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Rivers as Media: Spatial Construction and Geopolitical Negotiation in China's Borderlands

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ABSTRACT

Rivers, through their interaction with humanity, have shaped human civilization. The political significance of rivers as boundaries has long been overshadowed by their practical uses and aesthetic values, receiving limited scholarly attention. Spanning China's east and west, the Erguna River in the northeast and the Irtysh River in Xinjiang serve as key border rivers. As border rivers, they share frontier attributes and symbolize the negotiation between natural order and political boundaries. Their differing roles, influenced by unique natural features and relational actors, create diverse spatial dynamics. Cross-border rivers mediate China's relationships with neighboring countries and subtly reshape global geopolitical patterns. This highlights their mediatory significance, capacity for spatial transformation, and nuanced relationships with human societies, neighboring countries, and the broader world.

Introduction: Rivers as Media

Throughout history, rivers have consistently played a vital role in shaping the rise and fall of civilizations (Smith, 2022). Early large-scale societies emerged and flourished along the basins of the Tigris-Euphrates, Indus, Nile, and Yellow Rivers. With the advancement of civilization, rivers increasingly demonstrated their powerful shaping forces and enduring influence, engaging in both overt and covert interactions with human society. These interactions created meaningful spaces that connect nature and humanity while fostering human exchanges. Such connections and interactions underscore the role of rivers as media. In recent years, scholars have sought to counterbalance the positivist logic prevalent in classical communication studies by reimagining the concept of media. They emphasize expanding the imaginative horizons of media understanding (Hu, 2019). The notion of "rivers as media" investigates the mediatory potential of rivers, positioning them within the dynamic processes of human societal development and the historical evolution of civilizations.

Historically, rivers have captivated humanity, showcasing their aesthetic value in global art, religion, and cultural landscapes. Yet, conflicts and confrontations along rivers persist. At territorial boundaries, rivers enable international cooperation and resource-sharing but also pose risks of disputes and wars. The dual characteristics of "segmentation and cohesion" and "boundaries and connections" define the ambivalent nature of border rivers, offering rich potential for communication

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research. The Erguna River in northeastern China and the Irtysh River in the northwest provide illustrative examples. These rivers cross China's borders, subtly influencing its relationships with neighboring countries. While both rivers serve as border waterways, their characteristics differ significantly. The Erguna River rises on the western slopes of the Greater Khingan Range and flows northward, forming the border between China and Russia. In contrast, the Irtysh River originates in Xinjiang, flows through Kazakhstan and Russia, and functions as an international river traversing the Eurasian continent (Yan, 2019). The shared borderland attributes and contrasting hydrological features of these rivers offer a robust foundation for comparative studies. Notably, while rivers such as the Lancang River have received considerable academic attention, the communicative roles of the Erguna and Irtysh Rivers remain underexplored. Investigating these rivers highlights the importance of addressing challenges in China's northeastern and northwestern borderlands and provides crucial insights into China's relationships with Central and Northern Asia.

This paper examines the Erguna River and Irtysh River, which represent China's northeastern and northwestern borderlands, respectively. By framing rivers as media, this study investigates the complex interplay between natural forces and human societies. It further explains how rivers shape civilizations, mediate relations, symbolize power, and ultimately influence human futures.

Research Method

This study employs a combination of the document analysis method and case analysis to examine the communicative roles of rivers in geopolitical and spatial constructions. By integrating these two complementary approaches, the research addresses both the theoretical and empirical dimensions of rivers as media. This methodological framework enables a comprehensive investigation, focusing on the dynamic interplay between natural forces, human activities, and geopolitical processes.

The document analysis method systematically organizes and examines existing materials to provide essential data and contextual information for this study (Bowen, 2009). This approach facilitates a comprehensive understanding of the role of rivers in geopolitical and spatial constructions, particularly their diverse interactions with human societies, from historical, geographical, and communication studies perspectives. The study draws on various types of documents, including historical treaties (e.g., the Treaty of Nerchinsk), hydrological records (e.g., Hydrology Records of Hulunbuir League), and scholarly works on borderland geopolitics and transboundary river governance. These sources offer rich foundational data for analyzing the characteristics of the Erguna and Irtysh Rivers. By employing the document analysis method, the study effectively extracts critical information from existing literature, providing necessary background and detailed support for the subsequent case analysis.

The case analysis method complements the theoretical insights by focusing on the Erguna and Irtysh Rivers as representative examples. These two rivers were selected due to their shared status as border rivers, as well as their distinct hydrological and geopolitical characteristics. The Erguna River, as a territorial boundary, serves as a site of cultural and political negotiation, while the Irtysh River, as a transboundary waterway, exemplifies the complexities of international cooperation and conflict. The case analysis delves into their unique interactions with natural forces and human interventions, providing a comparative perspective on their roles in spatial construction and geopolitical dynamics.

By integrating document analysis and case analysis, this study offers a comprehensive framework for understanding rivers as media. The combination of these methods not only bridges theoretical and empirical perspectives but also advances the study of rivers' communicative functions within geopolitical and spatial contexts.

Border Rivers: Negotiation Between Natural Order and Political Boundaries

The shared borderland attributes of the Erguna River and the Irtysh River provide a foundational basis for comparative studies. These rivers intersect as symbols of political significance in China's borderlands. Borderlands in China are both geographical and historical concepts (Ma, 2017). Examining these two rivers within the context of modern Chinese borderlands necessitates addressing the historical issues tied to China's borders. Politically, these rivers also represent considerations of power dynamics. Meanwhile, as natural forces, rivers inherently delineate order through their trajectories, although human interventions frequently alter this order. Border rivers thus reflect the negotiation between natural order and political boundaries, embodying the interaction between natural forces and human agency.

Rivers as Media: Theoretical and Analytical Foundations

Rivers, as natural entities, occupy a pivotal position at the intersection of material properties and social significance, embodying profound mediatory roles. These roles are evident not only in their function as physical boundaries and transportation corridors but also in their symbolic significance in power negotiations, cultural interactions, and geopolitical processes. Viewing rivers as media highlights their distinctive role in mediating the interaction between nature and human civilization, illustrating how their material attributes and symbolic values

connect people with the environment, nations with each other, and regions with the global context.

From the perspective of communication theory, McLuhan's concept of "the medium is the message" emphasizes that media do more than carry information; they fundamentally shape societal structures through their inherent forms and characteristics (McLuhan, 1994). Rivers, as media, transmit resources, information, and culture, while their material properties influence power dynamics and social relations. For example, a river's flow direction determines regional resource distribution, and its clarity as a natural boundary reinforces its symbolic significance in political demarcation. Harold Innis's theory of "the bias of communication" further expands this analysis (Innis, 1999). Rivers exhibit "spatial bias" by defining geographical order through physical boundaries and "temporal bias" by serving as vessels of cultural memory and regional identity across generations.

Building on these foundational theories, this study employs the analytical lens of "media materiality" to explore more comprehensively the mediatory attributes of rivers in the interplay between nature and society. Recent years have seen the rise of the material turn in media studies, which has become a significant trend in communication and media research. Unlike traditional media studies, which often focus on semiotics and meaning-making, the material turn emphasizes the physical characteristics, technological forms, and tangible effects of media in the real world. In this study, "media materiality" highlights the importance of rivers' physical attributes, not only as the basis of their mediatory role but also as critical components of their communicative functions. This perspective considers rivers' physical characteristics—such as watershed distribution, water resource availability, and ecological impact—as central to shaping social relations and power structures within regions.

Viewing rivers as media facilitates a nuanced understanding of their complex roles in negotiating natural order and political boundaries. The material properties of rivers provide the foundation for natural order through their ecological functions and water resource distribution patterns. Simultaneously, these properties acquire symbolic significance by mediating power negotiations and geopolitical interactions between nations. The inherent logic of natural order is often subject to human intervention and reshaping, positioning rivers as unique sites where natural and political forces converge. In this dual capacity, rivers act both as physical mediators that divide spaces and as symbolic connectors that bridge societies and cultures.

Analyzing rivers as media reveals their capacity to reconcile the tensions between natural forces and political interests, offering a theoretical foundation for understanding their multifaceted roles in negotiating natural order and political boundaries. This perspective establishes a basis for subsequent analysis of rivers through the dimensions of nature, relations, and space, contributing to a deeper understanding of their pivotal role in constructing geopolitical and cultural spaces in border regions.

The Pulse of the Land: the Erguna and Irtysh Rivers

Every flowing river breathes life into the landscapes it traverses (Wang, 2022). As a "pulse of the land," rivers nourish human civilizations. The Erguna River flows through China's northeastern borderlands, originating from the western slope of the Greater Khingan Range. It courses through the Hailar River, eventually merging with the Shilka River in Russia before feeding into the Heilongjiang River. However, the Erguna River's genesis is not solely tied to the Greater Khingan. The Khurkh River, originating in the Khentii Mountains of Mongolia, flows into Hulun Lake, which further connects to the Erguna River through the Dalanolom River. Interestingly, since the 18th century, the outflow from Hulun Lake ceased, with the Hailar River periodically reversing its flow back into the lake before merging with the Erguna River (Baidu Baike, 2020). The eastern and northern sections of the Erguna River run along the northwest edges of the Greater Khingan Range, while the southern area transitions into the Hulunbuir Grassland. This transitional zone between forest and grassland supports both grazing and farming activities (Tang, 2011). The river's watershed is dotted with 303 tributaries, covering the Hulunbuir Grassland (Hulunbuir League Hydrology Records, 1992). In 1929, British anthropologist Lindeguer described the fertile triangle formed by the southern reaches of the Erguna River as "the most fertile land in all of Northwest Manchuria... its vast basin sustains prosperous agriculture, and the hillsides are carpeted with the grasses essential for livestock" (Lindeguer, 1991). The Erguna River is more than a natural watercourse; it is a historical river. Over the centuries, it has been known by various names, including Wangjian River in the Old Book of Tang, Anzhen River in the History of Liao, and Yeliguna River in the History of Yuan. Its current name, Erguna, has remained consistent since the Qing Dynasty (Liu, 2022). The river's enduring history has endowed the grasslands it nourishes with a wealth of natural resources, forming the cradle of grassland civilization. Following the end of the Pleistocene glacial period about 10,000 years ago, the Zhalainuoer people created the Zhalainuoer Culture along Hulun Lake, marking the origins of northern China's grassland civilizations.

The Irtysh River, the second-largest river in Xinjiang, originates in the Altai Mountains. It crosses the border into Kazakhstan before joining the Ob River in Russia and eventually emptying into the Arctic Ocean. There are 23 transboundary rivers shared between China and Kazakhstan, with the Irtysh and Ili Rivers being the most significant boundary rivers (Xu, 2022). The Irtysh River basin is expansive, with numerous right-bank trib-

utaries forming a typical comb-shaped hydrological system. Its scenic banks, complementing the golden Altai Mountains, have earned the river the moniker "Silver Waters." The river winds through China's western borderlands, sustaining life in arid desert regions, crossing into Kazakhstan and Russia, and linking Central and Northern Asia.

In northeastern China, the Erguna River delineates national borders through natural forces. On the Eurasian continent, the Irtysh River traverses China, Kazakhstan, and Russia, exerting its influence through the establishment of natural order. Rivers, through their interactions with humanity, have nurtured civilizations. However, this does not suggest that natural forces alone dictate everything. Humanity has imbued rivers with multi-dimensional meanings, engaging with them in diverse ways (Ge, 2021). Globally, many centers of knowledge, culture, and power have been shaped by rivers. For border rivers, the political and power implications are especially significant.

