to pay attention to the important role of social practice in strengthening students' cognition. Educators should widely collect ideological and political education materials and network comprehensive information in the field of new media, which can be post practice in different social public service industries, or social public welfare activities launched by social public welfare organizations. Educators should give students an interpretation of the existing ideological and political concepts in practice, so that students can deeply understand the connotation and spiritual extension of Ideological and political education, and gradually guide students' values and sound personality construction. The improvement of college students' values and personality is a gradual development process. Ideological and political education should also ensure the embodiment of the value of normalized education. Colleges and universities should actively expand various forms of social practice opportunities for students from the perspective of "micro ideological and political" and "refined ideological and political." At the same time, colleges and universities can also regularly organize thematic ideological and political education activities, take advantage of the Double Ninth Festival, the Mid Autumn Festival and other time opportunities to carry out traditional culture themed education activities, and use the "national drug control day", "constitutional Publicity Day" and other nodes to carry out rule of law themed education activities through online and offline channels. Through recessive education, the value of ideological and political education and the goal of moral education can be enlarged, so that students can experience the impact of their own values on various social activities, and strengthen students' perceptual cognition of society.

## **5.3. Innovation and refinement of Ideological and political education content**

The refined ideological and political education should be integrated into students' specific learning and life, carry out the innovation of educational content, change students' stereotype of traditional ideological and political education, reflect the link relationship and community effect between ideological and political education and social life, and make students truly feel the unique charm and spiritual enjoyment of ideological and political education. For example, teachers can introduce some social hot issues into classroom teaching activities, and directly take hot and difficult issues as the topics of classroom discussion. The classroom teaching process involves theoretical teaching and case orientation, requiring students to freely discuss and speak according to hot issues and case thinking. Teachers can see students' own thinking and cognition through students' statements, and use the debate between students to produce interaction between students, so that teachers can summarize teaching and spiritual interpretation, promote core values, and spread positive energy around them. Through this teaching method, students can create space to express their personal thoughts. At the same time, the application of innovative teaching content and methods can make students truly realize that ideological and political education can exist everywhere in life, and everywhere can also become the foothold for practicing the correct ideological and political concepts. College curriculum ideological and political education focuses on the teaching objectives



of value creation, ability training, and knowledge transfer, that is, to pay attention to value guidance when disseminating professional knowledge, and integrate ideological and political factors into the teaching process <sup>[7]</sup>.

#### **5.4. Constructing a refined ideological and political education system**

In order to achieve the purpose of refined ideological and political education, colleges and universities need to make full use of the application advantages of new media technology, build a refined ideological and political education system, and form an ideological and political education system combining “Ideological and political education in class + ideological and political education after class + normal ideological and political education” <sup>[7]</sup>. The so-called ideological and political education in class refers to the application of new media technology to the innovation of teaching content and teaching form; The so-called after class ideological and political education refers to the application of new media to build a network ideological and political education platform, which expands the ideological and political education to cyberspace and media areas. New media have become an important part of students’ learning and lives. New media ideological and political education conforms to students’ behavior habits and interests, and reflects the pertinence and professionalism of Ideological and political education; The so-called normal ideological and political education means that teachers implement ideological and political education in all aspects of students’ learning and life at school, infiltrate the concept of Ideological and political education and moral education in the construction of campus culture, pay attention not only to students’ professional development and theoretical knowledge, but also to students’ personality development and ideological form. Students’ social communication behavior, daily learning, and life behavior all play a guiding role and value guidance of ideological and political education for students, and take “educating people” as the fundamental purpose of higher education.

### **6. Conclusion**

Under the new media environment, the ideological and political education of college students is facing new challenges. Refined ideological and political education can meet the comprehensive demands of students. Colleges and universities can implement refined ideological and political education into practical work, improve the quality of ideological and political education in colleges and universities, and promote the realization of talent training goals in colleges and universities by ensuring the refinement of the concept of ideological and political education, paying attention to the practice of refined ideological and political education, innovating the content of refined ideological and political education, and constructing a refined ideological and political education system.

### **Disclosure statement**

The authors declare no conflict of interest.

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# Research on Integrating Chinese Cultural Elements into Online HSK Instruction

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**Abstract:** The extensive infusion of Chinese cultural elements into the Hanyu Shuiping Kaoshi (HSK) poses significant pedagogical and assessment challenges. However, existing HSK-oriented courses predominantly emphasize linguistic competence training while neglecting systematic cultural instruction. Although online HSK courses have improved instructional accessibility, they have concurrently exacerbated the complexities of effectively transmitting Chinese cultural knowledge. This study examines the HSK preparatory curriculum for international students at Y University, extracting prominent Chinese cultural markers from historical HSK test materials. Through a three-dimensional framework—teaching presence, cognitive presence, and social presence—the study identifies critical deficiencies in current online HSK course delivery. To address these gaps, three targeted recommendations are proposed: (1) a structured taxonomy of cultural elements to refine pedagogical design; (2) the development of modular cultural micro-lectures to augment digital learning resources; and (3) a hybrid AI-instructor model to foster learner autonomy.

**Keywords:** HSK; Online instruction; Chinese cultural elements; Pedagogical research

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## 1. Introduction

Considering the cross-regional and developmental issues of international Chinese education, online teaching has been widely used in international Chinese education in recent years, and has become the foundation of smart education development with a wealth of accumulated experience. With the introduction of the Online Chinese Proficiency Test (HSK), it has become inevitable to construct an online Chinese teaching system that serves online exams. However, it is difficult to achieve a balance between online Chinese language teaching guided by exam evaluation and the imparting of rich Chinese cultural knowledge contained in the Chinese language. Taking Y University as an example, the university collaborates closely with some Thai universities to jointly train Chinese language and literature majors, and has offered multiple HSK coaching courses. These international students bear the academic pressure of passing the Level 5 Chinese Proficiency Test and have an academic need to master

Chinese culture. How to balance the improvement of Chinese language skills, sufficient training, cultural literacy, and cultivation of Chinese thinking within a limited time is a problem that must be paid attention to.

## 2. The analysis of Chinese cultural factors in the HSK curriculum

### 2.1. The analysis of cultural elements in past test papers

The Chinese Proficiency Test (HSK) originally consisted of six levels, with additional levels 7–9 later introduced for advanced learners. Notably, HSK 7–9 explicitly incorporates content related to Chinese culture and general knowledge of China. Even in levels 3–6, a substantial presence of cultural elements can be observed in official mock tests, past exam papers, vocabulary outlines, and related textbooks. This study examines the HSK past papers collection, analyzing five sets each of HSK Level 5 and Level 6 exam papers to extract culturally significant vocabulary (excluding conceptual cultural terms) <sup>[1–2]</sup>. Drawing upon Chinese cultural item taxonomy, these cultural elements are categorized into four primary dimensions: National Conditions, Achievements, Daily Life, and Social Interactions, with further subdivisions into secondary and tertiary indicators as outlined in **Table 1** <sup>[3]</sup>.

**Table 1.** HSK level 5–6 exam list of Chinese culture projects

Category		Level 5 exam paper		Level 6 exam paper
National Conditions	Historical dynasties	The Spring and Autumn Period, Qin, Sui, Tang, The Eastern Jin Dynasty, Ming, Qing		The Yao and Shun Era, Pre-Qin, Qin, Han, Wei-Jin Southern and Northern Dynasties, Northern Wei, Tang, Southern Tang, Song, Southern Song, Yuan, Ming, Qing
	The people	Cultural celebrities	Yi Qiu, Qin Shi Huang (First Emperor of Qin), Meng Tian, Dai Kui, Emperor Taizong of Tang, Fang Xuanling, Du Ruhui, Emperor Xuanzong of Tang, Xu Xiake, Tan Yunxian, Cao Xueqin, Zuo Zongtang, Shen Yinmo, Liu Bannong, Liang Shiqiu	Qin Shi Huang (First Emperor of Qin), Wang Xizhi, Gu Kaizhi, Zhang Sengyao, Chen Zi'ang, Wu Daozi, Shen Kuo, Zhu Xi, Emperor Qianlong, Zhang Nanyang, Qiao Zhiyong, Qi Baishi, Li Shutong, Lu Xun, Lu Feikui, Tao Xingzhi, Gu Jiegang, Run Run Shaw, Lin Qingxuan
		Ethnicity		Tibetan, Dai, Dai bamboo house, Han, Jing, Li, Li boat-shaped house, Miao, Miao stilt house, Miao silver ornaments, Zhuang house, Zhuang, Zhuang Huashan rock paintings
	Cultural heritage	Metering		Coin, Zodiac Chronology, Ten thousand taels of silver
		Utensils	Ming-style furniture, Silk, Chess, Bottle	Porcelain, Cizhou kiln, Yellow Rosewood, Stilt, Gilding, Gong, Lacquer wood ware, Bronze Ware, Stone carving, Pottery, Tapestry, Rosewood furniture
	Geography	Region	Beijing, Northern China, Dali, Fujian, Heilongjiang, Huangshan Mountain, Jiangsu, Southern China, the Qinling Mountains-Huai River Line, Shanxi, the Silk Road, Suzhou, Taihu Lake, Yunnan	Anhui, Changqing Oilfield, Chengdu, Chongqing, Western Yunnan, Fujian, Guangzhou, Guangxi, Hainan, Hebei, Kaifeng (Henan), Hunan, Jingdezhen, Kunming, Qingdao, Qinling Mountains, Shanxi, Shaanxi, Shanghai, Sichuan, The Silk Road, Xi'an, Hong Kong, Xinjiang, Yunnan
		Organism	Ginkgo tree	Panda, Dove flower, Rhodiola rosea, Saffron
		Landscape	Butterfly Spring, "China Snow Town"	Furong Cave, Flame Mountain, Jin Si Gorge, Longting Lake, Antler beam, Lop Nur, Qiantang River tide



**Table 1 (Continued)**

Category		Level 5 exam paper		Level 6 exam paper
Achievements	Science and technology	“Sayings of a Female Doctor”		“Qi Min Yao Shu”, “Compendium of Materia Medica”
	Art	Calligraphy, Painting, Carving, Embroidery	Landscape painting	Bian Embroidery, A rubbing from a stone Inscription, Duan inkstone, Woodblock New Year Paintings, Calligraphy, Sugar painting, Wuhu Iron Painting, Yi River Inkstone, “Hell Scene Painting”, “The Mustard Seed Garden Manual of Painting”, “The Three Friends in Winter Painting”, “The Four Friends Painting”, “Painting Manual of Xuanhe Era”
		Dance, Opera, Movie, Music	Peking Opera, Xi’an wind and drum music	Bottle gourd silk, Jiangxi Yiyang Opera, Kunqu Opera, Water Sleeve Dance, The high stage lion dance, Taihu Quzi Opera, “Masters In Forbidden City”, “The Grandmaster”
		Building	Anping Bridge, Ajin Ancient City, “Red Walls and Green Tiles”, Zhidao Roads in Qin Dynasty, The Imperial Palace, Alley, Xi’an Guanyin Temple, “China Zun”	Terra Cotta Warriors, Great Wild Goose Pagoda, Fenghuang Ancient Town, The Imperial Palace, National Museum of Classic Books, Huaqing Hot Spring, Imperial Archives, Lugou Bridge, Mawangdui Han Tomb, Qingdao Zhanqiao Pier, Mausoleum of the First Qin Emperor, Study, Wuyin Bridge, Xi’an Datang Xishi Site, The Summer Palace, Moon gate, Yu Garden, Kiss Beast
	Wushu		Shadow Boxing	Wushu
	Literature		“Beijing Evening News”, “A Dream in Red Mansions”	“The Ancient Mirror Story”, “The History of the Han Dynasty”, “Dream Pool Essays”, “The Classic of Mountains and Rivers”, “Three-Body”, “Journey to the West”
	Languages	Character, word	“Xinhua Dictionary”	“Cihai”, Oracle
		Idiom	10 idioms	149 idioms
	Daily Life	Etiquette	Wedding	Capping Ceremony, Hair-pinning ceremony, Sacrificial Ceremony, Folding Willow (Farewell), Phoenix Three Noddles (Tea-making Etiquette), Etiquette of giving birth to girls in ancient Jiangnan, Dowry, Funerary object
		Dietary, Taste	Plain boiled water, Tea, Vinegar, Light, Tsingtao Beer, Fresh flavor, Soy sauce	Vinegar, Osmanthus Cake, Chrysanthemum meat, Pu’er tea, Jerky, Tie Guanyin, Noodles, Cantonese cuisine, Zhenjiang Pot Cover Noodles
Category		Level 5 exam paper		Level 6 exam paper
Daily Life	Dress and personal adornment	Blue calico		Purse, Wide and large sleeves
	Festivals and solar terms	Spring Festival, Chinese New Year’s Eve, Winter Solstice, National Day, Cold Food Festival, Labor Day, Celebrate the New Year, Mid-Autumn Festival, New Year’s Day		The twenty-four solar terms, Lantern Festival, Mid-Autumn Festival
	Symbol	Dragon, Fish symbol		The Four Gentlemen of Flowers (Plum blossoms, Orchid, Bamboo, and Chrysanthemum), Three Friends of Winter (Pine, Bamboo, Plum), “Immediately enfeoffment”
	Contemporary living	“Beijing Time”, Graduate, Returning to Southern Heaven, “Golden Week”, Express delivery, “Whitewashing”, Weibo, WeChat, Obtain employment, Seek employment		Iron Pak, BeiDou Navigation Satellite System, Dialect, Mandarin, Face recognition, Seckill, “Double Eleven”, QR code, Facial attractiveness
Social Interactions	Designation	Your pupil, A hanger-on of an aristocrat, Overpraise, Family name + Position, Little+ surname		The surname “Mi”, Surname + Occupation/Position, Little/old+ surname, Surname + Gender designation

This table shows that the number and coverage categories of Chinese cultural factors in HSK exam papers increase progressively. Intermediate and advanced Chinese language learners will inevitably face the examination of Chinese cultural knowledge in the Chinese proficiency test, which will affect their understanding and judgment of the exam content. In addition, the sharp increase in the number of idioms in the level 6 exam paper is due to the addition of idiom analysis questions alongside the idiom stories in reading, and a large number of sentences also contain idioms. Idioms pose a major challenge for Chinese learners to learn and use, requiring extensive vocabulary and cultural knowledge. Therefore, the coaching courses for the intermediate and advanced Chinese proficiency exams need to be equipped with a Chinese culture teaching module.

## **2.2. The analysis of classroom cultural factors**

As a second language pedagogy, Chinese language instruction embodies distinct linguistic characteristics and cultural dimensions, rendering the classroom not merely a linguistic training ground but also a vital conduit for cultural transmission. Consequently, cultural elements must extend beyond the analysis of national conditions, daily life, and achievements in testing materials and textbooks to encompass communicative and ideological cultures embedded in pedagogical processes. Taking Y University as a case study, while language skill courses tailored for HSK are incorporated into the curriculum, there is a conspicuous absence of complementary Chinese cultural courses. Consequently, language skill classrooms inadvertently assume the role of cultural instruction. Furthermore, the Chinese pedagogical paradigm imposes stricter temporal and disciplinary norms, coupled with an emphasis on intensive explanation and repetitive practice—a hallmark of Chinese language teaching principles.

China's examination culture also exhibits unique characteristics. As an internationally recognized language proficiency benchmark alongside IELTS and TOEFL, HSK lacks commensurate preparatory infrastructures. Domestically, foreign language testing has cultivated a mature ecosystem of examination-oriented pedagogy and training institutions, whereas HSK preparation remains markedly underdeveloped. An analysis of classroom assessment results reveals that learners initially struggle to adapt to HSK's examination tempo, exhibiting deficient test-taking strategies, misaligned reading and cognitive approaches, and an inability to complete tasks within stipulated timeframes. Moreover, due to the inherent complexity of Chinese character writing, learners demonstrate a pronounced preference for digital examinations and electronic composition, frequently adopting character-avoidance learning strategies.

Notably, extracurricular cultural engagement emerges as a salient learner demand. Y University's cohort—primarily young adults in their twenties—displays keen interest in popular and lifestyle cultures. Their active use of domestic social media platforms facilitates discussions on globally resonant Chinese cultural phenomena, including viral short videos (e.g., Li Ziqi), animated films (Ne Zha), and video games (Black Myth: Wukong). Post-class consultations frequently involve pragmatic concerns such as obtaining Chinese driver's licenses or renting housing. While such quotidian cultural elements receive limited representation in standardized assessments, their alignment with learner interests and practical needs renders them potent motivators for sustained language acquisition.

## **3. Issues with the online HSK course**

### **3.1. Insufficient cultural awareness among learners**

This study collected 107 valid questionnaires from international students with online HSK tutoring course

experience at Y University. The data reveal that 93.46% of respondents (100 students) opted to continue utilizing online learning modalities for Chinese language acquisition, demonstrating that digital instruction either aligns with learners' needs or provides distinct logistical advantages. A significant 72.89% identified "tuition-free access" as a key attraction of online HSK courses. This preference warrants two interpretations: first, these courses constitute non-profit academic collaborations between Y University and partner institutions, with additional free tutoring implemented during the pandemic; second, the virtual format eliminates ancillary costs associated with physical relocation, including transportation and accommodation. When learners can attain HSK certification exclusively through online preparation, the total cost of learning becomes substantially reduced compared to conventional methods. Notably, with Thailand's rapid digital education development—exemplified by established platforms like SkillLine—online Chinese instruction may emerge as the dominant regional learning paradigm. However, this pedagogical shift introduces new challenges: learners deprived of immersive linguistic environments often develop superficial cultural understanding, inhibiting the formation of intrinsic motivation based on genuine interest. Should cost advantages diminish, the program's appeal may consequently decline. Regarding learning motivations, professional and academic requirements predominated, while only 34.58% cited "affinity for Chinese language and culture" as their primary driver. This disparity suggests that while learners recognize the instrumental value of cultural knowledge for examination success, deeper cultural engagement remains limited. The fundamental pedagogical challenge—and concurrent cultural communication opportunity—lies in transforming utilitarian learning objectives into authentic cultural curiosity, thereby fostering autonomous exploration of China's cultural heritage.

### **3.2. Inadequate integration of cultural pedagogy**

Taking the HSK level 5 reading course as an example, the course is a reading skills training course, with the teaching objective of improving learners' HSK reading scores. There is no accompanying vocabulary course or Chinese culture course. This course requires learners to complete a large number of real reading exercises to improve their reading speed and accuracy. With only 3 hours of classroom training per week, the schedule is already quite tight, and the teaching content feels overwhelming. The implicit problem lies in the fact that learners' vocabulary has not reached the level of level 5, and sometimes reading classes may even deviate from the class type and become word classes, thereby shortening the reading training time. This is evidenced by 40.19% of the survey respondents' belief that "the logic of the teaching content is not clear enough." In addition, as mentioned earlier, the real test questions cover a lot of Chinese cultural factors, which may affect learners' understanding. Teachers need to spend classroom time explaining, and unfinished teaching tasks can only be left after class. However, teachers and students also lack interaction time after class. Regarding the question "Teacher's HSK homework tutoring method", 41.12% of the survey respondents received online centralized tutoring, 37.38% of the survey respondents self-corrected answers posted by teachers, and only 16.82% of the survey respondents received one-on-one tutoring, resulting in a lack of traditional offline classroom post class Q&A and Q&A sessions, and cultural knowledge explanations are not suitable to be placed outside of class. This creates a vicious cycle, with learners lacking cultural knowledge and classrooms lacking cultural teaching time.

### **3.3. Limited cross-cultural engagement in learning contexts**

The survey identified the top three reasons for lack of concentration in online HSK classes as: "weak self-control ability" (63.55%), "inability to complete exercises and keep up with teaching pace" (29.91%), and "insufficient

classroom interaction” (28.97%). Analysis reveals that many respondents struggle to maintain focus in online HSK instruction due not only to the confidence-diminishing effects of fast-paced, high-difficulty content, but also to the lack of interactive elements in virtual teaching. Meaningful interaction among online learning community members significantly impacts knowledge construction, yet current online teaching shows inadequate learning monitoring, with low-interactivity models leading to learner fatigue <sup>[4]</sup>. When asked “How would you rate your participation in classroom interactions?”, responses were: “excellent” (14.02%), “good” (30.84%), “average” (52.34%), and “poor” (0.03%), indicating insufficient interaction. Survey data shows the frequency of classroom interaction methods used, in descending order: being called on to answer, attendance check-ins, voluntary participation, online assessments, group discussions, and forum discussions. This suggests two primary reasons for inadequate interaction: first, limited interaction formats, and second, high-frequency interactions being predominantly passive (e.g., being called on, attendance checks), with low student initiative and voluntary participation. 16.82% of respondents reported that online platforms failed to meet learning needs. A key challenge of online versus offline teaching is teacher-student distance — the constrained screen space creates a weak classroom presence. Teaching presence demonstrated through nonverbal behaviors (teacher smiles, expressions, proximity) positively impacts learning outcomes, yet actual online teaching prevents proximity and implementation of certain instructional designs <sup>[5]</sup>. Instructors cannot flexibly adjust teaching based on observing student reactions and expressions as in offline settings, let alone conduct deeper cultural transmission through these nonverbal cues. Current online courses lack sufficient teacher-student and peer interaction, and have failed to establish multimodal Chinese cultural perception systems in teaching. Moreover, survey respondents’ pre-China exposure to Chinese culture came mainly through online channels like TV dramas, variety shows, and reading materials, resulting in symbolic-level cultural understanding, lacking interactive and immersive experiences.

#### **4. Instructional recommendations for online HSK courses: Systematize cultural elements to enhance pedagogical design**

HSK coaching courses can easily become boring, exam-oriented teaching, so the knowledge of Chinese culture in the test questions cannot be avoided. Instead, it is necessary to find ways to adjust the teaching direction appropriately, use cultural factors, tell Chinese stories well, increase the attractiveness to students, and exercise learners’ Chinese cultural thinking and exam thinking. Due to the nature of the course, HSK teaching is closely centered around the course type, with a focus on skill training. Under ideal teaching conditions, it is necessary to offer specialized courses on Chinese culture for learners with HSK level 5 and above. If this cannot be met, teaching design should be supplemented with pre-class and post-class tasks. Hence, it is necessary for teachers to sort out the Chinese cultural factors involved in teaching on the basis of sufficient lesson preparation, design teaching from the perspective of learner knowledge construction, and decompose and reconstruct cultural factors into various stages before, during, and after class. For example, simple language can be used in class to briefly describe its author, content, and literary status of “Dream of the Red Chamber”, which appears in the exam. Assign learning tasks related to the “Four Great Classical Novels of China”, arrange reasonable learning content and task volume, and specify the completion time and task presentation method. Through such cultural knowledge assignments, reverse Chinese language ability training can be carried out. In classroom training, it is also possible to break the original order of questions, split and combine real questions based on cultural factors, maintain continuous Chinese language training instead of high-intensity question sea tactics, adjust the difficulty



of homework in a timely manner, alleviate the tension caused by unclear learning outcomes in the short term, establish students' confidence in achieving learning goals, and actively participate in teaching communication and interaction.

Moreover, while the HSK test format is currently fixed, the timeliness of the language materials can fade over time. The cultural knowledge covered in the questions may not fully meet the learners' needs, necessitating the inclusion of popular culture knowledge in teaching. Popular culture, characterized by its hybridity and multimodality, can enhance learners' motivation to learn, reinforce their language practice, and effectively stimulate their creativity, promoting the development of critical thinking skills <sup>[6]</sup>. Therefore, such elements should be integrated into the curriculum, making full use of both pre-class and post-class time. Many students enter online meetings 5–20 minutes early, so playing Chinese songs, videos, or chatting with them to answer homework questions can be beneficial. When selecting topics, start with daily and national cultural elements that are relevant to learners' lives, then gradually delve into achievements, communication, and concepts that interest students. **Table 2** lists the cultural elements that the author believes are suitable for pre-class and in-class activities. The selection criteria include: (1) content that young learners find interesting, (2) themes that match students' abilities, and (3) cultural projects that align with the cultural factors covered in the curriculum. Sensitive topics like “religion” are not suitable for classroom presentation and have been omitted.

**Table 2.** HSK course cultural project list

Primary indicator	Daily life	National conditions	Achievements	Social interactions	Conception
Secondary indicator	diet	geography	art	daily communication	Simple Confucianism
	habitation	social security	literature	social media	Chinese traditional virtues
	dress and personal adornment	cultural heritage	languages		
	Study and work		science and technology		
	entertainment				
	health				
	festivals and solar terms				

## 5. Summary

In cross-cultural communication, the cultural elements behind language, such as value concepts, customs, and lifestyles, are crucial for effective communication. Learning Chinese is also learning about Chinese culture. The HSK is not just a test of Chinese language skills; it also includes questions that reflect rich aspects of Chinese culture. However, online teaching has two main drawbacks: first, it does not provide an immersive environment for learning Chinese, and second, it fails to integrate the cultural atmosphere of China. Educators should explore and incorporate relevant cultural elements to enhance the appeal of online classes, tell compelling Chinese stories in both classroom and extracurricular activities, deepen learners' understanding of Chinese culture, and thus improve their Chinese proficiency.

## Disclosure statement

The authors declare no conflict of interest.

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# Analysis of Pathways to Promote Cultural Confidence in the Process of Sinicizing Marxism

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**Abstract:** This paper discusses syncretized Marxism and gives a definition of cultural confidence and its connection to China's socialism. Firstly, the paper explores the strategy of Sinicizing Marxism from Yan'an to the present era and demonstrates how the culture that was practiced in a Marxist way then is the basis of the current Chinese people's cultural autonomy, with examples from practical life. Next, the paper tells about the global and information-based character of China's cultural environment and how far building cultural confidence has developed in those mentioned conditions. It then talks about the way of defending and promoting the socialist culture via legal and theoretical instruments, which is a statement that changing the system of culture and forceful leadership of the party is definitely a decided matter. Speaking of cultural enterprises, the text underlines the role of market-driven operations and technological innovation; it also suggests that with the ongoing supply-side changes, it is possible to get enriched with cultural products and achieve the identification of local people. The third paragraph discusses the results of two case studies, which are the safekeeping of intangible cultural heritage in rural areas and the setting up of an international platform for public opinion exchange through a "going global" strategy. At the end of the essay, the author introduces a series of countermeasures, e.g. reinforcing theoretical education, leading public opinion with the help of cultural education and practice platforms and so on, to combat ideological and external cultural challenges, providing a framework to conceptualize Sinicization of Marxism and cultural confidence in a more systematic way.

**Keywords:** Sinicization of Marxism; Cultural confidence; Institutional guarantees; Cultural industry; International discourse power

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## 1. Introduction

To ride the new type of socialism with Chinese characteristics, cultural confidence is necessary for the nation's rejuvenation and development. Chinese leader states that cultural confidence—based on socialism's cultural path—is a form of confidence which is the deepest and most solid. Understanding how Sinicized Marxism fosters cultural confidence illustrates the blending of Marxist theory and the Chinese cultural tradition, thereby providing

directions for the current construction of culture. Marxism, since its introduction to China, has harmonized with Chinese realities through the Yan'an era experiment, the post-1949 institutional innovation, and the reform-era theoretical refinement, thus forming a Sinicized Marxist system. By promoting the socialist core values, making cultural policies, and innovating industries, the CPC developed a positive attitude in the cultural sphere and built up the ideological and institutional support of cultural confidence. Nevertheless, the infusion of globalization and informatization results in value plurality conflicts, ideological challenges from foreign and industry homogeneity. In the presence of Sinicized Marxism, guidance on the systematic and sustainable paths is necessary to reinforce national cultural identity and pride.

## **2. Theoretical foundations and conceptual definitions**

### **2.1. The connotation of cultural confidence from the perspective of Sinicized Marxism**

The term cultural confidence stands for the firm belief of a nation in the value of its culture, including the acceptance of socialist core values and traditional Chinese culture, the affirmation of the cultural identity, and the trust in the socialist cultural development path. These three aspects are not independent; value recognition is the outcome of the provision of ideology, cultural recognition is the result of the provision of spiritual support, and institutional recognition ensures the implementation of the spirit. Out of its adaptation to the Chinese conditions, Sinicized Marxism has demonstrated that cultural confidence has been created through the combination of Marxist principles and the realities of China. In the Yan'an period, the "Let a hundred flowers bloom; let a hundred schools of thought contend" policy, which was guided by Marxism, not only absorbed Chinese cultural essence but also laid the foundation for cultural confidence. The party after 1949 was the main force to approach the public with the socialist cultural views of Marxism, thereby combining Chinese culture with traditional Chinese culture, thus making people realize themselves something worth existing <sup>[1]</sup>. When Reform and Opening Up was launched, Chinese leaders' theory put forth the idea that "culture must face modernization, the world, and the future", resulting in cultural system reform and its greater opening and changes. Since the 16th Party Congress, the cultural construction movement has been boosted, and cultural development, which is of service to the people and socialism, has been seen as the only way to ensure the sustainability of the culture. To transition into the new era, Chinese leaders' thought elaborately talked over cultural confidence as the most fundamental of the "Four Confidences", highlighting the Communists as the vanguard, the inheritance of traditional culture, and the realization of socialist core values as the main trends. The provided guidance ensures a continuous stream of innovative ideas in the cultural theory and its institutionalization in the era of globalization and informatization. In short, cultural confidence is an offspring of both the development of Marxism and Chinese tradition, calling for constant theoretical and institutional innovation to give impetus to national rejuvenation <sup>[2]</sup>.

### **2.2. The evolution of Sinicized Marxism and its interaction with cultural construction**

Ever since Marxism first came to China, it has been undergoing a process of Sinicization as a result of continuous adaptation. Chinese leader, during the Yan'an period, integrated the basic ideas of Marxism with the Chinese revolutionary reality and advocated "seeking truth from facts" and the "Mass Line", which was a revolutionary culture with the principle of "people helping the people" as its orientation. After 1949, with Chinese leaders' thought at the helm, the party officially took over cultural work, establishing the socialist literature, art, and education system. At the same time, cultural activities shifted from being revolutionary to covering broader

socialist things, such as collectivism and heroism, so that political unity was cemented. The Reform and Opening Up, Chinese leader Theory, and the “Three Represents” were the new drivers of Sinicized Marxism. Cultural development was pulling in the worldwide scene <sup>[3]</sup>. It connected Chinese core values with those of other countries, and at the same time, had the local elements usher in a new era. Market-oriented reforms diversified cultural production, and in addition, they promoted cultural industries. It emphasized innovation and the fusion of art with technology as the Marxist principles leading the way to the disclosed culture that was still socialist yet open. The new era of Sinicized Marxism under the Chinese leaders’ thought marked the transformation of the theory in China. It also marked the cultural status quo in China significantly. Chinese leader ushered in a moment of confidence in culture, and at the same time, had the goal of building a strong cultural nation. he also encouraged people to pay more attention to the cultural development of globalization. It also indicated that people would embrace the Marxist input and other modern aspects of the culture. Henceforth, it was obvious that through cultural plans, infrastructure upgradation, and system reforms, China succeeded in turning Sinicized Marxism into cultural soft power. It endeavors to tell a vivid and unique Chinese cultural story with the help of its creative industries and international exchanges <sup>[4]</sup>.

### **3. Analysis of historical context and current situation**

#### **3.1. From the New Democratic Revolution to Reform and Opening Up: Construction and transformation of cultural identity**

Throughout the New Democratic Revolution, culture was considered a pivotal strength to drive the masses and foster the national spirit. Members of the Communist Party suggested the literary and artistic policy of “mass culture” and “serving the people”, introducing new forms of education and cultural propaganda such that the people would identify themselves with revolutionary values in the struggle against imperialism and feudalism. Cultural identity, at this time, was identifying with unity in resistance to foreign aggression and national liberation, displaying collectivism and mass participation <sup>[5]</sup>.

At least from the early years of the People’s Republic of China to the period before Reform and Opening Up, socialist cultural construction went through a stage of standardization. The country further strengthened the socialist core values by means of general education and literary and artistic creation, encouraging works with collectivist and heroic themes, which in turn encouraged the populace to recognize the socialist system <sup>[6]</sup>. Yet, the cultural production was very much under the government’s control, and creative vitality was unable to flourish. The Cultural Revolution, along with the traditional culture and artistic expression, led to a serious blow to cultural identity <sup>[7]</sup>.

China first kicked off the policy of Reform and Opening Up, which marked the end of half a century of isolationist policies. This step led to a significant change where they permitted the entry of foreign cultures and allowed a new market-oriented and diversified domestic cultural industry. The party and government had been carrying out a series of reforms and revisions in the cultural system, forming a coexisting market and state-led mechanism that essentially upended the production and distribution of cultural products. With economic growth, the one-time pursuit of a traditional lifestyle began to wane in favor of a more balanced approach that emphasizes the values of the past but also appreciates the modern cultural achievements of foreign countries. Television and radio had become even more potent and were vying to control cultural direction during the late 1980s and the early 1990s. Peking opera and traditional festival cultures were a good example of this because they were being celebrated and



reemerging, while modern film, television, and popular music were being embraced by the younger generation, thus the degree of cross-generational cultural blending was on a continuous rise. It was also during this period of time that the cultural identities of people began to show traits of inclusiveness and transformation<sup>[8]</sup>. They not only continued to uphold the direction of socialist culture but also stressed cultural innovation and openness, which in turn led to the revival of traditional culture and the integration of modern culture, thereby establishing the groundwork for contemporary cultural confidence.

### **3.2. Current status and challenges of cultural confidence in the new era**

Guided by the Chinese leaders' thought on Socialism with Chinese Characteristics for a New Era, China's cultural confidence has advanced significantly. Policies such as the "Project for the Inheritance and Development of Fine Traditional Chinese Culture" support the protection and innovation of classical poetry, traditional opera, and intangible cultural heritage. The cultural industry has produced outstanding films, television series, and online literature, while distinctive cultural brands have gained international acclaim, boosting China's global cultural influence. Rural revitalization and urban community initiatives have diversified cultural activities, enhancing people's sense of cultural fulfillment and well-being, especially among younger generations. These developments show that cultural confidence has evolved from a theoretical concept into widespread social practice, energizing China's modernization efforts<sup>[9]</sup>. China's cultural confidence, inspired by Chinese leaders' thought on Socialism with Chinese Characteristics for a New Era, has made tremendous progress, and these are some of the reasons why. There is a "Project for the Inheritance and Development of Fine Traditional Chinese Culture" policy aimed at the preservation and innovation of classical poetry, traditional opera, and intangible cultural heritage. The cultural industry has created great works in the form of films, TV shows, and online literature. Perhaps the most notable aspect is the success of the various cultural brands in the international market, which has resulted in the boosting of China's global cultural influence. Regarding rural revitalization and urban community projects, they have been instrumental in the growth of different cultural activities and also in the enrichment of people's sense of cultural fulfillment and well-being, especially among the younger generations. The situation is such that the evolution of cultural confidence from a theoretical concept to a generalized social practice has occurred, and it has been electric in the whole drive towards modernization of China<sup>[10]</sup>.

## **4. Pathway exploration: From theory to practice**

### **4.1. Upholding and developing socialist culture with Chinese characteristics: Theoretical innovation and institutional safeguards**

Constantly innovating the ideology is a necessary step to enable the socialist culture with Chinese characteristics, as without it, there would be a lack of guidance. People need to fully understand and implement the Chinese leaders' thought on Socialism with Chinese Characteristics for a New Era, and especially the part that focuses on cultural confidence and the construction of a strong cultural country. Via this coupling of Chinese traditional culture and socialist core values, people create a spirit fit for the new age. Solving the challenges of cultural identity in the era of globalization and informatization is to use Marxist methods to deal with value conflicts and existential crisis, which enables cultural theory to address the needs and innovate. Within the organization, the establishment of a solid party leadership is indispensable<sup>[11]</sup>. Cultural development should not only be part of national governance modernization but also follow the principles of national governance with a clear direction, planned goals, and specific duties. Establishing and revising laws, for example, the Cultural Industry Promotion



Law, the Cultural Relics Protection Law, and the Intangible Cultural Heritage Law, provides a legal foundation for the conservation of resources, the development of industries, and the control of markets. The dedication of the state to culture is seen in the form of fiscal support, such as a special national cultural fund and approved grants; thus, this may be an issue of inspiration for the originality and branding of the culture<sup>[12]</sup>. Changes in the cultural system serve to prompt the government and the market to collaborate, improve public cultural services, and prevent market monopoly with the provision of useful support that will make the work of the cultural industry go faster. Talent cultivation is equally important. Higher education and research institutions must build systems for Marxist cultural studies and train interdisciplinary experts familiar with both traditional culture and modern industry. Collaboration between cultural enterprises and universities can accelerate professional training in management, creative design, and digital media<sup>[13]</sup>. Establishing robust incentives and career pathways will attract young talent to cultural innovation, sustaining the vitality of socialist culture with Chinese characteristics. Through theoretical innovation and institutional safeguards, people can enhance cultural consciousness and confidence, fueling the nation's rejuvenation.

## **4.2. Development of cultural undertakings and industries under the deepening of Reform and Opening Up**

Acknowledgment of excellence in the field of culture and science is not enough. It is necessary for educational and research institutions of higher learning to work out the organization of Marxist cultural studies and to train the research and practice of the experts in the interdisciplinary field who are familiar with both traditional culture and modern industry. Also, the partnership of cultural enterprises and universities is a prospective focus for helping in professional training in management, creative design, and digital media. In addition, adopting a strong system of funding and encouraging career pathways will bring cultural innovation to young talents who will then play a very important role in keeping the vitality of socialist culture with Chinese characteristics. Truly new theories and well-insured institutions empower not only national cultural awareness and confidence, it also are most important and a guarantee of the nation's resurgence<sup>[14]</sup>. The period of Reform and Opening Up has really contributed to the improvement of China's institutional framework, which is a very successful kind of culture, where joint progress is realized between cultural undertakings and industries. As far as the cultural undertakings are concerned, a government-led approach, while quite participatory on the societal level, is still very much in the game. Also, the increase of the investment in the local cultural stations, libraries, and centers not only stimulates the "In-depth culture for citizens" initiatives but also brings and renews the urban and rural life. By appealing to volunteer services, donations, and nonprofit foundations, the formation of public culture based on consensus and mutualism is achieved. The question of rural revitalization ought to be resolved by means of cultural poverty relief and heritage tourism, and this should be attained by establishing reading rooms, activity centers, and adult education classes; all these measures and endeavors are aimed at enhancing the local cultural industries' development and confidence. Exchange at a global level is of utmost importance. One of the ways in which China can increase its cultural soft power is to carry out performances, screenings, and exhibitions on "Belt and Road" platforms. Enterprises are supposed to implement a dual-circulation strategy with the focus on domestic as the primary market and international as the complement to open up the foreign market. The hosting of festivals and experiences, which incentivizes overseas cultural centers and Confucius Institutes, is one of the avenues taken to globally spread both the traditional and contemporary Chinese cultures. On the one hand, in the sphere of human resources and legal innovation, talent and regulatory issues cannot be overlooked. In universities, the introduction

of cultural-industry majors and practice bases is a way of making sure that there will be professionals with a variety of skills, like creativity, market operations, and digital skills. Credit systems that are robust and the market-access mechanisms will strike a balance between regulation and the necessary support needed to promote healthy competition. Cultural statistics and monitoring that are more detailed would assist policymakers in making the right decisions. These are the policies that help to underpin the confidence of the cultural world and the Chinese culture that is on the verge of flourishing.