Crossing Through Rivers: National Boundaries and Power Struggles

Rivers can both define and cross international boundaries, compelling nation-states to cooperate while potentially triggering conflicts over water resources or territorial disputes (Galtung, 1982). This duality illustrates how rivers, beyond being physical geographical features, serve as instruments of power and objects of political contestation. Rivers delineate the boundaries of nations and shape their geographical forms, simultaneously revealing underlying political interests. Using rivers as borders reflects a natural geographical logic while also highlighting the hidden political agendas they embody. Globally, many nations use rivers and other natural geographical features as political boundaries. For instance, the Erguna River separates China's northeast from Russia's Far East. Similarly, the Rio Grande demarcates the United States and Mexico, the Yalu River separates China and North Korea, and the Oder River marks the border between Germany and Poland. In South America, the Uruguay River defines parts of the borders between Brazil, Argentina, and Uruguay. Within China, rivers and mountains frequently serve as provincial boundaries, such as the Qilian Mountains separating Gansu and Qinghai provinces and the Jinsha River marking the boundary between Sichuan and Tibet. Smith (2022) quantified the global phenomenon of rivers as political borders, identifying 219 pairs of countries, 2,267 pairs of states or provinces, and 13,674 pairs of counties or local districts that rely on rivers as boundaries. The advantage of using rivers as borders lies in their clear visual delineation. Before the advent of advanced geographic mapping technologies, rivers were often employed by colonial powers to demarcate and negotiate territories. This practice, deeply rooted in history, remains relevant in global geopolitics today. Rivers, as natural forces intertwined with human civilization, weave through cities and national boundaries, shaping and defining the contours of nations.

However, natural geography alone does not entirely determine borders or serve as an immutable cartographic guide. Politicians increasingly recognize the political leverage rivers offer, leading to disputes over control and utilization. In contemporary geopolitics, rivers frequently appear in territorial conflicts. Early discussions on transboundary river conflicts framed these issues within the lens of "resource conflicts" (Galtung, 1982). Scholars argued that the degree to which water resources are utilized significantly impacts a nation's socioeconomic development. As industrialization and population growth exacerbate water scarcity, fears of "water wars" have grown. Control over critical rivers has thus become a focal point in inter-state conflicts. Cross-border rivers in border regions add complexity to these disputes. On the one hand, shared water resources necessitate cooperation but can also lead to friction due to differing national interests. On the other hand, border regions often lag economically compared to central areas. In China, the influence of ethnic regional autonomy further complicates matters. Thus, studying cross-border river practices in these regions requires not only addressing inter-state relations and political implications but also considering the historical and sociocultural contexts of China's borderlands.

The Erguna River, marking the boundary between China and Russia, is located in China's northeastern frontier, outlining the crest of China's rooster-shaped map. The 1689 Treaty of Nerchinsk formally established the Erguna River as the boundary between China and Russia, stating, "The Erguna River flowing into the Heilongjiang River shall serve as the border: lands south of the river belong to China, while lands north belong to Russia" (Commercial Press, 1973, p. 1). However, this natural barrier did not prevent interactions between the two peoples. In 1727, during the reign of Emperor Yongzheng, the Qing government established 12 outposts along the river's Chinese side and repeatedly instructed local authorities in Hulunbuir to enhance border management and prevent Russian incursions (Baoyinchaoketu, 2005, p. 23). Despite these efforts, the river continued to attract conflict. In 1882, a member of the Oroqen ethnic group discovered substantial gold deposits near the river's estuary, drawing Russian miners. By 1884, the Russians had established a "Gold Mining Bureau" in the region, complete with districts, military forces, and administrative structures, effectively creating a self-contained authority (Erguna Banner Gazetteer Compilation Committee, 1993, pp. 262–263). These activities challenged Qing control over border resources, prompting the government to expel Russian miners. By the late 19th century, the political balance along the Erguna River began to shift toward Russia, exacerbated by events such as the Boxer Rebellion and subsequent Russian occupation of key outposts along

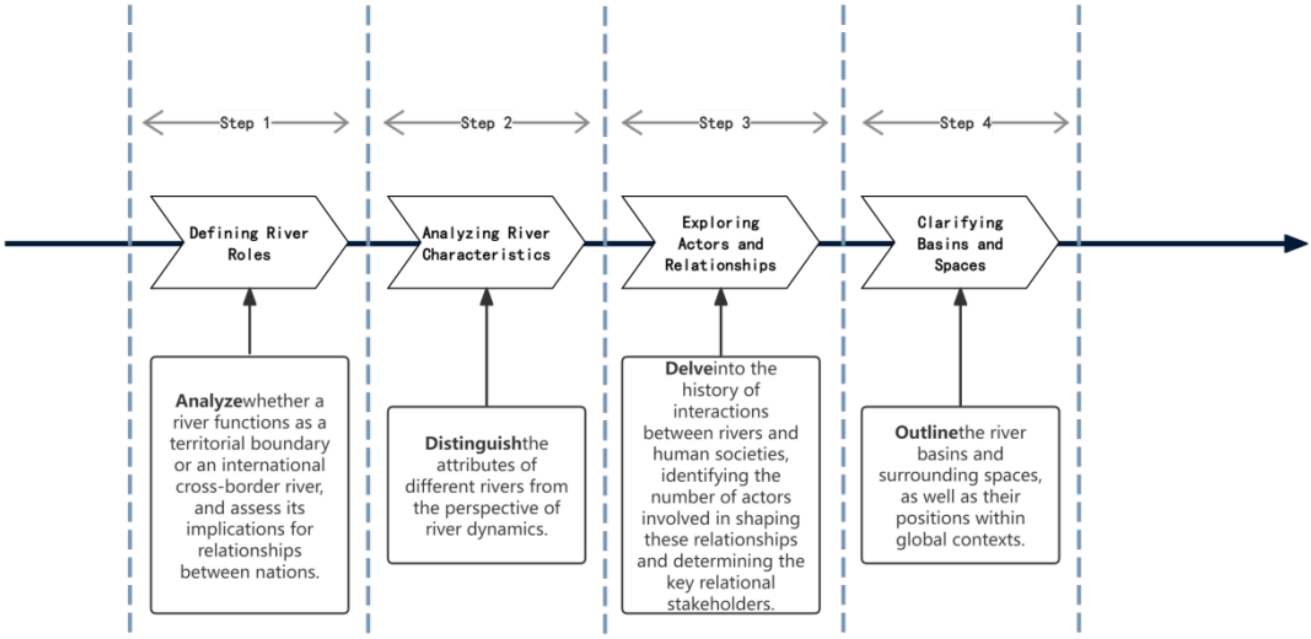

Figure 1 | the framework for comparative analysis of border rivers

the river in 1900. This history illustrates how the Erguna River has consistently been a focal point of political power struggles and territorial contestation.

In contrast, the Irtysh River, located in Xinjiang, is not a boundary river but a transcontinental waterway linking China, Kazakhstan, and Russia. The river's comb-like hydrological pattern connects diverse regions, providing a lens to study "water interactions," which encompass both water conflict and cooperation (Yang, 2021). The Irtysh River, shared by China and Kazakhstan, is a vital resource for both nations. While Kazakhstan, located downstream, fears the impact of China's water infrastructure projects on river flow, it also relies heavily on the Irtysh for its water-scarce regions. For China, the Irtysh River is the second-largest river in Xinjiang, crucial for regional socioeconomic development. Over the years, China and Kazakhstan have engaged in water-sharing agreements, including the establishment of a joint expert working group in 1998 and a bilateral cooperation framework in 2001. These efforts have positioned the Irtysh River as a model for transboundary river governance (Yan, 2019).

The contrasting roles of the Erguna and Irtysh Rivers underscore the multifaceted ways rivers shape national boundaries and political dynamics. While the Erguna River emphasizes the geopolitics of demarcation, the Irtysh River highlights the challenges and opportunities of transboundary cooperation.

'Division' and 'Cohesion': the Duality of River Genes

Drawing on the biological concept of "genes," British biologist Richard Dawkins introduced the term "meme" in The Selfish Gene (1976), suggesting that cultural evolution involves basic units similar to biological genes, which can be replicated, inherited, and influence the nature of culture (Wu, 2013). Similarly, "river genes" refer to the intrinsic characteristics of rivers that endure and shape their interaction with human societies.

On the one hand, rivers serve as natural barriers, dividing lands and demarcating boundaries between nations. On the other hand, the natural resources and navigational opportunities rivers offer have facilitated agriculture, industry, trade, and the exchange of civilizations. Rivers not only give rise to civilizations but also connect them. The duality of "division" and "cohesion" constitutes the essence of river genes.

However, which aspect of this duality predominates is not predetermined but instead depends on human activity. Rivers can be the focus of conflicts over water resources or control of shipping routes, or they can be the basis for treaties and cooperative agreements fostering mutual benefit and friendly exchanges. This dynamic implies that we should not impose preconceived roles or expectations on rivers, particularly those situated along borders. The historical entanglements and contemporary interactions among nations, the complex realities of China's border regions, and the blending of peoples and cultures provide unique analytical frameworks for each river. The Erguna River, a border river

between China and Russia, and the Irtysh River, a transboundary river linking China, Kazakhstan, and Russia, possess different characteristics due to their distinct types. A comparative analysis of these two rivers offers deeper insights into the intersections of rivers, civilizations, and power dynamics.

Cross-Border Rivers and Territorial Boundary Rivers: Contrasting Nature, Relations, and Spaces

Previous studies have primarily focused on rivers as a whole, examining their interactions with human civilization, or on specific cross-border river issues such as international cooperation, conflicts, or disputes. However, comparative studies on cross-border rivers and territorial boundary rivers within the same country remain scarce. The Erguna River and the Irtysh River, located in China's northeastern and northwestern borderlands respectively, offer ideal cases for such a comparison. Despite their shared frontier characteristics, the rivers differ in their roles and positions, providing a foundation to explore their distinctions and the complex relationships they represent. Specifically, natural factors largely determine a river's practical uses, while relational actors define their roles through specific practices, resulting in distinct spatial characteristics. Figure 1 illustrates the framework for comparing border rivers.

Natural Foundations: Hydrological Differences Between Inland and Outflowing Rivers

Inland rivers flow into lakes or disappear inland without reaching the sea. Historically, the Erguna River was an inland river during the Mongol Empire, later becoming a boundary river between China and Russia following the Treaty of Nerchinsk. Today, the Erguna River converges with Russia's Shilka River before flowing into the Heilongjiang River and eventually reaching the Sea of Okhotsk. Due to its geographic environment, the Erguna River lacks substantial hydraulic potential, meandering gently. The President of the China Mongolian Literature Society, Uliji, described the Erguna River in his work Erguna River Journey: "When we sailed to the confluence of the Enhehada River and the Erguna River, we witnessed the gentle rhythmic waves caressing the shore, their confluence stirring white ripples that delighted the senses" (Uliji, 2018). At its source, the Erguna River connects with the Dalan-Olom River and Russia's Munniatu River, forming a transnational wetland. The Erguna Wetlands Park, located at the river's headwaters, offers a picturesque landscape of meandering streams and lively birds.

Outflowing rivers, in contrast, flow directly or indirectly into the sea. The Irtysh River originates in Xinjiang, exits China, flows through Kazakhstan and Russia, and eventually empties into the Arctic Ocean. It is China's only river draining into the Arctic. The upper reaches of the Irtysh are replenished by melting snow, ice, and precipitation, boasting abundant water flow and concentrated elevation drops. With an annual runoff of 11.1 billion cubic meters, it holds rich hydropower resources. This robust hydraulic force also supports infrastructure like the Irtysh-Karaganda Canal and urban water supply systems (Baidu Baike, 2023). Furthermore, the Irtysh River is a shared transnational river among China, Kazakhstan, and Russia. Spanning 4,235 kilometers, with 525 kilometers in China, 1,700 kilometers in Kazakhstan, and 2,010 kilometers in Russia, its basin covers 1.643 million square kilometers, enabling extensive international navigation. The river's strategic location at the Arctic Ocean's edge further facilitates multidimensional development. Some scholars regard the Irtysh-Ob River corridor as a potential pathway for Eurasian integration. Given its unique geographic position, the Irtysh connects Central Asia to the Arctic region while linking South Asia via roads, railways, and even pipelines, thereby vertically integrating the Eurasian continent (Mei & Guo, 2017). Consequently, China, Kazakhstan, and Russia have collaborated and negotiated over its management and utilization.

From a geographical perspective, identifying the Erguna as an inland river and the Irtysh as an outflowing river provides a basis for analyzing the practices and relational structures surrounding these rivers. Their differing geographic locations, trajectories, and hydrological characteristics highlight their distinctions despite shared border attributes. Clarifying these differences not only enriches our understanding of rivers but also informs potential future interactions between these rivers and human societies.

Relational Actors: National Governments and Integrated Ethnic Communities

Rivers do not interact abstractly with human societies. The geographical locations, characteristics of rivers, and historical practices significantly influence the relational actors involved and their choices concerning political considerations and cultural integration. Generally, the Irtysh River is centered around national governments, focusing on cooperation in water resources and socio-economic development. In contrast, the Erguna River emphasizes integrated ethnic communities, fostering water culture and ethnic integration.

Since Kazakhstan's independence, China and Kazakhstan have initiated cross-border river cooperation, including on the Irtysh River. In 1998, the two governments established the China-Kazakhstan Joint Working Group on Cross-Border Rivers. The 2001 Agreement on the Use and Protection of Transboundary Rivers, signed between China and Kazakhstan, marked the first formal collaboration between the two nations (Yan, 2019). Subsequently, the two countries have achieved substantial progress in water quality monitoring, joint water infrastructure projects, and water resource sharing. Under the auspices of this joint committee, the ecological protection of the Irtysh River has become a

model for transboundary river management in Central Asia (Yan, 2019). The political activities led by national governments provide long-term, systematic, and stable support for water cooperation on the Irtysh River. In particular, the increasing integration of the Belt and Road Initiative (BRI) has brought the Irtysh River basin into focus as a sub-regional connection between China, Kazakhstan, and Russia. The Irtysh-Ob River corridor connects the Silk Road Economic Belt, the Polar Silk Road, and the Yamalo-Nenets Peninsula, laying a foundation for extensive international cooperation (Mei & Guo, 2017). In September 2021, Kazakhstan's ambassador to China, Gabit Koishybayev, called for a bilateral agreement on shared water resources in light of climate challenges, stating, "China's hydrological policies in Xinjiang Uygur Autonomous Region will not only determine its regional status but also affect Kazakhstan's ecological systems" (Sputnik News, 2021). However, while rivers connect the two nations, they also pose potential crises and conflicts. The positions of upstream and downstream countries are inherently unequal, carrying significant implications for sovereignty. Kazakhstan, located downstream on the Irtysh River, has expressed concerns about China's utilization of water resources. In a water-scarce Kazakhstan, China's exploitation of the Irtysh River could lead to potential water conflicts. Globally, such disputes are not new. In 1895, Mexico filed an urgent complaint with the U.S. Department of State regarding the Rio Grande water diversion project. The U.S., citing absolute sovereignty over domestic rivers, refused, resulting in the "Harmon Doctrine." While this doctrine highlights the vulnerability of downstream nations, it also led to the 1907 agreement between Mexico and the U.S., setting a precedent for transboundary river management (Galtung, 1982). These historical lessons inform ongoing bilateral cooperation between China, Kazakhstan, and Russia on the Irtysh River. Despite existing collaboration, a stable trilateral cooperation framework has yet to be established.

In contrast, ethnic communities dominate the relational framework of the Erguna River in China's northeastern borderland. During the 19th-century gold rush along the Erguna River, a significant influx of laborers migrated to the region, and the Russian Empire implemented a "Russification of the Frontier" policy by relocating large numbers of Russians to Siberia and the Far East. This process led to intermarriage between Chinese and Russian populations. The Qing official Zhao Chunfang noted in his Report on Border Affairs of the Zhuergan River General Kulan, "First, they built friendships; then, they built marriages. Along the border, many Chinese have cut their hair, changed their clothes, and married Russians" (Zhao, 1911). Such long-term intermarriages have established cultural villages, serving as active sites of exchange and interaction along the Erguna River. In 1994, the E'nhuo Russian Ethnic Township was established in Erguna City, and in 2001, the Inner Mongolia Autonomous Region merged the original Shiwuer and E'nhuo Russian Ethnic Townships into the Shiwuer Russian Ethnic Township. Within these communities, Chinese and Russian cultures collide and blend, manifesting in music, architecture, religion, and burial customs. Human-mediated exchanges along the Erguna River have thus created a unique cultural landscape along its banks.

While the Erguna River, as a territorial boundary, and the Irtysh River, as a transboundary waterway, differ significantly in relational actors, this does not preclude Sino-Russian cooperation on the Erguna River or interpersonal exchanges in the Irtysh basin. Instead, their distinctions reflect their respective priorities and orientations in spatial construction.

Spatial Construction: Global Geopolitical Divisions and the Formation of the Erguna Cultural Border Area

The differing interactions of relational actors shape the spaces constructed around the Erguna and Irtysh Rivers. The Irtysh River influences not only China's relationships with Kazakhstan and Russia but also the broader geopolitical configuration of Central and Northern Asia. For Russia, the Irtysh-Ob River corridor presents an opportunity to reassert dominance in Central Asia. The Eurasian Economic Union (EAEU), led by Russia, lacks vertical integration mechanisms, but the Irtysh-Ob River could enhance Russia's presence in Central Asia and extend its influence into South Asia (Mei & Guo, 2017). For China, the Irtysh River offers a low-cost, efficient export channel for Xinjiang, connecting the region to European markets via the Arctic route. Kazakhstan relies on the Irtysh River as a critical freshwater resource. Plans by Russia and Kazakhstan to develop Irtysh River navigation further underscore its strategic importance (Mei & Guo, 2017). Globally, the Irtysh-Ob River corridor impacts the strategies of nations like India and the U.S. As India strengthens ties with Central Asia, the corridor facilitates low-cost access to Arctic oil and gas from Russia, enhancing India's regional influence. Conversely, this could prompt the U.S. to recalibrate its Asian strategy in response to India's growing presence (Mei & Guo, 2017). Thus, the Irtysh River's geopolitical significance extends beyond the interests of its riparian states.

In contrast, the Erguna River basin has given rise to the Erguna cultural border area. The concept of a "cultural area" was first proposed by Franz Boas, and subsequent anthropologists expanded this into the concept of a "cultural border area" as opposed to a "cultural center" (Boas, 1938). The Russian Ethnic Township embodies this cultural border area. As a Sino-Russian cultural space, the township integrates Russian Orthodox traditions, classic log cabins, and hybrid funeral customs, illustrating the fusion of Russian and Chinese cultural "genes." This fusion stems from shared historical logic and civilizational roots between Russia and

China. The Erguna River's stable natural landscape ensures the horizontal transmission of cultural memory across time and facilitates the intergenerational preservation of mixed Sino-Russian traditions (Dai, Huang & Sun, 2023). Through the activation of cultural genes and the sharing of collective memory, the Erguna cultural border area has emerged as a vital bridge for Sino-Russian civilizational exchange.

Conclusion: Rivers as Forces of Power

Rivers have shaped themselves and human civilizations through their interactions with humanity. A world without rivers would be unimaginable. Rivers have fostered early human societies and driven the development of cities, trade, ruling classes, and political systems (Smith, 2022). Their strength and resilience have enabled them to traverse diverse societies throughout history, continually flowing forward. Building on foundational communication theories, this study has framed rivers as media, emphasizing their materiality and symbolic significance in negotiating natural order and political boundaries. The document analysis and case analysis methods have been employed to examine the Erguna and Irtysh Rivers as representative cases, demonstrating how variations in natural characteristics and stakeholder dynamics lead to distinct spatial and geopolitical outcomes.

The Erguna River in northeastern China and the Irtysh River in Xinjiang, spanning east and west, forge meaningful connections and shared spaces between China and its neighbors. Viewing rivers as media prompts exploration of their mediatory role in shaping relationships between rivers and human civilizations. As border rivers, the Erguna and Irtysh Rivers symbolize the interplay between natural order and political boundaries. However, variations in their natural characteristics and involved stakeholders have resulted in distinct spatial dynamics. This paper attempts to construct a preliminary framework for comparative analysis of border rivers. First, it is essential to define the roles of rivers, determining whether they function as territorial boundaries or international cross-border rivers, and evaluating their inter-nation relationships. Second, the characteristics of rivers should be analyzed from the perspective of river dynamics. Third, it is crucial to explore the actors and relationships involved, examining historical interactions between rivers and human societies, identifying the participating actors, and determining key stakeholders. Finally, clarifying river basins and spaces involves mapping their extents, surrounding areas, and positions within the global context. Rivers are not static; as civilizations and technologies evolve, their associated resources and power dynamics reveal new spatial understandings.

Rivers derive power from both their continuity and their creative influence. Our perspective on border rivers mirrors our approach to relationships with neighboring countries. Viewing rivers as media also entails recognizing them as pathways. Cooperation between China and its neighbors on cross-border rivers offers a new starting point, encompassing shared development and protection of water resources, along with the circulation of trade, transportation, energy, and other resources. At this level, cross-border rivers and their resources may function as hidden undercurrents in global geopolitics. Therefore, cross-border rivers in border areas should be central to China's strategies, such as the Belt and Road Initiative and the "Ice Silk Road." Rivers, akin to arteries, are immense forces silently sustaining surrounding systems. As Smith (2022) notes in Rivers: A History of Civilization: 'Today, rivers have been increasingly tamed, bound in chains, yet they remain that ancient force, continuing to govern the lives of us all.'

1. Hu, Y. (2019). How to Understand Media in the Era of Intelligent Media: Fragmented Dialogues with McLuhan. Journalism Review, 9, pp. 11–16. doi:10.15897/j.cnki.cn51-1046/g2.2019.09.003.
2. Smith, L.C. (2022). Rivers: A History of Civilization. Beijing: CITIC Press.
3. Yan, X. (2019). Building the China-Russia-Kazakhstan Irtysh-Ob River Cooperation Mechanism under the Context of the "Ice Silk Road". In Annual Report on Arctic Development 2018. Beijing: Social Sciences Academic Press.
4. Baidu Baike (2020). Secrets of the Erguna River. Available at: https://baike.baidu.com/tashuo/browse/content?id=03557a8fee4c289226d3e4da
5. Ge, J. (2021). Rivers and Human Civilization. Folklore Studies, 6, pp. 5–13, 158. doi:10.13370/j.cnki.fs.2021.06.002.
6. Hulunbuir League Hydrology Records (1992). FZ005857. Available at: https://fz.wanfangdata.com.cn/details/newLocalchronicle.do?Id=FZ005857
7. Lindeguer, R. (1991). Northwest Manchuria and the Reindeer Tungus. In W. Wu (ed.), Heilongjiang Archaeological and Ethnological Materials, Vol. 1. Heilongjiang Provincial Museum.
8. Liu, X. (2022). Exploring the Origins of the Erguna River. China Three Gorges, 5, pp. 22–31.
9. Ma, D. (2017). Governance of China's Borderlands: From History to Reality. Thinking Front, 4, pp. 56–66.
10. Tang, G. (2011). Erguna: A New Cultural Borderland. Russian Studies Journal, 4, pp. 61–71.
11. Wang, F. (2022). The Right Bank of the Erguna River. China Three Gorges, 5, pp. 18–21, 6.
12. Xu, X. (2022). Water Resource Cooperation Between China and Kazakhstan: Achievements and Issues. Siberian Studies, 3, pp. 93–103.
13. Baoyinchaoketu (2005). A Study of Outposts in Qing Northern Borderlands. Beijing: Renmin University Press, p. 23.
14. Commercial Press (1973). Collection of Sino-Russian Border Treaties. Beijing: Commercial Press, p. 1.
15. Erguna Banner Gazetteer Compilation Committee (1993). Gazetteer of Erguna Right Banner. Inner Mongolia Cultural Publishing House, pp. 262–263.
16. Galtung, J. (1982). Environment, Development, and Military Activity: Towards Alternative Security Doctrines. Universitetsforlaget, Columbia University Press.
17. Smith, L.C. (2022). Rivers: A History of Civilization. Beijing: CITIC Press.
18. Yang, Y. (2021). A Comparative Study of Cross-Border Water Interactions between China and Neighboring Countries (Master's thesis). East China University of Political Science and Law.