## **5. Case analyses and practical experiences**

### **5.1. Rural revitalization and the revival of traditional culture**

In a particular area, the intangible cultural heritage was used to initiate the process of integrating the rural revitalization strategy. This initiative gave birth to a new model that combined “culture + industry.” The local authorities formed a special working group to merge the traditional handicraft skills with the tourism sector. They reconstructed historic rural dwellings, furnished handicraft studios, and brought in cultural inheritors to do the demonstrations, such as dyeing and bamboo weaving in situ <sup>[15]</sup>. Cashing in on e-commerce platforms, they also developed an “online + offline” sales channel to market both agricultural products and crafts to local and tourist customers. During the festival periods, local people would perform folk music and traditional opera, and that would be the right choice to draw visitors from cities to make them understand more deeply the local customs and strengthen cultural identity. Through combining touristic leisure and cultural heritage events, the village’s economy as a whole experienced a considerable growth in income. As a result, a large number of young people expressed that they were willing to come back and create their own businesses. The project initiated collaborations with universities and research institutions for the digital documentation of traditional techniques and the design of new products, branding of the crafts, and standardization. The government offered policy subsidies and training support, thus guiding cooperatives and social organizations in the participation and management of work and guaranteeing that all stakeholders enjoy the benefits. Actually, it is only by the integration of top-level design and grassroots autonomy, and the government guidance that are combined with market operations the traditional culture can be well preserved and sustainable rural economies can be developed—this is an interesting case for cultural confidence building.

### **5.2. “Going global” cultural initiatives and building international discourse power**

With the Chinese characteristics of socialism entering a new era, cultural confidence has become the key to the country’s development and rejuvenation. Chinese leaders have said that the confidence in culture, which is the confidence of socialism’s cultural path, is the most foundational and profound form of confidence. Explaining the way by which Sinicized Marxism can boost cultural confidence will clear the integration of Marxist theory with Chinese culture and give directions for cultural construction in the new era. Since its arrival in China, Marxism has undergone Yan’an-era exploration, post-1949 institutional innovation, and reform-era theoretical refinement. The development has led to a Chinese edition of Marxism, represented by Chinese leader thought, Chinese leader theory, the “Three Represents”, the scientific outlook on development, and Chinese leaders’ thought on Socialism with Chinese Characteristics for a New Era. Through the advocacy of socialist core values, the shaping of cultural policies, and the innovation of cultural industries, the Communist Party of China has succeeded in creating a positive cultural atmosphere and has laid the ideological and institutional foundations for cultural confidence.

Nonetheless, globalization and informatization bring to the fore new challenges such as the conflict of value pluralism, the influence of foreign ideological thoughts, and the threat of homogenization in cultural industries. National cultural identity and pride must be saved in the latter case, and the method under Sinicized Marxism has been clearly spelled out: systematic and sustainable pathways development is the most urgent task for preserving them.

## 6. Conclusion

Implemented from a Sinicized Marxist viewpoint, this essay systematically explores the content and change trajectory of cultural confidence. It outlines how inspired the cultural workers were in their task and traces the processes China underwent in building the socialist culture from the Yan'an period to the present day. In the period of the Enlightenment, at the level of theory, it emphasizes that we should follow the Chinese leaders' thought on Socialism with Chinese Characteristics for a New Era and introduce Chinese excellent traditional culture into socialist core values in an innovative way of ideological theory and institutional structure. At the practical level, through establishing a public cultural service system, deepening the cultural-system reform, and invigorating the cultural industry, the paper proves the way to create both institutional and market support for cultural confidence. At the same time, it points out that combining local people's participation with the revitalization of rural areas and intangible cultural heritage protection, and at the same time, China's international discourses in culture taking the lead in the world market can make traditional culture and international dissemination of culture both more effective. The case studies rural revitalization and protection of intangible cultural heritage, and the "going global" cultural projects alongside with the discourse power of building the global international community demonstrate that traditional culture can also be re-vitalized and that local culture can be successful globally through a combination of designing at the top level with grassroots participation at the bottom level; and, governmental guidance combined with societal cooperation as well, of course, the substantial resources from the cultural sector. In the future, it will be necessary to further strengthen theoretical armament in the ideological sphere, innovate cultural education and communication methods, consolidate the foundation for regional cultural development, and cultivate globally oriented communicators in order to achieve higher-quality cultural confidence and build a culturally strong nation.

## Disclosure statement

The author declares no conflict of interest.

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# The Cornerstones of Maritime Governance: Administration, Law-Policy Dynamics, and Crew Welfare

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**Abstract:** This paper presents a comprehensive analysis of maritime law and policy as a fundamental global governance framework whose priority is enhancing maritime safety and trade efficiency through integrated regulatory systems. Drawing on established theoretical frameworks in maritime governance literature, the study systematically examines four interconnected dimensions: (1) the policymaking role of maritime administrations in bridging technical expertise and national interests, (2) the dynamic legislative process involving executive, legislative, and judicial interactions, (3) a comparative analysis of maritime governance models (liberal democratic vs. Chinese centralized systems), and (4) human element considerations in crew welfare and operational safety. The research covers the historical evolution of maritime governance mechanisms, evaluates their efficacy in balancing international obligations with domestic priorities, and identifies critical implementation gaps, particularly in seafarer rights protection and cross-jurisdictional policy harmonization. In addition to institutional analysis, this work further contextualizes contemporary challenges through technological advancements, environmental regulations, and COVID-19 impacts on seafarer well-being, arguing that effective maritime policy must reconcile technical rigor, governance adaptability, and human-centered design. Findings underscore the necessity of multidisciplinary approaches for sustainable global shipping governance.

**Keywords:** Maritime governance; Policy implementation; Comparative governance systems; International maritime law; Human element in shipping; Seafarer welfare

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## 1. Introduction

Maritime law and policy have a very central role in shaping the global market and international trade. This essay evaluates various aspects of maritime governance, particularly the function of the maritime administration, the dynamics of law and policy development, the comparative system of governance, and the human element considerations in shipping. Utilizing foundational works in maritime policy analysis alongside empirical sources,



it examines these interconnected themes that are crucial to properly manage and regulate the maritime industry.

## **2. The role of the maritime administration in the development of national maritime law and policy**

Maritime administrations are central government establishments that oversee maritime concerns and the formulation of the national maritime legal structures. Scholarly consensus indicates that maritime policy formulation typically occurs at senior administrative levels of the maritime administration. These administrators assume responsibility for identifying issues, gaps, and shortcomings in current maritime regimes from a technical viewpoint, as required by rational policy and planning.

The maritime administration's role encompasses several key functions. The first and foremost approach is policy formulation. Maritime administrators can formulate policies that may advance their country's maritime interests, although with regard to the international benefit. Ideally, their knowledge of maritime affairs should encompass technical, legal, economic, and managerial aspects. This integration of multiple disciplines is necessary to create holistic and efficient maritime policies capable of responding to modern shipping industry concerns.

Another major role of maritime administrations is to offer technical support. The administration provides vital technical input on matters such as ship safety, protection of the environment, and seafarer welfare. This technical knowledge primarily informs policy-making and other legislative proposals.

Another pivotal responsibility of maritime administrations is the consultation of stakeholders. The different groups engage with various stakeholders, mainly in the public and private sectors, to get different insights about certain policies or legislation. This consultative approach enhances the quality of policies, is well-rounded, and considers the interests of all relevant parties.

Maritime administrations are also crucial in international representation. They frequently act as their nations' representatives in global organizations such as the International Maritime Organization (IMO), participating in the creation of rules governing international shipping and safeguarding their nation's concerns. This international engagement is important in achieving the goal of harmonizing the international maritime regulatory regime, as aptly pointed out by Mansell on flag state implementation <sup>[1]</sup>.

Finally, after policies are formulated and laws passed, implementation and enforcement fall under the maritime administration's mandate. This includes functions like inspection of ships, issuing certifications, and checking on compliance with various international conventions. Therefore, the effectiveness of this implementation and enforcement role is very key to the success of maritime policies as well as to the safety and efficiency of the maritime sector.

## **3. Dynamics of the law and policy process in the maritime field**

The development of maritime law and policy is a complex, dynamic process involving multiple stages and actors. Academic analyses elaborate on this process, pointing out the interactions between the branches of power and other actors. Knowledge of these dynamics remains vital for the governance and implementation of policies within the maritime sector.

The process normally starts at the maritime administration level with policy initiation. It involves recognizing something as a problem or a need through the application of official technical expertise and experience. This initial policy proposal is then taken up through the policy process in the executive branch, and frequently this process



involves numerous interactions with other departments and other players outside the executive branch. This is an important stage since it forms the framework for any policy formulation process.

After a policy document has been formulated, it is forwarded to other authority levels such as the responsible minister and possibly the cabinet. It is in this stage that the policy undergoes further cold-blooded analysis as well as criticism because it must fit within the larger policy framework and objectives of the government. If the policy must be enacted through legislation, the process shifts to the legislative arm. Here, the policy is converted into a draft law, and this can be done by drafting lawyers with legislative drafting skills in collaboration with the maritime administration.

The legislative process includes several readings of a bill and possible revisions before it becomes law. This stage can be particularly complex in the maritime field, mostly because of the technicality of the issues involved and the need to align national legislation with international conventions. Karim has indicated that the steps to undertake the domestication of international maritime conventions into national law can be challenging, and consideration should be given to the local legal systems and practices <sup>[2]</sup>.

After being passed, the legislation returns to the executive for implementation, where the maritime administration would need to create subsidiary legislation or regulations to put into operation the underlying law. This implementation phase is crucial and often very essential, and is usually accompanied by lots of problems in the process of converting the legal requirements into practical operational measures.

Research indicates this process is non-linear but is characterized by back-and-forth movements and interactions between the various branches of government. For example, through constitutional interpretation, the judiciary can be called upon in a case where the constitutionality of the maritime law is questionable and may result in altering the law or policy on maritime. This dynamic nature of the process calls for flexibility and adaptability in maritime policy development.

This process is compounded by the international nature of shipping. As mentioned by Chircop, national maritime policies and laws can only be established bearing in mind the principles of international maritime law and global shipping practices <sup>[3]</sup>. This necessitates a careful balancing act between national self-interests and international obligations.

#### **4. Systems of maritime governance: A comparative analysis**

Maritime governance systems are also different depending on the jurisdiction due to political and legal traditions. Comparative governance studies typically analyze the liberal democratic model of government, which includes the legislative, executive, and judiciary. Nevertheless, he also recognizes the existence of other systems, for instance, the Chinese model. This is significant when comparing these systems to understand the variations in the modes of maritime governance around the world.

In the liberal democratic model involving the United Kingdom, Canada, and India, the three estates work under the principle of checks and balances. The work of the legislature is to generate laws, the work of the executive is to enforce laws, and the work of the judiciary is to interpret them. This system is marked by a separation of power between these three arms of government, meaning none of them wields excessive power. This system has important principles, such as the legislature (or Parliament) is supreme in the making of laws, there is a separate branch of government known as the executive branch headed by a Prime Minister or a President responsible for policy execution, and an independent judiciary that has the power of the judicial review.

The applicability of this system in the maritime field is supported by Ng and Gujar posited that this form of checks and balances ensures proper and clear decisions on matters relating to the maritime world <sup>[4]</sup>. They argue that this results in the formulation of policies that are fair to different players in the maritime industry.

However, comparative governance analysis identifies distinct models that diverge markedly from the liberal democratic separation of powers, notably exemplified by the Chinese system <sup>[1, 5]</sup>. In China's governance structure, as analyzed by scholars like Yu and Zhao, the National People's Congress (NPC) serves as the highest state organ, exercising unified leadership. The Chinese Communist Party (CCP) plays a central role in formulating and guiding national strategies and policies. Regarding the judiciary, China's constitutional structure establishes that courts operate under the framework of the National People's Congress (NPC) and its Standing Committee, a model differing significantly from the independent judicial branches typical of liberal democracies <sup>[5]</sup>.

This distinct governance structure, characterized by unified leadership, shapes maritime policy development in China. As Yu and Zhao observe, this structure can enable more rapid policy formulation and implementation compared to systems reliant on extensive checks and balances among separate branches of government <sup>[5]</sup>. However, Yu and Zhao also acknowledge that this model may present different mechanisms for accountability and stakeholder consultation compared to liberal democratic systems <sup>[5]</sup>.

These differences can make a complex formation of maritime laws and policies. In liberal democratic systems, the process may involve debate and involvement of more parties, and it causes more delay because checks and balances are in place. The Chinese system, however, may enable faster policy action and implementation, but with constraints like limited public involvement or judicial intervention.

Knowledge of these types of governance systems is important to the maritime industry personnel, particularly those in international shipping and business. In this manner, it facilitates an understanding of the different regulatory settings and the underlying decision-making about all matters of maritime law and policy. In that regard, the effectiveness of operating within and across these various systems of maritime governance will remain a crucial and growing issue for global shipping.

## **5. Human element and crew welfare in shipping**

The human element is an influential component that contributes to marine safety, security, and environmental protection. Addressing human factor issues is widely recognized as essential for minimizing maritime fatalities and enhancing overall shipping efficiency. This aspect of maritime operations has recently received more attention because the awareness of the significance of crewing and human elements in shipping safety and productivity has been noted.

Critical scholarship identifies two key components of the human element in shipping: proficiency and competence, and welfare and well-being. Both proficiency and competence deal with the effectiveness of the performance of tasks by seafarers, taking into consideration the principles of the regulations on maritime safety, security, and environmental protection. Studies link inadequate maritime education and training (MET) to human errors, which are a major cause of maritime incidents.

The welfare and well-being element includes the physiological, interpersonal, as well as emotional, and psychological state of the seafarers. Despite its centrality, seafarer welfare often receives insufficient attention. This neglect can have adverse effects, as seen by Sampson and Ellis, when they noted that increased stress, fatigue, and health issues can come about due to poor working conditions and a lack of support for the seafarers <sup>[6]</sup>.

To address these issues, several measures are important. Efforts must be made to enhance the quality and comparability of MET globally. The STCW Convention, especially the 1995 and 2010 amendments, seeks to provide a minimum standard of training and certification of seafarers. However, Emad and Roth noted that the standards set are not equivalent across countries; more efforts are required to establish high-quality and relevant training programs for seafarers around the world <sup>[7]</sup>.

International standards and guidelines, like those outlined in the Maritime Labour Convention (MLC) 2006, are essential and should be adopted and applied to the seafarers' welfare. These include provisions for rest periods, shore leave, and accommodation on the vessel. This claim is supported by Baumler et al., who assert that enhancing living and working conditions not only has positive impacts on seafarers but also creates a more effective and secure shipping industry <sup>[8]</sup>.

It becomes essential to find ways to decrease the human factors with measures such as ergonomic, fatigue, and improving the safety climate of ships. This encompasses acknowledging and combating the psychological issues of workers, such as anxiety, stress, and adverse effects of being away from home for long durations, as is the case with seafarers. Migration and socialization, digital connectivity and communication, physical and mental health, substance abuse, and work-life balance have all been negatively impacted by the COVID-19 pandemic, leading to a greater emphasis on psychological needs for seafarers <sup>[9]</sup>.

It is also essential to make sure that seafarers have adequate legal remedies, such as fair treatment in situations of maritime accidents or incidents. This also extends to protection from criminalization, which has become rife in the maritime industry. International consensus underscores the critical need to enhance protection for seafarers and safeguard their entitlements at both national and international levels.

## 6. Conclusion

The formulation and adherence to maritime law and policy are complex processes involving multiple actors and considerations. Maritime administrations are responsible for introducing and developing these policies; however, the efficiency of these policies is influenced by adequate knowledge of technical and non-technical factors in the sphere of maritime. The nature of the law and policy process suggests that there must be harmonious cooperation with several government branches and other participants.

While the maritime industry is progressive in its advancement, changes in maritime law and policy must capture these advances while not losing sight of the welfare of these seafarers. Advanced maritime education, as emphasized in academic discourse, is pivotal in producing the next generation of maritime administrators and decision-makers to navigate these complex issues effectively.

## Disclosure statement

The author declares no conflict of interest.

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# Research on the Development and Prospect of Hydrogen Energy Vehicles

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**Abstract:** With the increasing global attention to environmental protection and sustainable development, hydrogen energy vehicles, as an important development direction of clean energy vehicles, are receiving more and more attention. As a zero-emission or low-emission mode of transportation, hydrogen-powered vehicles can not only effectively alleviate environmental problems caused by fossil fuel consumption, but also provide strong support for the transformation of the energy structure. This article will delve into the current development status and future prospects of hydrogen energy vehicles, and provide a specific analysis based on actual cases of coal-to-methanol hydrogen production enterprises, especially the promotion policies of methanol heavy-duty truck production companies in the Indonesian market.

**Keywords:** Hydrogen-powered vehicles; Development; Prospect

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## 1. The development status of hydrogen energy vehicles

### 1.1. Overview of the global hydrogen energy vehicle market

The global hydrogen energy vehicle market has emerged as a pivotal sector in the transition toward decarbonized transportation, exhibiting a compound annual growth rate (CAGR) of 34.2% from 2020 to 2023, according to BloombergNEF. While hydrogen fuel cell vehicles (FCEVs) currently account for less than 0.2% of global vehicle sales, their adoption is accelerating in key markets<sup>[1]</sup>. Regional disparities in growth are pronounced: Asia-Pacific dominates with a 68% market share, driven by Japan and South Korea's national hydrogen strategies, while Europe and North America follow with aggressive infrastructure investments.

Government policies are the primary catalyst for this expansion. The European Union's "Hydrogen Strategy for a Climate-Neutral Europe" allocates €470 billion for hydrogen infrastructure by 2030, including subsidies of up to €8,000 per FCEV purchase. China's "Fuel Cell Vehicle Demonstration Cities" program targets 50,000 FCEVs on roads by 2025, supported by tax exemptions and R&D grants<sup>[2]</sup>.



## 1.2. Technological progress and cost reduction

Technological advancements are rapidly closing the performance and cost gaps between FCEVs and conventional vehicles. Fuel cell systems now achieve 60%–65% energy efficiency, a 15% improvement since 2018, owing to breakthroughs in proton-exchange membrane (PEM) durability and platinum catalyst optimization <sup>[3]</sup>. Toyota's second-generation Mirai, for instance, extends driving range to 650 km per tank while reducing platinum usage by 80% through nanostructured catalyst designs. Hydrogen storage solutions have also evolved: Type IV carbon-fiber-reinforced tanks operating at 700 bar now offer energy densities of 1.5 kWh/kg, outperforming lithium-ion batteries (0.15–0.25 kWh/kg) <sup>[4]</sup>.

Cost reduction trajectories are equally transformative. The stack cost for fuel cells has plummeted from 1,200/kW in 2010 to 45/kW in 2023, driven by economies of scale and automated manufacturing. Hyundai's XCIENT fuel cell trucks, produced at its 50,000-unit-capacity plant in Guangzhou, exemplify this trend, with per-unit costs declining by 22% annually since 2020. Meanwhile, green hydrogen production costs are projected to fall below \$2/kg by 2030, as electrolyzer capital expenditures decrease by 60% through gigawatt-scale deployments <sup>[5]</sup>. These developments position FCEVs to achieve total cost of ownership (TCO) parity with diesel trucks in long-haul logistics by 2027, according to McKinsey.

## 1.3. Hydrogen refueling station infrastructure construction

Hydrogen refueling infrastructure remains the critical bottleneck for mass FCEV adoption. As of Q3 2023, only 1,042 public hydrogen stations operate globally, with 35% concentrated in Japan and Germany. However, investment pipelines signal transformative growth: the EU's "Hydrogen Mobility Europe" initiative aims to deploy 1,500 stations by 2030, while China plans 1,000 stations under its "Hydrogen Corridor" projects <sup>[6]</sup>. Private-sector collaborations are accelerating progress—Shell and Air Liquide's joint venture, H2 Mobility, has installed 130 stations across Western Europe, prioritizing highway corridors and urban hubs.

Technological standardization is addressing early-stage hurdles. The ISO 19880-1:2023 standard for station safety and SAE J2601 protocols for 700-bar refueling compatibility are streamlining global deployment. Modular "containerized" stations, such as Nel Hydrogen's H2Station™, reduce installation costs by 40% and deployment time to 8 weeks <sup>[7]</sup>. Innovations in hydrogen distribution—including liquid organic hydrogen carriers (LOHCs) and ammonia cracking—are expanding geographic reach, enabling cost-effective fuel delivery to remote regions.

## 2. The role and opportunities of coal in methanol hydrogen production enterprises

### 2.1. Overview of coal-to-methanol hydrogen production technology

Coal-to-methanol hydrogen production is a three-stage integrated process comprising coal gasification, methanol synthesis, and methanol reforming <sup>[8]</sup>. In the gasification stage, pulverized coal reacts with oxygen and steam under high pressure (4–6 MPa) and temperature (1,300–1,500 °C) to produce syngas ( $\text{CO} + \text{H}_2$ ), achieving carbon conversion rates exceeding 95%. The methanol synthesis phase utilizes copper-zinc-alumina catalysts at 220–280 °C and 5–10 MPa, converting syngas to methanol with single-pass yields of 60%–70%. Methanol reforming then employs steam reforming (SRM) or autothermal reforming (ATR) technologies, generating high-purity hydrogen (99.99%) at 200–300 °C, with a hydrogen yield of 140–150 kg per ton of methanol <sup>[9]</sup>.

This technology leverages coal's abundance and existing infrastructure, particularly in coal-rich nations. China's Shenhua Group operates the world's largest coal-to-hydrogen facility in Ordos, producing 350,000 tons of hydrogen annually at a cost of \$1.3–1.6/kg, 40% lower than natural gas-based methods. The process also

synergizes with coal-chemical industries: by-products like syngas and CO<sub>2</sub> are repurposed for urea or polyolefin production, enhancing resource utilization. Global coal-derived hydrogen currently supplies 18% of industrial hydrogen demand, projected to reach 25% by 2030 due to scalability advantages in emerging economies <sup>[10]</sup>.

## **2.2. The position of coal to methanol hydrogen production in the hydrogen energy vehicle industry chain**

Coal-to-methanol hydrogen producers serve as critical enablers in the hydrogen mobility ecosystem, bridging upstream energy supply and downstream applications.

**Cost-efficient hydrogen supply:** A single 600,000-ton/year methanol plant can support hydrogen production for 15,000 fuel cell vehicles (FCVs), addressing the “chicken-and-egg” infrastructure dilemma.

**Infrastructure synergy:** Existing coal-chemical industrial parks provide ready-made pipelines, storage tanks, and logistics networks, reducing hydrogen distribution costs by 30%–50% compared to greenfield projects.

**Multi-sector integration:** By partnering with automakers and refueling station operators, coal-hydrogen producers enable integrated solutions. For instance, China Energy Investment Corporation collaborates with FAW Jiefang to deploy hydrogen-powered mining trucks in Inner Mongolia, cutting fuel costs to \$3.5/kg through onsite hydrogen production.

Policy frameworks further reinforce this role. China’s 2022 Hydrogen Industry Development Plan recognizes coal-to-hydrogen with carbon capture as a transitional solution, while Japan’s Green Growth Strategy allows limited coal-derived hydrogen imports with carbon offsets. Such measures position coal-to-methanol plants as scalable hydrogen hubs, particularly for heavy-duty transport where battery electrification remains impractical.

## **2.3. Challenges and response strategies of coal-to-methanol hydrogen production enterprises**

Despite its advantages, the sector confronts three existential challenges.

**Carbon intensity constraints:** Conventional coal-to-hydrogen emits 18–22 kg CO<sub>2</sub> per kg H<sub>2</sub>, over 20 times higher than electrolytic green hydrogen. The EU’s Carbon Border Adjustment Mechanism (CBAM) imposes €80–100/ton CO<sub>2</sub> tariffs on imports, threatening export-oriented projects.

**Technological disruption:** Proton-exchange membrane (PEM) electrolysis costs are falling by 14% annually, potentially undercutting coal-based hydrogen by 2030 without carbon pricing.

**Regulatory fragmentation:** Divergent standards—e.g., Japan’s <5 kg CO<sub>2</sub>/kg H<sub>2</sub> threshold for “clean hydrogen”—complicate market access.

### **2.3.1. Strategic responses**

**Carbon capture and utilization (CCUS) integration:** Advanced amine scrubbing and oxy-fuel combustion can capture 90%+ of process emissions. The Sinopec Xinjiang project demonstrates CCUS costs of \$40/ton CO<sub>2</sub>, reducing lifecycle emissions to 4.5 kg CO<sub>2</sub>/kg H<sub>2</sub>.

**Hybrid energy systems:** Coupling coal gasification with renewable-powered electrolysis creates “blue-green hydrogen” blends. Ningxia Baofeng’s pilot plant uses solar-powered electrolysis to displace 30% of coal-derived hydrogen, cutting carbon intensity to 8.2 kg CO<sub>2</sub>/kg H<sub>2</sub>.

**Vertical industry alliances:** Partnerships across the value chain mitigate risks. Yankuang Group collaborates with Weichai Power on fuel cell R&D and with CIMC Enric on mobile hydrogen refuelers, achieving a 25%

reduction in end-user hydrogen costs.

### **2.3.2. Policy advocacy priorities**

Establish tiered hydrogen certification (gray/blue/green) with differentiated subsidies. Expand carbon trading markets to include hydrogen production, incentivizing CCUS adoption. Develop transnational hydrogen corridors, such as the Asia Hydrogen Highway, to standardize trade protocols.

## **2.4. Future pathways: Transition and transformation**

Coal-to-methanol hydrogen will remain a transitional pillar for regions prioritizing energy security and affordability, particularly in heavy industries and freight transport. By 2035, advancements in sorption-enhanced gasification and chemical looping could reduce emissions by 50%, while co-processing biomass with coal may enable negative-carbon pathways. Ultimately, the technology's longevity hinges on its ability to evolve into a carbon-managed hydrogen backbone, complementing rather than competing with renewable hydrogen systems.

## **3. Analysis of promotion policies for the methanol heavy truck production company in the Indonesian market**

### **3.1. Overview of the Indonesian market and demand for methanol heavy-duty trucks**

Indonesia, Southeast Asia's largest economy with a GDP of 1.4 trillion (2023), is experiencing a logistics boom driven by infrastructure expansion and e-commerce growth. The heavy-duty truck market, valued at 2.8 billion in 2023, is projected to grow at a 6.5% CAGR through 2030, fueled by mining (23% of demand), agriculture (31%), and inter-island logistics (46%). However, diesel-powered trucks dominate 98% of the fleet, emitting 2.7 kg CO<sub>2</sub>/km, contributing 18% of the nation's transport-sector emissions.

Methanol-fueled trucks present a strategic solution. With 90% lower particulate emissions than diesel and 40% lower nitrogen oxides (NO<sub>x</sub>), they align with Indonesia's 2060 net-zero pledge. Methanol's advantages include the following.

**Fuel security:** Indonesia produces 4.2 million tons/year of methanol from natural gas, reducing import dependency.

**Infrastructure compatibility:** Methanol blends (M85-M100) require minimal retrofitting of existing diesel engines.

**Cost efficiency:** At 0.35/L (vs.0.68/L for diesel), methanol cuts fuel costs by 48%, critical for fleet operators facing 15%–20% profit margins.

The government's Blueprint for Sustainable Transport 2025 targets 5,000 methanol trucks by 2030, focusing on Java-Sumatra freight corridors and nickel mining operations in Sulawesi.

### **3.2. Market promotion strategy of the methanol heavy truck production company**

Leading manufacturers like China's Geely and Sweden's Scania are deploying tailored strategies.

#### **3.2.1. Product adaptation**

**Powertrain optimization:** Geely's M100 trucks feature 12.5L engines with 420 hp and 2,000 Nm torque, matching diesel performance while achieving 18% better fuel economy (7.5 km/kg methanol).

**Tropicalization:** Scania's Indonesia-specific models integrate corrosion-resistant fuel systems and enhanced

cooling for 35°C+ operations.

### **3.2.2. Policy engagement**

Subsidy advocacy: Collaborating with the Ministry of Transport to secure \$15,000/unit purchase incentives (25% of vehicle cost).

Carbon trading integration: Proposing methanol truck CO<sub>2</sub> savings (2.1 tons/month per truck) to offset mining sector emissions under Jakarta's cap-and-trade pilot.

### **3.2.3. Ecosystem development**

Refueling networks: Sinotruk partners with PT Pertamina to convert 50 diesel stations to methanol blends in Kalimantan by 2025.

Financing models: Volvo Financial Services offers methanol truck leases at 1,200/month, including fuel contracts locked at 0.30/L for 5 years.

### **3.2.4. Market education**

Pilot demonstrations: FAW Jiefang's 100-truck fleet in Sumatra's palm oil sector demonstrated 22% lower TCO over 18 months.

Technician training: Scania's Batam training center certifies 200 mechanics/year in methanol engine maintenance.

## **3.3. Specific measures and effect evaluation of Indonesian market promotion policies**

The Indonesian government has taken a series of policy measures to promote clean energy transportation. For example, providing car purchase subsidies, building hydrogen refueling station networks, promoting technology research and development, and industrial upgrading. These policy measures provide strong support for the promotion of methanol heavy-duty trucks in the Indonesian market. At the same time, relevant production companies have actively responded to the government's call, strengthened cooperation with the government and relevant institutions, and jointly promoted the popularization of methanol heavy-duty trucks in the Indonesian market.

From the perspective of effectiveness evaluation, the Indonesian government's promotion policies have achieved significant results. The sales volume of methanol heavy-duty trucks in the Indonesian market continues to grow, and their market share continues to increase. At the same time, the environmental performance and economic benefits of methanol heavy-duty trucks have been widely recognized, making positive contributions to the sustainable development of Indonesia's transportation industry.

## **3.4. Policy framework and impact assessment**

Indonesia's multi-tiered policy framework catalyzes methanol truck adoption.

### **3.4.1. Fiscal incentives**

Purchase subsidies: 15,000–15,000–20,000 per truck via the Low Carbon Vehicle Fund (2024–2027 budget: \$450 million).

Tax breaks: 0% import duty for methanol powertrain components vs. 15% for diesel parts.

### 3.4.2. Infrastructure mandates

Refueling targets: Mandating 150 methanol-compatible stations nationwide by 2026, prioritizing the Trans-Java Toll Road and Makassar Port.

Bunker fuel standards: Requiring 10% methanol blends for port-based logistics vehicles from 2025.

### 3.4.3. Industrial synergy

Mining sector rules: Mandating 20% clean-energy trucks for new nickel mining licenses (e.g., Weda Bay project).

Bio-methanol incentives: \$30/ton production credits for methanol derived from palm oil waste (target: 500,000 tons/year by 2030).

### 3.4.4. Performance outcomes

Adoption rates: Methanol truck sales reached 320 units in 2023 (4.2% of new HD truck sales), up from 45 units in 2020.

Emission reductions: Pilot fleets in East Kalimantan cut CO<sub>2</sub> by 6,300 tons in 2023, equivalent to 1,400 hectares of rainforest carbon sequestration.

Economic benefits: Fleet operators report 18%–25% lower operating costs, with payback periods of 3.2 years vs. diesel trucks.

### 3.4.5. Challenges persist

Fuel distribution: Only 12% of Indonesia's 8,600 fuel stations currently offer methanol, concentrated in Java.

Consumer perception: 63% of fleet managers in a 2023 survey expressed concerns about methanol's cold-start performance (-5% power at <15°C).

Policy execution: Regional autonomy laws delay standardization; Sulawesi's methanol tax rates vary 8%–12% across districts.

## 3.5. Strategic recommendations

Accelerate refueling rollouts: Leverage Pertamina's 5,000-station network to prioritize methanol in 15 key logistics hubs.

Hybrid solutions: Develop diesel-methanol dual-fuel kits for retrofitting 200,000 legacy trucks (potential 12% CO<sub>2</sub> reduction).

Export hub development: Position Batam as a methanol truck manufacturing base, targeting ASEAN's \$9.1 billion HD truck market.

Carbon monetization: Link methanol truck deployments to Indonesia's \$3.5 billion carbon credit export goals.

Indonesia's methanol truck market represents a \$1.2 billion opportunity by 2030. Success hinges on OEM-government synergy to balance emission goals with economic pragmatism in Southeast Asia's most complex archipelago logistics landscape.

## 4. Future prospects and challenges of hydrogen-powered vehicles

### 4.1. Technological innovation and industrial upgrading

In the future, the development of hydrogen-powered vehicles will rely on technological innovation and industrial upgrading. With the continuous breakthroughs and upgrades of key technologies such as fuel cell systems,



hydrogen storage technology, and hydrogen refueling station infrastructure, the performance of hydrogen energy vehicles will be further improved, and costs will be further reduced. This will provide strong support for the popularization of hydrogen energy vehicles.

#### **4.2. Collaborative development of the industrial chain**

The coordinated development of the hydrogen energy vehicle industry chain is the key to promoting its development. In the future, it is necessary to strengthen cooperation and collaboration between upstream and downstream enterprises and jointly promote the optimization and upgrading of the industrial chain. At the same time, it is necessary to strengthen exchanges and cooperation with international advanced enterprises, introduce advanced technology and management experience, and enhance the international competitiveness of China's hydrogen energy vehicle industry.

#### **4.3. Policy support and market mechanism construction**

Government policies play an irreplaceable role in promoting the development of hydrogen energy vehicles. In the future, it is necessary to continue to improve relevant policies, regulations, and standard systems to provide strong support for the promotion of hydrogen energy vehicles. At the same time, it is necessary to strengthen the construction of market mechanisms and promote the market-oriented and commercial development of the hydrogen energy vehicle industry.

#### **4.4. Challenges of environmental regulations and carbon emission restrictions**

With the increasingly strict environmental regulations and the continuous strengthening of carbon emission restrictions, hydrogen-powered vehicles will face greater challenges. To address these challenges, it is necessary to strengthen technological research and innovation and improve the environmental performance and energy efficiency of hydrogen energy vehicles. At the same time, it is necessary to strengthen cooperation and communication with the international community to jointly address global climate change issues.

### **5. Conclusion**

In summary, hydrogen-powered vehicles, as an important development direction for clean energy transportation, have broad application prospects and enormous market potential. Based on the actual case of coal to methanol hydrogen production enterprises and the promotion policy analysis of methanol heavy-duty truck production companies in the Indonesian market, it can be seen that the development of hydrogen energy vehicles requires joint efforts from multiple aspects such as technological innovation, industrial upgrading, coordinated development of the industrial chain, policy support, and market mechanism construction. In the future, with the continuous advancement of technology and the gradual maturity of the market, hydrogen energy vehicles will become an important force in promoting the sustainable development of the global transportation industry. At the same time, people also need to be aware of the challenges and difficulties faced by the development of hydrogen energy vehicles, actively seek solutions and response strategies, and contribute wisdom and strength to the popularization and promotion of hydrogen energy vehicles.

## Disclosure statement

The author declares no conflict of interest.

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# A Study on the Impact of Charitable Organization Capacity on Community Governance Performance: Based on the Perspective of Social Capital

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**Abstracts:** In the context of deepening the grassroots governance system in the new era, charitable organizations, as an important complementary force of the social governance system, have gradually become the focus of research on their functions and paths in community governance. Based on the social capital theory, this paper explores the influence mechanism of charitable organizations' resource integration, social mobilization, and information transfer capacity on community governance performance. The study finds that: (1) the capacity of charitable organizations significantly improves the performance of community governance; (2) social capital has a partially intermediary role; and (3) there is an operable interactive mechanism between the three.

**Keywords:** Charitable organizational capacity; Social capital; Community governance performance; Structural equation modeling

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## 1. Background and significance of the study

As China's social transformation and modernization of national governance advance, community governance is becoming increasingly important. Since the 19th National Congress of the Communist Party of China (CPC), policies have continued to emphasize the construction of a pattern of "common governance and sharing", promoting the downward shift of the center of gravity of governance, and explicitly requesting that the role of charitable organizations in grass-roots governance be brought into play. Documents such as the Charity Law provide institutional guarantees for their participation. In this context, how charitable organizations can effectively integrate into the community to improve governance performance has become a key issue. Although existing studies have explored the relationship between charitable organizations and community governance, there is a lack

of systematic research on their mechanism of action, especially through the intermediary path of social capital to influence governance performance.

Based on this, this paper intends to address the following research questions: Does the capacity of charitable organizations significantly affect community governance performance? Does social capital play a mediating role in it? Is the mechanism of the relationship between the three operational?

## **2. Literature review**

### **2.1. Study on the capacity of charitable organizations and their role in community governance**

The capacity of a charity organization refers to its systematic effectiveness in achieving its public welfare mission, covering the dimensions of resource integration, strategic management, social mobilization, and information dissemination. Early research was represented by Glickman's five-dimensional model (resources, governance, networks, coordination, projects) <sup>[1]</sup>. Domestic studies mainly focus on three aspects: resource integration capacity emphasizes strategic management and resource mobilization, which is regarded as the key to coping with the dependence on government resources <sup>[2]</sup>. Social mobilization capacity activates community participation through volunteer services and public incentives, reflecting organizational mobility <sup>[2]</sup>. Information dissemination capacity, especially in the digital era, affects the credibility of the public in emergencies and the efficiency of participation in governance <sup>[4]</sup>. In community governance, charitable organizations become key subjects by virtue of their flexibility and professionalism. Western studies have emphasized the synergistic governance through service provision and policy advocacy; domestic studies have paid more attention to the specific paths of their embedding in grassroots governance, such as playing the dual functions of "service supplementation" and "participation activation", enhancing the performance of weak governance structures through cultural embedding, and reflecting the organization-government-residents' participation in community governance. and the "welfare governance triangle model", which embodies the interaction between the organization, the government, and the residents <sup>[5]</sup>.