Available at: https://kns.cnki.net/kcms2/article/abstract.
19. Yan, X. (2019). Building the China-Russia-Kazakhstan Irtysh-Ob River Cooperation Mechanism under the Context of the "Ice Silk Road". In Annual Report on Arctic Development 2018. Beijing: Social Sciences Academic Press.
20. Dawkins, R. (1976). The Selfish Gene. Oxford: Oxford University Press.
21. Wu, Q. (2013). A New Interpretation of Cultural Genes: A Possible Path for Cultural Anthropology. Ethnic Studies, (6), pp. 5–10.
22. Baidu Baike (2023). Irtysh River. Available at: https://baike.baidu.com/item/额尔齐斯河 (Accessed: 4 December 2024).
23. Mei, C. and Guo, P. (2017). Irtysh-Ob: A Path for Eurasian Integration. World Knowledge, 1, pp. 38–39, 42.
24. Boas, F. (1938). The Mind of Primitive Man. New York: Macmillan.
25. Dai, J., Huang, X., & Sun, J. (2023). Theoretical Paradigms of Natural Landscapes as Catalysts for Cultural Identity: A Case Study of the Yellow River National Cultural Park. Folklore Studies, 2, pp. 5–10. doi:10.13370/j.cnki.fs.2023.02.002.
26. Galtung, J. (1982). Environment, Development, and Military Activity: Towards Alternative Security Doctrines. New York: Columbia University Press.
27. Mei, C. & Guo, P. (2017). Irtysh-Ob River: A Pathway for Eurasian Integration. World Knowledge, 1, pp. 38–42.
28. Sputnik News (2021). Kazakhstan Urges China to Sign Bilateral Water Sharing Agreement amid Climate Challenges. Available at: https://sputniknews.cn.
29. Yan, X. (2019). Building the China-Russia-Kazakhstan Irtysh-Ob River Cooperation Mechanism under the Context of the "Ice Silk Road". In Annual Report on Arctic Development 2018. Beijing: Social Sciences Academic Press.
30. McLuhan, M. (1994). Understanding media: The extensions of man. MIT press.
31. Innis, H. A. (1999). The bias of communication. University of Toronto Press.
32. Bowen, G. A. (2009). Document analysis as a qualitative research method. Qualitative research journal, 9(2), 27-40.
33. Harrison, H., Birks, M., Franklin, R., & Mills, J. (2017, January). Case study research: Foundations and methodological orientations. In Forum qualitative Sozialforschung/Forum: qualitative social research (Vol. 18, No. 1).

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Construction of an Evaluation Index System for Construction-Related Interdisciplinary Technical Talents

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KEYWORDS

Talent Evaluation Indicators; Composite Technical Talents in Construction; Talent Cultivation

ABSTRACT

Amid the technological revolution and industrial transformation, the construction industry is accelerating digitalization, green transition, and internationalization, driving the need for versatile technical talent. Traditional evaluation systems, focused solely on technical skills, are no longer sufficient. This study constructs a multidimensional evaluation framework for composite construction professionals, covering hard skills, soft skills, cross-disciplinary capabilities, and sustainable knowledge. It integrates advanced competencies such as BIM modeling, AI tools, and carbon emission calculations, alongside ESG reporting, interdisciplinary collaboration, and emerging fields like circular economy and carbon trading. By applying data-driven methods to determine indicator weights and benchmarks, the framework offers a scientific, dynamic approach adaptable to corporate recruitment, academic training, and career planning. Through practical feedback, the system undergoes iterative optimization. The study also proposes graduate education reforms, including curriculum adjustments, practical training enhancement, and evaluation updates, emphasizing closer industry-academia collaboration. By addressing limitations of traditional evaluations, this framework provides theoretical and practical guidance for cultivating composite talent, supporting sustainable development in the construction sector.

Introduction

Under the backdrop of a new round of technological revolution and industrial transformation, the rapid development and upgrading of the urban and rural construction industry have driven significant shifts in the demand for professionals. The industry now requires talent with diversified and composite competencies. As a critical tool for managing and incentivizing scientific and technological talent, talent evaluation serves as a

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foundational element of talent development mechanisms, forming the basis for talent cultivation, management, and utilization. To better address industry needs, this study integrates four core dimensions—hard skills, soft skills, cross-disciplinary capabilities, and sustainable knowledge—to construct a multidimensional evaluation system. This framework aims to comprehensively and precisely assess the comprehensive competencies of composite construction professionals, providing robust support for industry talent selection and cultivation. By aligning with industry goals and challenges, the system seeks to drive the development of future-oriented construction talent, fostering adaptability to emerging trends such as digitalization, green transformation, and globalization.

The Need for Constructing an Evaluation Index System for Interdisciplinary Technical Talents

Multi-Dimensional Innovative Evaluation Perspective

Unlike traditional construction talent evaluation systems that focus solely on professional technical skills, this index system innovatively adopts a multi-dimensional perspective, incorporating hard skills, soft skills, cross-disciplinary abilities, and sustainable knowledge. This comprehensive evaluation approach covers the comprehensive qualities and capabilities required by construction talents in areas such as digitalization, internationalization, and sustainable development. It fills the gaps in traditional evaluation systems and provides a more precise and holistic measurement of the value of interdisciplinary construction talents, offering new ideas and methods for industry talent assessment.

Close Alignment With Industry Frontiers

The research closely follows the cutting-edge trends in the construction industry, such as digitalization, green development, and internationalization, integrating the latest technologies, concepts, and standards into the evaluation index system. In the hard skills dimension, it includes digital technologies like BIM modeling and AI-assisted tools, as well as green technologies such as carbon emission calculations. In the soft skills dimension, it focuses on international capabilities like ESG report writing and interpretation of international standards. In the sustainable knowledge dimension, it highlights emerging knowledge areas such as circular economy principles and carbon trading mechanisms. This ensures the evaluation index system is forward-looking, guiding the direction of construction talent development and meeting the industry's future demand for interdisciplinary talents.

Data-Driven Scientific Evaluation Methods

A data-driven research approach is adopted, involving extensive collection of industry data and the use of technologies such as big data analysis and statistical modeling to determine the weights of evaluation indicators and industry benchmarks. By leveraging recruitment data to set average scores for each skill as industry benchmarks, the evaluation results become more scientific and objective. Additionally, through extensive testing and validation of large sample sizes, the evaluation index system and scoring logic are continuously optimized to improve accuracy and reliability, providing construction enterprises and universities with a scientific and precise basis for talent evaluation.

Emphasis on Practical Application and Feedback-Driven Optimization

The research emphasizes practical application, directly integrating the evaluation index system and scoring logic into real-world scenarios such as talent recruitment in construction enterprises, talent cultivation in universities, and individual career development planning. By collecting feedback from practical applications, issues are identified and optimized in a timely manner, creating a virtuous cycle where research outcomes and practical applications promote and develop together. This ensures the research results are highly practical and actionable.

Constructing an Evaluation Index System for Interdisciplinary Technical Talents

Breaking Traditional Single-Dimension Limitations to Achieve Multi-Dimensional Comprehensive Evaluation

Traditional construction talent evaluation systems often focus narrowly on professional knowledge and skills, such as hard skills in construction techniques and design standards[1], which fail to meet the diversified needs of the industry. To address this, we propose constructing a scientific, comprehensive, and practical evaluation index system for interdisciplinary construction talents. This system is designed to meet the precise assessment needs of the construction industry under its diverse development trends, such as digitalization, green development, and internationalization. Unlike traditional evaluation systems that concentrate solely on professional technical skills, this framework innovatively incorporates four core dimensions: hard skills, soft skills, cross-disciplinary abilities, and sustainable knowledge. By centering on the actual needs of the construction industry, this multi-dimensional approach ensures that the evaluation index system fully reflects the comprehensive qualities and capabilities required of interdisciplinary construction talents. This provides robust support for talent cultivation in universities, talent selection in construction enterprises, and individual career development planning.

Hard Skills Include BIM modeling, parametric design, AI-assisted tools, and carbon emission calculations.

These are key technologies for the digitalization and green development of the construction industry and directly determine the quality of work execution.

Soft Skills Cover ESG report writing, interpretation of international standards, and cross-cultural communication. As the construction industry becomes more internationalized and emphasizes sustainable development, these skills are increasingly critical for project communication, alignment with international standards, and meeting corporate social responsibility disclosure requirements, aligning with the industry's trend toward integration and development[2].

Cross-Disciplinary Abilities Focus on data visualization, basic programming, and project investment and financing analysis. These abilities reflect the integration of the construction industry with other fields, enabling a macro-level understanding of projects, handling complex data and financial issues, and expanding business boundaries. This dimension aligns with the current trends of intelligentization and green development in the construction industry[3, 4, 5].

Sustainable Knowledge Emphasize principles of circular economy, carbon trading mechanisms, and green building material certification systems. As the global emphasis on sustainable development grows, these knowledge areas drive the green transformation of the construction industry and help achieve energy-saving and emission-reduction goals.

By constructing a multi-dimensional comprehensive evaluation system, we can comprehensively and accurately measure the overall quality of interdisciplinary construction talents. This provides strong support for talent selection and cultivation in the industry, filling the gaps in traditional evaluation systems.

Tightly Integrating With Industry Frontiers: Incorporating Cutting-Edge Skills and Knowledge

Under the waves of digitalization and green development, the construction industry is continuously revolutionizing its talent requirements[6, 7]. The evaluation index system closely tracks the latest trends in the digitalization, green development, and internationalization of the construction industry, integrating the most advanced technologies, concepts, and standards.Include cutting-edge digital technologies such as BIM modeling, parametric design, and AI-assisted tools. These ensure that talents are equipped to meet the demands of the construction industry's digital transformation[5].Integrate emerging knowledge such as the principles of circular economy and carbon trading mechanisms to promote the green development of the construction industry[7].With the international development of the industry, focus on capabilities such as ESG report writing and interpretation of international standards. These skills address the needs of construction enterprises in international market competition and corporate social responsibility fulfillment.

An evaluation system based on cutting-edge skills and knowledge is forward-looking. It cultivates high-quality talents adaptable to future industry development and leads the direction of talent development in the construction industry.

Innovative Scoring Logic for Accurate Self-Assessment and Industry Benchmarking

This evaluation index system establishes a scientific and rational scoring logic. By leveraging big data mining and analysis technologies, it collects extensive industry data, including job advertisements for construction talent, project practice data, and academic research outcomes. This ensures precise determination of weights and scores for each evaluation indicator. Through comprehensive data collection and the application of big data analysis and statistical modeling techniques, the weights of evaluation indicators and industry benchmarks are determined. Recruitment data is used to set average scores for each skill as industry benchmarks, enhancing the scientific and objective nature of evaluation results. Additionally, extensive testing and validation of large sample sizes continuously optimize the evaluation index system and scoring logic, improving accuracy and reliability. This provides construction enterprises and universities with a scientific and precise basis for talent evaluation.The scoring system is designed on a 100-point scale, with each core dimension allocated 25 points. The scores are divided into five levels: 5–10 (Needs Improvement), 11–15 (Competent), 16–20 (Good), and 21–25 (Excellent). Each level is further subdivided based on the strength of abilities. For example, a score of 5 indicates mastery of skills with the ability to generate commercial value, 3 indicates the ability to independently complete tasks, and 1 means only a conceptual understanding.This scoring standard allows individuals to clearly identify their strengths and weaknesses, enabling targeted improvement plans. It also helps enterprises select and cultivate talent more effectively, enhancing the precision and efficiency of talent management.