### **2.2. Research on the role of social capital in the relationship between charitable organizations and community governance**

Social capital theory, proposed by scholars such as Bourdieu, Coleman, and Putnam, emphasizes trust, networks, and norms as important mechanisms of social resources. Coleman argues that social capital facilitates collective action through structural embeddedness and normative constraints <sup>[6]</sup>. Putnam, from the perspective of civic culture, points out that trust and social participation have a governance performance significant enhancing effect <sup>[7]</sup>. Lin Nan, on the other hand, distinguishes between structural and cognitive social capital and argues that social capital is a resource embedded in social relationships <sup>[8]</sup>. Zhang Qilin et al. empirically demonstrated that social capital is a mediating variable embedded in the governance network of charitable organizations, which enhances governance performance through a triple path: trust capital reduces transaction costs; relational networks enhance information symmetry; and institutional norms establish legitimacy of action <sup>[9]</sup>.

To sum up, the current research lacks the systematic modeling of "competence→social capital→governance performance" and needs to verify the specific paths of multidimensional competence. Therefore, this paper will try to construct an analytical framework of "charitable organization capacity — social capital — community governance performance", and systematically explore the role of the three paths and the mechanism of evolution.

### 3. Research design and hypotheses

#### 3.1. The capacity of charitable organizations and community governance performance

By virtue of their resource integration, social mobilization, and information transmission capabilities, charitable organizations have become a key force in enhancing the performance of community governance. The ability of resource integration systematically integrates fragmented resources of multiple actors (government, enterprises, media, individuals) to build a collaborative network, and its professionalism and transparency enhance credibility and facilitate the flow of knowledge, technology and other non-material resources, thus improving the accuracy of services and helping to break the dilemma of “fragmentation”<sup>[10]</sup>. The social mobilization capacity makes use of organizational flexibility to efficiently activate the community participation network, mobilize professional volunteers, and link external resources, and build a multi-dimensional co-management pattern under the leadership of the government<sup>[11]</sup>. Information transfer capacity is particularly important in the digital context, through specialized communication to transform complex governance information into easy-to-understand content, reduce information asymmetry, realize “governance visualization”, promote transparency in community decision-making, and enhance the legitimacy of governance<sup>[12]</sup>. Based on this, the following hypotheses are proposed:

Hypothesis H1: The resource integration capacity of charitable organizations positively affects community governance performance.

Hypothesis H2: The social mobilization capacity of charitable organizations positively affects community governance performance.

Hypothesis H3: The information transfer capacity of charitable organizations positively affects community governance performance.

#### 3.2. The mediating role of social capital

The resource integration, social mobilization, and information transfer capabilities of charitable organizations indirectly contribute to community governance performance by enhancing community social capital (networks, norms, and trust).

In terms of resource integration capacity, charitable organizations increase the density of community social networks by constructing multifaceted collaborative networks, thus enhancing the efficiency of public services<sup>[13]</sup>. In terms of social mobilization capacity, they use moral advocacy and institutionalized reciprocity mechanisms to activate residents’ participation in collective action, strengthen community reciprocity norms, and reduce governance friction<sup>[11, 14]</sup>. In terms of information transfer capacity, it utilizes digital channels to enhance transparency, correct principal-agent failures, and increase resident trust, which in turn improves governance responsiveness and satisfaction<sup>[15–16]</sup>.

In summary, social capital plays a key mediating role in the process of charitable organizations’ three types of capabilities affecting community governance performance. Based on this, it is proposed:

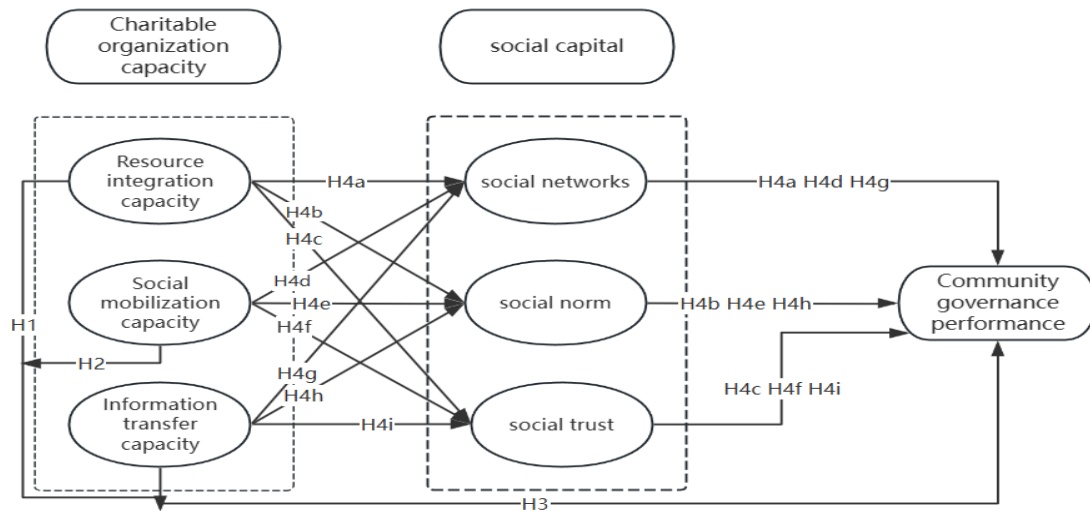
Hypothesis H4: Social capital plays a mediating role in the influence of charitable organization capacity on community governance performance.

Based on this, its sub-hypothesis is proposed accordingly:

H4a: The resource integration capacity of charitable organizations can enhance community governance performance by expanding the density of social networks. H4b: The resource integration capacity of charitable organizations can enhance community governance performance by strengthening the norms of community reciprocity. H4c: The resource integration capacity of charitable organizations can enhance community governance



performance by strengthening the trust of residents. Subsequent H4d–H4i as above (**Figure 1**).



**Figure 1.** Diagram of the relationship between the research hypotheses

## 4. Results of empirical analysis

### 4.1. Data sources and sample description

This study collects research data through a household questionnaire survey and a centralized questionnaire survey. Eventually, the first pre-survey questionnaire got 30 valid questionnaires, the second pre-survey got 30 valid questionnaires, and the official questionnaire distributed after analyzing the reliability and validity got 418 valid samples.

### 4.2. Structural equation modeling path coefficient analysis

According to the path analysis of the structural model, the results are shown in **Table 1**. From the path relationship between the variables, it is known that according to the significance level  $P$ -value, it is found that at the significance level of 0.05, the resource integration capacity of charitable organizations is  $0.003 < 0.05$ , the social mobilization capacity is  $0.002 < 0.05$  as well as the information transfer capacity is  $P < 0.001 < 0.05$ , all three dimensions have a significant effect on community governance performance, and according to the standard regression coefficient, it is found that The resource integration capacity, social mobilization capacity, and information transmission capacity of charitable organizations are positively correlated with community governance performance.

**Table 1.** Analysis of path coefficients for structural equation modeling

X	→	Y	Standardized regression coefficient	SE	$z$ (CR)	$P$
Resource integration capacity	→	Community governance performance	0.077	0.026	3.016	0.003
Social mobilization capacity	→	Community governance performance	0.100	0.032	3.136	0.002
Information transfer capacity	→	Community governance performance	0.367	0.061	5.971	***

### 4.3. Mediation effects test

From **Table 2**, it can be seen that all three sub-dimensions of social capital, social networks, social norms, and social trust, mediate the effect of charitable organization capacity on community governance performance. In particular, in the information transfer capacity → social norms → community governance capacity path, the mediation effect reaches 0.116, which has the highest mediation effect value among all paths, suggesting that institutional norms play a key role in the transformation of information flow and community performance.

**Table 2.** Summary of the results of the overall mediation test

	c	a	b	a*b	a*b (95% BootCI)	c'	Test conclusion
Philanthropic organization capacity → social capital → community governance performance	1.004**	0.827**	0.754**	0.623	0.489 ~ 0.578	0.380**	Partial Mediation

From **Table 3**, it can be seen that social capital has a partial mediating effect in the impact of charitable organization capacity on community governance performance.

**Table 3.** Summary of test results for sub-hypothesis mediation

	c	a	b	a*b	a*b (95% BootCI)	c'	Test conclusion
Resource integration capacity → social trust → community governance performance	0.197**	0.189**	0.237**	0.045	0.022 ~ 0.068	0.086**	Partial Mediation
Resource integration capacity → social norms → community governance performance	0.197**	0.121**	0.244**	0.030	0.010 ~ 0.053	0.086**	Partial Mediation
Resource integration capacity → social networks → community governance performance	0.197**	0.153**	0.236**	0.036	0.013 ~ 0.058	0.086**	Partial Mediation
Social mobilization capacity → social trust → community governance performance	0.267**	0.255**	0.237**	0.060	0.037 ~ 0.090	0.102**	Partial Mediation
Social mobilization capacity → social norms → community governance performance	0.267**	0.228**	0.244**	0.056	0.030 ~ 0.084	0.102**	Partial Mediation
Social mobilization capacity → social networks → community governance performance	0.267**	0.206**	0.236**	0.049	0.025 ~ 0.076	0.102**	Partial Mediation
Information transfer capacity → social trust → community governance performance	0.537**	0.384**	0.237**	0.091	0.070 ~ 0.121	0.222**	Partial Mediation
Information transfer capacity → social norms → community governance performance	0.537**	0.479**	0.244**	0.117	0.092 ~ 0.153	0.222**	Partial Mediation
Information transfer capacity → social network → community governance performance	0.537**	0.455**	0.236**	0.107	0.080 ~ 0.144	0.222**	Partial Mediation

## 5. Research conclusions

First, the capacity of charitable organizations significantly improves the performance of community governance: the capacity of resource integration alleviates the lack of grassroots resources and introduces multiple resources from the government, enterprises, and the public. The capacity of social mobilization expands the boundaries of participation and enhances the residents' sense of responsibility and awareness. The capacity of information transfer serves as an "information lubricant" and improves governance efficiency in policy interpretation, demand feedback, and risk early warning.

Secondly, social capital plays a partly intermediary role: empirical evidence verifies that there is a partly intermediary effect of social capital in the path of "organizational capacity→governance performance." Thirdly, the triadic interactive relationship: the interactive relationship of "charitable organization capacity-social capital-community governance performance" has empirical support and practical significance.

## Disclosure statement

The authors declare no conflict of interest.

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# Research on the Construction of International Consumption Center City from the Perspective of Innovative Talents —Taking Haikou City as an Example

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**Abstract:** This article focuses on the perspective of innovative talents and explores the development path for Haikou City to become an international consumer city. By analyzing the crucial role of innovative talents in building an international consumer center, and considering Haikou's advantages in policy and resources, as well as the current talent situation and challenges faced during the construction process, the article proposes strategies from multiple dimensions, including the introduction, cultivation, motivation, and optimization of the talent development environment. The aim is to provide theoretical support and practical guidance for Haikou to accelerate the construction of an international consumer center and achieve high-quality economic development.

**Keywords:** Innovative talents; International consumer city center; Haikou city; Talent strategy

**Online publication:** June 13, 2025

## 1. Introduction

In the context of economic globalization and consumption upgrades, international consumer cities, as key nodes that connect domestic and foreign markets, lead consumption trends and drive economic growth, and play a crucial role. In July 2021, the State Council approved Shanghai, Beijing, Tianjin, Guangzhou, and Chongqing to lead the development of international consumer cities <sup>[1]</sup>. This strategic move underscores the country's strong emphasis on the development of the consumption sector. Haikou City, as the capital of Hainan Province, has significant potential for becoming an international consumer city, thanks to the policy advantages of the Hainan Free Trade Port, its unique tourism resources, and its advantageous geographical location <sup>[2]</sup>.

Innovative talents are the core driving force behind urban development. For the construction of an international consumer center city, these talents can introduce new concepts, technologies, and business models,



fostering innovation in consumption scenarios, building strong consumer brands, and enhancing the consumption environment <sup>[3-4]</sup>. This, in turn, boosts the city's international competitiveness and appeal to consumers. Studying Haikou's international consumer center city construction from the perspective of innovative talents can help uncover the intrinsic connection between talent and urban development, explore more targeted and effective construction paths, and help Haikou stand out on the global consumer stage <sup>[5]</sup>.

## **2. The importance of innovative talents to the construction of an international consumer center city**

### **2.1. Promote consumption innovation and upgrading**

Innovative talents can keenly identify new trends and demands in the consumer market, driving consumption innovation through innovative product design, service models, and marketing strategies <sup>[6]</sup>. For instance, in Haikou's tourism sector, these talents can develop tourism products that blend local cultural elements with modern technology, such as VR historical and cultural tours and smart coastal resort services <sup>[7]</sup>. These offerings meet consumers' demand for personalized and high-quality travel experiences, thereby promoting the upgrade of tourism consumption. In the commercial retail sector, innovative talents introduce new sales models like unmanned retail and live-streaming sales, enhancing shopping convenience and fun, stimulating consumer purchasing desire, and driving the innovative development of retail consumption <sup>[8-9]</sup>.

### **2.2. Help build international consumer brands**

Brand building is a crucial component in the development of international consumer centers. Innovative talents possess unique skills in brand planning and promotion, enabling them to deeply explore the cultural essence of Haikou and integrate it into brand development, thereby creating local consumer brands with international influence <sup>[10]</sup>. For instance, leveraging Hainan's tropical agricultural products, innovative talents can position, design packaging, and promote these local specialties to create internationally recognized green and healthy food brands <sup>[11]</sup>. Additionally, by leveraging their international perspective and business negotiation skills, innovative talents can attract more international brands to Haikou, thereby enhancing the city's brand presence and consumer appeal <sup>[12]</sup>.

### **2.3. Optimize the consumption environment and services**

A favorable consumption environment and high-quality services are key indicators of an international consumer city. Innovative talents play a crucial role in enhancing the consumption environment <sup>[13]</sup>. They can leverage technologies like big data and artificial intelligence to improve the intelligent management of consumption venues, as well as enhance infrastructure services such as transportation, parking, and payment systems <sup>[14]</sup>. For example, smart traffic systems can optimize traffic flow around tourist attractions, and mobile payment technology can make shopping more convenient. In terms of service, innovative talents can introduce advanced international service concepts and management models, train service staff, and improve service quality and international standards, providing consumers with a more comfortable, convenient, and efficient experience <sup>[15]</sup>.

### **2.4. Promote industrial integration and coordinated development**

The development of international consumer cities involves multiple sectors, including tourism, commerce, culture, and finance, requiring coordinated development across these sectors. Innovative talents possess interdisciplinary knowledge and skills, enabling them to break down barriers between industries and foster integrated innovation <sup>[16]</sup>. For instance,

in Haikou City, innovative talents can drive the integration of tourism, culture, and commerce, creating culturally distinctive commercial districts, organizing tourism and cultural festivals, and organically combining tourism, shopping, and cultural experiences. This approach forms new consumption growth points and enhances the city's overall competitiveness in the consumer market <sup>[17]</sup>.

### **3. Analysis of the current situation of Haikou city in building an international consumer city and the demand for innovative talents**

#### **3.1. The current situation of Haikou city in building an international consumer center city**

##### **3.1.1. Significant policy advantages**

As the construction of the Hainan Free Trade Port advances, Haikou City has benefited from a series of preferential policies. These include the continuous optimization of the duty-free shopping policy, increased tax-free shopping quotas, and a wider range of products, all of which have significantly boosted the consumer market. In 2024, customs supervised a total of 30.94 billion yuan in Hainan's duty-free shopping, with 5.683 million shoppers and 33.082 million items purchased, highlighting Haikou's significant contribution to duty-free shopping <sup>[18–19]</sup>. Additionally, policies such as relaxed market access and tax incentives have attracted numerous domestic and foreign enterprises to invest in Haikou's consumer sector, laying a solid policy foundation for the development of an international consumption center city.

##### **3.1.2. Expansion of consumer market**

In recent years, the consumer market in Haikou has seen continuous growth. In 2023, the city's total retail sales of consumer goods reached 109.3 billion yuan, marking a 9% increase from the previous year. The city welcomed 23.95 million visitors, generating a tourism revenue of 38.6 billion yuan, representing increases of 28% and 31%, respectively. Key drivers of this growth include tourism consumption, duty-free shopping, and the integration of cultural, sports, tourism, commerce, and exhibition activities. For instance, by promoting Haikou's image as a New Year's Eve City and hosting events like the Hunan TV Mango TV New Year's Eve Gala, the city organized over 200 performances in 2023. Among these, 15 large-scale commercial performances attracted more than 10,000 attendees, drawing 380,000 visitors and generating 1.78 billion yuan in tourism revenue, significantly boosting the prosperity of the consumer market <sup>[20]</sup>.

##### **3.1.3. Increasing variety of consumption formats**

Haikou City is actively promoting the innovation of consumer formats. In addition to traditional sectors like tourism, shopping, and dining, new consumer formats are constantly emerging. For instance, the sports + tourism model centered on sailing and the cultural street + tourism model in the northern part of Haidian Creek, which integrates cultural and commercial elements, offer new consumer experiences to both residents and visitors. Meanwhile, new consumption models such as cross-border e-commerce and live-streaming e-commerce are rapidly developing. New consumption scenes, including the China-Japan-Korea consumption zone e-commerce experience center, are continuously emerging, enriching the consumer market's offerings.

#### **3.2. Demand for innovative talents in Haikou's construction of an international consumer city**

##### **3.2.1. Tourism consumption field**

There is a need for innovative talents who can design innovative tourism products and excel in marketing and

promotion. These talents should be capable of developing unique and appealing tourism products, such as high-end vacation packages and cultural experience tours, and promoting them through international marketing channels to attract more international tourists. Additionally, there is a need for innovative talents in tourism service management to enhance the quality and efficiency of tourism services, meeting the diverse needs of international tourists.

### **3.2.2. Duty-free shopping area**

There is a need for innovative talents proficient in international trade, cross-border e-commerce, brand operations, and management. These individuals should be able to understand the dynamics of the international goods market, optimize the categories and structure of duty-free products, and enhance the operational efficiency and service quality of duty-free stores. Additionally, there is a demand for talents with innovative thinking and the ability to integrate different industries, particularly in the integration of duty-free shopping with other sectors, to promote new models such as duty-free + tourism and duty-free + culture.

### **3.2.3. Integration of culture, tourism, and business exhibitions**

Innovative talents are needed who possess a range of skills, including cultural and creative planning, event organization and operation, business management, and marketing. They should be capable of organizing and hosting cultural and sports events, as well as commercial exhibitions with international influence, to promote the deep integration of industries such as culture, sports, tourism, and trade. For example, organizing international music festivals, international sports events, and international consumer goods expos requires a professional team for planning, organizing, and operating these events.

### **3.2.4. Digital consumption**

With the widespread application of digital technology in the consumer sector, there is a growing need for innovative talents skilled in big data, artificial intelligence, and the Internet of Things (IoT). These talents can enhance the intelligence of consumer scenarios, conduct precise marketing, and optimize consumer experiences by leveraging these technologies. For instance, big data analysis can help businesses gain insights into consumer shopping behaviors and preferences, providing them with accurate market information to achieve personalized recommendations and marketing strategies. Additionally, AI technology can be used to develop intelligent customer service and shopping guidance features, thereby improving service efficiency and quality.

## **4. The current situation and existing problems of innovative talents in Haikou City**

### **4.1. Insufficient number of innovative talents**

Compared to first-tier cities like Beijing, Shanghai, and Guangzhou, Haikou City has a relatively smaller number of innovative talents. According to relevant statistics, the number of innovative talents per 10,000 people in Haikou is significantly lower than the national average for developed cities. In key sectors such as tourism, commerce, and culture, the shortage of innovative talents is particularly pronounced, making it difficult to meet the rapid development needs of building an international consumer center city. For example, there is a lack of experienced and skilled innovative talents in developing high-end tourism products and managing international brands, which hinders the innovative development of these industries.

## **4.2. Unreasonable talent structure**

In terms of the professional structure of talents, Haikou City's innovative talents are mainly concentrated in traditional sectors such as tourism services and trade circulation. However, there is a relative shortage of talent in emerging industries and cutting-edge technologies, such as the digital economy, artificial intelligence, and cultural and creative design. Regarding the talent hierarchy, there is a lack of high-level innovative talents and leading figures, and there is a shortage of internationally influential industry experts and entrepreneurs. This imbalanced talent structure makes it challenging for Haikou City to establish a competitive edge in emerging consumption sectors and high-end consumer markets during its development as an international consumption center city.

## **4.3. Limited talent attraction**

Haikou City faces numerous challenges in attracting innovative talent. Firstly, compared to first-tier cities, Haikou's economic development, industrial support, and job opportunities are relatively limited, making it less attractive to innovative talents. Many outstanding innovative talents prefer to work and develop in more economically advanced cities with more development opportunities. Secondly, Haikou's talent policies fall short in terms of the extent of incentives, coverage, and implementation effectiveness, failing to meet the diverse needs of innovative talents. For instance, policies regarding housing, children's education, and medical care are not sufficiently robust, which affects the sense of belonging and stability of these talents.

## **4.4. The talent training system is not perfect**

Hainan City's higher education and vocational education face several challenges in fostering innovative talent. The curriculum of universities is not closely aligned with market demands, and some courses are outdated, lacking practical components, which results in students lacking innovation and practical skills. Vocational education lags behind, with a lack of high-quality training institutions that can effectively connect with the industry, making it difficult to meet the demand for skilled and innovative professionals from businesses. Moreover, enterprises do not fully leverage their role in talent development, lacking a robust internal training system and career advancement mechanisms, which hinders employee career growth and innovation enthusiasm.

# **5. Construction strategies of Haikou international consumption center city from the perspective of innovative talents**

## **5.1. Strengthen the introduction of innovative talents**

### **5.1.1. Formulate targeted talent introduction policies**

To meet the industrial needs of Haikou city's international consumer center city construction, the government will formulate attractive talent introduction policies. For innovative talents in key areas such as tourism, duty-free shopping, the integration of culture, sports, tourism, commerce, and exhibitions, and digital consumption, the government will provide policy support, including tax incentives, housing subsidies, and talent apartments. For instance, high-level innovative talents introduced will receive a certain period of personal income tax reduction; new talents will be provided with 3 to 5 years of talent apartment rental services to address their housing needs. Additionally, a special fund for talent introduction will be established to reward units and individuals who excel in talent introduction efforts.



### **5.1.2. Expand channels for talent introduction**

Strengthen cooperation with domestic and international universities and research institutions, establish talent liaison stations, and regularly organize job fairs and project matchmaking events to attract outstanding graduates and high-end talents to develop in Haikou. Actively participate in international talent exchange activities, leveraging the open platform of the Hainan Free Trade Port to attract globally-oriented and innovative talents from around the world. Additionally, encourage enterprises to introduce urgently needed innovative talents through headhunting companies and talent intermediaries, and provide financial subsidies to enterprises that successfully attract such talents.

## **5.2. Strengthen the training of innovative talents**

### **5.2.1. Optimize the setting of disciplines and majors in colleges and universities**

To guide universities in Haikou City to adjust and optimize their academic programs based on the needs of building an international consumption hub. Enhance the development of majors in tourism management, international trade, and cultural creativity, and introduce new majors such as digital economy, artificial intelligence, and cross-border e-commerce to cultivate innovative talents that meet market demands. Additionally, encourage universities to collaborate with enterprises in talent development, establish internship and training bases, and enable students to enhance their innovation and practical skills through hands-on experience.

### **5.2.2. Improve the vocational education system**

Increase investment in vocational education and develop a number of high-level vocational colleges and training institutions. Based on industry needs, offer courses in tourism services, business operations, cultural arts, and other related vocational skills to cultivate skilled and innovative talents. Establish a vocational qualification certification system, providing subsidies and rewards to those who have obtained relevant certificates through vocational skills training. Additionally, encourage companies to conduct internal training to enhance employees' professional skills and innovation capabilities, and provide policy support and financial incentives to companies that show significant results in their training programs.

## **5.3. Establish an incentive mechanism for innovative talents**

### **5.3.1. Improve the compensation incentive system**

Encourage enterprises to establish a performance-oriented compensation system, offering appropriate remuneration based on work performance and contributions of innovative talents. Talents who achieve outstanding results in technological innovation, product innovation, and business model innovation should be given substantial bonuses and equity incentives. Additionally, the government can establish an innovation talent reward fund to recognize and reward innovative talents who have made significant contributions to the development of Haikou as an international consumption center, thereby enhancing their social status and sense of honor.

### **5.3.2. Provide good career development space**

Enterprises should provide a broad career development space for innovative talents and establish a comprehensive talent promotion mechanism and career development plan. They should encourage these talents to participate in major projects and innovation activities, granting them full autonomy and decision-making power. The government can facilitate talent exchange by organizing various academic seminars, industry forums, and other events, providing opportunities for innovative talents to learn, exchange ideas, and showcase their achievements,



thereby promoting their professional growth and development.

## **5.4. Optimize the development environment for innovative talents**

### **5.4.1. Improve infrastructure and public services**

Increase investment in urban infrastructure to improve transportation, communication, education, and healthcare, thereby enhancing the quality of life and livability in cities. Optimize the allocation of public service resources to improve the quality of education and healthcare, providing high-quality educational and medical services for innovative talents and their families. For example, by introducing high-quality educational resources from both domestic and international sources, building international schools and hospitals to meet the diverse needs of talent.

### **5.4.2. Create an atmosphere for innovation and entrepreneurship**

The government should enhance its support and guidance for innovation and entrepreneurship by establishing incubation bases and co-working spaces. These facilities will offer one-stop services, including entrepreneurial venues, financial support, and technical services, to innovative talents. The government should also organize innovation and entrepreneurship competitions, training sessions, and other activities to ignite the passion for innovation and entrepreneurship among talents. Additionally, it is crucial to strengthen intellectual property protection, improve relevant laws and regulations, and create a fair competitive market environment to provide robust support for the innovative activities of talented individuals.

## **6. Conclusion**

Innovative talents are the core driving force behind Haikou's efforts to become an international consumer city. They play an indispensable role in promoting consumption innovation, brand building, environmental optimization, and industrial integration. While Haikou has made some progress in this area, it still faces challenges such as a shortage of innovative talents, an unreasonable structure, limited appeal, and an incomplete training system. By intensifying the recruitment of innovative talents, enhancing talent development, establishing incentive mechanisms, and optimizing the talent development environment, Haikou can attract and retain more innovative talents, providing a solid foundation for its international consumer city construction. In the future, Haikou should continue to emphasize the importance of innovative talents, continuously improve talent policies and measures, fully leverage its talent advantages, accelerate the pace of international consumer city construction, enhance the city's international competitiveness and influence, and contribute more to the development of the Hainan Free Trade Port and China's high-quality economic growth.

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# Innovative Development Path of Shaoguan Bamboo Industry from the Perspective of Ecological, Production, and Life Integration

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**Abstract:** In the context of the development of “replacing plastic with bamboo” and “integrating the three industries”, the bamboo industry in Shaoguan City boasts certain advantages, including abundant resources. However, the industry faces significant challenges, such as low utilization efficiency and a shortage of skilled labor. The present article employs a comprehensive analysis of bamboo resources and industry status, leveraging SWOT analysis to elucidate the strengths, weaknesses, opportunities, and challenges pertinent to the subject. The article further proposes an innovative development path for the bamboo industry. The objective of this initiative is to promote resource-intensive management, strengthen technical and talent support, expand diversified marketing channels, and deepen the integrated development of the bamboo industry. The overarching ambition is to achieve a rich and beautiful bamboo industry ecology, abundant production, and prosperous life in Shaoguan, thereby providing invaluable experience and reference for the development of China’s bamboo industry as a whole.

**Keywords:** Bamboo as a substitute for plastic; Three integrations; Common prosperity; Bamboo industry; Northern Guangdong mountainous area

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## 1. Introduction

The ongoing enhancement of environmental awareness in various countries and regions worldwide has led to a growing focus on bamboo, a natural renewable resource, among the public <sup>[1]</sup>. In the context of China’s initiative to substitute plastic with bamboo, bamboo resources have emerged as a pivotal element in promoting high-quality socio-economic development. This initiative is part of a broader strategy aimed at revitalizing rural areas, achieving the “dual carbon” goals, and advancing the construction of ecological civilization <sup>[2]</sup>. A case study of China’s recent initiatives to substitute plastic with bamboo reveals several key benefits of bamboo resources. These benefits include the support of bamboo production and processing enterprises, promotion of bamboo industry

agglomeration, enhancement of regional ecological environment and carbon sequestration capacity, and increased farmer income in bamboo production areas. These benefits extend across three primary domains: ecology, production, and life. Consequently, scholars have conducted continuous research on the integration of bamboo resources into the “three lives” in recent years. Furthermore, they have proposed innovative development ideas for the bamboo industry in the context of ecological, production, and life integration. This paradigm has emerged as the foundational framework for examining the synergistic evolution of regional economies and societies within the bamboo industry.

Bamboo, a natural renewable resource, possesses significant ecological, cultural, and economic value. Due to its distinctive benefits, it has progressively evolved into a pivotal pragmatic approach for bamboo-resource-abundant regions to encourage collaborative regional advancement and collective well-being <sup>[3]</sup>. Among them, Shaoguan City, which is renowned for its substantial bamboo resources in Guangdong Province, boasts an expanse of bamboo forest covering 2.278 million mu. The city’s abundant bamboo resources have established a substantial material foundation for the development and operation of the bamboo industry. However, the city of Shaoguan is located in the northern Guangdong region and is primarily composed of mountainous counties, which pose practical challenges for the development and utilization of local bamboo resources. A decline in operating profits has been observed among certain bamboo enterprises in Shaoguan City, indicating constraints in bamboo industry development. These constraints include insufficient utilization of bamboo resources, inadequate equipment intelligence, insufficient supply of high-end products, and limited innovation in development models. In order to address the practical challenges faced by the development of the bamboo industry in Shaoguan City, a development concept will be integrated into the industry’s development process. This concept will integrate the three elements of bamboo resources, providing support for the acceleration of a virtuous cycle of “using bamboo to promote development, enrich the people, and beautify the environment” in Shaoguan City. This cycle will promote urban green transformation.

## **2. The present state of bamboo resources and the evolution of the bamboo industry in Shaoguan City**

### **2.1. The following section will provide an overview of bamboo resources in Shaoguan City**

The total area of Shaoguan City is 18,400 square kilometers, with abundant forest resources and a total area of 19.18 million acres. Of these, the bamboo forest covers an area of 2.278 million mu, accounting for 11.9% of the total forest area, and thus ranking first in Guangdong Province. With respect to bamboo forest area, Shaoguan City boasts a substantial expanse of bamboo forests, predominantly situated in counties (cities) such as Nanxiong, Renhua, Shixing, and Xinfeng. The municipality of Nanxiong and the district of Renhua contain the most extensive bamboo forest areas, with a combined total area exceeding 900,000 acres, accounting for over 40% of the city’s total area. In recent years, the overall bamboo forest area in Shaoguan City has exhibited a relatively stable trend, with certain areas demonstrating an increase in bamboo forest area through artificial nurturing and scientific planting. The bamboo forest area’s stable situation provides a solid material foundation for the sustainable development of the bamboo industry. Shaoguan City is situated in the northern region of Guangdong Province, occupying a territory that extends from the southern foothills of the Nanling Mountains to the middle and upper reaches of the Beijiang River. The region’s distinctive geographical characteristics foster optimal conditions for bamboo cultivation. From the perspective of bamboo forest types, the Shaoguan area boasts a rich



and diverse variety of bamboo forest types, including more than 120 species such as moso bamboo, mugwort bamboo, pink bamboo, and hemp bamboo. The bamboo resource system in Shaoguan is distinguished by the presence of diverse bamboo species, which collectively serve as a foundation for regional economic and ecological development.

## **2.2. Development status of bamboo industry in Shaoguan City**

As of the conclusion of 2024, Shaoguan City has 144 bamboo processing and operation entities, including three national forestry leading bamboo and wood enterprises and four provincial leading enterprises. These leading enterprises have played a pioneering and exemplary role in the industry, helping to enhance the development level and market competitiveness of the entire bamboo industry. Concurrently, Shaoguan City boasts four bamboo industry enterprises with an annual output value exceeding 100 million yuan, thereby underscoring the fact that a number of bamboo enterprises in the region have attained a certain scale and economic strength <sup>[4]</sup>. The bamboo industry in Shaoguan City encompasses a diverse array of products, including those utilized in catering, home furnishings, and building materials. This industry boasts a wide variety of product types. These products are designed to address the diverse requirements of various market segments, thereby showcasing the Shaoguan bamboo industry's commitment to innovation and its capacity to meet the highest standards of professionalism in product development. Shaoguan City has developed a unique “bamboo+tourism” model, leveraging the region's abundant bamboo resources. This initiative aims to enhance the added value of the bamboo industry and promote its coordinated development. The “bamboo+tourism” model has also led to substantial improvements in the sales channels and sales volume of bamboo handicrafts. Furthermore, brand exposure has been significantly increased through promotional channels such as online media and tourism exhibitions. This has established a substantial foundation for the long-term development of the bamboo industry, thereby further enhancing its added value.

## **3. SWOT analysis of bamboo industry development in Shaoguan City**

### **3.1. Advantages of bamboo industry development**

The bamboo industry is characterized by a substantial abundance of resources. Shaoguan City boasts the largest bamboo forest resources in Guangdong Province, particularly in the border regions of Nanxiong, Renhua, and Shixing, where over 1 million acres of concentrated bamboo resources have been established, paving the way for substantial development prospects. Secondly, the foundation of the industrial chain is well-established. Following years of development, Shaoguan City has established an industrial chain system of “full bamboo utilization” in the bamboo industry. As of the conclusion of 2024, 140 bamboo processing enterprises of various types are located in Shaoguan City, and the spatial agglomeration effect of the industrial chain is significant. Thirdly, government policies provide comprehensive support. The municipal government of Shaoguan City has demonstrated a notable commitment to the advancement of the bamboo industry. In 2024, the Shaoguan Municipal Government issued the Action Plan for Promoting the High Quality Development of the Bamboo Industry (2024–2026), which created positive conditions and provided high-level promotion for the development of the bamboo industry <sup>[5]</sup>.

### **3.2. Disadvantages of bamboo industry development**

Firstly, the efficiency of resource utilization is suboptimal. The bamboo forest resources in Shaoguan are primarily managed by a dispersed network of farmers, exhibiting a low degree of intensification in management practices. The proportion of bamboo forests managed on a large scale through the “leading enterprise+cooperative+base+

farmers” model is insufficient. This fragmented management approach has resulted in extensive bamboo forest management, a lack of scientific nurturing, and subsequent degradation of bamboo forests, low yield, and high harvesting costs, which have collectively undermined industrial competitiveness <sup>[6]</sup>. Secondly, there is a shortage of infrastructure and technical personnel. Infrastructure in forest areas, including roads and irrigation facilities, is deficient. With respect to the professional talent team, there is a dual shortage of high-end R&D talents and skilled craftsmen. Furthermore, Shaoguan’s economic development is relatively lagging behind, especially in rural areas. The underdeveloped infrastructure and comparatively limited educational attainment within these regions have collectively resulted in a paucity of talent cultivation, thereby impeding the fulfillment of rural economic development needs <sup>[7]</sup>. Thirdly, an established market mechanism for high-quality and high-price products does not currently exist. The market mechanism for high-quality and cost-effective bamboo resources has yet to be established, creating challenges for bamboo farmers in sharing the value-added benefits of processing.

### **3.3. Opportunities for the development of the bamboo industry**

Firstly, there is a necessity for robust support from national policies. The national government has issued a three-year action plan to accelerate the development of “replacing plastic with bamboo.” This plan includes the incorporation of bamboo products into the green product certification system and the promotion of bamboo substitution in daily necessities, building materials, and other fields. Secondly, there has been an explosive growth in market demand. In recent years, there has been a notable trend in China of “replacing plastic with bamboo” in various sectors. This shift has led to the emergence of a substitute market with significant economic value, estimated at billions of yuan. The adoption of bamboo-based materials has seen a substantial increase in various applications, including packaging, construction, and daily necessities, among others <sup>[8]</sup>. Thirdly, advanced technology is a prerequisite. The high-value utilization technology of bamboo in some bamboo processing enterprises in Shaoguan City continues to make significant advancements while actively integrating industry, academia, and research practices. This integration is expected to facilitate the successful implementation of major industrial projects.

### **3.4. Challenges in the development of the bamboo industry**

Firstly, the bamboo forests in Shaoguan City have been severely degraded. Most bamboo forests in Shaoguan City continue to adhere to the extensive management model, characterized by placing logging above management for a long time. Secondly, the financial burden of collection and transportation is significant, and there is a shortage of labor. The bamboo harvesting and transportation industry in Shaoguan City is mainly characterized by manual handling, which results in significant intermediate losses and is accompanied by low costs and high efficiency. At the same time, the average age of bamboo cutting tools is relatively high, and the number of young people engaged in the bamboo industry is relatively small, leading to a shortage of labor. Thirdly, marketing channels are not optimal. At present, the bamboo industry in Shaoguan City continues to mainly adhere to the traditional offline sales model, and the overall market expansion model still relies heavily on traditional methods.

## **4. Innovative development path of the bamboo industry in Shaoguan City**

### **4.1. Accelerate the intensive management of bamboo resources**

In addressing the challenges posed by the fragmented management and suboptimal utilization of bamboo forests in Shaoguan, the government must implement comprehensive policy measures. These measures should include

the following. First, the government must provide stronger guidance to farmers, encouraging them to invest in land and bamboo forest resources through policy support. Second, the government must expand the coverage of the “leading enterprise+cooperative+base+farmers” model. Third, the government must increase the proportion of intensive management of bamboo forests. Concurrently, a scientific nurturing system for bamboo forests must be established, and a professional technical guidance team must be constituted. Moreover, training on bamboo forest management and protection must be provided to farmers on a regular basis, and efforts must be made to improve the quality and yield level of bamboo forests. Furthermore, the enhancement of infrastructure within forest areas, including roads and transportation networks, is imperative. This initiative should be accompanied by a reduction in the cost of bamboo harvesting and transportation, thereby ensuring cost-effectiveness. Additionally, measures must be undertaken to enhance industrial competitiveness.