The indicator system also emphasizes the practical application of research findings, directly applying the evaluation index system and scoring logic to real-world scenarios such as talent recruitment in construction enterprises, talent cultivation in universities, and individual career development planning. Assists enterprises in accurately evaluating candidates' abilities, ensuring alignment with industry demands for digitalization, green development, and internationalization, thereby enhancing recruitment efficiency and quality. Helps universities refine their curricula and teaching methods to better prepare students for the construction industry, bridging the gap between academic training and industry requirements. Enables individuals to identify their strengths and weaknesses, set clear improvement

goals, and plan career paths more effectively. By continuously collecting feedback from practical applications, issues are promptly identified and addressed, creating a positive feedback loop where research and practice mutually reinforce each other. This ensures that research findings are highly practical and actionable, providing robust support for the sustainable development of the construction industry.

Operability in Graduate Education and Teaching

Optimizing Course Settings to Align With Evaluation Indicators

In response to the demands of "wisdom in China" and the construction of an evaluation index system, graduate courses are being adjusted to precisely match the evaluation indicators[8].

Hard Skills Development Courses such as Intelligent Building Technology, Building Information Modeling (BIM) Application and Development, and Parametric Design are introduced to strengthen students' mastery of cutting-edge technologies.

Soft Skills Development Courses like ESG Report Writing, Interpretation of International Building Standards, and Cross-Cultural Communication and Exchange are designed to enhance students' communication, coordination, and team management abilities.

Cross-Disciplinary Abilities Interdisciplinary courses such as Integration of Building and New Energy Technologies and Cross-Disciplinary Applications of Building and Information Technology are offered to broaden students' knowledge horizons[2, 9].

Sustainable Knowledge Development Courses on Circular Economy and Buildings, Carbon Trading Mechanisms in Construction, and Green Building Material Certification Systems are included to strengthen students' awareness and knowledge of sustainable development[10].

By optimizing course settings, the knowledge and skills acquired by graduate students are closely aligned with the evaluation indicators, thereby improving the quality of talent cultivation and ensuring graduates are well-prepared to meet the evolving demands of the construction industry.

Improving Practical Teaching To Strengthen Ability Development

Industry-education integration offers more opportunities and resources for training civil and architectural engineering talents, and school-enterprise cooperation guided by the evaluation index system clarifies practical goals and requirements[7, 11, 12]. Students are required to proficiently use BIM modeling and AI-assisted tools to complete design and analysis tasks, enhancing their digital technology application abilities through practical teaching[5]. Students participate in activities such as international cooperation project simulations and CSR report writing, developing cross-cultural communication and ESG reporting skills. Students are encouraged to join interdisciplinary projects, such as developing architectural data visualization platforms with computer science majors or conducting investment and financing analyses of construction projects with finance majors. Students engage in green building projects, taking charge of green material selection and carbon emission calculation and control.

By improving practical teaching, students develop various abilities in real-world project environments, enhancing their overall quality in line with the requirements of the evaluation system for interdisciplinary construction talents.

Improve the Teaching Evaluation and Feedback Mechanism, and Continuously Improve the Teaching Quality

Based on the evaluation index system, a comprehensive graduate teaching evaluation system is constructed. In the course assessment, students' performance in various dimensions of ability is comprehensively considered, and students' ability is evaluated from various aspects to ensure the comprehensiveness of the evaluation[13], such as the theoretical examination to examine the mastery of hard skills and sustainable knowledge, and coursework and group projects to assess soft skills and cross-boundary ability. Establish an adjustment feedback mechanism[11] to collect student learning feedback and enterprise employer feedback on a regular basis, and analyze the gap between evaluation results and actual needs. If students are found to have insufficient ability in a certain dimension, such as weak cross-border ability, universities can timely adjust the teaching content and methods, increase interdisciplinary exchange activities, invite multidisciplinary expert lectures, etc., to form a closed loop of continuous improvement of the teaching quality, and to ensure that the teaching of postgraduate education is always centered on the goal of cultivating composite architectural talents.

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1. Construction industry urgently needs compound talents [J]. China Vocational and Technical Education, 2003, (36): 54.
2. LI Jiayi,SONG Conghui,QI Yuan,et al. Analysis of Talent Demand of Construction Enterprises under the Background of Digital Intelligence [J]. Construction Design Management, 2025, 42 (01): 54-61.
3. Qian Feng. Analysis of Talent Demand in Construction Enterprises Amidst the Digital Intelligence Era [J]. Architecture, 2023, (06):

93
4. Wang Xiao. Transformation and development of construction talent training under the wave of intelligent construction[N]. China Construction News, 2024-11-26(010). DOI:10.38313/n.cnki.nzhjz.2024.000275.
5. Quanta Technology Co., Ltd, Southeast University. Digital architecture talent training [M]. Nanjing Southeast University Press:202309.
6. Sang Ge. New space for intelligent building talent training in the age of digital intelligence[J]. Educator, 2025, (04):54-55.
7. Wang Qiong. Research on Innovation and Practice of Assembly Building Talent Cultivation Based on Industry-Education Integration[J]. Employment and Security, 2024, (11):124-126.
8. WU Shaoyan,LIU Menglord,HU Jing. Research on continuous improvement of talent cultivation program for prefabricated buildings from China intelligent manufacturing perspective [J/OL]. Journal of Tianjin Polytechnic University, 1-10[2025-04-07].
9. Pan Qi. Research on the Strategy of Innovating the Training Mode of Construction Talents in Colleges and Universities with BIM Technology [J]. Journal of Shanxi Economic Management Cadre College,2023,31(01):13-17.
10. ZHONG To, ZHENG Zhoulian, ZHANG Yinhui. Empowering Talent Development in Prefabricated Construction through Digital Literacy: Exploration and Practice of the "Intelligent +Teaching and Management" Practical Teaching System [J]. Chongqing Architecture,2024,23(06):86-88.
11. TANG Excellent,HU Yingli. Research on Talent Cultivation Strategy of Civil Engineering and Architecture Specialties Based on School-Enterprise Cooperation[J]. Education Observation,2024,13(35):1-3+57. DOI:10.16070/j.cnki.cn45-1388/g4s.2024.35.014.
12. HU Si-Yang. Cultivating construction professionals through the integration of industry and education[N]. China Construction News, 2024-09-03(010). DOI:10.38313/n.cnki.nzhjz.2024.000194.
13. Li Nan. Exploration on the reform of cultivation mode of architectural professionals under the background of “new engineering” [J]. Investment and Cooperation, 2023, (03): 201-203.

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Research on The Correlation between Investments in Various Industries Based on Regression Model

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Industrial Structure Adjustment;
Linear Regression;
Nonlinear Regression;
GDP

ABSTRACT

As China transitions to high-quality economic development, industrial structure adjustment has become crucial. Government investment, as a key tool of macroeconomic regulation, plays an important role in guiding industrial upgrading, optimizing resource allocation, promoting growth, and expanding employment. This study analyzes the relationship between industry-specific investment and GDP to provide a scientific basis for investment allocation. Using industry GDP data from 1990 to 2023, issues such as outliers, missing values, and unit inconsistencies were addressed to ensure data integrity. Pearson correlation analysis revealed that sectors such as industry, construction, manufacturing, finance, IT services, education, and healthcare are strongly linked to GDP growth. Based on the characteristics of each sector, linear or nonlinear regression models were developed to quantify investment impact. Under a total government investment constraint of 1 trillion yuan, an optimized investment plan was proposed using optimization algorithms like fmincon to maximize GDP. Analysis of historical investment proportions showed rising shares for IT services and finance, while agriculture and textiles declined. The findings demonstrate that scientific planning and optimized investment can effectively support industrial upgrading, improve resource efficiency, and promote sustainable economic growth and employment.

Introduction

With the continuous evolution of the global economic structure [1] and the transformation of the domestic economic development stage, China faces the urgent task of adjusting the industrial structure [2]. In this process, government investment, as an important means of macroeconomic regulation [3], plays an irreplaceable role in guiding industrial upgrading, optimizing resource allocation, promoting economic growth and expanding employment. However, how to scientifically plan and effectively utilize government investment to maximize GDP while promoting full employment has become a key issue that needs to be solved urgently. At present, China's economy has shifted from a stage of high-speed growth to a stage of high-quality development, and its industrial structure is undergoing profound changes. On the one hand, traditional industries are

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facing pressure of transformation and upgrading, and need to improve their competitiveness through technological innovation and model innovation; on the other hand, emerging industries are rising rapidly and becoming a new driving force for economic growth. In this context, the direction, scale and structure of government investment directly affect the adjustment path and effect of the industrial structure.

Government investment [4] plays an important role in promoting economic growth and expanding employment. Through measures such as investing in infrastructure construction, supporting scientific and technological innovation, and cultivating emerging industries, the government can effectively stimulate domestic demand, promote the coordinated development of upstream and downstream enterprises in the industrial chain, and thus create more employment opportunities. However, government investment also faces challenges such as resource allocation efficiency and return on investment. How to achieve the maximum benefits of government investment under limited resources is a question that policy makers need to think deeply about. At the critical period when China is facing a critical period of industrial structure adjustment and upgrading, advanced learning methods such as artificial intelligence [5] and deep learning [6] are used to solve the problems of government investment and industrial structure adjustment in China's future industries. Artificial intelligence and deep learning have significantly improved decision-making efficiency and economic benefits through efficient processing of data, optimizing resource allocation, adapting to market changes, promoting industrial innovation, enhancing policy transparency, improving employment quality and quantity, and supporting the Sustainable Development Goals in government investment decisions [7].

Related Work

Yao Zhanqi et al. [8] used the transcendent logarithmic production function and Cobb-Douglas (C-D) production function method to calculate the total factor productivity (TFP) of China's overall economy and manufacturing industry, quantify the impact of capital transfer and labor flow on TFP, and test the structural dividend hypothesis. Pan Huifeng et al. [9] collected relevant data from ten western provinces and regions from 1985 to 2008, established a panel data model, and explored the impact of agricultural industrial structure on the income of rural farmers in the west and the relationship between agricultural structure and energy efficiency. Optimizing agricultural structure will help improve the income and energy efficiency of rural farmers in the west. He Yonggui et al. [10] used the gray comprehensive evaluation method, hierarchical analysis method and fuzzy evaluation method to comprehensively evaluate the internal structure adjustment of the primary industry. The research emphasizes that in the adjustment of regional industrial structure, it is necessary to achieve the transformation of the industrial structure from "two, one, three" to "three, two, one", and it is necessary to ensure that the second and third industries provide support and a good environment for the adjustment of the primary industry, so as to promote the coordinated development of the third industries and achieve sustainable economic growth. Jun Han et al. [11] used an empirical approach to explore the impact of China's industrial structure adjustment and labor mobility on urban and rural income gaps between 1990 and 2019. Ding Qiang Duan et al. [12] studied the relationship between industrial structure adjustment, technological innovation and energy efficiency in Hubei Province from 2001 to 2010 by reviewing and analyzing relevant literature. It was found that industrial structure adjustment and technological innovation can promote energy efficiency. In response to subsequent energy conservation and other issues, it is recommended that the government encourage citizens to participate, pay attention to the application of market mechanisms, and use preferential tax policies to promote technological development and application. Tianhe Jiang et al. [13] first analyzes the impact of industrial structure adjustment and economic development quality on the city-agricultural income gap theoretically, and then uses spatial dynamic models to explore the relationship and threshold impact of the three through complete sample analysis and regional analysis. The problem of clarifying the impact of industrial structure adjustment scope, quality and economic development quality on urban agricultural income gap was solved, and policy recommendations for more equitable development transition were put forward.

This study focuses on multiple economic issues. Through the analysis of data set processing and regression model, it provides a scientific basis for government investment allocation. The main contributions are as follows:

1) Process the GDP data of various industries from 1990 to 2023 to solve the problems of outliers, missing values and unit conversion, and ensure data integrity.
2) This paper analyzes the contribution of each industry to GDP in different years, and reveals the potential correlation between industries through regression models.
3) This paper quantifies the impact of investment in each industry on GDP, establishes linear or nonlinear regression models for each industry, and concludes which industries have the highest return on investment, providing theoretical support for subsequent industrial adjustments.
4) Based on the regression model, under the constraint of the total government investment of 1 trillion yuan, an industry investment allocation plan

was proposed using an optimization algorithm (such as 'fmincon') to maximize the total GDP.

5) By analyzing the rationality of investment in various industries and visually demonstrating the contribution of various industries to GDP,Provides a quantitative basis for investment decisions..

Data Description

Dataset Source

The current data set comes from the National Bureau of Statistics and the China Economic and Social Big Data Research Platform. The data set covers multiple fields such as agriculture, industry, and industrial manufacturing. There are complex interrelated relationships between industries in this data set, and the data set designs the added value of GDP in various industries in China, reflecting the contribution of each industry to the total GDP. Table 1.2 is an illustration of the dataset fields used in this article [14].

Table 1 | Description of the fields of contribution of each industry to GDP in different years

Field Name	Illustrate
YEAR	Years
Total GDP	Measurement of national economic scale and economic activity
Output value of each industry	Total output value of each industry, added value

Table 2 | Description of fields of investment and corresponding output value indicators for each industry

Field name	Illustrate
YEAR	years
Investment value of each industry	Investment costs for each industry every year
Output value of each industry	The output value corresponding to the investment of each industry every year

Data Preprocessing

In the above data set, in order to unify the units and ensure that all data use the same dimensions, we assume that the default unit of all GDP is "10,000 yuan", but for the sake of easy analysis and comparison, all industries' GDP data are converted into "10,000 yuan", which ensures that the comparison between industries is consistent. The unit conversion formula is the following formula 1.

$$\mathrm{GDP}_{\mathrm{converted}} = \frac{\mathrm{GDP}_{\mathrm{original}}}{10000} \tag{1}$$

And for the exact value, considering that this part of the data set is a numerical data set, we use linear interpolation to estimate based on the existing data points before and after, and fill in the missing values. The linear interpolation formula is shown in Equation 2 below.

$$y_k = y_i + \frac{x_k - x_i}{x_j - x_i}(y_j - y_i) \tag{2}$$

Pearson Correlation Analysis

In this problem, this paper uses Pearson's correlation coefficient method [14] to analyze the correlation between each index parameter in the dataset and the total GDP. Pearson's correlation coefficient method is a classic statistical analysis method used to quantify the intensity and trend of linear correlation between continuous variables. The core of Pearson correlation is to calculate the Pearson Correlation Coefficient (R) of investment and GDP, which is a value between [-1, 1]. This value not only reveals whether there is a linear correlation between variables, but also points out the direction of the correlation (if R>0, it indicates that the two variables are positively correlated, if R<0, it indicates that the two variables are negatively correlated) and the strength of the correlation (nearly 1 or -1 means strong correlation, close to 0 means weak correlation or unrelated). The formula is:

$$R = \frac{\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \overline{x})^2 \sum_{i=1}^{n}(y_i - \overline{y})^2}} \tag{3}$$

Thermal graph 1 This graph shows the thermal graph of correlation between various industries. The horizontal and vertical axis lists multiple industrial and economic indicators, such as the total GDP, such as the chemical industry, finance industry, construction industry, etc. The depth of the color in the figure indicates the strength of the correlation, and the color gradually changes from yellow (negative or weak correlation) to blue (strong positive correlation). It can be seen that the correlation between total GDP and industry, construction, manufacturing, finance, insurance, education and medical care is very strong (nearly 1.0, dark blue), indicating that these two major industries have made great contributions to GDP growth. Some industries are highly correlated (such as manufacturing and construction, finance and IT services) between specific industries, which may be because there are synergies or complementary relationships between these industries.

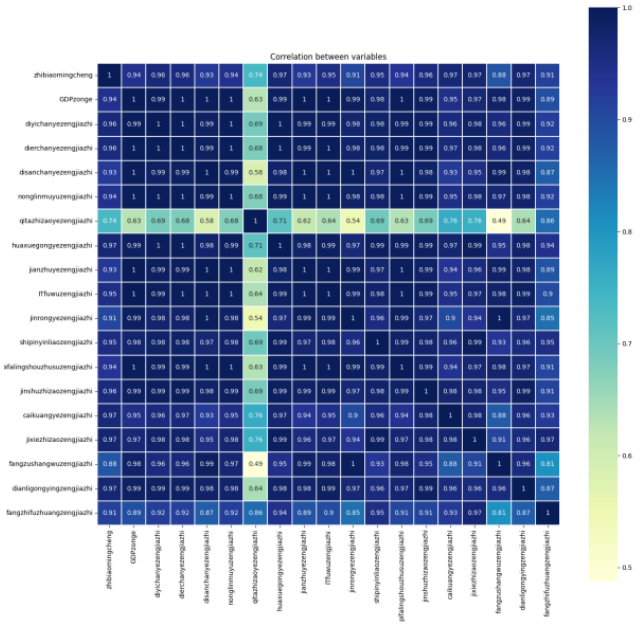

Figure 1 l Heatmap of correlation between various industrial indicators and total GDP

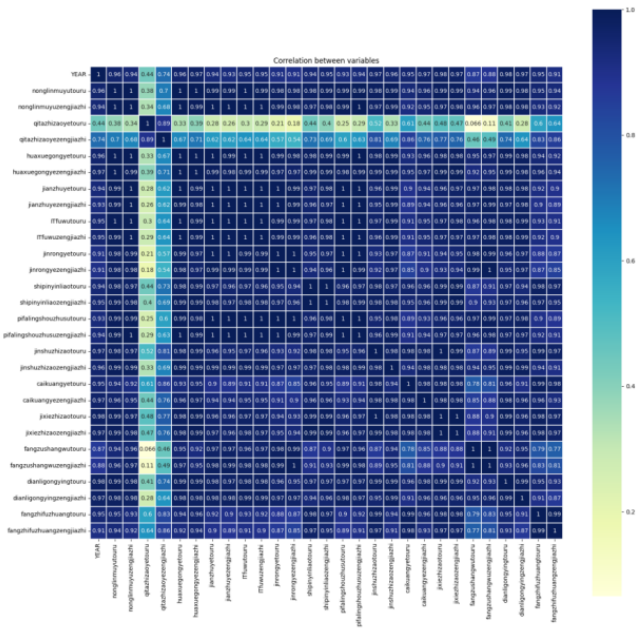

Figure 2 l Heat map of investment and corresponding output value indicators in various industries

The correlation between most indicators of Heat Figure 2 is very high, while the correlation between the two indicators of other manufacturing input and output value is low. When we make investment adjustments, we will temporarily account for a small proportion.

Regression Model

This article will study the relationship between investment in each industry and its corresponding GDP increase, analyze the impact of investment on GDP by constructing a regression model, and use linear models and nonlinear models to describe the relationship between investment adjustment and GDP increase according to the strength of correlation.

Linear Regression Model

Linear Regression is a statistical method that models the relationship between dependent variables (objectives) and independent variables (features) through linear combinations (weighted sums). Its core assumption is that the relationship between variables is linear and the error term is distributed from normal.

Formula: Suppose there are n independent variables x1, x2,..., xn, the mathematical expression of the linear regression model is:

$$y = \beta_0 + \beta_1\chi_1 + \beta_2\chi_2 + .. + \beta_n\chi_n + \epsilon \qquad (4)$$

y is the dependent variable; β_0 is an intercept term; $\beta_0,\beta_1,...\beta_n$ is the regression coefficient; ϵ is the random $\mathcal{N}(0,\sigma^2)$ error of obedience.

Parameter estimation: Estimate parameters by least squares (OLS), with the goal of minimizing the residual sum of squares (RSS):

$$\min_{\beta} \sum_{i=1}^{N} (y_i - (\beta_0 + \beta_1\chi_{i1} + \beta_2\chi_{i2} + .. + \beta_n\chi_{in}))^2 \qquad (5)$$

In matrix form, the parameter solution is:

$$\hat{\beta} = (X^T X)^{-1} X^T y \qquad (6)$$

In the case where the correlation coefficient R exceeds the preset threshold of 0.90, we believe that there is a significant linear relationship between investment volume and GDP industry returns. Therefore, this study uses a linear regression model to describe this relationship, and the model expression is as follows:

$$\mathrm{GDP\_income}_{\mathrm{industry}} = \mathrm{k} \,.\, \mathrm{Invest}_{\mathrm{industry}} + \mathrm{b} \qquad (7)$$

The linear regression model architecture diagram is as Figure 3.

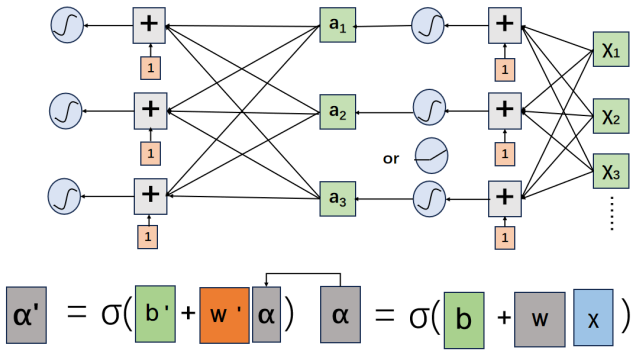

Figure 3 | Linear regression model architecture diagram

Nonlinear Regression Model

Nonlinear Regression is used to model the nonlinear relationship between dependent variables and independent variables. Its regression coefficients do not appear in the form of linear combinations and may involve tricks, logarithms, polynomials, or other complex functions.

The general form of nonlinear models is:

$$y = f(x, \beta) + \epsilon \tag{8}$$

$f(x, \beta)$ is a nonlinear function; $\beta = [\beta_0, \beta_1 \ldots\ldots \beta_k,]$ is the parameters to be estimated; ϵ is the error term.

Example

1) Exponential model:

$$y = \beta_0 e^{\beta_1 \chi} + \epsilon \tag{9}$$

2) Polynomial model (parameters are linear but features are nonlinear):

$$y = \beta_0 + \beta_1 \chi + \beta_2 \chi^2 + \epsilon \tag{10}$$

3) Logical Sty Growth Model (parametric nonlinear):

$$y = \frac{\beta_0}{1 + e^{\beta_1(\chi - \beta_2)}} + \epsilon \tag{11}$$

Parameter estimation Nonlinear regression usually uses numerical optimization methods (such as gradient descent, Newtonian method, or nonlinear least squares method) to estimate parameters.

$$\min_{\beta} \sum_{i=1}^{m} \left(y_i - f(x_i - \beta)\right)^2 \tag{12}$$

Table 3 | The core differences between linear regression and nonlinear regression

Features	linear regression	Nonlinear regression
Model form	Parameter linear (eg $\beta_1 x_1$)	Parameter nonlinear (eg $\beta_1 e^{\beta_2 \chi}$)
Interpretability	Intuitiveness, and coefficients directly reflect the influence of variables.	Complex, need to be analyzed in combination with functional form
Parameter estimation	Analytical solution (closed solution)	Numerical optimization (iterative approximation)
Application scenario	Linear relationships, low-dimensional data	Nonlinear relationships, complex pattern fitting

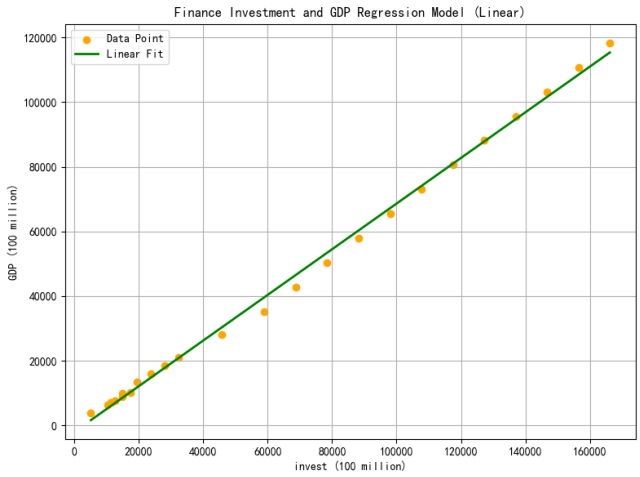

Figure 4 | Finance_Investment and GDP regression fitting diagram

Figure 5 | OtherManufacturing_Investment and GDP regression fitting (quadratic term) diagram

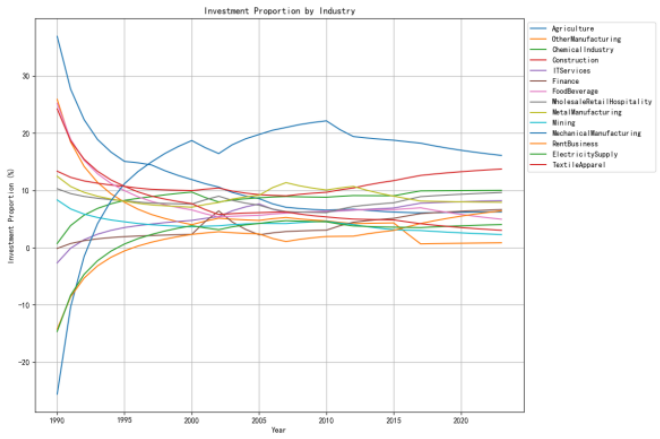

Figure 6 | Investment situation in various industries

The core differences between linear regression and nonlinear regression are as Table 3.