#### **4.2. Continuously strengthening technological innovation and talent support**

It is imperative to augment investment in the domain of bamboo industry technology research and development. Moreover, the establishment of cooperative research platforms between industry and universities, as well as research institutions, is of paramount importance. A concerted effort must be made to prioritize technological breakthroughs in high-value-added fields, such as bamboo-based new materials and biomass extraction. The establishment of a special talent fund, in conjunction with the formulation of preferential policies, is imperative for the purpose of attracting high-end R&D talents and skilled craftsmen to the bamboo industry in Shaoguan. Concurrently, the local vocational colleges are being utilized to offer bamboo industry-related majors, with the objective of providing targeted training to professional talents and thereby ensuring continuous intellectual support for the industry’s development. Furthermore, the integration of intelligent production equipment into bamboo processing enterprises has been demonstrated to enhance automation and intelligence levels, thereby reducing labor costs.

#### **4.3. Expanding diversified marketing channels**

It is imperative to encourage bamboo enterprises to proactively adopt digital transformation, fostering collaboration with prominent e-commerce platforms. This entails the strategic implementation of online stores, such as those found on TikTok and Amazon, in addition to the augmentation of sales channels through the integration of emerging models, including live streaming and cross-border e-commerce. Concurrently, a market mechanism for high-quality and low-priced bamboo should be established. The market premium ability of high-quality bamboo should be enhanced through quality certification, brand building, and other methods. Furthermore, bamboo farmers should be enabled to fully share the value-added benefits of processing. An exploration of the development of bamboo forest carbon sequestration projects is warranted, as is an improvement of ecological value accounting and compensation mechanisms. Furthermore, it is essential to transform ecological advantages into economic advantages.

#### **4.4. Exploring the development model of multi-industry integration**

The present study will build upon the existing “bamboo+tourism” model to further explore the connotation of bamboo culture. The objective is to develop diversified cultural and tourism products, such as bamboo culture-themed homestays, bamboo art experience workshops, and bamboo culture research and learning. The final aim is to create an immersive bamboo culture tourism experience. It is imperative to fortify the collaborative relationships

with proximate tourist attractions, conceptualize bamboo-themed tourism pathways, and augment the brand influence of “Yangtze River Bamboo Sea” and analogous brands. Integration of culture and tourism, extension of the bamboo industry chain, driving the development of related industries such as bamboo handicrafts and bamboo food, and achievement of deep integration of ecology, production, and life are the objectives of the aforementioned initiative.

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# News Framing Analysis of Local Government's Internet Public Opinion Crisis and Media Coverage: A Case Study of the Qingdao Prawn Incident

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**Abstract:** Utilizing news frame theory, this study analyzed the media coverage of the Qingdao prawn incident. It examined the attribution of responsibility to local government and restaurant owners, along with the framing of the local government's response. Out of 199 analyzed news reports, 28.6% emphasized the local government's responsibility, and 22.6% highlighted the restaurant owners'. In terms of the local government's response frames, negative responses were most prevalent at 21.1%, followed by positive (15.1%) and neutral (12.6%) frames. The data suggests that the media often holds the local government most accountable in public opinion crises, attributing significant blame to restaurant owners. The prevalence of negative framing indicates a bias towards critical coverage. Given the scarcity of neutral reporting, the need for balanced, objective reporting that scrutinizes the root causes and truth of events such as the Qingdao prawn incident is highlighted rather than adhering to superficial or biased narratives.

**Keywords:** Qingdao prawn incident; Local government; Media coverage; Responsibility attribution; News frame theory

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## 1. Introduction

### 1.1. Problem statement

Online public opinion holds a powerful social influence, and with the rapid spread of information on the internet, public incidents can quickly escalate into internet public opinion crises <sup>[1]</sup>. The frequency of government-related crises has increased in the digital age, spreading rapidly via the internet and social networking sites (SNS) <sup>[2]</sup>. As the speed of online information dissemination accelerates, crises involving local governments garner significant public attention. The public's interest in such crises, as seen in the news coverage, further amplifies their effects. This is evident in the comparative study of the Qingdao prawn incident, a representative case of the local



government internet public opinion crisis.

Originating on the Chinese SNS platform Weibo (equivalent to Twitter), the incident negatively affected several local government agencies in Qingdao, such as the Tourism Bureau, the Price Bureau, and the Public Security Bureau. The incident, which occurred in Qingdao, a popular tourist city in China, involved topics of high public interest, such as inflation and the government's role, resulting in substantial social impact. News reports on the Qingdao prawn incident received widespread attention, reflecting its research value. Moreover, it underscored that news coverage of internet public opinion crises directly influences public sentiment and social stability, thereby increasing its societal influence.

Internet public opinion crisis events are typically characterized by their suddenness, destructiveness, staged nature, and persistence, often inciting significant societal attention and discussion. The media's coverage of these events shapes the public's perception, with the press's core mission demanding neutrality and objectivity in news reporting<sup>[3]</sup>. However, specific frames can sway news reporting, leading to a lack of objectivity depending on the adopted perspective.

News frames, common in media coverage, can selectively highlight, amplify, or eliminate news content. These frames dictate how journalists craft their articles based on collected data and cited coverage, further shaping the presentation of the news<sup>[4]</sup>. The frames allow the public to glean an in-depth understanding of the facts, emphasizing the potent influence of news frames on public perception and understanding.

News frames, underpinned by the responsibility attribution theory, form the background of all media coverage. They represent the methods journalists use to construct reality through the media, influenced by concepts, ideologies, and knowledge<sup>[5]</sup>. Thus, an accurate grasp of these news frames is critical when analyzing media coverage of the Qingdao government's internet public opinion crisis events. Such analysis extends to how the media report on the causes and countermeasures of the Qingdao incident from a societal perspective, underscoring the importance of understanding the influence of news frames on responsibility attribution.

## **1.2. Research objectives**

The Qingdao incident first surfaced on Weibo, triggering intense online debates and culminating in a substantial internet public opinion crisis for the local government. As a response, the media released continuous coverage on the incident, with elements such as frequency, topics, news genres, and editorial stances contributing to the news framing. This, in turn, shaped the media's information dissemination and the public's perception and interest in the news.

To examine this incident, the study employed news framing theory as its theoretical framework and analyzed news coverage collected from the "Hydeus" search database between October 5, 2015, and October 31, 2015. Frame analysis was used to scrutinize the responsibility attributed to the local government and restaurant owner, as well as the local government's response, further classified into positive, negative, and neutral coverage.

The aim was to determine whether the media's framing of the Qingdao incident as a public opinion crisis was apt, and to offer insights on how local governments could respond to media coverage during such crises.

## **2. Literature review**

### **2.1. Qingdao shrimp incident**

On October 5, 2015, a netizen posted on Weibo about being overcharged at a street restaurant, sparking a heated online controversy known as the Qingdao incident. The user complained that a single plate of ordinary shrimp cost 38 yuan (approximately 6 USD), and a dish cost 1,500 yuan (around 236 USD). This post was shared over 6,000

times, attracting considerable attention from the media and other netizens. Numerous news outlets reported on the Qingdao Incident, leading to a rapid spread of public opinion related to the incident.

In response, the Qingdao Price Bureau's official Weibo account announced that the restaurant in question had been dealt with according to relevant regulations and laws. Three days following the incident, the Qingdao City Propaganda Department announced plans to impose an administrative penalty of 90,000 yuan (around 14,173 USD) on the restaurant.

## **2.2. Internet public opinion crisis and media coverage**

### **2.2.1. Study on media coverage of local government's internet public opinion crisis incidents**

Western academia often categorizes research on media coverage of local government's internet public opinion crises as part of the broader study of crisis incident news coverage. Given the rising frequency of these incidents, several theories have been formulated and studied extensively overseas. These include Steven Fink's "Stepwise Separation Theory", Thomas Birkland's "Agenda-setting Theory", and Grunig's "Excellence Theory", all of which contribute to the understanding of crisis communication.

Moreover, American scholar Robert Heath expanded the realm of crisis management theory. Drawing on corporate crisis management experiences, Heath proposed the 4R model of crisis management encompassing Readiness, Response, Reduction, and Recovery <sup>[6]</sup>.

Crisis reporting, the media coverage of crisis events, holds high news value due to its social significance, often commanding considerable public attention <sup>[7]</sup>. Active and accurate media engagement creates a conducive atmosphere for crisis resolution, enabling relevant government departments to devise practical solutions to social issues. Additionally, by summarizing the issues and lessons learned during crisis events, crisis reporting provides valuable feedback for future management, making it an essential task for Chinese media today.

Given the inherent news value of crisis events and the media's societal responsibilities, crisis reporting remains a vital component of news coverage. Importantly, the accuracy of reporting often proves crucial to crisis resolution, given the influence of news media.

In the past, Chinese media tended to downplay or even contradict crisis reporting. However, as Chinese society has developed, so too has the media's approach to crisis reporting. Notably, since 2000, the quality of crisis reporting has seen consistent improvement, with the media assuming a proactive role in the crisis management process <sup>[8]</sup>.

### **2.2.2. News framing theory**

In news production, the concept of framing guides how journalists shape news events. It's a tool for simplifying the complexities of society and packaging a vast amount of information into news stories, aligned with general concepts and examples <sup>[9, 11]</sup>.

The concept of "framing" first emerged in the field of psychology. Scholar Thesen, in his 1955 paper "On Comedy and Phantasy", posited that "frames" are psychological constructs guiding human perception. People usually focus on the information within the frame, showing interest in related details, while disregarding the information outside of it. As such, to assist in understanding, the information within a frame should be presented suitably, considering that "frames" influence people's perceptions by controlling the scope of information <sup>[10]</sup>.

Sociologist Erving Goffman was instrumental in introducing the concept of "framing" into sociological studies in 1959 with his book "The Presentation of Self in Everyday Life." Goffman posited that the various

features of objects present in social life are organized within a unified frame. This not only aids readers in integrating their prior experiences but also offers researchers a directional guide <sup>[12]</sup>.

In his 1974 book “Frame Analysis: An Essay on the Organization of Experience”, Goffman defined frames as tools used by individuals to perceive societal objects, serving as criteria for the perception and judgment of these objects. Frames represent experiences manifested through linguistic symbols, used to create a fundamental structure for processing and interpreting the external world. Goffman’s “frame” is, thus, an individual’s subjective interpretation or cognitive structure through which the public perceives and assesses events. This demonstrates that the objective truth of society can be transmuted into individuals’ subjective perceptions.

Following Goffman, scholars like Gitlin adopted the frame theory for media research, thereby facilitating its rapid spread into the field of media studies. Building on Goffman’s theoretical foundation of frames, Gitlin highlighted the role and significance of frames within the media realm as mechanisms for classifying information and structuring news, thereby influencing the public <sup>[13]</sup>.

Research on news frames has been heavily influenced by Erving Goffman’s frame analysis. The concept of “frame” as outlined by Goffman forms the crux of news frames. While scholars may have differing viewpoints on news frames, there is a shared understanding of their meaning. Generally speaking, news frames are the objective and realistic processes that structure the transition and delivery of social events in public communication <sup>[14]</sup>.

There are three main categorizations of definitions for news frames:

- (1) Frames have been considered as a tool for selective screening. Gitlin viewed frames as consistent models for cognition, interpretation, and expression, with journalists constructing news through a process of selection, emphasis, and exclusion <sup>[15]</sup>. Thus, the styles of reporting in news coverage can be viewed as news frames constructed by the media. News frames can be seen as determining the content and manner of media coverage.
- (2) Emphasis has been placed on the effects of news frames. Entman viewed frame theory as the process of building frames, which involves selection and focus. By choosing and emphasizing certain aspects of an event, it facilitates the definition, interpretation, moral evaluation, and treatment of particular issues <sup>[16]</sup>. Entman’s definition of news frames can be interpreted as how journalists influence public perception by selecting information and emphasizing certain aspects of news events.
- (3) Frames have been seen as a process of creating positive meaning. Gamson, in particular, saw the frame as the central idea of news coverage, attributing meaning to news events <sup>[17]</sup>.

The frame analysis of news reporting is a critical theory in communication studies. Frames are structures that shape the general perception, explanation, and representation of objects. Through the process of symbol transformation and adjustment, frames select and construct specific meanings and representations that reflect certain core meanings and ideologies, as well as specific sociocultural values <sup>[18]</sup>.

In conclusion, the theory of frames has evolved through the realms of psychology, sociology, and communication studies. It has broadened its research domain from individual cognitive processes to group studies. Building on Erving Goffman’s frame theory, the concept of news frames emerged as an extension of communication studies. Today, news frames significantly influence journalists, the public, and society as a whole.

### **2.3. The frame of responsibility**

The theory of responsibility framing stems from psychology and is employed to elucidate and analyze the causal relationships in human behavior resulting from environmental influences and their effects. It is also referred to as

“attribution theory”, as it interprets, manages, and predicts behavior through the lens of responsibility. In essence, it can be viewed as a theory that modifies and governs human behavior by altering individuals’ self-concept and self-awareness. Communication scholar Iyengar integrated the theory of responsibility attribution with frame analysis and introduced the concept of “frame of responsibility”, suggesting that news media defines the causes and solutions of specific social issues through three frames: “episodic/thematic frames”, “causal/reactive frames”, and “individual/social responsibility frames”<sup>[19]</sup>.

Iyengar proposes that in certain news reports, although the causes or solutions of news events are not explicitly stated, they indirectly present or provoke judgments on “who caused the event” and “who should bear responsibility” by constructing episodic or thematic news frames. The “episodic frame” distills complex social issues into individual problems, while the “thematic frame” treats social issues as macro-level social phenomena, discussing the in-depth causes and solutions of the news. From the viewpoint of responsibility attribution, Iyengar analyzed the framing strategies of news coverage and the effects of communication, introducing the “causal/reactive frame” that analyzes the causes of the event from two perspectives: “cause” and “response.” News media tend to focus on the questions of “causes of the problem” and “responsibility for the event” when reporting social issues. Hence, the ultimate goal of news coverage on social issues can be perceived as discussing the causes of the event and solutions to the problem<sup>[20]</sup>.

Iyengar further argues that news media frames the responsibility for social events in terms of individual responsibility and social responsibility. The frame of individual responsibility emphasizes that the event reported in the news is a result of accidental or individual actions, underscoring the responsibility of individuals or a small group of people in the emergence or resolution of the issue. In contrast, the frame of social responsibility focuses on the underlying causes that make the event a matter of social concern and seeks macro-level solutions.

## 2.4. Research problem

For this study, news coverage of the Qingdao prawn incident from October 5, 2015, to October 31, 2015, was gathered using the “Hydeus Search” database. This database incorporates news reports from the incident’s onset to the period when its influence began to wane. The investigation period represented a concentrated period of the internet public opinion crisis of the local government in relation to the Qingdao prawn incident. The news coverage during this time was deemed valuable for research based on the agenda-setting theory of news framing. Hence, a detailed analysis was conducted for this investigation period.

The Qingdao prawn incident serves as a representative case of an internet public opinion crisis involving a local government. This study utilized the attribution theory and news framing theory as foundations for a content analysis intended to extract the themes and alterations in stance in the news coverage of the Qingdao prawn incident from October 5 to October 31, 2015.

Through this analysis, the study identified how the framing of the Qingdao prawn incident news coverage was constructed, how it evolved over time, and the issues and influencing factors embedded within the framing. This deepened understanding allows for a more nuanced grasp of the way news frames shape and are shaped by public opinion, thereby influencing the narrative and potentially the resolution of crises.

Based on the data selected and analyzed in this study, the study has defined the following research questions:

Research question 1:

What is the volume of articles that adopt the local government accountability frame?

Research question 1-1:



In the early phase of coverage, how many articles adopt the local government accountability frame?

Research question 1-2:

In the mid-phase of coverage, how many articles adopt the local government accountability frame?

Research question 1-3:

In the late phase of coverage, how many articles adopt the local government accountability frame?

Research question 2:

What is the volume of articles that adopt the store owner accountability frame?

Research question 2-1:

In the early phase of coverage, how many articles adopt the store owner accountability frame?

Research question 2-2:

In the mid-phase of coverage, how many articles adopt the store owner accountability frame?

Research question 2-3:

In the late phase of coverage, how many articles adopt the store owner accountability frame?

Research question 3:

What is the volume of articles that adopt the local government response frame?

Research question 3-1:

How many articles convey a positive representation of the local government's response?

Research question 3-2:

How many articles convey a negative representation of the local government's response?

Research question 3-3: How many articles provide a neutral portrayal of the local government's response?

These questions aim to quantify and understand the framing of the Qingdao prawn incident by analyzing the attribution of responsibility and response in news media coverage across different phases of the event.

### **3. Methodology**

#### **3.1. Research methodology: Content analysis method**

Content analysis is a systematic and objective research method that involves statistically classifying existing communication content, minimizing subjective intervention based on data statistics to enhance the accuracy and objectivity of research<sup>[21]</sup>. Berelson defined content analysis as an objective, systematic, and quantitative research method for communication content<sup>[22]</sup>. Kerlinger identified content analysis as a systematic and objective method for measuring variables and analyzing communication content<sup>[23]</sup>. The advantages of content analysis include the ability to use a wide range of samples without excessive subjectivity, as well as a comprehensive analysis method that emphasizes qualitative analysis in addition to quantitative analysis during the analysis process, which can enhance the accuracy and validity of content analysis.

Hence, content analysis was chosen as the primary method for this study, with news coverage of the Qingdao prawn incident serving as the sample for a systematic and quantitative content analysis. This approach was intended to discern patterns in the framing structure of news coverage of the Qingdao prawn incident.

#### **3.2. Analysis subject and period**

The focus of this study is news coverage of the Qingdao prawn incident. For a comprehensive and reliable sample, the "Hydeus Search Database" was utilized to gather news articles related to the incident.



The chosen research period spans from October 5th, 2015, to October 31st, 2015. The selection of news topics is generally based on their potential for impact, utility in regulation, and promotability. Preference is given to topics that can generate positive effects, unique topics, and fresh topics not yet covered by others. The selected research period considers the value of meaning transmission and practicality. The period from October 5th to October 31st, 2015, marks the onset of the Qingdao prawn incident and its gradual fade from influence. This period likely has the most concentrated and plentiful news coverage related to the incident, making it an optimal research period. To visually analyze the quantity and status of research samples according to the research period, the 27-day period from October 5th to October 31st, 2015, was divided into three nine-day segments: early, middle, and late.

In this study, the sample selection criteria were based on the keyword “Qingdao Prawn” in the news headlines. News reports collected from the data search database from October 5th, 2015, to October 31st, 2015, were selected as the analysis samples. Videos and photos were excluded from the analysis samples due to the difficulties in analyzing their topics and information sources. Consequently, a total of 199 articles were gathered from October 5th to October 31st, 2015. This study also confined the scope of analysis within the news articles included in the data search database for the specified period, excluding news reports from other platforms.

### **3.3. Analysis unit**

Based on established theoretical perspectives and the research goals and questions of this study, the units of analysis were constructed around the following frames, determined by the article titles: the frame attributing responsibility to the local government, the frame attributing responsibility to the restaurant owner, and the frame centered on the local government’s response, which was further divided into positive, negative, and neutral frames.

### **3.4. Operational definition of frames**

#### **3.4.1. Frame of local government accountability**

The frame of local government accountability refers to news articles that predominantly assert the responsibility for the prawn incident lies with the Qingdao local government. For instance, if the title of an article includes phrases like “Government agencies feign ignorance”, “Prompt resolution from government departments expected”, or “Qingdao prawn is priced at \$5.89 per person, each prawn billed as \$5.89 at checkout”, indicating that the accountability for the incident is attributed to the local government, the article is categorized under the frame of local government accountability.

#### **3.4.2. Frame of restaurant owner accountability**

The frame of restaurant owner accountability pertains to news articles that predominantly assign the responsibility for the prawn incident to the restaurant owners. For instance, if the title of an article includes phrases like “\$5.89 for one prawn, is this even real?”, “Restaurant owner accused of food pricing fraud”, or “Condemnation of restaurant owner’s unlawful actions relating to the incident”, indicating that the accountability for the incident is attributed to the restaurant owners, the article is categorized under the frame of restaurant owner accountability.

#### **3.4.3. Frames of local government’s response**

Frames of local government’s response are subdivided into positive coverage, negative coverage, and neutral coverage. Positive response frame refers to news articles that present the Qingdao municipal government’s

response to the prawn incident in a favorable light. For example, if the title of an article includes phrases like “New administrative measures in response to the prawn incident”, “Actions that the government should take in response to the prawn incident”, or “Reform of the work system in relevant departments following the prawn incident”, indicating a positive response from the local government towards the prawn incident, the article is categorized under the positive response frame. Negative response frame refers to news articles that present the Qingdao municipal government’s response to the prawn incident in an unfavorable light. For example, if the title of an article includes phrases like “Government departments need to immediately resolve the prawn incident”, “prawn incident highlights the insufficient response from relevant government departments”, or “Internet public opinion crisis for the government due to the prawn incident”, indicating a negative response from the local government towards the prawn incident, the article is categorized under the negative response frame. Neutral response frame refers to news articles that neither positively nor negatively present the Qingdao municipal government’s response to the prawn incident. For example, if the title of an article includes phrases like “How should the government prevent incidents like the prawn incident?” “Evaluation of each department’s response to the prawn incident”, or “Measures taken by the local government in response to the internet public opinion crisis caused by the prawn incident”, indicating a neutral stance towards the local government’s response to the prawn incident, the article is categorized under the neutral response frame.

### 3.5. Reliability measurement

In order to ascertain the dependability of the content analysis, this study underwent an inter-coder reliability verification process. A batch of twenty article titles, constituting about 10% of the total articles analyzed, was chosen as the focus for an initial analysis conducted by the researcher and another graduate student. This preliminary analysis was based on the operational definitions of the key frames. The inter-coder agreement tied to the analysis was determined to be 85%. This result underscores the established reliability of conducting content analysis in a consistent manner, using the news article title data employed in this study.

## 4. Results

### 4.1. Analysis of research question 1

Research question 1 addresses the analysis of the frame attributing blame to the local government in the context of the Qingdao Incident. As depicted in **Table 1**, out of the total 199 news reports concerning the Qingdao Incident, 57 reports, which equate to 28.6% of the total, framed the blame on the local government. This shows that a notable percentage of the news articles ascribed the responsibility for the Qingdao Incident to the local government or pertinent governmental departments. This suggests a prominent frame that assigns blame to the local government.

**Table 1.** The frame of blame attribution to the local government

Category	Local government responsibility frame	Total
Quantity (count)	57	199
Percentage (%)	28.6	100.0

The analysis of the frame attributing responsibility to the local government was subsequently carried out

by time period. As illustrated in **Table 2**, following the occurrence of the Qingdao prawn incident, it attracted considerable attention as a prominent issue across various media outlets in China. From October 5, 2015, to October 31, 2015, a total of 57 news reports associated with the local government responsibility frame were identified. Of these, from October 5 to October 13, encompassing the initial period of the research timeline, there were 47 news reports related to the local government responsibility frame, accounting for 82.46% of the total during this period. This suggests that during the early stages of the research timeline, the media concentrated on constructing a frame, attributing responsibility to the local government. It is also noticeable that coverage was densely packed during this initial period, as public and media attention was primarily focused on who was responsible for the Qingdao prawn incident.

**Table 2.** Number of news reports on local government responsibility frame by time period

Time period	Initial (10.05–10.13)	Midterm (10.14–10.22)	Post-term (10.23–10.31)	Total
Number of news reports	47	7	3	57
Percentage (%)	82.46	12.28	5.26	100

Moving on to the middle period of the research timeline, from October 14 to October 22, only 7 news reports relating to the local government responsibility frame were found, accounting for 12.28% of the total for this period. This represents a significant drop compared to the initial period and can be interpreted to mean that media criticism towards local governments markedly decreased during this middle phase of the research timeline.

Finally, for the latter period of the research timeline, from October 23 to October 31, only 3 news reports related to the local government responsibility frame were found, accounting for 5.26% of the total for this period. This shows a continued decline from the middle period and indicates that media criticism towards local governments ceased during the latter part of the research timeline.

## 4.2. Analysis of research question 2

Research question 2 centers on the framing of the restaurant owners' accountability in relation to the Qingdao prawn incident, implying articles that underscore the responsibility of the restaurant owners. As demonstrated in **Table 3** below, from a total of 199 articles, there were 45 articles, which constitute 22.6% of the total, that framed the responsibility on the restaurant owners for the incident.

**Table 3.** Framing of restaurant owners' responsibility

Category	Framing of restaurant owners' responsibility	Total
Quantity (count)	45	199
Percentage (%)	22.6	100.0

Continuing with the analysis of the frame attributing responsibility to restaurant owners, as indicated in **Table 4**, a total of 45 news articles were published that framed the restaurant owners' responsibility during the period from October 5, 2015, to October 31, 2015, the 27 days following the Qingdao prawn incident. Of these, during the initial period of the research window from October 5 to October 13, there were 42 news articles, making up the majority, or 93.3%, of articles for the entire research period. This signifies that most news reports framing the

restaurant owners' responsibility were concentrated in the initial period, implicating the restaurant owners directly as the immediate cause of the Qingdao prawn incident.

**Table 4.** Number of news articles on restaurant owners' responsibility by reporting period

Time Period	Initial (10.05–10.13)	Midterm (10.14–10.22)	Post-term (10.23–10.31)	Total
Number of News Reports	42	3	0	45
Percentage (%)	93.3	6.7	0	100

From October 14 to October 22, which falls within the middle part of the research period, there were only 3 news articles focusing on the restaurant owners' responsibility, accounting for a mere 6.7% of the entire research period, demonstrating a significant drop compared to the initial period.

From October 23 to October 31, encompassing the latter portion of the research period, there were no news articles emphasizing the restaurant owners' responsibility. This suggests that the media's focus on framing the restaurant owners' responsibility dwindled after the initial period, as the restaurant owners were merely superficially implicated as the immediate cause of the Qingdao prawn incident. Instead, the media's attention shifted towards framing the responsibility of the local governments and their response to the incident during the middle and later parts of the research period.

### 4.3. Analysis of research question 3

Research question 3 seeks to explore the volume of news articles associated with the local government's response frame to the Qingdao prawn incident. This is further dissected into three specific sub-questions, namely Research questions 3-1, 3-2, and 3-3, which are designated as the positive, negative, and neutral local government response frames, respectively. These distinct frames will be examined to provide a comprehensive overview of the various perspectives and sentiments expressed in the media coverage regarding the local government's response to the incident.

#### 4.3.1. The analysis for research question 3-1

Research question 3-1 relates to the positive local government response frames, specifically spotlighting those articles which cast the actions and responses of the Qingdao municipal government to the prawn incident in a positive light. As displayed in **Table 5**, out of a total of 199 collected articles, 30 articles, accounting for 15.1% of the total, were classified as having a positive frame regarding the response and measures taken by the Qingdao municipal government.

**Table 5.** Positive frame on Qingdao municipal government's response and measures

Category	Positive framing of Qingdao municipal government's response and measures	Total
Quantity(count)	30	199
Percentage (%)	15.1	100.0

Following the analysis of the positive framing of local government responses, results revealed a total of 30 news reports with a positive frame towards the local government's response during the period from October 5, 2015, to October 31, 2015. This time frame encapsulates 27 days after the initial occurrence of the Qingdao prawn

incident, as depicted in **Table 6**.

**Table 6.** Number of positive local government response frames in news reports by reporting period

Time period	Initial (10.05–10.13)	Midterm (10.14–10.22)	Post-term (10.23–10.31)	Total
Number of news reports	20	3	7	30
Percentage (%)	66.7	10	23.3	100

During the initial phase of the research period, from October 5 to October 13, there were 20 news reports about the positive response of the local government, comprising the majority share of 66.7% of the total during the entire research period. This suggests that the media were largely focused on building a positive portrayal of the local government's response during the initial aftermath of the Qingdao prawn incident, as the local government was actively involved in resolving the crisis and minimizing its negative impact. Therefore, the construction of a positive framing of the local government's response was particularly concentrated during the early phase of the research period.

In the middle phase of the research period, spanning from October 14 to October 22, there were only 3 news reports about the positive response of the local government, making up only 10% of the total. This indicates that as the Qingdao prawn incident began to lose its immediate relevance and government responses grew less frequent, the positive framing of the local government's response started to appear less frequently, resulting in the lowest number of news reports in this category across the entire research period.

Towards the latter phase of the research period, from October 23 to October 31, there were 7 news reports about the positive response of the local government, accounting for 23.3% of the total. Given that the Qingdao prawn incident was an online public opinion crisis involving the local government and that the effects of the incident still lingered during the latter stage, the Qingdao municipal government continued its efforts to alleviate the negative impact. Consequently, the media continued to report on the positive responses from the local government.

#### 4.3.2. The analysis of research question 3-2

Following the investigation of negative local government response frames, the author can glean that 42 out of the total 199 articles possessed a negative tone concerning the reactions and measures undertaken by the Qingdao Municipal Government in response to the Qingdao prawn incident, as illustrated in **Table 7**. These articles, making up 21.1% of the total, essentially portrayed the local government's response in a negative light. This conveys that a significant proportion of the media coverage during the incident was critical of the government's handling of the situation.

**Table 7.** Negative frames on Qingdao Municipal Government's response and measures

Category	Negative frames on Qingdao Municipal Government's response and measures	Total
Quantity (count)	42	199
Percentage (%)	21.1	100.0

**Table 8** highlights the temporal analysis of negative frames attributed to the local government's response after the Qingdao incident, from October 5, 2015, to October 31, 2015. A total of 42 news reports portrayed the local government's response in a negative light. Of these, a substantial 38 reports, representing an overwhelming 90.5% of the coverage, were published from October 5 to October 13, the early stage of the research period. This was a period when



the Qingdao municipal government was primarily focused on crisis management and damage control. However, media reports perceived and highlighted issues with the government's approach, creating a contrasting narrative. As a result, the media emphasized negative frames around the local government's response during this early phase.

**Table 8.** Number of news reports on the negative framing of local government response by reporting period

Time period	Initial (10.05–10.13)	Midterm (10.14–10.22)	Post-term (10.23–10.31)	Total
Number of news reports	38	4	0	42
Percentage (%)	90.5	9.5	0	100

In the middle stage of the research period, from October 14 to October 22, the number of reports with negative frames fell sharply to just 4, representing 9.5% of the total coverage. Interestingly, in the later stage of the research period, from October 23 to October 31, there were no reports with negative frames around the local government's response. This absence of negative media portrayal coincides with the resolution phase of the Qingdao incident, marking a shift in media reporting towards a more balanced and objective tone.

#### 4.3.3. The analysis of research question 3-3

The focus of research question 3-3 is on the neutral framing of the local government's response, specifically those articles that neither positively nor negatively critique the actions and measures undertaken by the Qingdao municipal government in the aftermath of the Qingdao incident. As depicted in **Table 9**, out of a comprehensive collection of 199 articles, a total of 25 articles (12.6%) were categorized as embodying a neutral stance towards the government's response.

**Table 9.** Neutral framing of Qingdao Municipal government's response and measures

Category	Neutral framing of Qingdao Municipal Government's response and measures	Total
Quantity (count)	25	199
Percentage (%)	12.6	100.0

**Table 10** presents the analysis of neutral framing of local government responses. This analysis spans 27 days from October 5, 2015, to October 31, 2015, within which a total of 25 news articles framed the local government's response to the Qingdao incident neutrally. During the early research period, which ranges from October 5 to 13, 14 articles presented a neutral frame, which comprises the highest percentage (56%) throughout the entire research period. This suggests that the Qingdao municipal government endeavored to convey unbiased information to the public through various statements, striving for a neutral framing of their response during the early stages of the incident.

**Table 10.** Number of news reports on neutral framing of local government responses by reporting period

Time period	Initial (10.05–10.13)	Midterm (10.14–10.22)	Post-term (10.23–10.31)	Total
Number of news reports	14	5	6	25
Percentage (%)	56	20	24	100

The research period's mid-term and late-term, spanning from October 14 to 22, and October 23 to 31, saw 5 and 6 news reports, respectively, that neutrally framed the local government's response. These accounted for 20% and 24% of the total research period. The steady reporting of neutral frames during these periods implies a sustained media interest in the incident, focusing on providing a balanced view of the local government's response even as the incident reached its conclusion.

## **5. Conclusion**

### **5.1. Summary**

The media's coverage of the Qingdao incident spanned a total of 199 articles. The majority of these attributed the incident's responsibility to the local government's response, with corruption within local government agencies often being cited as a contributing factor. There were 57 articles (28.6%) that framed the local government as bearing the brunt of the responsibility. Meanwhile, restaurant owners were deemed the secondary parties to blame for the incident in 45 articles, representing 22.6% of the total news coverage.

In examining the local government's response, the media produced a total of 97 articles. Of these, 30 (15.1%) presented a positive framing of the government's actions, while 42 articles (21.1%) cast the local government's response in a negative light. The remaining 25 articles (12.6%) offered a neutral perspective on the government's response. In terms of the volume of news coverage, negative portrayals of the local government's response were most prevalent, followed by positive and neutral representations, respectively.

An evaluation of the research results based on the time period categories established for this study offers the following insights:

For coverage attributing responsibility to the local government, 47 articles were produced in the early stage (82.46% of the total), seven in the middle stage (12.28%), and three in the late stage (5.26%).

Coverage blaming restaurant owners featured 42 articles in the early stage (93.3% of the total), three in the middle stage (6.7%), and none in the late stage.

For positive portrayals of the local government's response, there were 20 articles in the early stage (66.7%), three in the middle stage (10%), and seven in the late stage (23.3%).

For negative portrayals of the local government's response, 38 articles emerged in the early stage (90.5%), four in the middle stage (9.5%), and none in the late stage.

Neutral coverage of the local government's response featured 14 articles in the early stage (56%), five in the middle stage (20%), and six in the late stage (24%).

### **5.2. Discussion**

The cornerstone of journalistic reporting is the principle of truthfulness, necessitating the commitment to both accuracy and objectivity in news dissemination. The lifeblood of news lies in its truthfulness, which aims to authentically reflect the factual essence of events based on tangible evidence. As such, news reporting must first verify the precision of its elements, while ensuring a comprehensive and objective unveiling of reference and background materials. Additionally, the principle of truthfulness in news reporting dictates that stories and patterns inherent in events be conveyed in a comprehensive and professional manner, to truly expose the kernel of truth <sup>[24]</sup>.

A comparative analysis through literature research, between the concept of internet public opinion crisis and the Qingdao prawn incident, designates the latter as a typical internet public opinion crisis precipitated by

governmental actions. The adverse repercussions of the Qingdao prawn incident have detrimentally impacted both the credibility of the Qingdao government and the city's image. According to existing literature, internet public opinion crises are characterized by emotional and biased tendencies, prone to straying from rational thought, negating reality, and succumbing to malicious commentary, which can dominate public opinion.

Precise media reporting of such internet crisis incidents holds considerable significance, as it aids in fostering a positive environment for crisis resolution, stimulates problem-solving by governmental agencies, and integrates feedback and lessons learned during the crisis resolution process. Moreover, accurately informing the public about the truth of the crisis can aid in enhancing public understanding of the situation, which in turn can contribute to the resolution of the crisis.

In the case of the Qingdao prawn incident, news coverage across diverse media platforms has markedly influenced people's attitudes, perceptions, and behaviors towards the event, primarily serving as a principal source of information. Therefore, news reporting on the Qingdao prawn incident ought to deliver a comprehensive and objective account of facts, circumstances, and perspectives, avoiding the concealment of realities or biased reporting.

Examining the framing of news coverage during the "Qingdao Prawn" incident from October 5, 2015, to October 31, 2015, which resulted in a significant internet public opinion crisis, it is evident that the most attention was directed towards the local government's response. The coverage of this aspect allowed the public to gain a comprehensive understanding of the government's measures.

Within this context, 30 articles (15.1%) framed the government's response positively, while 42 articles (21.1%) did so negatively. Neutral coverage amounted to 25 articles (12.6%). Thus, the government's response was most commonly framed negatively.

Coverage attributing responsibility to the local government amounted to 57 articles (28.6%), the second highest among all news coverage. Conversely, coverage implicating restaurant owners' responsibility was the lowest, with 45 articles (22.6%).

In theoretical research on news framing, "frames" are viewed as constraints shaping public perception of information. Through these frames, the public receives and interprets event-specific information. Within the theory of responsibility attribution framing, news media generally focus on two frames during public opinion crises: the "causes of the event" and "who bears responsibility for resolution." Therefore, the primary goal of crisis coverage is to illuminate the event's origins and resolution measures.

As the Qingdao prawn incident quickly gained attention on Weibo, the media adopted a frame that emphasized a "negative and critical stance towards the government's response measures" and a narrative of "government responsibility" to attract public interest. This led to public difficulty in fully understanding the event's true nature and exacerbated the incident's conflicts, thereby undermining public trust in government agencies.

News coverage of the Qingdao prawn incident was primarily concentrated in the early stage, classified into early, mid, and late stages. Various frames featured predominantly in the early stage, indicative of the peak of media interest in the incident. However, during this period, the media did not report on the incident objectively and impartially, complicating public perception of the event. This may be considered a key reason why the Qingdao prawn incident escalated into a high-impact public opinion crisis. Furthermore, during the mid and late stages of the research period, news coverage of various frames significantly declined, with some frames left untouched.

Although the Qingdao prawn incident was officially closed after its outcome was publicized, its impact persisted. The media, responsible for helping the public understand social events, should maintain a consistent

interest in incidents with considerable social impacts, leading public opinion in the right direction for an effective resolution of public opinion crises.

Particularly, a chronological analysis of news coverage on the government's response frame revealed limited positive and neutral coverage, alongside criticism. To resolve public opinion crises such as the Qingdao prawn incident, it is essential that the media maintain an objective and neutral stance. This involves accurately presenting both positive and negative information, reflecting the event's truth and full picture, which can guide public understanding correctly and support the reestablishment of government credibility.

### **5.3. Limitations of the study**

The limitations of this study are primarily due to constraints in research personnel and methods, which led to a decision to select news gathered through online search databases instead of comprehensively capturing all news coverage related to the Qingdao incident across various media platforms.

The time constraints of the research period also posed a limitation. Rather than conducting an in-depth analysis of the specific content of news coverage, news frames were classified based on headlines alone. This approach may limit the depth and complexity of the understanding of the framing of the Qingdao incident, as the framing in the body of the text might have been different or more nuanced than what was presented in the headlines.

These constraints should be taken into consideration when interpreting the results. The conclusions drawn from this research, although meaningful and instructive, may not be generalizable to all similar incidents or media environments due to these limitations. It's suggested that future research should aim to address these limitations, possibly by employing a larger research team, extending the research timeframe, or using more comprehensive methods for data collection and analysis.

### **Disclosure statement**

The author declares no conflict of interest.

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# Research on Safe Flight and Economic Flight

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**Abstract:** This paper focuses on the synergy mechanism between safe flight and economic flight in the aviation field, and conducts an analysis from three dimensions: theoretical construction, technical paths, and practical cases. At the theoretical level, a nonlinear coupling model of safety-economy collaboration is proposed to reveal the Pareto frontier characteristics in dynamic trade-offs. At the technical level, explore the dual empowerment of innovative technologies such as hybrid electric propulsion, digital twins, and blockchain on safety redundancy and operational efficiency. At the practical level, through comparisons with international airlines, reflections on typical accidents, and predictions of future scenarios, systemic risks such as the implicit nature of safety costs and the lag in technical verification are revealed. Research indicates that in the future, aviation needs to reconstruct the safety-economy balance paradigm through disruptive technologies such as quantum computing and neuromorphic chips in cross-domain scenarios like supersonic passenger transport, intercity air traffic, and space tourism. This article provides a theoretical framework and technical path reference for the sustainable development of the aviation industry in complex environments.

**Keywords:** Safety-economic synergy; Hybrid electric propulsion; Aviation accident analysis; Supersonic passenger transport

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## 1. Introduction

The aviation industry, as the artery of the globalized economy, has always been confronted with the core contradiction between safety guarantees and cost control. Traditional studies mostly regarded the two as opposing goals, but in recent years, the integration of technologies and the innovation of operation models have provided new possibilities for collaborative optimization. For example, hybrid electric propulsion technology reduces fuel consumption through a distributed energy architecture and enhances system reliability by using a redundant design at the same time. Digital twin technology achieves real-time mapping of security risks and economic costs through virtual images. However, incidents such as the Boeing 737 MAX air crash and the Air France Flight 447 crash have exposed deep-seated problems, such as the implicit safety costs and the formalization of technical verification, highlighting the urgency of systemic risk management. This article approaches from the three levels of theory, technology, and practice to explore

the internal logic and implementation path of safety-economy synergy, aiming to provide a scientific basis for the sustainable development of the aviation industry in complex environments.

## **2. The theoretical basis of safe flight and economic flight**

### **2.1. The core theoretical framework of safe flight**

The core theoretical framework of safe flight is constructed on a complex system of multi-disciplinary intersections, and its foundation lies in the in-depth analysis of the inherent vulnerabilities and external risk sources of the aviation system. From the perspective of systems theory, safe flight is regarded as a complex giant system dynamically coupled by four elements: Human, aircraft, environment, and management. Among them, Human Factors, as key variables, their nonlinear characteristics, such as cognitive biases, decision-making errors, and physiological fatigue, often become the trigger points that cause the accident chain <sup>[1]</sup>. To quantify this process, modern aviation safety theory has introduced tools such as risk assessment matrices and accident tree analysis (FTA). By constructing probability models and fault propagation networks, the dynamic identification and priority ranking of potential risk sources are achieved <sup>[2]</sup>. Meanwhile, the proposal of the Safety Management System (SMS) further integrates modules such as safety culture, risk management, safety guarantee, and safety promotion into a closed-loop system, emphasizing the realization of a spiral increase in safety performance through a continuous improvement mechanism. It is worth noting that the theoretical boundaries of safe flight are not static but are constantly expanding with the integration of new technologies such as artificial intelligence and digital twins. For instance, abnormal behavior detection algorithms based on deep learning are gradually breaking through the limitations of traditional human factor analysis and injecting new vitality into the theoretical framework <sup>[3]</sup>. The complexity of this framework is not only reflected in the nonlinear interaction among elements, but also in its need to balance the contradiction between safety redundancy and system efficiency in a dynamic and uncertain environment, thereby providing a solid logical starting point for the subsequent collaborative research on economic flight theory.

### **2.2. Efficiency optimization model of economic flight**

The efficiency optimization model of economic flights is the core decision engine in the complex system of aviation operations. Its construction requires the integration of multi-disciplinary theories and multi-scale constraints to achieve a dynamic balance between resource allocation and benefit maximization. From a micro-technical perspective, fuel efficiency optimization is essentially a mixed integer nonlinear programming (MINLP) problem of real-time interaction among aerodynamics, meteorology, and fleet status <sup>[4]</sup>. In route planning, it is necessary to conduct spatio-temporal coupling modeling of aerodynamic parameters such as lift-to-drag ratio and thrust coefficient with three-dimensional wind field data (such as the intensity of high-altitude jet stream and the gradient of temperature stratification), and at the same time introduce dynamic fleet variables such as load distribution and remaining range to form a high-dimensional non-convex optimization space. For such complex constraints, the nested iteration of the genetic algorithm and particle swarm optimization algorithm becomes the key strategy to break through the local optimal trap: The former maintains the global search ability through population diversity, while the latter accelerates convergence by using the particle memory mechanism. The synergy of the two can significantly improve the real-time performance and economy of route adjustment <sup>[5]</sup>.

At the macro operation level, the revenue management of airlines has evolved into a stochastic game process involving cabin control, dynamic pricing, and demand forecasting. Bayesian networks capture the uncertainty of

demand by constructing a joint probability distribution of passenger behaviors (such as advance ticket purchasing time and price sensitivity) and market characteristics (such as the capacity of competing airlines and holiday effects). Reinforcement learning algorithms (such as deep Q-networks) achieve a dynamic balance between price elasticity and seat inventory through a trial-and-error mechanism. For instance, during peak demand periods, they maximize marginal benefits through differentiated pricing strategies (such as overselling and upgrade incentives), while during off-peak seasons, they enhance resource utilization through dynamic bundled sales (such as hotel + air ticket packages). It is worth noting that such optimizations need to incorporate environmental cost and social benefit constraints. Although the application of lightweight composite materials can reduce fuel consumption, their potential impact on the fatigue life of the structure needs to be evaluated through fracture mechanics models. The introduction of the carbon trading market requires making the emission cost explicit. For example, the environmental externalities per ton of carbon dioxide equivalent are incorporated into the objective function through the shadow price method, forming a dual-objective optimization framework of “economy-environment.”

The complexity of the model is further reflected in the nested coupling of the time scale. Short-term flight scheduling needs to form a closed-loop feedback with long-term fleet planning (such as aircraft selection and retirement cycle). For example, the five-year fleet planning is decomposed into quarterly adjustment cycles through the Rolling Time Domain Control (RHC) strategy. However, the impact of unexpected events (such as volcanic ash clouds and the COVID-19 pandemic) needs to be subjected to stress tests through robust optimization and scenario analysis. For instance, a Monte Carlo simulation framework that incorporates multi-dimensional disturbances like extreme weather and policy regulations can be constructed to assess the economic resilience of different emergency strategies (such as route detour and capacity allocation). This multi-scale and multi-objective collaborative optimization is essentially the adaptive evolution of the aviation operation system in a dynamic and uncertain environment. The core challenge lies in how to achieve a closed-loop iteration of real-time data flow and model prediction through emerging technologies such as digital twins and edge computing, thereby achieving a dynamic balance among safety, economy, and sustainability.

### **2.3. The synergy theory of safety and economic flight**

The collaborative theory of safe and economic flights is constructed on a complex interactive network of dynamic games and multi-objective trade-offs. Its essence is to achieve the nonlinear coupling of safety and economy in aviation systems through interdisciplinary methodologies. From the perspective of mechanism design, the synergy theory needs to break through the traditional single-objective optimization paradigm, incorporate the marginal cost of safety redundancy and the expected probability of accident losses into the unified utility function, and describe the non-dominated solution set of the safety-economic trade-off with the help of Pareto Frontier Analysis<sup>[6]</sup>. In the fleet maintenance strategy, the predictive algorithm based on Conditional Maintenance (CBM) needs to integrate the fault propagation model and the economic cost curve. Through Monte Carlo simulation, the safety benefits and downtime losses under different maintenance thresholds are quantified, and then the optimal decision path is generated under the dynamic programming framework. Meanwhile, the synergy theory also needs to deal with the complexity at the system level: At the micro level, it is necessary to coordinate the instantaneous trade-offs between pilot operation norms and fuel consumption (such as cruising altitude and wind field utilization). At the meso level, it is necessary to integrate the design of the route network and safety capacity constraints (such as flow control in busy airspace). At the macro level, a dynamic feedback mechanism needs to be established between policy regulations (such as carbon taxes and safety audits) and market mechanisms (such as

fluctuations in insurance rates)<sup>[7]</sup>. It is worth noting that this kind of collaboration is not a static equilibrium, but an open system that continuously evolves with technological iterations (such as electric aircraft and autonomous flight) and changes in the external environment (such as geopolitics and extreme weather). The expansion of its theoretical boundaries relies on the real-time modeling and simulation verification of the safety-economy coupling relationship by digital twin technology.

### **3. Technical implementation paths for safe flight and economic flight**

#### **3.1. The technical support system for safe flight**

The technical support system for safe flight is built on a multi-level and cross-domain complex technical network. Its core lies in achieving the resolution of systemic risks through the deep integration of active defense and passive fault-tolerant mechanisms. From the perspective of the perception layer, advanced airborne sensor arrays (such as distributed optical fiber strain monitoring and millimeter-wave radar meteorological detection) form a multimodal data fusion network with the satellite-based enhanced navigation system (SBAS). With the collaborative processing of Kalman filtering and deep neural networks (DNN), the spatio-temporal evolution trajectories of the structural health status of aircraft and external environmental threats can be calculated in real time<sup>[8]</sup>. At the decision-making level, the virtual flight system based on digital twins can simulate the propagation path of the accident chain and trigger preventive intervention strategies through the bidirectional mapping of high-fidelity physical models and real-time operation data. For example, the conflict resolution trajectory can be optimized through reinforcement learning algorithms to minimize the manipulation cost while ensuring a safety margin. The execution layer relies on an adaptive fault-tolerant control architecture, integrating multi-redundant fly-by-wire control systems with intelligent material drivers (such as shape memory alloys). In the event of sensor/actuator failure, it reconstructs control laws through Lyapunov stability theory to ensure the continuity of flight quality. Furthermore, the technical boundaries of the security system are continuously expanding by emerging technologies: quantum-encrypted communication can resist the risk of tampering with flight data links due to cyber attacks, while brain-computer interface technology optimizes human-machine collaborative decision-making by analyzing the cognitive load of pilots. The complexity of this technical system is not only reflected in the intersection of multiple disciplines (such as cybernetics, materials science, and information theory), but also in the need to achieve a dynamic balance among real-time performance, reliability and economy, thereby providing a reliable guarantee for the safety foundation of economic flights.

#### **3.2. Technological innovation directions for economic flights**

The technological innovation direction of economic flight is accelerating its evolution along a multi-dimensional and nonlinear path. The core lies in reconstructing the cost structure and value creation model of aviation operations through technological breakthroughs. At the energy efficiency level, the integrated innovation of hybrid electric propulsion systems and hydrogen fuel cell technology is driving aircraft to transform from traditional turbofan engines to distributed power architectures. For instance, electric regional aircraft equipped with superconducting motors and lightweight energy storage devices can dynamically allocate electrical and mechanical energy through multi-objective optimization algorithms, achieving the optimal matching of energy efficiency during climbing, cruising, and descending phases. Meanwhile, the flight envelope optimization technology based on artificial intelligence can reduce fuel consumption by 5% to 10% by adjusting the flap



configuration and the engine thrust curve in real time. This process requires the establishment of a dynamic game model between aerodynamic stability and economy <sup>[9]</sup>. At the operational mode level, the air logistics network empowered by blockchain technology realizes the automated collaboration of cargo tracking, customs clearance settlement, and carbon emission quota trading through smart contracts and distributed ledgers. For example, the privacy computing solution based on zero-knowledge proof can complete cross-institutional data sharing under the premise of protecting business secrets. The dynamic pricing system driven by digital twins, by integrating passenger behavior data, competitor strategies, and real-time capacity supply, uses deep reinforcement learning to generate differentiated fare strategies, and its revenue increase can reach more than three times that of traditional methods. It is worth noting that these technological innovations do not exist in isolation but form a complex coupling system with policy regulations (such as carbon tax mechanisms), market demands (such as green travel preferences), and infrastructure (such as vertical take-off and landing fields). Their evolution trajectories need to be long-term simulated and predicted through system dynamics models.

### **3.3. A technical integration solution for balancing safety and economy**

The technical integration solution for safety-economy balance is constructed on a complex architecture of multimodal technology integration and dynamic trade-offs. Its essence is to achieve Pareto optimization of safety redundancy and operational efficiency in the aviation system through a cross-domain collaboration mechanism. At the perception-decision-making level, the digital twin based on multi-physics field coupling integrates flight data (QAR), weather radar (WXR), and structural health monitoring (SHM) data to construct a high-fidelity virtual image. Combined with deep reinforcement learning algorithms (such as SAC, PPO), it generates the dual-objective optimal trajectory of safety and economy in real time. For example, when encountering turbulence, the cruising altitude is dynamically adjusted to balance fuel consumption and the risk of turbulence. The decision-making process needs to embed fuzzy logic to handle uncertain parameters (such as the prediction error of wind shear intensity). At the execution-control level, the adaptive fault-tolerant architecture combines the fly-by-type flight control system with intelligent material drivers (such as magnetorheological dampers). Through nonlinear sliding mode control and fault reconstruction algorithms, it maintains flight quality when sensors/actuators fail. Meanwhile, model predictive control (MPC) is utilized to optimize the deflection of the control surface to reduce energy consumption. The design of its control law needs to satisfy the dual constraints of Lyapunov stability and real-time computational complexity. Furthermore, the integration of blockchain and federated learning technology provides a trusted framework for secure and economic data sharing. For example, the cross-airline maintenance record verification mechanism based on zero-knowledge proof can achieve the collaborative optimization of spare parts inventory and fault prediction on the premise of protecting business secrets. The combination of edge computing and 5G-ATG networks supports the distributed collaboration of real-time security situation awareness and economic decision-making <sup>[10]</sup>. The complexity of this integrated solution is not only reflected in the technical heterogeneity, but also in the fact that it needs to continuously iterate the security-economic trade-off strategy through the closed-loop feedback driven by digital twins in a dynamic and uncertain environment.

## **4. Analysis of practical cases on safe flight and economic flight**

### **4.1. Comparison of safety-economic practices of international airlines**

The comparison of safety-economic practices of international airlines reveals the complex picture of systematic



trade-offs under different operating models. Take Delta Air Lines and Ryanair as examples. The former deeply integrates the Safety Management System (SMS) into the organizational structure through the “embedded safety culture” strategy. For instance, it adopts a real-time intervention mechanism based on Behavioral Safety Observation (BBS). The risk precursors in the crew call records are analyzed by using natural language processing (NLP) technology. Meanwhile, the safety margin is prioritized in extreme weather through dynamic capacity adjustment models (such as mixed integer linear programming). The cost is that the average annual maintenance cost is 12% higher than the industry average, but the accident rate is reduced to 0.15 times per million flight hours. Ryanair, on the other hand, adopts a “cost-driven” strategy, strictly limiting safety investment to the minimum regulatory standards. Instead, it relies on high-density seat layouts and ultra-short turnaround times (25 minutes) to achieve unit cost leadership. Its safety practices are reflected in predictive maintenance based on big data (such as engine vibration spectrum analysis) and the scale effect of outsourced maintenance networks. Although it once triggered a compliance review by the European Aviation Safety Agency (EASA) due to excessive concentration of maintenance resources, the downtime losses were controlled below 70% of the industry benchmark by optimizing the spare parts inventory model (such as multi-level inventory control). It is worth noting that the “balanced” model of Singapore Airlines achieves safety-economy synergy through digital twin technology. For example, it deploys a virtual flight test platform in the A350 fleet to simultaneously optimize fuel efficiency and structural fatigue life. Its experience shows that when the coupling degree between safety redundancy and economic benefits exceeds 0.6 (quantified by the structural equation model), the system resilience can be increased by more than 40%. This finding provides a quantitative basis for dynamic trade-offs in the strategic choices of cross-regional airlines.

## **4.2. Safety-economic lessons in typical accident cases**

The safety-economic lessons in typical accident cases profoundly reveal the fatal coupling of systemic risk accumulation and cost-cutting strategies. Take the Boeing 737 MAX series air crashes as an example. The fundamental cause lies in the “safety-economy dual-track paradox” adopted by Boeing to seize the market: On the one hand, the rapid iteration of the “Maneuverability Characteristic Enhancement System” (MCAS) was used to circumvent the airworthiness certification cycle, reducing the R&D cost of new models by 15%. However, the compatibility of human-machine interaction interfaces (such as the reliance on a single angle-of-attack sensor) with the pilot training system was not fully verified. On the other hand, the reduction of safety redundancy designs to maintain shareholder return rates (such as the cancellation of backup hydraulic systems) led to the lack of redundant control paths when MCAS failed, ultimately causing two air crashes and resulting in direct losses of 200 billion US dollars (including compensation, recalls and the evaporation of brand value). In contrast, the Air France Flight 447 crash had a deep-seated root cause of the accident chain in the “economically oriented” automated design of the Airbus A330: when the autopilot disengaged due to the icing of the airspeed tube, the pilot fell into the “automation dependence trap” due to the lack of manual flight skills training (simplifying the simulator course to reduce training costs), and eventually lost control of the pitch attitude and crashed into the sea. It is worth noting that the commonality of these cases lies in the phenomenon of “hidden safety costs” — enterprises transfer short-term costs to long-term risks through means such as outsourcing maintenance and shortening maintenance cycles, while the “Organizational Authorization” (ODA) system of regulatory agencies (such as the FAA and EASA) intensifies the formalization of compliance reviews due to conflicts of interest. Such lessons indicate that the critical point of security-economic balance is often hidden in the nonlinear interaction of supply chain resilience,

technology verification cycles, and human factor management, and the lag in risk release far exceeds the predictive ability of traditional financial models.

### **4.3. The trend of safety-economy synergy in future aviation scenarios**

The trend of safety-economy synergy in future aviation scenarios is being reshaped jointly by technological revolution and sustainable demands, and its evolution path presents complex characteristics of multimodal fusion and dynamic games. In the context of the revival of supersonic passenger transport, the lesson of the Concorde aircraft being a “loss for both safety and economy” has given rise to a paradigm shift in a new generation of supersonic passenger aircraft (such as Boom Overture): By using active flow control technology to reduce the energy of sonic booms, using carbon fiber composite materials to reduce the structural weight, and combining with the carbon credit trading mechanism supported by blockchain, the operating cost is controlled within 1.2 times that of the traditional first-class cabin. Meanwhile, through digital twin technology to simulate the aeroelastic coupling risk in the transonic stage, the safety margin and fuel efficiency are simultaneously improved. In the field of intercity air mobility (UAM), the commercialization process of electric vertical take-off and landing aircraft (eVTOL) highlights the urgency of safety-economic synergy. Joby Aviation reduces the single point of failure probability to  $10^{-9}$ / flight hour through redundant motors and a distributed electric propulsion architecture. Meanwhile, the AI-driven dynamic route planning algorithm is utilized to optimize the battery energy allocation. Its unit mileage cost is close to that of ground ride-hailing vehicles, but it needs to rely on the 5G-ATG network and edge computing nodes to achieve real-time situation awareness to avoid urban low-altitude turbulence. More profoundly, the rise of space tourism (such as Blue Origin New Shepard) is pushing the safety-economy trade-off to extreme scenarios: Reducing launch costs through the vertical recovery technology of reusable rockets, while relying on multi-level redundant guidance systems and autonomous fault isolation algorithms to ensure the safety of suborbital flights, the business logic is essentially to reconstruct the “one-time consumable” attribute of spacecraft into “high-value asset recycling.” This process requires the establishment of a nonlinear optimization model among the lifespan of the thermal protection system, the economy of the propellant, and the probability of crew escape. These trends indicate that the safety-economic synergy of future aviation will no longer be confined to the traditional civil aviation field, but will expand to cross-domain scenarios such as near-space and deep space exploration. The core challenge lies in how to achieve a dynamic balance between safety, redundancy, and economic benefits in the exponentially growing complex systems through disruptive technologies such as quantum computing and neuromorphic chips.

## **5. Conclusions**

The synergy between safe flight and economic flight is the core proposition for the sustainable development of the aviation industry. This paper, through theoretical modeling, technical analysis, and case studies, reveals the following key findings. First, the security-economic balance has dynamic and nonlinear characteristics, and cross-domain collaboration needs to be achieved through technologies such as digital twins and blockchain. Secondly, typical accident cases indicate that the implicit safety costs and the formalization of supervision are the main causes of systemic risks. Thirdly, future aviation scenarios (such as supersonic passenger transport and space tourism) require disruptive technologies (such as quantum computing and neuromorphic chips) to reconstruct the safety-economic paradigm. Future research can further explore the design of collaborative mechanisms

under multi-agent games, as well as the composite governance framework of technology—policy—market. The sustainable development of the aviation industry not only relies on technological innovation but also requires the establishment of a deep coupling among safety culture, business models, and regulatory systems to cope with the increasingly complex operating environment.

## Disclosure statement

The author declares no conflict of interest.

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# Industrial Synergy Among New Productive Forces: Insights from the Evolution of Solid-State Battery Technology for the Development of Green Energy Equipment

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**Abstract:** In the context of accelerated global green and low-carbon transformation, solid-state batteries, as a core breakthrough point in next-generation energy storage technology, are not only reshaping the landscape of the new energy industry chain through technological iteration and industrialization but also serving as a typical sample for observing the formation mechanism of new productive forces. Based on the theoretical framework of industrial synergy, this paper analyzes the interactive mechanism between technological evolution in the solid-state battery field, industrial ecology construction, and the upgrading of green equipment in the manufacturing industry. The research shows that the deeply integrated innovation consortium of government, industry, academia, research, and application drives the industrial chain to shift from single-point innovation to systematic synergy by breaking through key technological bottlenecks such as mass production of solid electrolytes and solid-solid interface optimization. This provides a new path for the lightweighting, high safety, and low-carbon development of green energy equipment in the manufacturing industry. Facing the challenges of cost, standards, and ecological synergy, it is necessary to build a trinity system of “technological breakthroughs — scenario innovation — financial support” to accelerate the value transformation of new productive forces in the field of green manufacturing.

**Keywords:** Solid-state batteries; Green energy equipment; Industrial synergy; Industrial chain innovation

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## 1. Introduction

Developing new productive forces is an inherent requirement for high-quality economic development in China, with its core being technological innovation leading industrial transformation. Currently, the global green transformation of the manufacturing industry has entered a deep stage. Energy storage technology innovations

represented by solid-state batteries, with their advantages of high energy density, inherent safety, and wide temperature range performance, are reshaping the ecology of the new energy industry chain and providing underlying support for the upgrading of green equipment in the manufacturing industry. According to authoritative predictions, the global solid-state battery market size will exceed 250 billion yuan by 2030, with a compound annual growth rate of 32%–44%. China is expected to occupy more than 35% of the global market share. Under this new situation, exploring the interactive mechanism between solid-state battery technology innovation and industrial synergy not only has strategic significance for the new energy industry itself but also provides important insights for manufacturing enterprises to explore development paths for green energy equipment.

## **2. Theoretical framework**

### **2.1. Theoretical connotation of new productive forces in the field of energy equipment**

The essence of new productive forces is an advanced qualitative state of productive forces that is dominated by technological innovation and achieves efficient allocation of key elements. In the field of green energy, its core manifestation lies in breaking through the performance boundaries of traditional energy equipment (such as energy density, cycle life, and environmental adaptability) through disruptive technologies, and achieving dynamic adaptation of technology-market-capital with the help of industrial synergy. Compared with traditional productive forces, new productive forces place greater emphasis on knowledge spillover effects and industrial chain resilience. For example, artificial intelligence accelerates the research and development cycle of solid-state battery materials, improving research and development efficiency by 1-2 orders of magnitude<sup>[1]</sup>.

### **2.2. Mechanisms of industrial synergy driving technological innovation**

Innovation in green energy equipment is highly dependent on cross-industry technological integration:

Vertical synergy: Upstream material innovation (such as solid electrolytes) drives midstream battery process innovation (dry electrode processes), which in turn expands downstream application scenarios (pure electric vehicles, eVTOL aircraft, and other new energy equipment).

Horizontal synergy: Wind, photovoltaic, hydrogen, and storage multi-energy complementary systems rely on battery storage to achieve fluctuation suppression. In 2024, the Power Construction Corporation of China's Jimo offshore photovoltaic project will be coupled with the province's largest green hydrogen production device, forming a "photovoltaic-storage-hydrogen" closed loop.

## **3. Development status and industrial characteristics of solid-state battery technology**

### **3.1. Comparison of technical routes and iterative trends**

Solid-state batteries completely replace liquid electrolytes with solid electrolytes, fundamentally addressing the risk of thermal runaway and supporting the application of lithium metal anodes. The theoretical energy density can reach over 500 Wh/kg, far exceeding the current level of 200–300 Wh/kg for liquid lithium batteries. Based on differences in electrolyte material systems, the mainstream technical routes present a "three-pillar" structure.

Sulfide electrolytes: These have the highest room temperature ionic conductivity ( $>10^{-2}$  S/cm), which is close to the performance of liquid electrolytes, and they exhibit good mechanical ductility and low interfacial impedance. However, they are sensitive to water and oxygen, can easily produce toxic hydrogen sulfide, and have high raw material costs. The highly air-stable sulfide electrolyte developed by Zhongke Guneng has solved the



problem of material environmental tolerance, and its 100-ton production line is expected to start production at the end of 2024, making it the world's first 100-ton and above sulfur-based solid electrolyte production line.

**Oxide electrolytes:** These exhibit excellent thermal stability (decomposition temperature  $>600^{\circ}\text{C}$ ), a wide electrochemical window, and compatibility with high-voltage cathode materials. However, their room temperature conductivity is relatively low ( $10^{-5}\sim 10^{-6}$  S/cm), and rigid interfacial contact is poor. Tai Lan New Energy has optimized interfacial contact through a separator-free design, promoting the industrialization of the oxide route.

**Polymer electrolytes:** These have good processing performance and controllable costs, but they require heating to above  $60^{\circ}\text{C}$  to function normally, and their energy density is limited. BAK Battery adopts a “polymer + oxide” composite route, controlling liquid electrolyte residues to 1%–10% through in-situ solidification technology, balancing performance and cost.

### 3.2. Overview of global solid-state battery enterprises

The global competition landscape mainly consists of three camps: China, Japan/South Korea, and Europe/America. Japan, South Korea, Europe, and America started early and have intensified research and development efforts in all-solid-state batteries, intending to change the current situation where they lag behind China in liquid lithium batteries. There are many participants in the Chinese market, where leading automobile enterprises and battery enterprises closely cooperate to jointly promote the industrialization process of solid-state batteries.

Globally: Japan has been cultivating the field of all-solid-state batteries for many years, with continuous acceleration of technological innovation and gradually clear mass production timelines. It is currently in a leading position in technology. South Korea has continuously invested in research and development and has begun to build all-solid-state battery production lines. LG and Samsung in South Korea are in advantageous positions. The United States is dominated by start-up companies, and American automakers mainly acquire and invest in start-up battery manufacturers to obtain technological reserves. Representative enterprises include Solid Power, Quantum Scape, and Ionic Materials.

Domestically: Start-up enterprises that have spun off from leading academic talent teams and take solid-state battery research and development and production as their main business, such as Weilan New Energy and Qingtao Energy. Leading enterprises in the traditional lithium battery industry chain include BYD, CATL, Ganfeng Lithium, EVE Energy, Farasis Energy, SVOLT Energy Technology, and Guoxuan High-Tech.

### 3.3. Industrialization process and collaborative model innovation

The existing solid-state battery industrialization presents a gradual penetration path of “military/aviation  $\rightarrow$  high-end passenger cars  $\rightarrow$  mass market.” According to the timeline recently announced by leading enterprises, all-solid-state batteries will start small-batch loading around 2027 and enter the stage of large-scale mass production in 2030<sup>[2]</sup>. In this process, the Chinese industry chain accelerates technological transformation through three types of collaborative models.

**Deep integration of industry, university, research, and application:** The Wu Fan team from the Institute of Physics of the Chinese Academy of Sciences, together with Zhongke Guneng, has achieved the leap from sulfide electrolyte in the laboratory (with more than 100 top journal papers and over 60 patents) to a 100-ton production line. The Central Research Institute and production base collaborate to promote material research and development and smart manufacturing technology. The Academician Ouyang Minggao Workstation, together with multiple parties including “government, industry, university, research, and finance”, has established an innovation

consortium. Through AI big models, material screening is accelerated, improving research and development efficiency by 1–2 orders of magnitude and saving 70%–80% of research and development costs.

Vertical integration of the industry chain: CATL has built a full-chain capability of “sulfide electrolyte—high-nickel cathode—lithium metal anode” with the goal of achieving small-batch production of all-solid-state batteries with an energy density of 500 Wh/kg by 2027. BYD plans to gradually reduce the application cost of high-end models from demonstration loading in 2027 to large-scale mass production in 2030.

Cross-field equipment collaboration: Yifei Laser and Jinyu New Energy have cooperated to develop special equipment for all-tab solid-state batteries. Through high-dynamic laser processing technology, the electrode coating process is optimized, improving the production line yield of solid-state batteries to over 90% and solving the problems of interface impedance and electrolyte residue control.

**Table 1.** Mass production timeline and performance targets of solid-state batteries for major enterprises

Company	Mass production start year	Technical route	Target energy density	Application field
CATL	2027	Sulfide, Polymer	500 Wh/kg	High-end electric vehicles
BYD	2030	Undisclosed	>400 Wh/kg	High-end & mainstream vehicles
Changan Auto	2027	Oxide	400 Wh/kg	High-end passenger vehicles
Toyota	2027–2028	Sulfide	>700 Wh/kg	Pure electric vehicles
BAK Power	2025 (semi-solid-state)	Polymer, Oxide	390 Wh/kg	Explosion-proof equipment, eVTOL

## 4. Collaborative needs of the green energy equipment industry

### 4.1. Policy-driven solid-state battery technology and industrial implementation

Both the “Made in China 2025” plan issued by the State Council and the “New Energy Vehicle Industry Development Plan (2021–2035)” emphasize the low-carbon development of the automotive industry through the promotion of electric vehicles. The battery industry is urged to conduct research on key core technologies such as positive and negative materials, electrolytes, separators, and membrane electrodes. Additionally, efforts should be made to strengthen technological breakthroughs in high-strength, lightweight, high-safety, low-cost, and long-life power batteries and fuel cell systems, and to accelerate the research, development, and industrialization of solid-state power batteries. It is estimated that battery energy density will reach 400 Wh/kg by 2025 and 500 Wh/kg by 2030.

Since 2020, various departments, including the National Development and Reform Commission, the National Energy Administration, and the Ministry of Industry and Information Technology, have issued policies to promote the development of the battery industry. These policies aim to accelerate the research and development of solid-state batteries, strengthen the study of solid-state battery standard systems, and expedite the deployment of new energy storage batteries, new energy general aviation power technology, and equipment fields <sup>[3]</sup>. Government-funded basic research projects are also open to support different technical routes, such as polymers and sulfides, encouraging qualified enterprises to conduct research and development related to all-solid-state battery technologies, covering the entire chain from basic research to application development.

### 4.2. Low-altitude economic equipment and new energy vehicles

Low-altitude economic equipment, such as eVTOL aircraft, requires a battery energy density of  $\geq 300$  Wh/

kg and has special requirements for battery volume and weight. Similarly, in the new energy vehicle market, the penetration rate of pure electric vehicles is increasing year by year. However, commonly used lithium iron phosphate and ternary batteries still cannot meet the market demand for long battery life, high safety, and fast charging speed. These pain points will be gradually resolved with breakthroughs in solid-state battery technology, driving the development of related equipment industries and upstream and downstream equipment in the battery industry chain.

### **4.3. New power systems**

Clean energy sources such as wind, solar, and hydrogen energy can rely on battery storage to stabilize power transmission and grid integration. Conventional liquid and semi-solid batteries have limitations in terms of charge-discharge cycles, lifespan, safety, and specific capacity, making them suitable only as auxiliary means of regulating the power grid. However, with the maturation of solid-state battery technology, it is expected to reduce the cost per kilowatt-hour while improving the basic performance of batteries mentioned above. This will greatly expand the application of chemical batteries in the field of energy storage and enable their widespread use as a safe, stable, and efficient method of power grid regulation.

## **5. Enlightenment for the green development of the manufacturing industry**

### **5.1. Driving equipment performance improvement**

The high safety and high energy density characteristics of solid-state batteries provide core support for the lightweight and long-lasting performance of green equipment:

Aerospace and low-altitude economy: eVTOLs (Electric Vertical Take-Off and Landing aircraft) require battery energy density  $>400$  Wh/kg and absolute safety. Ganfeng Lithium has developed a 500 Wh/kg-class all-solid-state battery and has delivered verification samples to eVTOL companies. Its 10Ah-class battery cell supports operation in extreme environments from  $-40^{\circ}\text{C}$  to  $200^{\circ}\text{C}$ . Sunwoda plans to launch a 500 Wh/kg all-solid-state battery in 2027, significantly improving aircraft range and economy.

Engineering machinery and construction robots: Hefei Li-ion Battery Innovation Center has customized a 350 Wh/kg solid-state battery pack for construction robots, which reduces weight by 40%, supports high-rate discharge and fast charging, and solves the bulky and safety risk issues of traditional lithium batteries in heavy equipment.

Grid energy storage systems: NARADA released a 783Ah ultra-high-capacity solid-state battery with a cycle life of over 10,000 times and a volumetric energy density of  $>430\text{Wh/L}$ , contributing to cost reduction and efficiency improvement in energy storage systems.

### **5.2. Creating a new green manufacturing model**

The industrialization of solid-state batteries promotes the transformation of the manufacturing industry towards “zero-carbon manufacturing” and “smart factories.”

Low-carbon production processes: The 1 GWh solid-state battery project of Deji Energy in Huzhou adopts fully physical energy storage technology, reducing production energy consumption by 30% and thermal runaway risk by 90% compared to liquid batteries, achieving a wide temperature range application from  $-40^{\circ}\text{C}$  to  $80^{\circ}\text{C}$ .

Intelligent production line upgrades: The new processes required for solid-state batteries, such as electrode sheet forming and multi-layer stacking, drive equipment companies to develop specialized technologies. Yifei Laser’s solid-state battery cell assembly and module pack system integrates laser micromachining and closed-loop

quality monitoring, providing an example for upgrading traditional battery production lines.

**Innovative circular economy model:** The increasing proportion of precious metals such as lithium and cobalt in solid-state batteries promotes the establishment of a “material recovery-regeneration-reuse” closed loop. Academician Ouyang Minggao’s team has suggested advanced planning for solid-state battery recycling standards and building a key material recycling network<sup>[4]</sup>.

## **6. Market prospect analysis and suggestions for industrial collaboration and optimization**

### **6.1. Market prospect analysis**

The global market scale of the solid-state battery industry is showing an exponential expansion trend. According to the latest industry data, the global solid-state battery market size is expected to reach US\$18 billion (approximately RMB 120 billion) by 2025, with China accounting for 48% of the global market, becoming the largest single market and exceeding RMB 57 billion in size.

The core growth drivers come from three major areas: Firstly, new energy vehicles, where the demand for solid-state batteries in the electric vehicle sector is expected to exceed 30GWh by 2025, accounting for 70% of the overall demand, and the penetration rate of high-end models will exceed 15%. Secondly, the low-altitude economy, where the eVTOL aircraft market is expected to reach a scale of RMB 1.5 trillion by 2025. Solid-state batteries account for 10%–20% of aircraft costs and need to meet energy density requirements of over 300 Wh/kg. Thirdly, energy storage systems, where the global energy storage market will exceed US\$150 billion by 2025. Solid-state batteries are accelerating penetration due to their inherent safety, and three major solid-state battery energy storage projects in China have already started bidding with procurement demands exceeding 412 MWh.

Currently, development bottlenecks are focused on three aspects: cost pressure, lack of standards, and insufficient ecological collaboration. The material cost of all-solid-state batteries reaches RMB 2/Wh, which is 3–5 times that of liquid batteries. Sulfide electrolyte precious metals account for a high proportion, and large-scale cost reduction relies on industrial chain collaboration. Solid-solid interface impedance testing methods and thermal runaway evaluation systems are not yet unified, restricting product certification and market promotion. The technical routes of materials, cells, and equipment enterprises are scattered. For example, the oxide route requires special sintering equipment, which has low compatibility with existing production lines.

### **6.2. Suggestions for industrial collaboration and optimization**

Build a trinity system of “technological breakthroughs—scenario innovation—financial support”:

At the technical level, universities should strive for national special technology fund support based on their technological research and development capabilities, cooperate with mature industrial application enterprises, and jointly establish solid-state battery innovation centers. These centers should promote the rapid industrialization of scientific and technological achievements such as solid electrolytes, cathode materials, and solid-solid interface technologies. Additionally, they should reduce usage costs through production equipment improvements, production efficiency enhancements, and yield improvements.

At the scenario level, through policy guidance, implement solid-state battery application demonstration projects in emerging fields such as new energy vehicles, energy storage systems, and the low-altitude economy. This will provide a transformation platform for product applications from experimentation to mature mass production, driving the growth of market demand.



At the financial level, utilize ultra-long-term special national debt to provide investment subsidies for various stages of solid-state battery technology breakthroughs, from research and development to mass production (such as the 2025 national special policy). Establish risk compensation funds to share the research and development risks of start-up enterprises.

To build an industrial ecological alliance, form a “material-cell-automobile enterprise-equipment” consortium to promote the localization of core equipment. Provide targeted support for key equipment such as coating machines and hot press forming equipment in battery material production to achieve localization and replacement. Take the lead in formulating safety testing (such as needle puncture and thermal runaway) and cycle life evaluation standards for solid-state batteries, promote the internationalization of Chinese solutions, and establish international standard discourse power.

## 7. Summary and outlook

The iteration of solid-state battery technology is not only a revolution in the field of energy storage but also a vivid practice of new productive forces in green manufacturing. Through deep collaboration between government, industry, academia, research, and application, China has made breakthrough progress in key areas such as solid electrolyte research and development, mass production, and high-energy-density cell development. This provides solid support for the lightweight, high-safety, and low-carbon development of green energy equipment in the manufacturing industry. With continuous technological breakthroughs in the battery industry in recent years and the accelerating industrialization of solid-state batteries, it is necessary to further strengthen the closed-loop ecological construction of “material innovation—equipment upgrading—scene application” and transform technological advantages into market competitiveness.