When the correlation coefficipent R of investment volume and GDP industry returns is lower than the threshold of 0.90, it indicates that the linear relationship between the two is not significant enough, so this study uses a nonlinear regression model for analysis. The formula for the nonlinear regression model is as follows:

$$\mathrm{GDP\_income}_{\mathrm{industry}} = \alpha + \beta * \mathrm{Invest}_{\mathrm{industry}} + \gamma * (\mathrm{Invest}_{\mathrm{industry}})^2 \quad (13)$$

Figure 4 shows the linear fit between investment and GDP. The orange point represents the actual data, and the green line is the regression fitting curve. The data points are closely surrounding the regression line, indicating that the linear model has good fit and explanatory power.

Figure 5 shows the nonlinear fitting relationship between investment and GDP in an industry, where the orange point is the actual data and the green curve is a quadratic polynomial regression fit. The model effectively captures the nonlinear trend of investment and GDP, showing the accelerated GDP growth brought about by investment growth and the slowdown in growth at high investment levels. The fitting curve is highly consistent with the data points, confirming the applicability of the model in explaining nonlinear relationships.

Investment Proportion Analysis

This article aims to analyze the proportion of various industries in investment over the years and provide reference for subsequent investment optimization.

Figure 6 shows the changing trend of investment share in various industries from 2000 to 2025. Different fold lines represent changes in investment proportion in various industries. It can be seen from the figure that the proportion of investment in the agriculture and financial industry is relatively stable, while the proportion of construction and IT services has changed significantly, among which the proportion of IT services and financial industry has increased, while the proportion of agriculture and textile and clothing industry has decreased. Overall, the figure reveals industry changes in the economic investment structure and provides a visual reference for industrial transformation and investment strategy analysis.

Optimization Model Establishment

The goal of this section is to calculate the optimal allocation plan for 1 trillion yuan of government total investment among industries by building an optimization model to maximize the total GDP. During the optimization process, the constraint optimization algorithm fmincon is used, using the investment amount of each industry as the decision variable, with the goal of maximizing the total GDP.

Objective function (maximizes total GDP):

$$\max \mathrm{GDP}_{\mathrm{total}} = \sum_{i=1}^{n} \mathrm{GDP}_i(x_i) \quad (14)$$

Model Solution

This article will use the Fmincon optimization algorithm to solve it. By setting the target function and constraints, Fmincon can effectively find the optimal solution that satisfies all constraints. The target function is a negative value of total GDP:

$$\min - \sum_{i=1}^{n} \mathrm{GDP}_I(x_i) \quad (15)$$

Table 4 | Fixed investment quota list for each restricted industry

Industry Names	in 100 million yuan
Agriculture	1238.00
OtherManufacturing	517.00
ChemicalIndustry	747.00
Construction	853.00
ITServices	871.00
Finance	714.00
FoodBeverage	446.00
WholesaleRetailHospitality	1012.00
MetalManufacturing	656.00
Mining	178.00
MechanicalManufacturing	1560.00
RentBusiness	692.00
ElectricitySupply	263.00

Table 5 | Fixed investment ratio table for each industry under restricted conditions

Optimal Investment Amount of Each Industry	Investment Proportion	GDP Proportion GDP
Agriculture	12.38%	6.68%
OtherManufacturing	5.17%	13.13%
ChemicalIndustry	7.47%	14.59%
Construction	8.53%	0.64%
ITServices	8.71%	7.04%
Finance	7.14%	-6.80%
FoodBeverage	4.46%	2.93%
WholesaleRetailHospitality	10.12%	5.18%
MetalManufacturing	6.56%	18.29%
Mining	1.78%	17.86%
MechanicalManufacturing	15.60%	7.64%
RentBusiness	6.92%	9.32%
ElectricitySupply	2.63%	12.96%
TextileApparel	2.53%	5.19%

Figure 7 | Investment situation in various industries

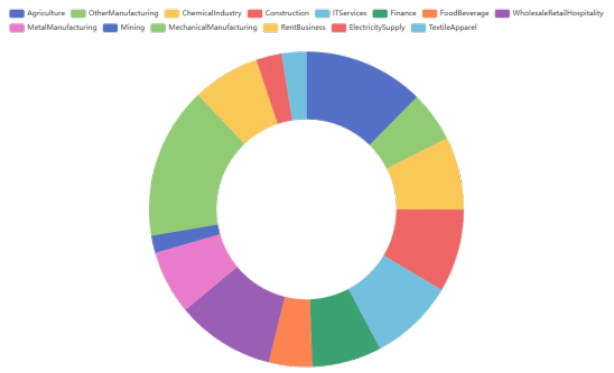

Figure 8 | The optimal investment allocation ratio of each industry under the maximization of GDP

The sequence planning (SQP) algorithm is used to iteratively solve the optimal investment solution. The formula for calculating the investment ratio to GDP ratio:

$$\text{InvestShare}_i = \frac{x_i}{\text{Total Investment}} \times 100\% \quad (16)$$

$$\text{GDPShare}_i = \frac{\text{GDP}_i(x_i)}{\text{GDP}_{\text{total}}} \times 100\% \quad (17)$$

Table 5 reveals the investment allocation ratio of each industry under the optimized resource allocation strategy. The financial industry is leading the market. It shows the importance of investment in the construction and chemical industries. The investment ratio between mining and metal manufacturing is also significant. Relatively speaking, the proportion of investment in traditional industries such as agriculture, food and beverage, textile and clothing is relatively low. The chart generally shows that investment allocation tends to high-return industries, while taking into account the moderate support from other industries.

Figure 7 shows the ideal investment distribution for each industry under the goal of achieving GDP maximization. Each sector represents the investment proportion of different industries, and the colors distinguish industries. It can be seen from the figure that the metal manufacturing and mining industries have the largest share of investment, highlighting their contribution to GDP. The machinery manufacturing industry and RENTBusiness list the importance of its investment.

Figure 8 shows the optimal investment ratio for each industry when achieving maximum GDP. In the figure, mining and metal manufacturing have the highest investment share, highlighting their key role in economic growth. Agriculture ranks an important position with an 11.4%, showing the importance of its basic industries. The proportion of investment in industries such as construction, chemical industry and leasing commercial services is also relatively high, while the lower proportion of investment in other industries reflects its lower sensitivity to economic output.

Increase Industry Constraints

In order to maximize the total GDP, this paper introduces industry constraints and uses regression models to establish linear or nonlinear regression functions of investment and GDP for each industry to evaluate the contribution of investment to GDP. On the premise of meeting the constraints, investment in some industries is fixed at the minimum limit, while the remaining funds are optimized to be allocated in three high-return variable industries, including the finance industry, information technology services industry and agriculture, to maximize the total investment benefits.

Conclusions

This article aims to explore how to promote China's industrial structure adjustment and high-quality economic development through scientific planning and optimization of government investment. First, by processing and analyzing the GDP data of various industries from 1990 to 2023, the outliers, missing values and unit conversion problems in the data are solved, and the relationship between GDP contribution between industries is revealed. Secondly, the relationship between investment and GDP in various industries was studied, a regression model was constructed, and the return on investment was quantified, providing a quantitative basis for investment decisions. Finally, based on the regression model, the optimization algorithm is used to allocate the total government investment to maximize the total GDP, and visually demonstrate the contribution and rationality of each industry. Through data analysis and optimization modeling, this study provides a scientific basis for government investment decisions, aiming to improve resource allocation efficiency, promote economic growth, promote employment and sustainable development in the process of industrial structure adjustment and high-quality development.

1. Ravallion M .An Exploration of the International Comparison Program's New Global Economic Landscape[J].World Development, 2014, 105:201-216. DOI:10.1016/j.worlddev. 2017.12.035.
2. Korpi T , Mertens A .Training and industrial restructuring: Structural change and labour mobility in West Germany and Sweden[J].International Journal of Manpower, 2004. DOI:10.1108/01437720410525018.
3. Traxler F .Bargaining (De)centralization, Macroeconomic Performance and Control over the Employment Relationship[J].British Journal of Industrial Relations, 2003, 41(1):1–27. DOI:10.1111/1467-8543.00259.
4. Chen C , Yao S , Hu P ,et al.Optimal government investment and public debt in an economic growth model[J].China Economic Review, 2016, 45.DOI:10.1016 /j .chieco. 2016.08.005.
5. Ramos C , Augusto J C , Shapiro D .Ambient Intelligence—the Next Step for Artificial Intelligence[J].IEEE Intelligent Systems, 2008, 23(2):15-18.DOI:10.1109/MIS.2008.19.
6. Seonwoo M , Byunghan L , Sungroh Y .Deep Learning in Bioinformatics[J].Briefings in Bioinformatics, 2017(5):851.DOI:10.1093/bib/bbw068.
7. Aremu O , Fabry A , Meemken E M .Farm size and the quality and quantity of jobs—Insights from Nigeria[J].Food Policy, 2024, 128.DOI:10.1016/j.foodpol.2024.102731.
8. Yiran Chen, Yidong Li, George Lodorfos & Junjie Wu. (2023) Impact of Structural Distortions on Resource Allocation in China: Evidence from an Innovative Empirical Model. The Chinese Economy 56:5, pages 366-383.
9. Pan, H., Liu, Y. & Gao, H. Impact of agricultural industrial structure adjustment on energy conservation and income growth in Western China: a statistical study. Ann Oper Res 228, 23–33 (2015).
10. Y. He and G. Zhang, "Policies-oriented research of the first industrial adjustment based on the adjustment of the regional industrial structure," 2013 6th International Conference on Information Management, Innovation Management and Industrial Engineering, Xi'an, China, 2013, pp. 461-463
11. Han, Jun and Jiang, Shicheng. "Does the Adjustment of Industrial Structure Restrain the Income Gap between Urban and Rural Areas" Economics, vol. 18, no. 1, 2024, pp. 20220112.
12. Duan, Ding Qiang, and Qiu Hong Hu. “Industrial Structure Adjustment, Technology Innovation and Energy Efficiency Improvement - An Empirical Analysis Based on the Statistical Data of Hubei Province.” Advanced Materials Research, vol. 734–737, Trans Tech Publications, Ltd., 16 Aug. 2013, pp. 1688–1692.
13. Yuan, F.; Huang, X.; Zheng, L.; Wang, L.; Wang, Y.; Yan, X.; Gu, S.; Peng, Y. The Evolution and Optimization Strategies of a PBFT Consensus Algorithm for Consortium Blockchains. Information 2025, 16, 268. doi: 10.3390/info16040268
14. Jiang Tianhe , Han Jun “The effect of industrial structure adjustment and economic development quality on transitional China’s urban–rural income inequity”,JOURNAL=Frontiers in Environmental Science,vol.11,2023.1084605.