There are two issues that need to be addressed in the collaborative development of the battery industry chain in the future. Firstly, the technical barriers for electrolytes in solid-state batteries are high, and upstream manufacturers producing all-solid-state electrolytes have strong bargaining power. Balancing innovation incentives and the efficiency of industrial chain cooperation is key to the healthy and benign development of the industry. Secondly, different technical routes for solid electrolytes and cathode materials have flourished in recent years. Grasping the direction of future technological maturity and achieving industrial breakthroughs pose significant opportunities and challenges for equipment manufacturing enterprises that are preparing to enter the market. As Academician Ouyang Minggao said, “The market share of all-solid-state batteries does not need to reach 50%. Replacing just 1% is a breakthrough significance”<sup>[5]</sup>. This process will not only reshape the energy industry landscape but also provide a replicable collaborative innovation paradigm for the green transformation of the manufacturing industry.

## Disclosure statement

The author declares no conflict of interest.

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# The Integration and Innovation of Hainan's Intangible Cultural Heritage Inheritance in the Construction of Vocational Undergraduate Art Design Specialty under the Background of Free Trade Port

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**Abstract:** As the construction of the Hainan Free Trade Port advances, the cultural sector is facing new opportunities and challenges. Hainan's intangible cultural heritage (ICH), a treasure of local culture, is rich in unique artistic value and cultural significance, making its preservation and innovation crucial. This article focuses on the development of distinctive undergraduate art design programs, exploring the integration and innovation pathways of Hainan's ICH within these programs. By analyzing the current integration of Hainan's ICH with art design, the article identifies existing issues and proposes targeted innovative strategies, including curriculum development, teaching method reform, practical platform establishment, and faculty team building. The aim is to cultivate high-quality professionals who possess both artistic design skills and an awareness of ICH inheritance and innovation, thereby providing strong support for the development of Hainan's ICH and the cultural development of the free trade port, achieving a harmonious advancement of culture and education.

**Keywords:** Hainan intangible cultural heritage; Vocational undergraduate; Art design; Integrated innovation

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## 1. Introduction

The development of the Hainan Free Trade Port is a significant national strategic initiative. While the economy and trade are rapidly growing, enhancing cultural soft power is equally important. Hainan's intangible cultural heritage (ICH) embodies the historical memories, life wisdom, and aesthetic tastes of the people from various ethnic groups in the region, serving as a vital symbol of Hainan's culture. As an essential part of higher education, vocational undergraduate education aims to cultivate applied and skilled professionals<sup>[1-2]</sup>. Integrating the inheritance of

Hainan's ICH into the distinctive construction of art design programs at the vocational undergraduate level not only enriches the content of art design education and enhances students' cultural literacy and innovation capabilities but also opens new avenues for the protection and inheritance of Hainan's ICH. This initiative promotes the development of Hainan's cultural industry and supports the cultural development of the free trade port <sup>[3-4]</sup>.

## **2. The unique value and artistic characteristics of Hainan's intangible cultural heritage**

### **2.1. Diversity of intangible cultural heritage in Hainan**

Hainan's intangible cultural heritage spans a wide range of fields, including traditional crafts, music and dance, drama, and folk customs. In the realm of traditional crafts, the Li ethnic group is renowned for its intricate spinning, dyeing, weaving, and embroidery techniques, each step reflecting the wisdom and creativity of the Li people <sup>[5]</sup>. The Miao ethnic group's traditional embroidery and batik techniques are also distinctive, showcasing their unique patterns and exquisite craftsmanship <sup>[6]</sup>. Traditional music and dance include Danzhou Tiaosheng, known for its lively rhythms and unique song contest format, which reflects the life and emotions of the people in the Danzhou region <sup>[7]</sup>. The Li ethnic group's Chai Dance is rich in ethnic flavor, symbolizing the harmonious coexistence of the Li people with nature <sup>[8]</sup>. In terms of traditional drama, Qiong Opera, the main form of drama in Hainan, blends the local dialect, music, and folk stories, offering a unique artistic charm. Among the traditional folk customs, the March 3rd Festival of the Li and Miao ethnic groups is a significant event for the minority communities in Hainan, featuring a variety of activities such as sacrifices, song contests, and dances, which help to preserve and promote ethnic culture <sup>[9]</sup>.

### **2.2. Artistic characteristics**

Hainan's intangible cultural heritage (ICH) is characterized by distinct regional features and ethnic styles. In terms of patterns, it often incorporates natural elements such as marine life and tropical plants, highlighting Hainan's unique natural environment. In terms of color, Li ethnic brocade predominantly uses vibrant colors like red, yellow, and blue, creating a striking contrast that is visually impactful <sup>[10]</sup>. Miao embroidery and batik, on the other hand, primarily use blue and white, reflecting the Miao people's appreciation for nature with a fresh and elegant style. In terms of design, Hainan's ICH works emphasize the integration of practicality and artistry <sup>[11]</sup>. For example, the Li boat-shaped house construction technique not only meets living needs but also embodies the Li people's migration history and cultural significance through its distinctive boat shape. In terms of craftsmanship, Hainan's ICH is renowned for its exquisite and delicate workmanship. For instance, Hainan coconut carving transforms ordinary coconut shells into exquisite artworks through techniques such as carving and inlaying <sup>[12-13]</sup>.

## **3. The goal and demand of the construction of characteristics of vocational undergraduate art design majors**

### **3.1. Training objectives**

The vocational bachelor's degree in art design is designed to cultivate well-rounded individuals who excel in moral, intellectual, physical, aesthetic, and labor aspects. Graduates will have a solid foundation in art design theory and practical skills, along with innovative capabilities and a craftsman's spirit. They will be capable of engaging in design, production, and management roles in the art design field <sup>[14]</sup>. Students should master the fundamental principles and methods of art design, be proficient in using various design software and tools, and

possess strong creative expression and aesthetic abilities. Additionally, they should demonstrate good professional ethics and teamwork, and be adaptable to the demands of social and economic development and industry changes <sup>[15]</sup>.

### **3.2. Industry demand**

With the rapid development of the cultural and creative industry, the demand for talent in the art design sector is becoming more diverse and sophisticated. On one hand, companies need innovative and practical design professionals who can create products and works that are competitive in the market <sup>[16]</sup>. On the other hand, there is a growing demand for individuals with cultural heritage and an innovative spirit. In the context of the Hainan Free Trade Port, industries such as cultural tourism and the development of distinctive cultural and creative products are thriving. There is a significant need for professionals who can integrate local Hainan cultural elements into their designs, thereby infusing new vitality into the industry <sup>[17]</sup>.

## **4. Analysis of the integration of Hainan's intangible cultural heritage inheritance and vocational undergraduate art design majors**

### **4.1. Practice exploration of integration**

Currently, some vocational undergraduate institutions in Hainan have started to integrate Hainan's intangible cultural heritage (ICH) with art design programs. In terms of curriculum, these institutions offer elective courses related to Hainan's ICH, such as Li ethnic group brocade weaving and Hainan coconut carving, to help students understand and learn about the basic knowledge and skills of Hainan's ICH. In teaching practice, teachers guide students to incorporate elements of Hainan's ICH into their design projects and competitions. For example, they organize students to design cultural and creative products themed around Hainan's ICH and participate in various design competitions, achieving notable results. Additionally, some institutions collaborate with ICH inheritors and enterprises to establish internship and training bases, providing practical opportunities for students to engage closely with and learn from ICH techniques <sup>[18]</sup>.

### **4.2. Existing problems**

Despite some achievements, numerous challenges remain in the integration process. Firstly, the curriculum system is incomplete and lacks systematicness and coherence. Most existing intangible cultural heritage (ICH) courses are elective, with limited class hours, failing to form a comprehensive curriculum that enables students to deeply study and master ICH knowledge and skills <sup>[19]</sup>. Secondly, the teaching methods are monotonous, focusing primarily on theoretical instruction, while practical teaching components are weak, leaving students without opportunities for hands-on practice or innovative application. Furthermore, there is a shortage of qualified teachers, as most lack the necessary professional background and practical experience in ICH, hindering high-quality teaching and guidance. Additionally, the collaboration between schools and enterprises is not deep enough, with loose cooperation forms and a lack of long-term mechanisms, which hinders the full play of enterprises in talent development <sup>[20]</sup>.

## **5. Integration strategies of Hainan's intangible cultural heritage inheritance in the construction of characteristic professional art design majors at the vocational**

## **undergraduate level**

### **5.1. Build a curriculum system integrating Hainan's intangible cultural heritage**

#### **5.1.1. The basic curriculum integrates elements of intangible cultural heritage**

In the foundational courses of art design, such as design sketching, color composition, and plane composition, elements like patterns, colors, and shapes from Hainan's intangible cultural heritage (ICH) are integrated. By analyzing the artistic features of Hainan's ICH works, students are guided to learn and draw inspiration from these elements, thereby enhancing their understanding and appreciation of local culture. For instance, in the design sketching course, students can be assigned to sketch and create works based on Hainan coconut carving and Li brocade patterns, allowing them to gain a deeper understanding of the structural forms and line characteristics of these designs.

#### **5.1.2. Specialized courses are set up in the direction of intangible cultural heritage**

In the professional curriculum, a module on Hainan's intangible cultural heritage (ICH) inheritance and innovation is established. This includes practical training in traditional Li ethnic group spinning, dyeing, weaving, and embroidery techniques, research into traditional architectural decoration art in Hainan, and design of ICH-themed cultural and creative products. These courses emphasize practical teaching, inviting ICH inheritors or industry experts to teach, enabling students to systematically learn about ICH skills and cultural significance, and apply them to their professional designs.

#### **5.1.3. Special lectures and elective courses on intangible cultural heritage will be set up**

Regularly organize specialized lectures on Hainan's intangible cultural heritage (ICH), inviting experts, scholars, and inheritors to share insights into the historical roots, current protection status, and innovative development of Hainan's ICH, thereby broadening students' perspectives. Additionally, a variety of elective courses on ICH are offered, such as the culture and art of the Miao people in Hainan and research on the navigation routes of the South China Sea, to cater to students' individual learning needs.

### **5.2. Innovative teaching methods and means**

#### **5.2.1. Project teaching**

Using Hainan's intangible cultural heritage (ICH) projects as a platform, project-based teaching is implemented. Teachers collaborate with ICH enterprises and cultural institutions to undertake practical projects, such as designing spaces for showcasing Hainan's ICH culture and creating themed tourism souvenirs. Students are divided into project teams and, under the guidance of teachers, they complete the entire process from project research, design planning, implementation of the plan, to the final presentation. Through this project-based approach, students' practical skills, innovation, and teamwork are developed.

#### **5.2.2. Digital teaching**

Leverage modern information technology to implement digital teaching. By establishing a digital resource library for Hainan's intangible cultural heritage (ICH), we can collect and organize images, videos, and audio materials, providing rich resources for educational purposes. Additionally, by utilizing technologies such as virtual reality (VR) and augmented reality (AR), students can experience the charm of Hainan's ICH in a vivid and immersive way. For example, a virtual exhibition platform for Hainan's ICH can be developed, allowing students to visit exhibitions and learn about ICH skills anytime and anywhere via their computers or mobile phones.



### **5.2.3. Practical teaching**

Enhance practical teaching components and establish a comprehensive practical teaching system. In addition to collaborating with intangible cultural heritage (ICH) enterprises and inheritors to set up internship and training bases, students can also participate in various ICH activities, such as ICH inheritance experience sessions and cultural outreach programs. Encourage students to engage in the protection and inheritance of ICH projects, such as assisting ICH inheritors in organizing materials and recording instructional videos, thereby enhancing their understanding and ability to pass on ICH through practical experience.

## **6. Innovative path of intangible cultural heritage inheritance in the construction of characteristic professional art design majors at the vocational undergraduate level in Hainan**

### **6.1. Industry-university-research collaborative innovation**

#### **6.1.1. Establish a platform for industry-university-research cooperation**

Vocational colleges should collaborate with government departments, intangible cultural heritage (ICH) research institutions, and enterprises to establish a platform for industry-university-research cooperation. This platform aims to integrate resources from all parties and jointly conduct research and practice on the inheritance and innovation of Hainan's ICH. The platform can regularly organize academic exchanges, project seminars, and other activities to enhance communication and collaboration among the industry, university, and research sectors. For example, the School of Art and International Design at Sanya College has partnered with the Sanya Nanshan International ICH Center to host the Nanshan ICH Space Construction Festival. Through creative spatial design, this festival aims to create a unique ICH cultural experience venue, enhancing the display and experience of Hainan's ICH culture and boosting its local influence.

#### **6.1.2. Cooperation in scientific research projects**

Institutions and partner organizations can collaborate on research projects focusing on key issues of intangible cultural heritage (ICH) inheritance and innovation in Hainan. For example, they can explore innovative applications of ICH in modern design and the digital preservation and inheritance technologies for ICH in Hainan. Through these research projects, practical problems can be addressed, and the research and innovation capabilities of teachers and students can be enhanced. Additionally, the outcomes of these research projects can be transformed into practical productivity, thereby promoting the development of Hainan's ICH industry.

### **6.2. Development and marketing of cultural and creative products**

#### **6.2.1. Creative design and development**

Encourage teachers and students to draw inspiration from Hainan's intangible cultural heritage (ICH) for the creative design and development of cultural and creative products. Explore the cultural significance and artistic value of Hainan's ICH, integrating modern design concepts and market demands to create innovative, practical, and competitive cultural and creative products. For example, incorporate the Li ethnic group's brocade patterns into clothing, accessories, and home items to develop fashionable products with ethnic characteristics; design small, portable souvenirs based on Hainan coconut carving.

### **6.2.2. Marketing and marketing**

Establish effective market promotion and marketing mechanisms to introduce the developed cultural and creative products to the market. Utilize e-commerce platforms, cultural exhibitions, and tourist attractions for product display and sales. Additionally, enhance brand building by creating a Hainan-characteristic intangible cultural heritage (ICH) cultural and creative brand to boost product recognition and reputation. For example, participate in international events like the China International Consumer Goods Expo to showcase and sell Hainan's ICH cultural and creative products, thereby enhancing their global influence.

## **6.3. International exchange and cooperation**

### **6.3.1. Participate in international intangible cultural heritage exchange activities**

Encourage vocational colleges and their faculty and students to actively participate in international intangible cultural heritage (ICH) exchange activities, such as those organized by UNESCO and the International ICH Forum. By participating in these events, they can showcase the unique charm of Hainan's ICH, learn from advanced international practices in ICH protection and inheritance, and enhance the international recognition and influence of Hainan's ICH.

### **6.3.2. Carry out international cooperation projects**

Collaborate with international universities and cultural institutions to jointly conduct research, teaching, and the inheritance of Hainan's intangible cultural heritage. For example, co-develop courses related to intangible cultural heritage with foreign universities, organize student exchange programs, and promote cultural exchange and integration. Additionally, introduce advanced design concepts and technologies from abroad to provide new ideas and methods for the innovative development of Hainan's intangible cultural heritage.

## **7. Building a faculty team**

### **7.1. Cultivate the intangible cultural heritage literacy of teachers in schools**

Regularly organize art and design faculty members to attend intangible cultural heritage (ICH) training courses and academic seminars, inviting ICH experts and practitioners to teach and provide guidance. Encourage teachers to conduct in-depth research on Hainan's ICH, engage in relevant scientific research projects, and implement teaching reforms. For example, select teachers for internships at ICH heritage bases to learn from the skills and experiences of ICH practitioners, thereby enhancing their practical skills and teaching abilities.

### **7.2. Introduction of professional talents in intangible cultural heritage**

Actively recruit talents with expertise in intangible cultural heritage (ICH) and practical experience to strengthen the teaching staff. Hire ICH inheritors and scholars as full-time or part-time teachers to provide students with more professional guidance. Additionally, establish ICH master studios, inviting ICH masters to the school to conduct teaching, research, and creative activities, thereby fostering students' craftsmanship and innovation.

## **8. Conclusion**

Integrating the inheritance of Hainan's intangible cultural heritage (ICH) into the distinctive construction of vocational undergraduate art design programs is a significant step to meet the demands of the times and promote

cultural innovation. By developing a curriculum that integrates Hainan's ICH, innovating teaching methods, exploring collaborative innovation pathways among industry, academia, and research, enhancing the development and market promotion of cultural and creative products, and engaging in international exchanges and cooperation, people can cultivate art design professionals with innovative capabilities and a deep cultural foundation. This will provide robust talent support and intellectual backing for the protection and inheritance of Hainan's ICH, the development of the cultural industry, and the cultural development of the free trade port. In future development, it is essential to continuously summarize experiences and advance integration and innovation efforts, ensuring that Hainan's ICH thrives and remains vibrant in vocational undergraduate art design education.

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## Disclosure statement

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# Research on the International Promotion of Acupuncture Based on Health Economics

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**Abstract:** This study explores international promotion strategies for acupuncture from a health economics perspective, aiming to provide both theoretical support and practical pathways for its global dissemination. As a key component of Traditional Chinese Medicine (TCM), acupuncture has gained increasing global recognition due to its simplicity, affordability, effectiveness, and safety. With the advancement of initiatives such as “Healthy China” and the One Belt One Road Initiative, acupuncture has played a leading role in TCM’s international outreach. Research indicates that acupuncture offers notable cost-effectiveness across various diseases and shows considerable potential in cost-utility. However, its international promotion still faces challenges, including insufficient economic evidence, legal and policy barriers, limited insurance coverage, lack of standardized practices, and cultural differences. To address these issues, this study recommends enhancing the quality of health economic evaluations, prioritizing high-burden diseases, increasing localized research in target countries, and strengthening international collaboration, with the goal of achieving high-quality global integration of acupuncture.

**Keywords:** Acupuncture; Traditional Chinese Medicine; Health economics

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## 1. Introduction

As an important component of TCM, acupuncture is a traditional therapeutic method that involves inserting fine needles into specific acupoints on the human body to regulate qi and blood, unblock meridians, and restore the balance of yin and yang, thereby achieving the goals of disease prevention and treatment. As early as the Jin and Southern-Northern Dynasties, acupuncture began to spread beyond China, gradually reaching East Asia, Europe, and the Americas through multiple historical stages, ultimately forming a diverse pattern of international dissemination <sup>[1]</sup>. With the ongoing implementation of the “Healthy China 2030” strategy and the One Belt One Road Initiative, the internationalization of TCM has become a key national agenda <sup>[2]</sup>. Due to its simplicity, safety, and cost-effectiveness, acupuncture has become a leading force in the global promotion of TCM <sup>[3]</sup>. However, its international dissemination still faces significant challenges, including insufficient evidence from evidence-based medicine, lack of standardized service protocols, and underdeveloped policy and regulatory frameworks <sup>[4-5]</sup>.



Health economics is an interdisciplinary field that studies the efficiency of medical resource allocation and the relationship between cost control and health outcomes<sup>[6]</sup>. Conducting health economic evaluations of acupuncture not only helps to objectively and comprehensively reveal its advantages in cost control and economic benefits, but also provides strong evidence for government decision-makers in developing clinical guidelines, adjusting health policies, conducting program evaluations, and optimizing clinical decision-making, thereby offering a theoretical foundation for promoting its international dissemination and policy support<sup>[7–8]</sup>. This review aims to systematically examine the economic value of acupuncture from the perspective of health economics, analyze the barriers to its international promotion, and propose feasible strategies, with the goal of providing theoretical support and policy recommendations for the internationalization of acupuncture.

## **2. The health economics value of acupuncture**

Health economics evaluation is a method that systematically analyzes the relationship between the input of health resources (i.e., costs) and the output (including effects, benefits, or utilities)<sup>[6]</sup>. Its value in the field of acupuncture is primarily reflected in the following two aspects.

### **2.1. Prominent cost-effectiveness advantage**

Acupuncture has demonstrated significant advantages in health economics across various disease areas, primarily through its superior cost-effectiveness characterized by “high efficacy and low cost.”

First, clinical studies consistently show that acupuncture combined with other treatments is not only more effective but also less costly than conventional therapies. For example, Wang et al. found that massage combined with auricular magnetic therapy was superior to massage alone in treating cervical spondylotic radiculopathy, with a higher cure rate (42.9% vs. 17.6%) and lower per-treatment cost (CNY 3,324.46 vs. CNY 4,016.86)<sup>[9]</sup>. Similarly, Shi et al. reported that a combination of traditional Chinese acupuncture and herbal medicine achieved a 91.1% cure rate for the common cold—much higher than the 79.8% in the conventional treatment group—at a significantly lower cost (CNY 128.58 vs. CNY 367.77), highlighting a superior cost per effective outcome<sup>[10]</sup>.

Second, some specialized acupuncture techniques have shown better efficacy and lower costs compared to traditional methods. For instance, the Xingnao Kaiqiao (brain-awakening) technique was found to be more effective in improving neurological function and quality of life in stroke patients, with a lower cost per unit of effectiveness, saving CNY 813.84 for every one-point reduction in the Clinical Stroke Scale (CSS) score<sup>[11]</sup>.

Third, acupuncture offers long-term benefits in chronic disease rehabilitation, demonstrating favorable long-term cost-effectiveness. A study on ischemic stroke patients found that although the initial cost of acupuncture was slightly higher, the effective rate significantly increased after three months (92.0% vs. 74.7%), resulting in a lower cost per effective outcome and a better long-term cost-benefit ratio<sup>[12]</sup>.

Finally, a systematic review and network meta-analysis by Zhao et al. indicated that various acupuncture techniques, such as fire needling, warm needling, and moxibustion, were more effective than pharmacological treatments for peripheral neuropathic pain, with more favorable incremental cost-effectiveness ratios<sup>[13]</sup>. Among them, fire needling showed the most outstanding cost-effectiveness.

### **2.2. Significant potential for cost-utility advantage**

In China, health economic evaluations in the field of acupuncture have largely focused on cost-effectiveness analysis (CEA)<sup>[14]</sup>. However, relying solely on CEA is insufficient to fully capture the multidimensional

therapeutic value of acupuncture. CEA primarily compares quantitative clinical indicators, such as symptom relief, but fails to encompass improvements in patients' quality of life<sup>[15]</sup>. As a therapeutic modality that modulates the neuro–endocrine–immune systems with multifaceted mechanisms and layered efficacy, acupuncture often demonstrates its strengths in enhancing quality of life, alleviating chronic symptoms, and improving overall functional status<sup>[16]</sup>. These benefits are not adequately reflected in CEA.

Therefore, there is a need to incorporate methods such as cost-utility analysis (CUA) and cost-benefit analysis (CBA), which translate treatment outcomes into comprehensive indicators like quality-adjusted life years (QALYs) or disability-adjusted life years (DALYs), providing a more accurate assessment of the overall value of acupuncture interventions. For example, Oberoi et al. conducted a CUA on 74 cancer patients and found that the cost per QALY gained in the acupuncture group was \$1,265—well below the commonly accepted societal threshold of \$35,628<sup>[17]</sup>. Similarly, a study by Skonnord et al. involving 171 patients with acute low back pain also supported the high cost-utility of acupuncture<sup>[18]</sup>. These findings indicate that acupuncture has already demonstrated promising results in CUA evaluations. With further support from high-quality studies, its potential in health economics is expected to become even more prominent.

### **3. Barriers to the international promotion of acupuncture**

Acupuncture has gained increasing recognition and promotion globally in recent years. According to the World Health Organization's statistics, 113 member countries are using acupuncture as a diagnostic and therapeutic method, 29 member countries have established relevant laws and regulations for its application, and 20 member countries have included acupuncture in their healthcare reimbursement systems<sup>[19]</sup>. Despite this, its international promotion still faces numerous challenges.

#### **3.1. Institutional barriers and evidence dilemmas in international promotion**

Currently, acupuncture faces multiple institutional barriers in its international promotion, which are interwoven and mutually reinforcing, limiting its effective integration into global healthcare systems. Specifically, most countries have not incorporated acupuncture into their health insurance schemes; its legal status remains ambiguous, technical and service standards are lacking, and it has yet to be included in mainstream international clinical guidelines<sup>[4, 5, 20]</sup>.

Limited insurance coverage remains a major constraint on accessibility and affordability. For instance, in Egypt, acupuncture is not included in the national healthcare system, and treatment costs are not reimbursed, which significantly hinders its adoption<sup>[4]</sup>. In the United States, although some commercial insurance plans reimburse acupuncture, it remains excluded from both federal and state government insurance programs, reflecting its marginal position in mainstream healthcare coverage<sup>[20]</sup>. In contrast, while acupuncture is reimbursed under Germany's national health insurance, the coverage is limited to specific conditions and restricted in the number of sessions allowed<sup>[21]</sup>.

Legal recognition of acupuncture varies widely across countries, raising concerns about market uncertainty. In the United States, legality is determined at the state level: 44 states have enacted laws recognizing TCM and offer licensure for acupuncture practitioners; 4 states allow acupuncture under the supervision or recommendation of a medical doctor; and in Wyoming, acupuncture is still not legally recognized<sup>[22]</sup>.

One major reason acupuncture lacks broad policy support is the insufficient availability of high-quality health

economic evidence<sup>[5]</sup>. According to Li et al., existing economic evaluations of acupuncture often suffer from weak research designs, inadequate control of confounding variables, a lack of long-term outcome data, poor reporting quality, and limited alignment with real-world policy-making contexts<sup>[23]</sup>. Moreover, the lack of consistency in acupoint selection, needling techniques, and control group design leads to heterogeneity in efficacy studies, making it difficult to demonstrate acupuncture's superiority over pharmacological treatments and reducing the comparability and persuasiveness of economic evaluations<sup>[24-25]</sup>. Zeng et al., further highlight that the scarcity of survival and quality-of-life data, as well as the cost variability across regions, also contributes to the low homogeneity and limited publication of health economic assessments of acupuncture<sup>[5]</sup>.

### **3.2. Language and cultural barriers**

Language barriers hinder the accurate translation and understanding of TCM terminology by the international community, thereby impeding the dissemination of its core concepts<sup>[4]</sup>. Culturally, Western medicine emphasizes standardization and precision, which makes it difficult to accept non-standardized concepts in acupuncture such as the Eight Principles, Qi and Blood, Yin-Yang theory, Zang-Fu differentiation, and meridian theory<sup>[26]</sup>. As a result, some Western acupuncture practitioners have abandoned traditional meridian and acupoint theories, advocating instead for dry needling techniques grounded in anatomy and pathophysiology, to align with Western diagnostic and therapeutic standards<sup>[25]</sup>. In the United States, more than 20 states currently allow physical therapists to perform dry needling<sup>[27]</sup>. These developments illustrate that language and cultural barriers not only obstruct the global promotion of acupuncture but also pose challenges to traditional Chinese acupuncture theories, potentially even leading to their replacement.

## **4. Strategies for international promotion of acupuncture based on health economics**

### **4.1. Increase high-quality health economics analyses of acupuncture**

Enhancing the scientific rigor of research design remains a key priority. It is recommended to prioritize multicenter, large-sample randomized controlled trials (RCTs) to improve methodological robustness. Greater attention may also be given to accounting for confounding factors such as patients' underlying conditions and concurrent therapies. Including long-term follow-up in study protocols could facilitate a more comprehensive evaluation of acupuncture's sustained efficacy and potential cost-effectiveness, particularly in the context of chronic disease management. Research reporting is advised to follow international guidelines, such as the Consolidated Health Economic Evaluation Reporting Standards (CHEERS), to enhance transparency and reproducibility. Moreover, careful consideration should be given to the design of control groups, including comparisons with placebo or standard care, to more accurately assess the incremental effects of acupuncture.

### **4.2. Focus on key disease research**

Although acupuncture has a broad range of indications, prioritizing in-depth research on certain global high-burden diseases or conditions with poor cost-effectiveness of existing treatments may help more rapidly demonstrate its unique value. For instance, chronic pain, neurological disorders, and mental health conditions such as anxiety and depression are often associated with prolonged disease duration, high recurrence rates, substantial healthcare costs, and conventional treatments that may involve considerable side effects or limited efficacy<sup>[28-29]</sup>.

### 4.3. Increase localization research in target countries

Given the significant differences among countries in disease patterns, healthcare resource pricing, insurance reimbursement mechanisms, and cultural acceptance, directly applying findings from domestic Chinese studies often lacks persuasiveness. Therefore, it is advisable to encourage collaborations with local healthcare institutions, universities, or research centers in target countries to conduct data collection and economic evaluations based on local clinical practice. These efforts could yield region-specific cost-effectiveness, cost-utility, and budget impact analyses. Establishing a comprehensive acupuncture database that systematically collects data on clinical outcomes, adverse events, and resource utilization—along with the use of health-related quality of life instruments such as EQ-5D or SF-36—would provide strong support for cost-utility assessments. To reduce heterogeneity across studies, it is also recommended to promote the standardization of acupuncture procedures, including unified acupoint selection, stimulation intensity, needle retention time, and treatment duration.

## 5. Conclusion

Acupuncture, with its distinctive health economic characteristics, demonstrates substantial value and potential within global healthcare systems. This study, from the perspective of health economics, systematically analyzes the economic value of acupuncture, its current status, and challenges in international dissemination, and proposes targeted strategies for global promotion. The findings indicate that acupuncture offers significant cost-effectiveness advantages, particularly in chronic disease management, pain relief, and rehabilitation, delivering both health and economic benefits. Several countries and regions have already integrated acupuncture into their health insurance systems, laying a foundation for broader international adoption. However, further globalization of acupuncture faces critical challenges, including insufficient health economic evidence, legal and policy constraints, limited insurance coverage, lack of standardized practices, and cultural misunderstandings. From a health economics evaluation standpoint, it is recommended that future research place greater emphasis on high-quality economic analyses of acupuncture, focus on high-burden diseases, conduct localized studies in target countries, and strengthen international collaborations, ultimately aiming to achieve high-quality global dissemination of acupuncture.

## Disclosure statement

The authors declare no conflict of interest.

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# Product Design for Instant Stress Relief: A Study on Fragmented Scenes for High-pressure Groups

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**Abstract:** Increasingly severe fragmented stress problems. Through systematic analysis, this study finds that such stress has three major characteristics: high frequency, instantaneity, and contextualization. The causes mainly come from the fast-paced workplace culture, the “always online” mode of smart devices, and individuals’ procrastination coping strategies. Research shows that 92% of urban residents will spontaneously take stress-relieving actions within 3 minutes after stress occurs, presenting a behavioral pattern of “immediate relief — quick switch — minimum cost.” Based on this, this paper proposes a complete set of stress-relief product design strategies. First, achieve psychological regulation through multi-sensory feedback; second, adopt the design principles of simplicity and contextualization; and finally, develop intelligent stress-relief products with a three-level feedback system. Empirical data from the MIT Media Lab show that such products can increase the efficiency of emotional release by 40%, effectively meeting the immediate stress-relief needs of modern people in fragmented scenarios. This study provides a theoretical basis and practical guidance for the design of stress management products.

**Keywords:** Timely stress relief; Stress-relief products; Product design; Interactive experience

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## 1. Introduction

With the acceleration of digital transformation, the Chinese Academy of Social Sciences mentioned in 2023 that the number of stressful events faced by Chinese workplace populations per week has surged from 3.2 in 2019 to 8.7 in 2023. The cumulative effect of this “micro-stress” has led to persistent anxiety symptoms in 75% of respondents. Traditional stress relief products, with slow response times averaging 15 minutes to take effect and poor scene adaptability, have become inadequate to meet modern needs. Based on stress cognitive evaluation theory and emotional design framework, this study proposes the “3E” design principles for instant stress relief products: Effective (rapid onset), Embedded (scene embedding), and Emotional (emotional connection), verifying their effectiveness through biofeedback experiments. According to 2023 World Health Organization data, approximately 70% of the global workplace population experiences cumulative “micro-stress” issues. The Chinese

Psychological Association’s “2024 White Paper on Urban Stress” indicates that 92% of respondents require instant stress relief solutions within 5 minutes. Therefore, there is a growing need for portable products that alleviate stress, which can create an emotion that helps reduce stress and promote a harmonious atmosphere.

## 2. Analysis of instant stress relief needs and scenes for high-pressure groups

### 2.1. Background and characteristics of fragmented stress formation in high-pressure groups

Modern populations face fragmented stress, making it difficult to effectively release emotions. Fragmented stress in high-pressure groups exhibits three distinct characteristics: high frequency, instantaneity, and contextualization. This type of stress demonstrates high-frequency outbreaks. According to Li Min et al.’s 2023 study in “Acta Psychologica Sinica”, Chinese workplace populations experience an average of 7.2 micro-stress events per day <sup>[1]</sup>. A 2022 study by Smith et al. revealed that urban workplace populations encounter an average of 5–8 short-lived stress events daily, forming a unique “pulsed” stress pattern. However, each stress event lasts for a short duration, typically under 10 minutes (**Figure 1**). The Chinese Psychological Association proposed in 2023 that 67% of stress events last less than 5 minutes <sup>[2]</sup>. It is worth noting that this type of stress has a strong situational dependence, often deeply tied to specific scenarios such as task interruptions at work, crowded commuting environments, or temporary meeting notices. This fragmented stress pattern reflects that stress sources in modern work life originate from dispersed stress points, rather than single significant events, requiring targeted instant intervention measures.

The causes of fragmented stress in high-pressure groups can be analyzed from three dimensions: social, technological, and individual. At the social level, the fast-paced modern workplace culture has led to task fragmentation. Multifaceted and multilevel work results in dispersed stress, such as the performance-oriented management style that keeps workers in a continuous low-intensity stress state. On the technological front, work has transformed into an “always-on” mode with the widespread adoption of intelligence. Instant messaging tools contribute to the fragmentation of attention among workgroups. For instance, a sudden work assignment from a superior after work hours can trigger negative emotional stress. At the individual level, procrastination has become the norm among modern populations. Adopting passive coping strategies against stress sources leads to the accumulation of short-term stress, further exacerbating the psychological load of high-pressure groups.

In summary, fragmented stress in high-pressure groups originates from multiple sources, causing individuals to accumulate stress in various scenarios. This leads to the externalization of stress and increasing emotional repression.



**Figure 1.** Frequency and duration of pressure outbreaks (Image source: Created by the author)

### 2.2. Behavioral logic and trigger mechanism of immediate pressure relief needs

A portion of stress often originates from a few seconds and is of an immediate nature. When facing sudden stress, modern people often follow the behavioral logic of “instant emotional relief — quick emotional switching — minimal cost to achieve emotional release.” When stress hits suddenly, people instinctively seek quick and

effective ways to relieve it, such as deep breathing, playing small games, or taking a brief moment of emptiness. This demand is essentially an “instant gratification” for emotional regulation, like pressing the pause button for tense nerves. At the same time, effective stress relief behavior must seamlessly connect with the current scene — the office requires subtle and unobtrusive methods, such as small desktop toys (**Figure 1**), which not only achieve minimal cost for emotional release but also allow emotions to be quickly relieved and switched to the corresponding state.

The trigger mechanism for immediate stress relief needs stems from the body’s automatic stress response. When exposed to external stimuli, such as sudden work instructions, interpersonal conflicts, or environmental disturbances, it prompts the rapid secretion of adrenaline, leading to physiological changes like accelerated heartbeat and muscle tension. If this stress state is not relieved in a timely manner, it will continuously consume psychological energy. According to a 2023 behavioral psychology report, 92% of city dwellers spontaneously initiate some form of stress relief behavior within 3 minutes of feeling stressed. This trigger-relief loop is characterized by immediacy, contextuality, and personalization, providing an important basis for the design of stress relief products.

As a result, there is a growing demand for timely stress relief, requiring short-term measures to alleviate negative emotions, meet the psychological compensation of different groups, release pent-up emotions, and achieve minimal cost for emotional release.



**Figure 1.** Small desktop stress relief toys (Image source: Internet)

### 2.3. Typical scenario extraction for fragmented scenes

Different fragmented scenes can evoke specific negative emotions. American psychologist Lazarus proposed the emotional cognition theory, which advocates that human emotions are influenced by environmental events, physiological conditions, and cognitive processes <sup>[3]</sup>. According to a 2024 cross-cultural study, 92% of repressed emotions are scene-dependent. Work break scenes can reduce people’s cognitive abilities, and multitasking can increase error rates, leading to a surge in stress and repressed emotions.

Based on various studies, let’s look at several typical scenes. Different scenarios can evoke different negative emotions in people, leading to the externalization of stress (**Table 1**).

**Table 1.** Manifestation of stress from typical scenarios (Image source: drawn by the author)

Scenario type	Typical stressors	Induced stress types
Work scenario	1. Forced work interruption 2. Drastic workload increase	1. Cognitive interruption stress 2. Task overload stress
Commuting scenario	Rush hour crowding	Loss-of-control anxiety stress
Home scenario	1. Rest interrupted 2. Poor hygiene conditions	1. Recovery obstruction stress 2. Environmental aversion stress
Social scenario	Long waiting times (e.g., restaurant queues, waiting for friends)	1. Time perception stress 2. Social expectation stress

In general, different scenarios induce different types of stress, all of which originate from negative emotions. People need a perfect outlet to vent these emotions, which can improve the quality of subsequent work and study, and also effectively alleviate mental health issues.

### 3. Design strategies for stress relief functions and product design

#### 3.1. The concept and psychological mechanism of stress relief functions

Stress relief functions help individuals release pressure and alleviate tension through specific methods. Their core purpose is to provide consumers with effective ways to release pressure, reduce physical and mental tension, and ultimately improve mental health. As Adler believed, when a person feels inferior to others, they may experience feelings of inferiority, and he also suggested that people have a motivation to seek superiority, thus compensating for feelings of inferiority<sup>[4]</sup>. Based on the above, the interactive mechanism to achieve psychological adjustment mainly involves three aspects.

Firstly, tactile feedback design is utilized to elicit a response from the skin. Experiments have confirmed that stress levels can be reduced by 25%–30%, triggering the release of serotonin in the brain. Sensory feedback is an indispensable part of the stress relief function, as it can enhance the experience and lead to emotional release.

Secondly, tool-assisted methods are employed to strengthen the sense of control. Utilizing complementary products can improve people's inner compensation mechanism, increasing dopamine secretion by 15%–20%. For example, in Hong Kong, a slipper was designed as a complementary product for stress relief toys, facilitating an immersive experience and providing higher emotional feedback.

Lastly, sound effects are incorporated to regulate emotional balance. The sound emitted by the product during interaction increases heart rate variability by 18%–22%. For instance, a product may incorporate a mechanism similar to that of a screaming chicken toy, which makes a sound when squeezed, enhancing the user experience.

In conclusion, the synergistic effect of multiple aspects makes the stress relief function an effective psychological adjustment system for coping with the pressures of modern life.

#### 3.2. Types and development of product design

Product design is a functional, aesthetic, and usable entity that integrates creativity and technology. It can be classified into various types based on different dimensions and goals. According to functional attributes, it mainly includes practical product design, which focuses on functionality (e.g., home appliances, tools), experiential product design that emphasizes user emotional interaction (e.g., smart wearable devices), and healing design with psychological adjustment functions (e.g., stress relief toys as shown in **Figure 3**).



Modern product design has evolved from being a single product to being aligned with people's psychological needs. In terms of design dimensions, it has shifted from being "function-centered" to being "human-centered", with more focus on user experience and social value. For example, healing product design incorporates local folk culture. Emotionally, precise multi-modal sensory stimulation directly affects the user's limbic system, activating a pleasant emotional response. From a social identity perspective, specific cultural symbol systems are integrated. This design strategy elevates the product beyond its practical function, making it a material carrier for users to construct their social identity and achieving a value transition from being instrumental to being symbolic.

In summary, product design is moving towards a human-centered approach. Different products offer varying functional and emotional values, providing diverse experiences to different groups of people.



**Figure 3.** Stress relief toy (Image source: Internet)

### **3.3. Core elements and methods of immediate stress relief product design**

Rapid stress relief is the core of immediate stress relief products. However, tactile, auditory, and visual multimodal feedback form the foundation of stress relief. For example, squeezing a stress relief toy activates tactile senses through tactile feedback, triggering the release of serotonin in the brain and quickly achieving stress relief. This type of product is relatively simple and direct to use, allowing users to squeeze and relax for stress relief<sup>[8]</sup>. In 2023, Nature Neuroscience proposed that specific frequencies of sound waves can stimulate nerves and relieve stress. For instance, respiratory guidance stress relief products utilize specific sound waves to stimulate the parasympathetic nervous system.

In terms of design elements, immediate stress relief products should follow the principle of simplicity. An experiment at the University of Manchester showed that simple repetitive actions reduce cortisol levels by 23% more than complex puzzle-solving tasks. Therefore, simple operational conditions can bring faster physical and mental pleasure. In terms of operational conditions, instant feedback can enhance the sense of pleasure, such as the sound effect of bubble wrap popping. When designing stress relief products, timely feedback and simple operation are more conducive to enhancing people's positive emotions. The entire process must be completed almost "unconsciously" and naturally, requiring no preparation and creating no additional burden, just like a conditioned reflex integrated into the rhythm of daily life. This low threshold and high adaptability are the core logic of immediate stress relief product design.

Therefore, when designing immediate stress relief products, attention should be paid to incorporating tactile and auditory elements. The design should also be kept simple in terms of both form and operation, facilitating faster emotional changes when people interact with the product.

## 4. Practice of designing stress relief products in immediate scenarios

### 4.1. Positioning of stress relief products in immediate scenarios

In immediate scenarios, stress relief products should closely align with users' needs for emotional catharsis and instant gratification. Through interactive, fun, portable, and low-threshold designs, these products provide a rapid stress relief experience. Zhang Wei proposed the “5-second principle”, stating that effective stress relief products should produce positive feedback within 5 seconds <sup>[6]</sup>. These designs typically adopt portable, user-friendly operations and quick feedback mechanisms. Through physical interaction or sensory stimulation, they help users achieve a relaxed state and alleviate inner anxiety in a short time <sup>[7]</sup>. Their core value lies in providing an instant emotional outlet through interactions such as hitting, destroying, or squeezing, offering both entertainment and stress relief. Unlike traditional stress relief toys, these products are portable and incorporate interactive sound effects. Using these products not only releases emotional stress but also enhances user engagement. The target audience primarily consists of high-pressure professionals, students, and young people, meeting their need for stress relief during fragmented time. By combining portability with stress relief products, they not only satisfy immediate stress relief but also become symbols that carry group emotions, achieving both product dependence and emotional release.

In summary, products that combine entertainment and immediate stress relief are more competitive in modern society. They allow consumers to timely vent their dissatisfaction with life and things and engage in cathartic behaviors, thereby alleviating negative emotions.

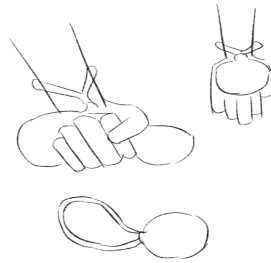
### 4.2. Transforming timely decompression products in fragmented scenarios

Modern psychological research has shown that high-pressure environments are more likely to quickly trigger negative emotions such as anxiety and depression, and decompression products can provide instant emotional regulation through physical or virtual interactions. According to a 2022 survey by the American Psychological Association, 85% of people under high pressure tend to relieve stress through “destructive behaviors” such as hitting and squeezing. These behaviors can stimulate the brain to release dopamine and temporarily inhibit the secretion of stress hormones. Targeting the sources of stress for high-pressure individuals in fragmented scenarios, transforming products into attacks on tangible objects aligns with the psychological theory of displacement aggression, where consumers project real-life stress onto manipulable objects, avoiding real interpersonal conflicts. Therefore, decompression products not only satisfy the need for timely emotional release but also enhance the psychological healing effect through specific actions, such as squeezing an object to release emotional pressure when stress increases.

In terms of design transformation, the portable spherical design allows the source of stress to be tangibly represented anytime and anywhere, aligning with the theory of metaphorical concretization in cognitive psychology and improving the efficiency of emotional transfer. Adopting a simplified spherical shape, the design aims to be easily carried by various groups. The outer layer utilizes a soft, rubbery material that ensures it can be hit, squeezed, and kneaded while also possessing slow resilience. By adding a perfectly adhesive material, hanging rope to the top of the product, consumers can use the rope to relieve stress through squeezing and hitting behaviors in different fragmented scenarios where stress is externally manifested (**Figure 4**). This can increase consumers' pleasure during interaction with the product, utilizing the product's reversible “destruction-restoration” mechanism to allow users to experience a sense of control within a safe range, avoiding real violent tendencies. Additionally, a built-in pressure sensor can trigger sound effects or vibration feedback in a timely manner when hit, enhancing the sense of catharsis.

Based on previous theoretical research and practical validation, a three-stage closed-loop design framework

of “perception-feedback-regulation” has been constructed. This framework integrates the pressure perception layer with a multi-modal signal acquisition system, the intelligent feedback layer with a dynamic response algorithm engine, and the emotional regulation layer with a multi-sensory collaborative output mechanism. By combining timeliness and portability, decompression products form a three-tier progressive relationship of “external manifestation of stress — behavioral hitting — stress catharsis.” The combination of specific characters, objects, and products more closely aligns with the objects consumers want to vent their emotions on, enabling them to immerse themselves more deeply in the hitting behavior and thereby release their pent-up emotions.



**Figure 4.** Squeezed State (Source: Drawn by the author)

### 4.3. Interactive experience design for stress relief products in immediate scenarios

Interactive experiences in product design allow consumers to quickly grasp the product’s design philosophy in timely scenarios, enabling immersive product usage and maximizing the effectiveness of the product’s functionality. In interactive experience design, focus is placed on the interactive experience between the consumer and the product to create a user-friendly, easy-to-use, and satisfying interactive experience <sup>[8]</sup>. Additionally, interaction is utilized to enhance emotional venting efficiency.

The product utilizes a non-Newtonian fluid material to achieve a dynamic touch sensation of “hardening upon impact — softening upon holding.” This material can instantaneously harden when subjected to rapid impact and maintain its softness under slow pressure. According to MIT Media Lab data, this body-sensing consistency design can increase emotional venting efficiency by 40%.

To enhance this physical interaction experience, the product specially includes an erasable pen that allows users to write down the names of people they want to vent against or things they are dissatisfied with, maximizing emotional pressure release. Johnson confirmed in 2022 that multimodal feedback is 35% more efficient than single modal feedback <sup>[9]</sup>. A carefully calibrated operational feedback system constructs a three-tiered interactive relationship: The first level is regular tapping, triggering low-frequency vibrations paired with low groans of “ouch.” The second level involves slightly harder hits, causing high-frequency vibrations accompanied by pleading screams. The third level, a full-force hit, elicits a combined feedback including powerful vibrations and stereo sound effects simulating bone crushing. This graded reinforcement mechanism strictly follows Skinner’s operant conditioning theory, maintaining consumer engagement through a variable ratio reinforcement schedule. Neuroscientific research confirms that when the correlation coefficient between force and feedback is above 0.8, it effectively activates the brain’s reward circuitry <sup>[10]</sup>. Meanwhile, the product innovatively incorporates a “traumatic memory” function, utilizing thermosensitive ink technology. Each heavy hit temporarily leaves a red indentation on the material’s surface. This visual feedback not only satisfies the need for venting but also avoids

the psychological burden of permanent damage.

The above demonstrates that effective interactive experience design can continuously enhance consumers' positive emotions. Maintaining engagement through gradual progression at different levels, using a combination of touch, hearing, and vision, satisfies consumers' emotional venting needs.

## 5. Conclusion

This study systematically explores the characteristics of fragmented stress among high-pressure groups and their need for stress relief, proposing a complete framework for immediate stress relief product design. Analysis reveals that the fast-paced lifestyle of modern society has led to a unique “pulse-like stress pattern”, requiring stress relief products to possess features such as rapid response, scene adaptation, and multi-sensory collaboration. Based on Adler's compensation theory and Lazarus's emotional cognition theory, people have developed a smart stress relief product with a three-level feedback system. Utilizing innovative technologies like non-Newtonian fluid material and thermosensitive ink, it achieves a complete closed loop of “stress manifestation — behavioral tapping — stress relief.” The three-level feedback system improves efficiency by 40%. Research confirms that this design effectively activates the brain's reward circuitry, enhancing emotional venting efficiency by 40%.

## Disclosure statement

The author declares no conflict of interest.

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# Research on the Restructuring of the Visual Communication Design Curriculum System Driven by Management Principles

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**Abstract:** Against the backdrop of accelerating global digital transformation, Visual Communication Design (VCD), as an interdisciplinary field involving creativity, technology, market dynamics, and other factors, is undergoing unprecedented change. Particularly with the rapid development of internet technology and the widespread adoption of new media, the industry demands increasingly higher comprehensive competencies from design professionals. In the modern business environment, entities like advertising agencies and internet companies place greater emphasis on user experience. Industry demand has shifted from purely aesthetic output towards strategically driven solutions. However, traditional VCD curricula predominantly emphasize skills and aesthetic cultivation, lacking systematic training in management thinking and capabilities. This gap results in graduates struggling to meet the industry's need for versatile talent. Therefore, exploring the integration of management principles into VCD education to construct a curriculum system that cultivates both artistic aesthetic ability and strengthens management competence and practical skills is critically important. This paper conducts an in-depth analysis of current problems in VCD education, such as the disconnect between course content and industry needs, monotonous teaching methods, and insufficient practical opportunities.

**Keywords:** Visual communication design; Curriculum system construction; Management principles

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## 1. Introduction

As the global economy transitions towards knowledge-based and experience-driven models, the creative industries have become a core driving force for national strategic emerging industries. Visual Communication Design, as a crucial pillar of the creative industries, is undergoing a profound transformation in its value proposition<sup>[1]</sup>. Firstly, domestic industrial upgrading is driving a shift in the role of design. Design services are evolving from traditional “visual beautification” towards “strategically driven solutions.” Designers are now required to participate in the entire decision-making process, including brand positioning, user research, and market strategy. Industry expectations for design outcomes have expanded beyond mere aesthetic value to encompass commercial value conversion (e.g.,



user growth, brand premium, user experience optimization), necessitating designers to possess business acumen and resource integration capabilities. Secondly, the design service model is transforming towards user-centricity. Large-scale cross-media communication and digital interaction projects require coordination among development, marketing, supply chain, and other resources, compelling designers to assume a “project manager” role <sup>[2]</sup>. Remote team collaboration and cross-cultural communication have become the norm, placing higher demands on designers’ team management and communication efficiency. Industry research indicates a severe “competency gap” among VCD professionals, with a lack of management literacy emerging as a key bottleneck hindering career development.

The current VCD talent cultivation system fails to meet contemporary demands. Professional courses primarily focus on technical skills training (software operation, visual expression) and aesthetic education, neglecting the systematic cultivation of management thinking (e.g., project workflow, resource allocation, quality control). Furthermore, practical course modules, often exemplified by studio-based or project-based contextual teaching, frequently remain at the level of simulated projects. They lack the management pressures inherent in real commercial scenarios (e.g., client negotiations, cost control, risk response), resulting in students’ management abilities not being substantially honed.

## 2. Discussion on the concept of “Master Teacher Studio”

### 2.1. Core management principles (focused on the design context)

The application of management principles within VCD is not merely an interdisciplinary fusion but a key factor in enhancing design thinking and practical capabilities. It involves integrating management concepts and principles with visual design to improve the efficiency, innovation, and impact of design projects. For instance, applying the Outcome-Based Education (OBE) concept and drawing from enterprise management theory, a highly integrated, open, and innovative curriculum system can be built through practical teaching, project-based learning, and enterprise project learning. This system cultivates students’ practical abilities, enabling them to undertake internships in real or simulated work environments, thereby accumulating valuable practical experience and enhancing employability. Furthermore, by applying Lean Production principles, designers can optimize processes, reduce waste, and achieve optimal resource allocation during the creative process. Introducing innovation management concepts into VCD curriculum construction can effectively stimulate students’ innovative thinking and creativity, empowering them to apply theoretical knowledge more effectively to solve practical problems encountered in their work. The core of integrating management principles into design education lies in selecting modules highly compatible with design practice (**Table 1**).

**Table 1.** Modules of management principles into design education

Management field	Core principles	Design scenario application
Organizational behavior	Teamwork, Leadership, Conflict Resolution	Design team role allocation, Cross-departmental collaboration (Planning/Tech/Marketing)
Strategic management	SWOT Analysis, Competitive Positioning, Resource Allocation	Brand strategy design decisions, Design-driven business innovation path planning
Outcome-based education (OBE)	Emphasizing education linked to practice, providing internships/jobs via industry-academia collaboration	Design proposal iteration/optimization, User testing feedback mechanisms, Design deliverable standardization
Innovation management	Open Innovation, Creative Incentives, Knowledge Management	Design thinking workshop organization, Creative solution evaluation systems, Design knowledge base construction
Marketing management	User Insight, Market Segmentation, Value Proposition Design	User persona construction, Verification of design strategy alignment with market positioning

## 2.2. Industry-education integration and university-enterprise collaboration

Industry-education integration and university-enterprise collaboration are pivotal trends in contemporary education. They emphasize the need for education to be closely linked with practice. By collaborating with enterprises, students gain access to internships and job opportunities, helping them accumulate practical experience and enhance their employability. Students cultivated under this model typically possess strong practical abilities, enabling them to integrate rapidly into the workplace and contribute effectively <sup>[3]</sup>. This integration has become an indispensable part of modern education systems, advocating a teaching philosophy that combines theory with practice.

Under this model, educators and enterprises collaborate closely to create a practical learning environment for students. Through internships in real or simulated work settings, students gain exposure to industry operations and workflows, accumulating invaluable practical experience. This exposure not only aids in understanding the application of theoretical knowledge but also strengthens their ability to tackle workplace challenges, boosting their competitiveness. Driven by industry-education integration, graduates often possess solid practical skills and can quickly adapt to workplace changes, transforming their knowledge into problem-solving capabilities. Such graduates are more attractive to employers, having demonstrated adaptability and innovative thinking in fast-changing environments. Furthermore, university-enterprise collaboration optimizes the allocation of educational resources, allowing institutions to adjust curricula based on market demands, ensuring graduates meet the requirements of society and industry for professional talent. Overall, the industry-education integration and university-enterprise collaboration model is crucial for improving education quality and reforming talent cultivation approaches.

## 3. Strategies for restructuring the visual communication design curriculum system

### 3.1. Restructuring course content

The essence of Visual Communication Design is solving information dissemination problems through visual symbols. Its traditional competency framework encompasses three dimensions: visual expression ability, technical implementation ability, and cultural translation ability (**Table 2**).

**Table 2.** Modules of management principles into design education

Traditional skills	Specific manifestations
Visual expression	Typography, color composition, graphic creativity, type design, image processing
Technical implementation	Printing technology, digital media technology (PS/AI/ID), basic interactive prototyping (Figma/XD), AIGC tools (Midjourney, etc.)
Cultural translation	Semiotic Semantic analysis, visual translation of regional culture, visualization of social issues

### 3.2. Reconstructing the design competency matrix

The specific pathway for integrating management principles into specialized courses involves addressing deficiencies in the current teaching system by incorporating management theory into elective courses and establishing modules such as “Project Planning & Execution”, “Team Management & Motivation”, and “Design Marketing.” These modules are designed to complement core professional courses, enhancing the systematicity

and comprehensiveness of the teaching content <sup>[4]</sup>. This adjustment aims to cultivate students' comprehensive abilities, preparing them to navigate complex and dynamic work environments with solid theoretical foundations and practical operational skills <sup>[5]</sup>. The curriculum system serves as the bridge, transforming competency objectives into educational practice. Its construction should follow a four-dimensional logic (**Table 3**).

**Table 3.** Modules of management principles into design education

Construction dimension	Connotation interpretation	Key elements
Target positioning	Defining the competency coordinates for talent cultivation	Industry needs analysis, Career development pathway mapping
Content structure	Modular integration of Knowledge-Skills-Literacy	Foundational course cluster, Professional core course cluster, Management-integrated course cluster, Interdisciplinary electives
Implementation pathway	Synergistic mechanism of Theory-Practice-Evaluation	Industry-education project-based teaching, Studio system, Enterprise credit recognition system
Quality assurance	Dynamically optimized closed-loop system	Graduate tracking feedback, Student satisfaction evaluation, Course iteration model

### 3.3. Restructuring teaching models

To align with industry practice, diversified teaching methods such as case-based teaching and project-based learning should be adopted. Increasing the proportion of practical teaching and encouraging student participation in actual design projects will enhance students' comprehensive practical abilities. These approaches not only reinforce theoretical knowledge but also improve hands-on skills and problem-solving capabilities, preparing students to effectively and confidently face future workplace challenges <sup>[6]</sup>. This model provides a platform for holistic development, allowing students to learn through practice.

### 3.4. Restructuring faculty resources

Continuous enhancement of teachers' professional capabilities and teaching levels is essential to ensure teaching content and methods remain synchronized with industry standards. This includes: regularly organizing professional development workshops and seminars for faculty to master the latest design concepts and management techniques; actively introducing experienced industry experts to inject fresh perspectives and broaden horizons; and implementing continuing education programs to continuously assess and elevate teaching competence, ensuring alignment with market standards and industry trends <sup>[7]</sup>. Only through such measures can educators cultivate truly qualified "dual-qualified" teachers (possessing both academic and industry expertise) capable of providing students with up-to-date professional knowledge and skills.

## 4. Conclusion

In summary, by innovating management concepts, deepening industry-education integration, optimizing teaching models and evaluation systems, and strengthening faculty development, the teaching quality and talent cultivation outcomes in Visual Communication Design can be significantly enhanced. This approach not only cultivates professionals who meet contemporary demands but also lays a solid foundation for the future development of VCD education. Moving forward, continuous exploration and refinement of this model are necessary to propel VCD education towards a more scientific, professional, and practical direction, better adapting to societal

development needs.

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# Comparative Analysis of the Mining Acts in Kenya and Tanzania

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**Abstract:** Kenya and Tanzania passed new mining acts in 2016 and 2010, respectively. This paper intends to compare and analyze the mining acts of two countries from the aspects of legislative background, legislative status, legislative purpose, legislative structure, administrative power setting, mineral rights, environmental protection, and financial regulations. From the above comparison, the paper can see that Kenya and Tanzania are in the same pursuit of economic development, and both pay more attention to the use of tax policies and the supervision of administrative power.

**Keywords:** Mining act; Mineral rights; Royalty

**Online publication:** June 13, 2025

## 1. Introduction

In recent years, African countries have been interested in adjusting their industrial structure, shifting from traditional agriculture and planting to some industries with potential for development. Mining is one of the goals that African countries aim for. In order to promote the development of the mining industry and improve the mining structure, it is necessary to revise and promulgate the mining act again. Kenya and Tanzania also followed the trend and revised their mining acts successively. Kenya and Tanzania are not only geographically connected by the same root, but also have many similarities in the choice of economic development direction. This paper compares and analyzes the mining acts of the two countries from the aspects of legislative status, legislative purpose, legislative background, and legislative content, with a view to providing some reference for the revision of China's mineral resources law.

## 2. Comparison of basic information

### 2.1. Legislative background

Kenya is rich in mineral resources. Compared with neighboring Tanzania and Uganda, Kenya's mineral resources



are far from being developed, and the proportion of the mineral industry in the national GDP is also small, which was only about 0.1% before 2010 <sup>[1]</sup>. In recent years, many mineral resources with commercial value have been discovered in Kenya. At the same time, Kenya's mineral industry is also growing, and its contribution to the national GDP has increased from 0.5% in 2012 to 0.8% in 2013. With the increasing proportion of the mineral industry in the national economy, the Kenyan government has paid more and more attention to the mineral industry, and even plans to turn it into a mining center in Africa. Of course, this beautiful vision needs strong legal support.

Tanzania is rich in mineral resources, with a lot of coal, cobalt, copper, diamonds, gold, nickel, silver, and uranium. Tanzania is currently the fourth largest gold producer in Africa, and Tanzania is also the only tanzanite producer in the world <sup>[2]</sup>. In terms of the national economy, the mineral industry is one of the fastest-growing industries in Tanzania in recent years. In 2013, the output value of the mining industry increased by 6.9%, and the mining and quarrying industry accounted for 3.3% of Tanzania's GDP. In terms of employees, about 670,000 artisanal miners produced colored gems, diamonds, gold, and other commodities in 2012; The employment of large mines is about 12,000 <sup>[3]</sup>. Tanzania formulated the Industrial Policy of Mineral Industry in 1997, striving to build the mining industry into a dynamic, well-structured, moderate-scale, and environmentally friendly public-private partnership industry within 25–30 years, accounting for more than 10% of GDP.

## **2.2. Legislative status**

In recent years, in order to improve the mining investment environment in Kenya, the government has made major amendments to the mining act, continuously improved the mining management system, and formulated a series of preferential mining investment policies in order to attract more investors to look for mineral deposits there. Kenya's parliament and cabinet passed the new mining act in early 2016, which was signed and promulgated by President Kenyatta in May.

Tanzania is a country in East Africa that pays more attention to the mining act and policies. It promulgated the mining act as early as 1979, and then successively promulgated some laws and regulations related to mining investment, and made important supplements and amendments to the mining act in 1989. After that, a new mining act was promulgated in 1998. Since then, with the different international mineral investments and the constant changes in the development of the domestic mineral industry, Tanzania has promulgated and implemented a new mining act in 2010. Its mining act has been revised frequently, which is the highest in East Africa.

## **2.3. Legislative purpose**

Kenya's 2016 mining act does not explain the legislative purpose, but it is clearly pointed out in the government announcement issued by Kenya's Ministry of Mining that the promulgation of the mining act is to promote the sustainable development and utilization of mineral resources, manage and deal with mineral exploration, mining, processing and other mining-related activities, and to promote foreign investment and local equity participation in the mining industry and balance the interests of all parties <sup>[4]</sup>.

Tanzania's 2010 mining act did not explain the legislative purpose, but stipulated the vision and mission of policy implementation in its mineral policy in 2009. It is hoped that through the formulation and promulgation of the policy, an effective mineral industry can be established, and the sustainable development and effective utilization of mineral resources will promote the rapid development of the social economy before 2025 <sup>[5]</sup>.

## **2.4. Legislative structure**

Kenya's 2016 mining act is divided into 15 parts with a total of 225 articles, including preliminary, ownership of minerals, general principles, administration, mining institution and bodies, general provision of mineral rights, mineral agreements, surrender, suspension and revocation and of mineral right, surface rights, compensation and disputes, dealings in minerals, healthy, safety and environment, financial provisions, records and registration of mineral rights, monitoring and compliance and enforcement, miscellaneous provisions, repeals, savings and transitional provisions. Tanzania's 2010 mining act consists of 116 articles in eleven parts, including preliminary provisions, general principles, administration, mineral rights, licenses for dealing in mineral or minerals, royalties, fees and other charges, restrictions, reports and the right of entry, disputes settlement, registration of mineral rights, miscellaneous provisions, repeal and savings provisions.

## **3. Mining act content comparison**

### **3.1. Administrative supervision**

Kenya's 2016 mining act stipulates the functions and powers of the Ministry of Mining, and specifically stipulates that the Ministry of Mining has the power to declare strategic minerals. It also establishes the Bureau of Minerals and Geological Survey and defines its functions. Tanzania's 2010 mining act stipulates the appointment of mineral commissioners and other government officials, the performance and entrustment of mineral commissioners' duties, geological services such as geological exploration, mapping, and exploration, the mining advisory council and its functions, and the prohibition of information disclosure by administrative agencies.

### **3.2. Mineral rights**

Kenya's 2016 mining act prescribes reconnaissance license, prospecting license, retention license, artisanal mining operation, and mining license for large-scale operations; For small-scale operations, it prescribes reconnaissance permit, prospecting permit, and mining permit <sup>[6]</sup>. The term of the reconnaissance license shall not exceed two years and shall not be extended; The term of the prospecting license shall not exceed three years at the longest and shall not be extended more than twice; The term of the mining license shall not exceed 25 years or the predicted life of the mine, whichever is shorter, and shall be specified in the license; The extension period of the mining license shall not exceed fifteen years or the remaining life of the mine, whichever is shorter, and shall be specified in the license. The maximum area covered by the reconnaissance license is one block or any block with no more than 5,000 adjacent blocks; The area covered by the exploration license is a block or the largest area with no more than 1,500 adjacent blocks. The term of the exploration license shall not exceed five years and may be renewed once. The duration of a mining license shall be specified in the license and shall not exceed five years. The area contained in the exploration license shall not exceed twenty-five adjacent blocks, and the area contained in the mining license shall not exceed two adjacent blocks.

Tanzania's 2010 mining act prescribes prospecting license, retention license, special mining license, mining license, primary license, processing, smelting, and refining license <sup>[7]</sup>. In terms of the size of the region, Tanzania's 2010 mining act does not provide for it. In terms of duration, the initial period approved by the prospecting license shall not exceed four years, the first period of renewal shall not exceed three years, and the second period of renewal shall not exceed two years. The period for the retention license shall not exceed five years. The term of the special mining license is the estimated life of the ore mentioned in the feasibility study report or the period that the applicant can request, whichever is shorter. The longest term of a mining license is ten years, and an application

can be made for renewal, and the renewal shall not exceed ten years. The primary license is valid for seven years and can be renewed, but the renewal period is not specified. The term of the processing license shall not exceed ten years and may be renewed. The validity period of the smelting license and refining license shall not exceed 25 years and shall be renewed.

### **3.3. Health, safety, and environment**

Kenya's 2016 mining act stipulates that mining owners should abide by the domestic water law, occupational health and safety law, and related environmental protection laws and regulations. In terms of land use, mining owners should ensure the sustainable use of land through the restoration of abandoned mines and quarries; Leakage of toxic waste to streams, rivers, lakes and wetlands should be avoided, and toxic waste should be disposed of in approved areas; Blasting and other operations that can cause great vibration should be carried out properly, and the vibration and impact caused by blasting should be controlled to a reasonable degree in accordance with the provisions of the Environmental Management and Coordination Law; After the completion of exploration or mining, the treated land should be restored to its original state or as close to its original state as possible to an acceptable and reasonable degree <sup>[8]</sup>. Tanzania's 2010 mining act did not specifically stipulate the environmental protection of mining activities, but simply stipulated that the rights conferred by mining rights should be exercised reasonably <sup>[9]</sup>.

### **3.4. Financial provisions**

Kenya's 2016 mining act stipulates that the mining right owner should pay royalties to the state for obtaining different grades of minerals due to mineral rights, and the Minister of Mining stipulates the proportion of royalties; 70% of the royalties paid belong to the central government, 20% to the county government and 10% to the local community <sup>[10]</sup>. According to the constitutional bulletin issued by Kenya in 2013, rare earth, niobium and titanium are listed as precious minerals, which are charged at a royalty rate of 10% of total sales; The royalty rates of coal and gold have doubled from 2.5% of total sales to 8% and 5% respectively; The royalty rate for gold and copper is 10%; The royalty rate for diamonds is 12%. Tanzania's 2010 mining act stipulates that the royalty rate is 5% for uranium, 5% for precious stones and diamonds, 4% for metal minerals such as copper, gold, silver and platinum group minerals, and 3% for all minerals in other minerals including building materials, salt and industrial minerals <sup>[11]</sup>.

## **4. Analysis of the mining acts of the two countries**

### **4.1. The demands are relatively consistent**

As the largest economy in East Africa, Kenya achieved a gross national income of US\$63.398 billion in 2015, and Tanzania led the East African countries with good economic growth momentum. Generally speaking, the economic strength of the two countries is relatively strong, and the common ground of their economic development mainly depends on traditional industries such as agriculture and planting. How to develop the development potential of different industries and strengthen the development momentum of different industries, so as to make greater contributions to the national economy, is the common thinking of the two countries, and the answers invariably point to the mineral industry. Tanzania is an excellent example. In 2024, Tanzania's national economy achieved 5.5% growth, among which arts and entertainment (17.1%), electricity generation and distribution (14.4%), information and communication (14.3%), financial and insurance services (9% and 13.8% respectively), and health made great contributions, and the growth of the mineral industry has also achieved remarkable results <sup>[12]</sup>.

The mineral resources of the two countries are relatively rich, and the degree of development is extremely low. Revising and perfecting the mining act, gradually updating the domestic mining policy, improving the domestic mining investment environment, and attracting more domestic and foreign funds, so as to develop and strengthen the domestic mining industry, all these measures reflect the common aspirations of the two countries.

#### **4.2. Emphasizing the use of tax policies**

From the comparison of the above financial regulations, it can be seen that both countries, without exception, have chosen to levy a certain percentage of royalties, collect various application fees, renewal fees, etc. To increase national fiscal revenue, which Kenya has a relatively high proportion of. Levying royalties on mineral activities is a trend in the mining policies of various countries in recent years, which not only increases the national economic income but also can be used as compensation for resource consumption and environmental restoration. It can be said that the two countries are killing several birds with one stone. The choice of the two countries is understandable, only by paying attention to the reasonable determination of the collection ratio and the reasonable distribution and utilization of income among all levels can they meet the original intention of setting policies.

#### **4.3. Focus on the supervision of administrative power**

In order to guide the overall normative development of the mineral industry, the two countries have adjusted their corresponding government departments in recent years. Kenya established the Ministry of Mining in 2013, and Tanzania established the Ministry of Energy and Mines. These departments are specialized in petroleum, minerals, and energy-related affairs, and their responsibilities are also stipulated in the mining act of their countries. However, illegal trading and even smuggling in the mineral industries of the two countries are serious, and the efficiency and transparency of government departments have been criticized by the public. How to implement the responsibilities stipulated in the mining act, continuously improve the administrative efficiency and transparency of the corresponding departments, and effectively promote the development of the mining industry is also an aspect that the two countries should continue to pay attention to after the introduction of the new mining act.

#### **4.4. The effectiveness of the implementation of the law is yet to be examined**

There is always a certain gap between the ideal and reality. The introduction of new mining acts by the two countries is either to crack down on illegal mining activities, guide the regularization and legalization of mining activities, standardize the development of the mining industry, or attract more mining investment. In general, it is to promote the development of the national economy. Kenya's mining act was promulgated in 2016, and Tanzania's mining act was implemented as early as 2010. mining act has been promulgated for a period of time, has the purpose of amending mining act been achieved? The answer is not always yes. Judging from the above financial data, only Tanzania's mining industry has achieved gradual growth, and Kenya's mining development has not improved significantly. As for the detailed reasons, it cannot be summarized. The implementation effect of the new mining act promulgated by the two countries to regulate the development of their own mineral industry remains to be further investigated and analyzed.

### **5. Conclusion**

Kenya and Tanzania, as important economies in East Africa, have demonstrated their common aspiration to promote the development of the mining industry by amending the mining act in recent years. The mining acts



of the two countries have both similarities and significant differences in legislative background, administrative supervision, mining rights setting, environmental protection, and financial regulations. Kenya's 2016 mining act has a more detailed structure, clearly defines the classification and duration of mining rights, and pays attention to environmental protection and land restoration; However, the mining act of Tanzania in 2010 is more diversified in the types of mining rights, but the provisions on environmental protection are relatively simple. Financially, both countries increase their fiscal revenue by collecting royalties, but Kenya has a higher rate and a more specific distribution mechanism.

Although the revision of the mining acts of the two countries aims at standardizing industries, attracting investment, and promoting economic growth, the implementation effect remains to be seen. Tanzania's mining industry has grown significantly, while Kenya's mining industry has not yet reached its expected goal. This shows that the improvement of the law is only the first step, and the follow-up needs efficient administrative execution, a transparent supervision mechanism, and reasonable policy adjustment as support.

Generally speaking, the revision of mining acts in Kenya and Tanzania reflects the efforts of African countries to promote resource development through legal means, and their experiences and lessons can be used for reference by other developing countries. In the future, the two countries need to further optimize the implementation of laws and balance economic development and environmental protection in order to realize the sustainable development of the mineral industry.

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# The Application of On-Site Analysis and Detection Technologies in the Conservation and Restoration of Polychrome Cliff Carvings

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**Abstract:** Scientific analysis and testing of cultural relics are often carried out during the design phase prior to restoration, serving as the foundation for subsequent conservation treatment. Given the diversity and complexity of cultural relics, uncertainties are often present at all stages of conservation and restoration, making on-site analysis and testing at the conservation site highly significant for guiding protection and treatment. This paper, focusing on on-site conservation work for polychrome cliff carvings, discusses the application scenarios of several relatively simple and practical analysis and testing instruments—such as infrared thermal imagers, Leeb hardness testers, and spectrophotometers—at conservation and restoration sites.

**Keywords:** Cultural relic conservation; Polychrome cliff carvings; Non-destructive testing; Infrared thermal imaging; Leeb hardness; Spectrophotometer

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## 1. Introduction

With the increasing investment in China's cultural heritage conservation efforts and the continuous improvement of various analysis and testing technologies, as well as the decreasing cost of testing, some simple and practical non-destructive testing technologies have become feasible for wider application at conservation and restoration sites. This is highly beneficial for addressing the practical issues encountered during on-site conservation and restoration work. The combination of concrete scientific evidence with traditional experience enables more accurate protection measures to be taken against the deterioration of cultural relics, helps avoid negative impacts on relics caused by errors in on-site judgment, and at the same time, enhances the rigor and scientific validity of conservation and restoration documentation. Taking the conservation and restoration project of the Lotus Cave polychrome cliff carvings at Qianfoya as an example, this paper introduces some of the techniques applied during the project implementation phase, aiming to provide a reference for the application of analysis and testing technologies at conservation and restoration sites.

Testing at cultural relic conservation and restoration sites is different from that in cultural relic conservation laboratories. Laboratory testing in the early stage tends to focus on reproducing the materials and processes of cultural relics to determine the causes of deterioration and develop response plans. Instruments such as FT-IR, XRD, and SEM-EDS are used to conduct targeted testing on the composition and structure of samples—including pigments, coatings, and pollutants—extracted from cultural relics. On-site testing at conservation and restoration sites, however, focuses more on evaluating restoration effects and responding to the needs of on-site detection. The technologies used on site should be simple and reliable to operate, enabling even first-time users to obtain accurate measurement results, with qualitative assessment as the main focus and quantitative analysis as a supplement.

## 2. Instruments used for on-site detection in the conservation and restoration of polychrome cliff carvings

### 2.1. Leeb hardness tester

At the conservation and restoration sites of polychrome cliff carvings, a portable Leeb hardness tester is selected for use. The local cliff carvings are made of quartz yellow sandstone, which has loose grains and large pores. If a rebound hammer or a penetration-type mortar strength tester commonly used for ancient brick and stone structures were applied, it would leave obvious impact marks on the carved relics, and in cases of severely weathered sandstone, it could even cause flaking. The instrument used on site is the Equotip 3 portable Leeb hardness tester produced by Proceq, with a type D impact device (impact device mass: 75 g).

The Leeb hardness method was first proposed by Dr. Leeb from Switzerland in 1978. Its basic principle is to use spring force to propel an impact body with a certain mass and indenter towards the surface of the sample. The impact velocity and rebound velocity at a specific distance from the sample surface are measured to calculate energy loss. Utilizing electromagnetic principles, a voltage proportional to the velocity is induced, and the signal processed by electronic technology provides the hardness value for display and storage. The Leeb hardness value is expressed as the ratio of the rebound velocity to the impact velocity of the impact body.

$$HL = \frac{V_r}{V_i} * 1000 \quad (1)$$

In Formula 1, HL stands for the Leeb hardness value;  $V_r$  represents the rebound velocity of the impact body;  $V_i$  refers to the impact velocity of the impact body.

Although this type of portable Leeb hardness tester was originally designed for testing metal materials, it is also widely used for suitable samples of other materials. For example, the School of Engineering and Technology at China University of Geosciences (Beijing) used Leeb hardness testing on marble cultural relics in Beijing <sup>[1]</sup>; the Stone Age Archaeology Laboratory at George Washington University used the same model Equotip 3 portable hardness tester to test the mechanical properties of stone samples in research related to stone selection for tool making <sup>[2]</sup>. Due to the special nature of the cultural relic samples being tested, it is not always necessary to strictly follow the standard procedures described in the user manual. However, the main challenge in testing low-strength samples lies in the fact that the hardness of the sample may be below the measurable range, making it impossible to obtain readings. This is also a common occurrence in on-site analysis and testing: at conservation and restoration sites, the conditions are not always as ideal as in laboratories, with appropriate instruments and materials readily available, so it is important to make full use of existing resources to solve practical problems.

## 2.2. Spectrophotometer

When evaluating whether the color of a cultural relic has changed or if glossiness has occurred at the conservation and restoration site, such judgments were usually made by visual inspection in the past. However, visual inspection is highly subjective and can easily lead to disagreement, especially under different lighting conditions. With data provided by a spectrophotometer, it is possible to retain quantitative reference values in the conservation and restoration records.

A spectrophotometer contains an optical component that can disperse light. When light is directed onto a sample and reflected to the dispersing element, the principle of dispersion is used to analyze single color information and convert the optical signal into an electrical signal. According to the internally set color space and calculation formula, the chromaticity information is displayed, which can then be converted to Hunter Lab or CIE  $L^*a^*b^*$  indices or other chromaticity scales.

Taking the Konica Minolta CM-700d1 portable spectrophotometer as an example, the measurement results are ultimately displayed in the  $L^*a^*b^*$  color model. In the application of cultural relic conservation and restoration, the main focus is typically on changes in the L value, i.e., the brightness axis, to determine whether glossiness has developed on the surface of pigments after consolidation. The values for the a and b color channels generally do not change significantly; if there are large fluctuations, it may indicate a color change and should be carefully noted.

## 2.3. Infrared thermal imager

Infrared thermal imaging, as a non-destructive testing method, is simple and reliable and is suitable for use at cultural relic conservation sites. It helps to safely and rapidly identify situations such as voids and water seepage. By using an infrared thermal imager, the temperature field distribution on the surface of an object can be detected, making it easy to visually identify abnormal temperature regions on the surface of a cultural relic. Combined with site analysis, potential deterioration can be quickly inferred, thus playing a positive role in conservation and restoration work. This paper mainly introduces passive thermal imaging. Although the imaging results are not as pronounced as those produced by active infrared thermal imaging methods—which require high-power flash lamps, hot air, or other thermal stimulation devices—passive thermal imaging is more suitable for conservation site testing, as it is more reliable, lower in cost, and easier to operate<sup>[3]</sup>.

The infrared thermal imager used on site is a FLIR E40, with a thermal image resolution of  $320 \times 240$ . The resolution of thermal images is directly related to the price of the thermal imager, and this level of resolution in a handheld device is already sufficient for conservation and restoration work on site. The imager is equipped with a built-in digital visible light camera, which can generate visible light reference images at the same time. However, due to differences in focal length between the infrared and visible light lenses, the imaging area is not consistent. It is therefore recommended to use a separate camera to take visible light reference images. With the advancement of domestic thermal imaging technology, the cost of using such equipment will continue to decrease.

## 3. Application cases of on-site detection technologies in the conservation and restoration of polychrome cliff carvings

### 3.1. Application in the conservation process of the lotus cave carvings

According to the technical roadmap for the conservation of the Lotus Cave carvings, the application of detection technologies at each step is described as follows<sup>[4]</sup>. On-site detection personnel should be familiar with the names,

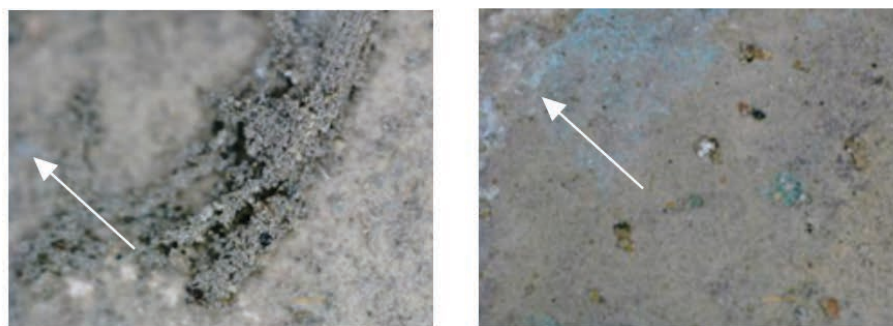
purposes, operation methods, materials used, and corresponding types of deterioration at each step of the conservation and restoration of polychrome cliff carvings, and should understand the sequence of the workflow. Before testing begins, it is necessary to clarify the day's work plan, using the conventional workflow as a framework and refining it in communication with conservators on site. With clear objectives, aimless testing can be avoided.

### 3.1.1. Removal of inappropriate restorations

The inappropriate restorations referred to here are repairs made with materials that have aged and are highly incompatible with the original relic, negatively impacting the overall harmony and artistic value of the grotto, and all are documented traces of modern repairs <sup>[5]</sup>. Earlier historical restoration traces are not subject to intervention. As needed, areas that may be vulnerable, such as edges, can be pre-consolidated before and after the removal process <sup>[6]</sup>. When testing hardness, it is important to distinguish between areas that have undergone pre-consolidation and untreated areas, to avoid confusing the data. After removing inappropriate restorations, the underlying rock surface of the cliff carving is exposed—these areas were previously repaired due to rock flaking and powdering. After exposure, a portable Leeb hardness tester is used to measure and record the surface hardness. The measured hardness values at this stage are usually very low, and in cases of severe powdering, no readings may be obtained; such cases should also be documented for reference.

### 3.1.2. Dust removal and cleaning

Accumulated dust on the surface of polychrome paintings can seriously affect color detection. As shown in **Figure 1**, only a faint blue pigment layer is visible at the location indicated by the arrow before dust removal, while a larger area of blue polychrome painting is revealed after cleaning <sup>[7]</sup>. At this point, a spectrophotometer is used to detect and record the color information of the pigment layer. When using the spectrophotometer, it is necessary to accurately record the position of each test point, which can be achieved by marking on drawings or photographing the working position, to ensure that future comparative tests can be carried out at the same point.



**Figure 1.** Micrographs of the same area before and after dust removal

### 3.1.3. Rock consolidation

After rock consolidation, the portable Leeb hardness tester is used again to measure the surface hardness (**Figure 2**). The hardness of the area is taken as the average of multiple test points—generally, 20 points are randomly selected within the area to be measured, and the instrument automatically calculates the average value. If the test area is small, it is sufficient to take the average of the measurements directly <sup>[8]</sup>. The test data can verify whether the consolidation effect meets the design standard, and should correspond with the results of earlier laboratory and on-site tests, while also confirming that each consolidated area meets the requirements. The detection data should be recorded in the relevant restoration documentation.



Although the portable Leeb hardness tester causes only a minor impact on the sample, the probe tip may still leave marks when pressed against the surface; therefore, it should not be used on polychrome surfaces<sup>[9]</sup>. Attention should also be paid to the routine cleaning of the probe tip to avoid contaminating the cultural relics it touches.



**Figure 2.** Testing the surface hardness of rock with a portable Leeb hardness tester

#### 3.1.4. Pigment consolidation

After pigment consolidation, the main concern is color change, including glossiness and brightness variations. Although the safety and effectiveness of the consolidation material have already been verified during preliminary experiments in the design phase, data collected on-site provide a more accurate assessment of the actual protection effect. Once the pigment consolidation material has fully stabilized, the spectrophotometer is used again to test the same points measured after dust removal (**Figure 3**)<sup>[10]</sup>. The results are recorded in the restoration documentation, and the two sets of data can be quantitatively and visually compared.



**Figure 3.** Detecting the color of the polychrome surface with a spectrophotometer

#### 3.1.5. Repair

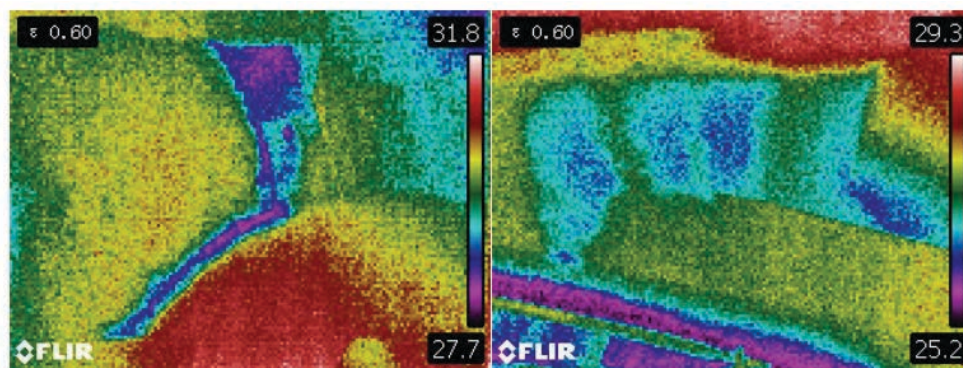
Due to continuous powdering, the rock may become recessed inward. If not consolidated and repaired in time, the weathering depth of the rock will accelerate, resulting in ongoing deterioration in the affected area. The hardness of the repair material should not be too high; it should be similar to the hardness measured on the normal rock

surface and the consolidated, powdering rock surface <sup>[11]</sup>. In the preliminary laboratory tests, these hardness values are compared to select a suitable repair material. After the new repair areas have been cured and hardened, the portable Leeb hardness tester is used to test and record the hardness.

### 3.2. Meeting on-site testing requirements

#### 3.2.1. Detection of water seepage

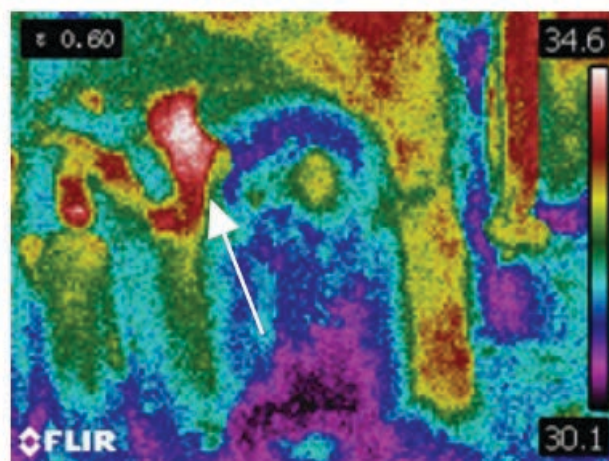
The conservation work took place in summer, during a period of frequent rainfall. Although a protective shelter was erected outside the cave to prevent rainwater from entering, water continued to seep through the cave ceiling after heavy rains <sup>[12]</sup>. Using an infrared thermal imager and on-site inspection, it was determined that the water seepage at the top of Lotus Cave was caused by surface water accumulation near the upper neighboring cave <sup>[13]</sup>. Once the source of the seepage was identified, timely measures were taken <sup>[14]</sup>. In the thermal image shown in **Figure 4**, the blue low-temperature area indicates traces of water seepage.



**Figure 4.** Thermal image of water seepage from cracks in the ceiling of Lotus Cave

#### 3.2.2. Detection of delamination (Hollowing)

In **Figure 5**, the red high-temperature area indicated by the arrow marks the delaminated area at the upper right corner of the carving niche. Due to severe weathering, the entire left side of the niche wall has become an open groove that needs to be filled with grout <sup>[15]</sup>. Infrared thermal imaging can also be used to inspect the condition of delaminated areas after grouting, providing an assessment of the effectiveness of the restoration.



**Figure 5.** Thermal image of the delaminated area at the edge of the carving niche

## 4. Conclusion

Cultural relic conservation is a long-term and challenging task, serving to protect the precious heritage of our civilization for our nation and future generations. Scientific work in cultural relic conservation is not only about the development of new technologies, but also about expanding the application of existing testing technologies. Promoting the use of simple and practical on-site analysis and detection technologies to address the actual needs of conservation work is an important mission for the field.

Those engaged in conservation and restoration work need to establish a relatively complete and scientific knowledge system. The implementation of conservation and restoration provides more opportunities for research, especially for uncovering valuable information that is often hidden within cultural relics. However, if great care is not taken during the restoration process, some information may be missed or even lost. The interdisciplinary nature of conservation and restoration makes it particularly important for professionals from different fields to collaborate and divide the work according to their expertise.

## Disclosure statement

The author declares no conflict of interest.

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# Study on the Distribution Characteristics of Tourism Elements in the Grand Canal Cultural Belt of Cangzhou City

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**Abstract:** This article focuses on the cultural belt of the Grand Canal in Cangzhou City, analyzing the spatial distribution and correlation of its tourism elements. Based on a total of 14,192 Points of Interest (POI) data collected through the Gaode Map Application Programming Interface (API), the study employs spatial analysis methods such as spatial syntax analysis, kernel density estimation, average nearest neighbor analysis, global spatial autocorrelation test, and bivariate spatial autocorrelation test. These methods reveal the spatial patterns and interdependencies of the six core tourism elements: food, accommodation, transportation, tourism, shopping, and entertainment. The results indicate significant agglomeration in the spatial distribution of various tourism elements, accompanied by distinct characteristics of differentiation among them. This research provides valuable insights and references for the reconstruction of tourist spaces and the coordination of functional areas within the cultural belt of the Grand Canal in Cangzhou City.

**Keywords:** Grand Canal; POI; Distribution characteristics

**Online publication:** June 13, 2025

## 1. Introduction

In June 2019, the President of the CCP emphasized that the Grand Canal is a precious heritage left by ancestors, representing a flowing culture that must be protected, inherited, and utilized in a coordinated manner. Following this, the Central Committee of the Communist Party of China and the State Council issued a plan, identifying the construction of the Grand Canal Cultural Tourism Belt as a key task in the “14th Five-Year” cultural and tourism plan. The plan aims to promote regional coordination through culture, with cities as the unit of layout. In 2022, taking advantage of hosting the 6th Hebei Provincial Horticultural Exposition, Cangzhou City advanced 18 key projects (with a total investment of 22.5 billion yuan) to develop the Grand Canal cultural protection zone, ecological landscape belt, and cultural tourism belt. Recently, Cangzhou City formulated the “Implementation Plan for High-Quality Integrated Development of Culture and Tourism in Cangzhou City (2024–2025).” This plan integrates cultural tourism projects along the Grand Canal in the central city, aiming to create a 5A-level



scenic area by improving landscapes, services, and environmental quality. The goal is to establish the Grand Canal Cultural Tourism Belt as the preferred weekend destination for tourists from Beijing and Tianjin. Simultaneously, the plan aims to enhance the cultural tourism scene in the main city area, improve the service level of dining, accommodation, and transportation, develop branded cultural tourism products, enhance public services and infrastructure, optimize the environment, shape the “Cangzhou Cultural Tourism” brand, and enhance tourism attractiveness and service quality. Given this context, exploring the distribution characteristics and agglomeration status of cultural tourism resources along the Grand Canal in Cangzhou City is of great significance. It will help to clearly grasp the spatial distribution pattern of local cultural tourism resources, scientifically guide industrial integration and coordinated development, effectively update tourism products and service content, and reasonably transform tourist attractions and surrounding environments.

The tourism industry encompasses six elements: attractions, dining, accommodation, shopping, entertainment, and transportation. It is characterized by inclusivity, wide coverage, and strong correlation, spatially manifested as a combination of point and linear elements. Each type of tourism industry has its own spatial distribution, and there are rich associations among the various tourism industries<sup>[1]</sup>. In recent years, domestic experts have focused their research on the spatial pattern of tourism, drawing on and improving foreign tourism location theories while considering the actual situation of China’s tourism industry. The research has primarily concentrated on the distribution of tourism resources, the spatial pattern of tourism-related single business formats, and the evolution of tourism elements<sup>[2–10]</sup>. However, there has been relatively little research on the distribution pattern of tourism at the micro level of cities, which limits the understanding and grasp of the overall development of urban tourism to some extent. In studies aiming at spatial layout, Points of Interest (POI) data stand out due to their wide distribution, abundant information, and low acquisition threshold, making them highly applicable in research on the spatial layout of elements at various scales and regions. Foreign scholars have achieved remarkable results in POI data research, primarily focusing on identifying urban hotspots, analyzing macro spatial patterns, and exploring behavioral patterns among different populations<sup>[11–13]</sup>. These studies lay a foundation for researching the spatial characteristics and optimization of tourism formats. In comparison, domestic scholars have also made considerable progress in POI big data applications, particularly in studying tourism spatial patterns, primarily concentrating on leisure tourism and scenic spots<sup>[14–18]</sup>. However, there are still few research results on the spatial distribution and spatial correlation characteristics of the six elements of tourism (food, accommodation, transportation, tourism, shopping, and entertainment).

In summary, this article conducts an in-depth study on the POI data of tourism elements in Cangzhou City, analyzing the spatial distribution patterns and characteristics of the city’s tourism elements. The aim is to provide a scientific basis for resource allocation and related industrial layout planning in urban tourism development strategies.

## **2. Data sources and research methods**

### **2.1. Overview of the study area**

Cangzhou City is located in the southeast of Hebei Province, bordering Bohai Sea in the east, Tianjin in the north, Baoding in the west, and Dezhou and Binzhou in Shandong Province in the south. It is situated in the central and southern plain of Hebei and is an important part of the Beijing-Tianjin-Hebei city cluster. With convenient transportation, it is integrated into the “one-hour transportation circle” of Beijing-Tianjin-Hebei, facilitating

connections with surrounding cities and scenic spots. The Beijing-Hangzhou Grand Canal passes through the city. In recent years, in response to national policies, multiple canal attractions have been developed, driving an increase in local residents' tourism demand and an influx of tourists from the Beijing-Tianjin-Hebei region. This study focuses on the enclosed area formed by four expressways, G307, Xin'an Avenue, Bohai Road, and Jingba Road, in the main urban area of Cangzhou City.

## 2.2. Data sources

This study utilizes the Gaode Map API to collect POI (Point of Interest) data and road network data for tourism elements in Cangzhou in February 2025. The data includes key information such as the name, category, longitude, and latitude of each POI. Subsequently, based on the characteristics of the study subject, referencing POI classification systems from previous studies, and according to the "National Tourism and Related Industries Statistical Classification (2018)" standard published on the Statistics Bureau website, POI data involving tourism elements such as dining, accommodation, transportation, travel, shopping, and entertainment were precisely filtered, totaling 14,192 data entries (**Table 1**).

**Table 1.** Types and quantities of POI data for tourism elements in Cangzhou City

Tourism element	Secondary classification	Quantity	Proportion
Dining (Food)	Chinese restaurants, food-related venues, fast food restaurants, beverage shops, pastry shops, foreign restaurants, cafes, dessert shops, casual dining venues	8,554	60.27%
Accommodation (Lodging)	Hotels, guesthouses/lodges	647	4.56%
Transportation (Travel)	Parking lots, bus stops, long-distance bus stations, ferry terminals, train stations	1,592	11.22%
Sightseeing (Touring)	Parks/plazas, scenic spots, museums	34	0.24%
Shopping (Purchasing)	Convenience stores, supermarkets, specialty stores, shopping malls, markets, specialty commercial streets	2,102	14.81%
Entertainment (Recreation)	Spa/massage facilities, entertainment venues, sports facilities, leisure venues, sports & recreation services, theaters/cinemas	1,263	8.90%
Total		14,192	100%

## 2.3. Research methods

### 2.3.1. Space syntax

Space syntax is a quantitative analysis method for spatial structure based on topological networks. This study applies space syntax to three travel scales: walking, non-motorized vehicles, and motorized vehicles<sup>[19]</sup>. Using the axis analysis method, global integration and local integration are employed to quantify the accessibility of roads in Cangzhou City. The higher the integration value, the stronger the road accessibility, and the local accessibility can be visually judged by the axis color on the local integration axis map.

Integration is an indicator used to quantify the accessibility between a spatial unit and other spatial units in a spatial system. The calculation formula for integration is as follows:

$$I_i = \frac{n[\log_2(\frac{n+2}{3} - 1)] + 1}{(n - 1(MD_i - 1))}$$

Among them,  $I_i$  represents the integration of the  $i$ th spatial unit,  $n$  is the total number of spatial units, and  $MD_i$  is the average depth of the  $i$ th spatial unit.

### 2.3.2. Kernel density

Kernel density analysis is a non-parametric estimation method used to evaluate the density of points around each sample location. It involves placing a kernel function (usually a smooth curve) at each sample point and then stacking the values of these kernel functions to generate a density surface. The calculation formula is as follows:

$$f(x) = \frac{1}{n \cdot h} \sum_{i=1}^n k\left(\frac{x - x_i}{h}\right)$$

### 2.3.3. Average nearest neighbor

The average nearest neighbor is an important indicator used in spatial analysis to quantify the distribution characteristics of point patterns. By comparing the actual observed values with theoretical random distribution values, it determines whether the point set is clustered, dispersed, or randomly distributed. The formula is as follows:

$$\bar{d} = \frac{1}{n} \sum_{i=1}^n d_i, \bar{d}_{random} = \frac{0.5}{\sqrt{\lambda}}, R = \frac{\bar{d}}{\bar{d}_{random}}$$

Where  $\bar{d}$  is the distance from a point to its nearest neighbor,  $d_i$  is the average nearest neighbor distance of all points,  $n$  is the total number of points,  $\bar{d}_{random}$  is the theoretical average nearest neighbor distance,  $\lambda$  is the number of points per unit area, and  $R$  is the nearest neighbor index.  $R < 1$  indicates a clustered distribution,  $R = 1$  indicates a random distribution, and  $R > 1$  indicates a uniform distribution.

### 2.3.4. Spatial autocorrelation

Global spatial autocorrelation is a statistical indicator that measures the similarity or correlation of variable values distributed spatially in spatial data. In this study, Moran's  $I$  index is used to quantify the spatial distribution, thereby assessing the spatial clustering characteristics of point coordinates. The calculation formula is as follows:

$$I = \frac{N}{W} \cdot \frac{\sum_{i=1}^N \sum_{j=1}^N \omega_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^N (x_i - \bar{x})^2}$$

Where  $N$  is the total number of spatial units,  $\sum$  is the sum of all spatial weights  $\omega_{ij}$ ,  $\omega_{ij}$  is the spatial weight matrix, representing the spatial relationship between spatial units  $i$  and  $j$ ,  $x_i$  and  $x_j$  are the attribute values of spatial units  $i$  and  $j$ , and  $\bar{x}$  is the average attribute value of all spatial units. Moran's  $I > 0$  indicates that adjacent units have similar attributes (positive correlation),  $I < 0$  indicates significant differences (negative correlation), and  $I \approx 0$  indicates no significant spatial autocorrelation.

### 2.3.5. Bivariate spatial autocorrelation

Unlike traditional spatial autocorrelation analysis, which focuses on a single variable, bivariate spatial autocorrelation further reveals the spatial dependency relationships between different types of elements. The formula is as follows:

$$I_{XY} = \frac{n}{\sum_{i=1}^n \sum_{j=1}^n \omega_{ij}} \cdot \frac{\sum_{i=1}^n \sum_{j=1}^n \omega_{ij} (X_i - \bar{X})(Y_j - \bar{Y})}{\sqrt{\sum_{i=1}^n (X_i - \bar{X})^2} \sqrt{\sum_{j=1}^n (Y_j - \bar{Y})^2}}$$

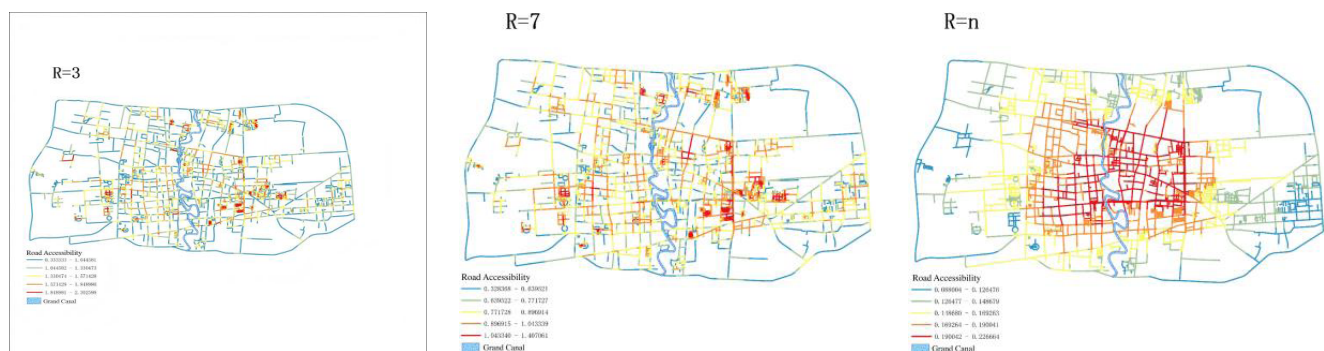
where  $n$  is the number of spatial units,  $x_i$  and  $Y_j$  representing the  $X$  value of unit  $i$  and the  $Y$  value of unit  $j$ , respectively, and  $\omega_{ij}$  represents the Queen contiguity weight matrix.

### 3. Distribution characteristics of tourism elements in Cangzhou City

#### 3.1. Accessibility analysis

Using Depthmap software and adopting a multi-scale integration system, the accessibility of transportation in the study area was evaluated (**Figure 1**). The integration colors gradually increase from cold to warm, indicating that accessibility gradually improves as the color tone becomes warmer. Topological steps are denoted by  $R$ : for tourist walking,  $R=3$  is chosen to reflect the walking activity status of tourists; considering that tourists often have stronger touring needs or tend to use non-motorized transportation,  $R=7$  is extended to reflect the characteristics of medium and long-distance activities; the global integration  $R=n$  is introduced to study the accessibility of tourist driving activities and conduct a comprehensive analysis of the accessibility of the region.

Conducting a horizontal analysis with the Grand Canal in the city center as the core, it can be seen that spatial accessibility presents significant differences under different topological scales. When  $R=3$ , multiple locally accessible cores are formed along the canal, mainly concentrated in iconic cultural tourism nodes such as the Garden Expo Park, People's Park, South Lake Park, and Nanchuan Tower. The color gradient analysis shows that these areas exhibit high integration characteristics, confirming that tourists can reach nearby areas on foot. As the topological steps expand to 7, accessibility demonstrates broader connectivity. The color gradient transition indicates that the distribution of road integration tends to be more balanced. Originally isolated hotspots further extend to surrounding areas, and the distribution of road integration becomes more uniform. The radiation range of integration extends along the canal axis into the hinterland, indicating that tourists have a strong desire or ability to expand their range of activities with the help of non-motorized vehicles and other transportation means. When integration  $R=n$ , the road integration around the Grand Canal in the city center exhibits distinct high-value areas. The red core area and the orange expansion area form a multi-center collaborative transportation network, reflecting that when tourists travel by car, they can quickly and easily reach various major attractions and functional areas of the city, indicating high overall accessibility of the city.

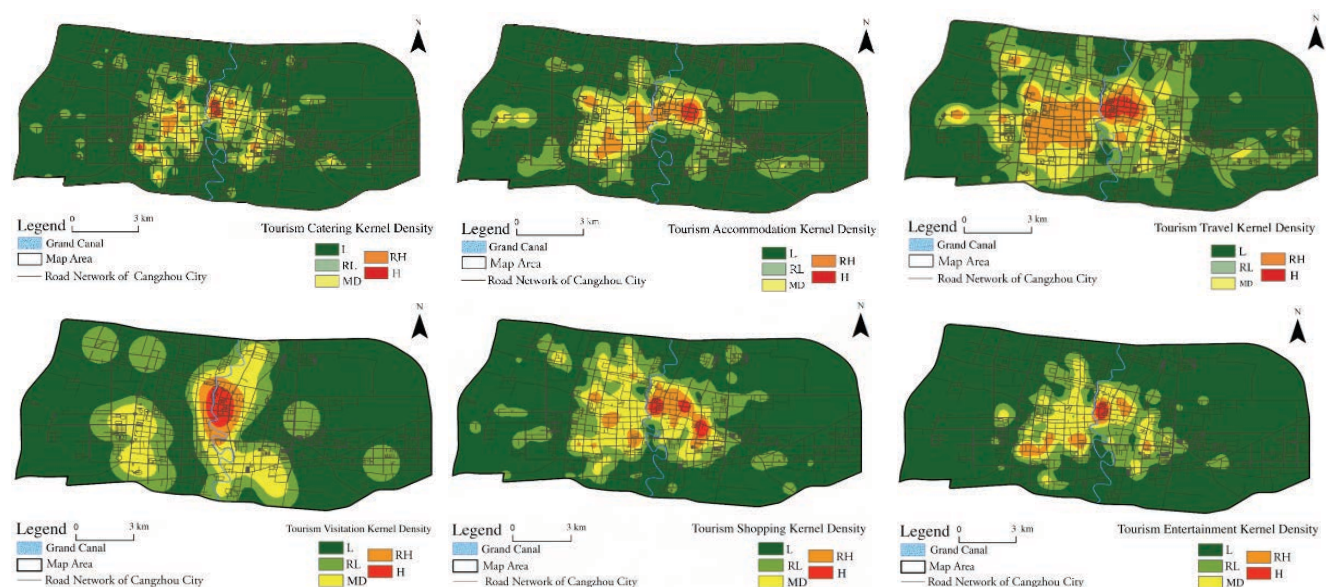


**Figure 1.** Integration of roads in the Cangzhou urban area



### 3.2. Kernel density analysis

The kernel density distribution analysis of various tourism POIs in the main urban area of Cangzhou City enables a comparison of spatial layout differences among different POI categories, revealing their inherent spatial correlations (**Figure 2**). In the center of the city, there is a region where various POIs are distributed in a red circular high-density pattern, indicating that the tourism supporting facilities in this area are well-developed and comprehensive. Further analysis shows that the spatial distribution of tourism dining, accommodation, transportation, and shopping is more widespread than that of sightseeing and entertainment, with a higher number of high-density areas. Specifically, although the clustering of tourism dining POIs is relatively weak, they are widely distributed in various corners of the main urban area. Tourism accommodation POIs have formed a distinct clustering area in the west of the main city, which is highly consistent with the actual situation, considering its proximity to the high-speed rail station. Additionally, tourism transportation POIs are more evenly distributed with a higher overall density, which is conducive to the development of Cangzhou's cultural tourism industry. Tourism sightseeing POIs are significantly clustered only on both sides of the Beijing-Hangzhou Grand Canal, forming a narrow, high-density distribution belt from north to south. The western clustering area mainly includes cultural attractions such as the Cangzhou Museum and Shicheng Park. The distribution of tourism shopping POI is mainly concentrated in commercial areas with high economic levels and strong consumption capabilities, and the phenomenon of distribution along the city's main transportation routes is also typical. On the other hand, tourism entertainment POIs are relatively concentrated, with lower kernel density values on the east and west sides of the central city, indicating poor spatial matching between entertainment elements and other types of tourism elements in these areas, which needs further optimization and improvement in the future.



**Figure 2.** Kernel density of tourism elements in the Cangzhou urban area

### 3.3. Average nearest neighbor

Spatial analysis based on the six tourism elements of “food, accommodation, transportation, sightseeing, shopping, and entertainment” POI in the main urban area of the Grand Canal cultural belt in Cangzhou City shows that the overall tourism elements and the five categories of dining, accommodation, transportation, shopping, and entertainment all exhibit significant spatial agglomeration distribution (**Table 2**). The R-index of overall tourism



elements is 0.38, which is similar to the agglomeration degree of accommodation ( $R=0.44$ ) and shopping ( $R=0.48$ ) elements, reflecting that the tourism service system in the main urban area is highly concentrated in several core areas. The spatial agglomeration intensity of each element, from high to low, is: dining ( $R=0.28$ ) > accommodation ( $R=0.44$ ) = entertainment ( $R=0.44$ ) > shopping ( $R=0.48$ ) > transportation ( $R=0.59$ ) > sightseeing ( $R=0.87$ ). The highest concentration of the dining industry is mainly due to the highly concentrated distribution of industrial clusters such as snack streets and food cities. The high agglomeration of accommodation and shopping elements stems from their rigid demand attributes as basic tourism facilities. Especially in the context of consumption upgrading, the shopping function has evolved from a single demand to a composite experience carrier, further driving its spatial agglomeration. The spatial agglomeration of entertainment and transportation elements is moderate. Entertainment demands are usually met after dining, accommodation, and shopping, while transportation elements mainly undertake the function of connecting other types of tourism functional areas. The sightseeing element has the lowest agglomeration degree, and its spatial distribution is relatively the most dispersed.

**Table 2.** Nearest neighbor index and spatial structure type of tourism elements in Cangzhou City

Category	Mean observed distance (m)	Mean expected distance (m)	z-score	P-value	R-index	Distribution type
Overall	20.92	50.96	-141.18	0.00	0.38	Clustered
Dining	20.14	78.81	-126.69	0.00	0.28	Clustered
Accommodation	112.63	255.65	-27.41	0.00	0.44	Clustered
Transportation	96.75	164.11	-31.33	0.00	0.59	Clustered
Sightseeing	976.43	1122.97	-1.45	0.15	0.87	Random
Shopping	67.94	142.82	-45.98	0.00	0.48	Clustered
Entertainment	81.52	184.25	-37.91	0.00	0.44	Clustered

### 3.4. Spatial autocorrelation analysis

Using GeoDa software and based on a 500m×500m grid, the number of POIs within each unit was counted. A spatial weight matrix was constructed using the queen contiguity principle, and a global spatial autocorrelation analysis was conducted for various tourism elements. The analysis results showed that the spatial agglomeration of dining elements was the most significant, with a Moran's I index of 0.45, indicating a high degree of positive spatial autocorrelation (**Table 3**). Shopping elements (Moran's I = 0.42) and entertainment elements (Moran's I = 0.40) also demonstrated strong spatial agglomeration characteristics, typically concentrated in commercial centers or specific blocks. Although the agglomeration degree of accommodation elements (Moran's I = 0.33) and travel elements (Moran's I = 0.32) was relatively lower, there was still a significant positive spatial autocorrelation, indicating their clustered distribution in space. In contrast, the spatial autocorrelation of sightseeing elements was the weakest, with a Moran's I index of only 0.05. This result might be related to the linear geographical constraints of the canal: although cultural attractions were mainly distributed along the canal corridor, their narrow morphological characteristics and limited number of elements resulted in significantly larger point spacing between attractions than other types of elements, making the spatial agglomeration less prominent.

**Table 3.** Spatial autocorrelation analysis table of tourism element POIs in Cangzhou City

Element	Moran's I	P-value	Z-score
Dining	0.45	0.005	36.0
Accommodation	0.33	0.005	27.9
Transportation	0.32	0.005	30.1
Sightseeing	0.05	0.005	4.6
Shopping	0.42	0.005	34.0
Entertainment	0.40	0.005	34.7

### 3.5. Bivariate spatial autocorrelation analysis of tourism elements

According to the results of the bivariate spatial autocorrelation analysis, tourism elements such as dining, accommodation, travel, shopping, and entertainment within the Grand Canal cultural belt of Cangzhou City showed a certain degree of positive correlation (**Table 4**). Among them, the correlation between dining elements and other elements was more significant, with the highest correlation of 0.41 with shopping elements. This indicated a strong consistency in the spatial distribution of dining and shopping elements, which often clustered together. Additionally, the correlation between dining elements and accommodation and travel elements reached 0.30 and 0.40, respectively, demonstrating the synergy in their spatial distribution. The correlation between accommodation and travel elements was 0.30, suggesting a certain spatial association between them, possibly concentrated around transportation hubs or tourist attractions. The correlation between shopping elements and travel elements was 0.36, which might imply mutual coordination in the layout of shopping venues and transportation facilities, facilitating travel and shopping for tourists. The correlation between entertainment elements and shopping elements was 0.38, indicating a strong interrelationship between entertainment facilities and shopping venues, typically clustered near commercial centers. In contrast, the correlation between sightseeing elements and other elements was generally low, with correlations below 0.08 for dining, accommodation, travel, shopping, and entertainment elements. This suggested that the spatial distribution of sightseeing elements was relatively independent of other tourism elements, showing weaker synergy with them.

**Table 4.** Bivariate spatial autocorrelation analysis table of tourism element POIs in Cangzhou City

Element	Dining	Accommodation	Transportation	Sightseeing	Shopping	Entertainment
Dining	-					
Accommodation	0.30	-				
Transportation	0.40	0.30	-			
Sightseeing	0.07	0.30	0.08	-		
Shopping	0.41	0.31	0.36	0.05	-	
Entertainment	0.42	0.29	0.36	0.07	0.38	-

## 4. Conclusion and discussion

This study relies on POI data obtained from the Gaode Map API and employs spatial analysis techniques to investigate the spatial distribution patterns and intrinsic connections of tourism elements in the core area of the

Grand Canal cultural belt in Cangzhou City. The analysis results show that the tourism elements in the study area exhibit significant spatial agglomeration characteristics: the catering elements have the highest degree of agglomeration, mainly due to the dense layout of specialized dining areas such as snack streets and food cities; accommodation and shopping elements also have significant agglomeration, reflecting their rigid demand characteristics as tourism infrastructure. Under the trend of consumption upgrading, the shopping function has transformed from a single consumption place to a composite experience space, further strengthening the spatial agglomeration effect. The agglomeration intensity of entertainment and travel elements is at a moderate level, while the agglomeration of touring elements is the lowest, and their discrete distribution state is closely related to the linear geographical constraints of the Grand Canal corridor.

Spatial correlation analysis reveals a positive spatial correlation between various elements. The spatial synergy of catering elements is most prominent, and its correlation strength with shopping elements reaches 0.41 (Moran's I), indicating a high degree of overlap in their spatial distribution, often forming functionally complementary agglomeration areas. Accommodation and travel elements also show clear spatial correlation characteristics, manifesting as a coordinated distribution around transportation hubs and scenic areas. Touring elements exhibit spatial independence, with correlation strengths with other elements all below 0.08. This characteristic is mainly influenced by the dual factors of natural landscape distribution and geographical location.

This study reveals the distribution characteristics of tourism elements through empirical analysis, providing a theoretical basis for regional tourism planning. With the continuous development of the tourism industry in Cangzhou City, the spatial configuration of tourism elements should be further optimized, strengthening the synergy between various elements and enhancing the overall competitiveness of the tourism industry. In subsequent research, more data sources and analysis methods, such as tourist behavior data and social media data, can be considered to provide a scientific basis for sustainable development.

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## Disclosure statement

The author declares no conflict of interest.

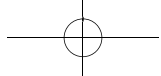
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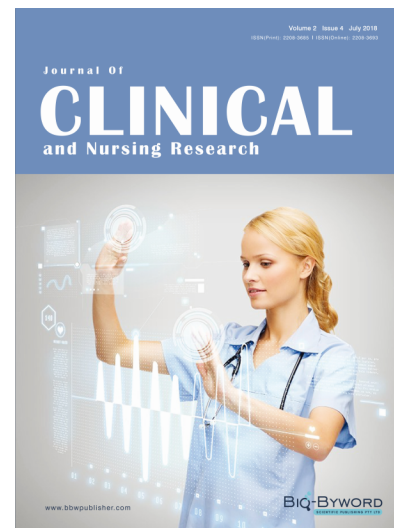
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