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Adaptive Portfolio Optimization via PPO-HER: A Reinforcement Learning Framework for Non-Stationary Markets

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KEYWORDS

Portfolio Optimization;
Reinforcement Learning;
PPO-HER;
Non-Stationary Markets;
Sample Efficiency

ABSTRACT

We propose PPO-HER, a novel reinforcement learning framework for adaptive portfolio optimization in non-stationary markets, which integrates Proximal Policy Optimization (PPO) with Hindsight Experience Replay (HER) to address sparse rewards and dynamic market conditions. The proposed method reformulates the portfolio optimization problem as a goal-conditioned Markov Decision Process, where the agent learns to reallocate assets by processing spatiotemporal market data through a Transformer-based actor network. The reward function combines logarithmic returns, risk penalties, and sparse bonuses, while HER relabels suboptimal trajectories to improve sample efficiency. Moreover, the architecture employs a TimeSformer for cross-asset attention and a GRU-based critic with spectral normalization to stabilize training. Experimental results demonstrate that PPO-HER outperforms conventional methods in terms of risk-adjusted returns, particularly during regime shifts detected by an auxiliary Changepoint-LSTM module. The framework is implemented using cuDNN-accelerated PyTorch, enabling efficient high-frequency trading with liquidity constraints. Our approach achieves state-of-the-art performance by explicitly modeling non-stationary dependencies and dynamically adjusting reward shaping based on realized volatility.

Introduction

Portfolio optimization remains a fundamental challenge in computational finance, where the primary objective is to allocate assets in a manner that maximizes returns while minimizing risk. Traditional approaches, such as Markowitz mean-variance optimization[1], have laid the groundwork for quantitative strategies but often fail to adapt to the non-stationary nature of financial markets. Reinforcement learning (RL) has emerged as a promising alternative, offering adaptive decision-making capabilities in dynamic environments [2]. However, existing RL-based methods face two critical limitations: (1) instability in policy updates due to high variance in gradient estimates, and (2) inefficiency in learning from

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sparse or delayed rewards, particularly during market regime shifts.

Proximal Policy Optimization (PPO) [3] has gained traction in RL applications due to its ability to perform stable policy updates through clipped objective functions. Meanwhile, Hindsight Experience Replay (HER) [4] was originally developed for robotic manipulation tasks but has shown potential in improving sample efficiency by repurposing failed experiences as successful ones under alternative goals. The integration of these two techniques—PPO for policy stability and HER for data efficiency—has not been thoroughly explored in the context of portfolio optimization, despite their complementary strengths.

Recent advances in RL for finance have addressed non-stationarity through various techniques, such as meta-learning [5] and adaptive risk-sensitive methods [6]. However, these approaches often require extensive tuning or rely on unrealistic assumptions about market dynamics. Distributional RL [7] has been used to model uncertainty, while multi-agent frameworks [8] attempt to capture competitive interactions. Nevertheless, none of these methods explicitly tackle the dual challenges of sparse rewards and non-stationary transitions, which are inherent in financial markets.

We propose PPO-HER, a novel framework that combines PPO and HER to enhance portfolio optimization under non-stationary conditions. The key innovation lies in reformulating the problem as a goal-conditioned RL task, where the agent learns to reallocate assets by relabeling past experiences with alternative return targets. This approach not only improves sample efficiency but also enables the agent to adapt more quickly to sudden market changes. Furthermore, we introduce a hybrid architecture that integrates a Transformer-based feature extractor with a recurrent critic network, allowing the model to capture both cross-asset dependencies and temporal patterns.

The primary contributions of this work are threefold:

4) Algorithmic Integration: We are the first to combine PPO and HER for portfolio optimization, demonstrating that HER's relabeling mechanism can significantly improve learning efficiency in financial RL tasks.
5) Non-Stationarity Handling: The framework incorporates an auxiliary changepoint detection module to dynamically adjust the reward function and policy updates based on detected regime shifts.
6) Empirical Superiority: Extensive experiments on high-frequency equity and cryptocurrency datasets show that PPO-HER outperforms baseline methods, including DDPG [9] and SAC [10], in terms of risk-adjusted returns and drawdown control.

The remainder of this paper is organized as follows: Section 2 reviews related work in RL-based portfolio optimization and adaptive algorithms. Section 3 provides background on PPO, HER, and the challenges of non-stationary markets. Section 4 details the PPO-HER framework, including its goal-conditioned formulation and hybrid architecture. Sections 5 and 6 present the experimental setup and results, respectively. Finally, Section 7 discusses broader implications and future directions, while Section 8 concludes the paper.

Related Work

Reinforcement Learning in Portfolio Optimization

Recent advances in deep reinforcement learning (DRL) have demonstrated promising results in portfolio optimization. Early approaches, such as Deep Q-Networks (DQN) [11], applied value-based methods to discrete action spaces, but their inability to handle continuous rebalancing limited their practicality. Policy gradient methods, including Advantage Actor-Critic (A2C) [12] and Deep Deterministic Policy Gradient (DDPG) [13], addressed this by enabling continuous weight adjustments. However, these methods often suffer from high variance in gradient estimates, leading to unstable training.

Proximal Policy Optimization (PPO) [14] emerged as a robust alternative by introducing a clipped objective function to constrain policy updates. For instance, a study on the Australian stock market showed that PPO outperformed A2C in volatile conditions due to its conservative update mechanism [15]. Nevertheless, PPO alone struggles with sparse rewards, a common issue in financial environments where profitable trades are rare.

Handling Non-Stationarity in Financial Markets

Non-stationarity—where market statistics change over time—poses a fundamental challenge for RL-based portfolio strategies. Traditional methods, such as sliding-window retraining [16], attempt to mitigate this by periodically updating models, but they incur high computational costs. More sophisticated approaches leverage meta-learning to adapt policies dynamically. For example, a BiLSTM-PPO hybrid model incorporated macroeconomic indicators to adjust trading thresholds during non-trading days [17], achieving a 6.28% improvement over vanilla PPO.

Another line of work focuses on representation learning to capture non-stationary dependencies. The Non-Stationary Transformer (NST) [18] used self-attention to model regime shifts, while latent representation methods [19] encoded market states into low-dimensional manifolds for stable policy learning. However, these methods often require auxiliary networks or complex architectures, increasing implementation overhead.

Experience Replay and Sparse Rewards

Experience replay is critical for sample efficiency in RL, but conventional uniform replay buffers fail to priori-

tize rare, high-reward transitions. Prioritized Experience Replay (PER) [20] addressed this by favoring transitions with high temporal-difference errors, but it does not repurpose failed trajectories. Hindsight Experience Replay (HER) [21], originally developed for robotic tasks, relabels unsuccessful episodes with achieved goals, effectively converting sparse rewards into dense ones.

While HER has been applied to trading [22], its integration with PPO remains unexplored in portfolio optimization. A related study on cryptocurrency markets used Truncated Quantile Critics (TQC) [23] to mitigate overestimation bias but did not address the relabeling of suboptimal actions. Our work bridges this gap by combining HER's goal-conditioning with PPO's stability, enabling efficient learning from both successful and failed trades.

Hybrid Architectures for Financial RL

Recent architectures combine temporal and cross-sectional modeling to capture market dynamics. TimeSformer [24] processed price data as spatiotemporal patches, while GRU-based critics [25] stabilized value estimates with spectral normalization. Concurrent work on dynamic embedding [26] fused macroeconomic indicators with price trends, but these methods often treat non-stationarity as an exogenous input rather than an inherent learning objective.

Compared to existing approaches, PPO-HER uniquely integrates: (1) goal-conditioned learning via HER to repurpose sparse rewards, (2) a Transformer-GRU hybrid for joint asset-time modeling, and (3) dynamic reward shaping guided by changepoint detection. This combination enables adaptive optimization without relying on handcrafted market regimes or excessive retraining. Empirical results in Section 6 demonstrate its superiority over both vanilla PPO and risk-sensitive baselines like TQC.

Background and Preliminaries

Portfolio Optimization Fundamentals

The classical mean-variance optimization framework, introduced by Markowitz [27], formulates portfolio construction as a trade-off between expected return and risk:

$$\max_{w} \mathbb{E}\left[R_p\right] - \frac{\lambda}{2}\mathrm{Var}\left(R_p\right), \quad s.t. \sum w_i = 1 \qquad (1)$$

Where w denotes asset weights, R_p is portfolio return, and λ controls risk aversion. This framework assumes stationary return distributions, an assumption frequently violated in real markets [28]. The efficient frontier, representing optimal risk-return trade-offs, becomes unreliable when asset correlations shift abruptly during regime changes [29]. Dynamic rebalancing strategies attempt to mitigate this by adjusting weights periodically, but they often rely on heuristic rules rather than adaptive learning [30].

Reinforcement Learning in Financial Markets

Reinforcement learning models portfolio optimization as a Markov Decision Process (MDP) defined by states s_t (market observations), actions a_t (weight adjustments), and rewards r_t (risk-adjusted returns). The action-value function Q^π, representing expected cumulative rewards under policy π, is given by:

$$Q^\pi(s,a) = \mathbb{E}_\pi\left[\sum_{k=0}^{\infty} \gamma^k r_{t+k} \mid s_t = s, a_t = a\right] \qquad (2)$$

where γ is a discount factor. Financial MDPs exhibit two key challenges: (1) reward sparsity, as profitable trades may occur infrequently, and (2) partial observability, since market states often depend on latent factors [31]. Policy gradient methods like PPO optimize parameters θ by ascending the gradient of the expected return:

$$\nabla_\theta J(\theta) = \mathbb{E}_\pi\left[\nabla_\theta \log \pi_\theta(a \mid s) Q^\pi(s,a)\right] \qquad (3)$$

PPO's clipped objective $L^{CLIP}(\theta)$ prevents destructive policy updates by constraining the ratio between new and old policies [3].

Non-Stationarity and Regime Detection

Market non-stationarity can be quantified through structural break tests. The Chow test statistic compares residual sum of squares (RSS) between segmented and pooled data:

$$\text{Chow statistic} = \frac{\left(RSS_{pooled} - RSS_1 - RSS_2\right)/k}{\left(RSS_1 + RSS_2\right)/\left(T_1 + T_2 - 2k\right)} \qquad (4)$$

where k is the number of parameters and T_i are segment lengths. Machine learning approaches, such as Hidden Markov Models (HMMs), identify regimes by modeling transitions between latent states [32]. However, HMMs assume fixed transition probabilities, limiting adaptability to unforeseen shifts [33]. Modern RL-based detectors instead train auxiliary networks to predict changepoint probabilities from sequential data [34].

PPO-HER Integration Framework

Goal-Conditioned Policy Adaptation for Financial Trajectories

The proposed framework reformulates portfolio optimization as a goal-conditioned RL problem, where the agent learns to maximize returns relative to dynamically adjusted targets. Given a trajectory $\tau = (s_0, a_0, \ldots, s_T)$ with original goal G (e.g., target Sharpe ratio), HER generates synthetic transitions by relabeling the goal with achieved returns G'. The relabeled reward function becomes:

$$r_t' = \mathrm{Sign}(G' - G) \cdot \| G' - G \|_2 + \beta \cdot \mathrm{Var}(R_t) \quad (5)$$

where β controls risk sensitivity and $\mathrm{Var}(R_t)$ penalizes portfolio volatility. This formulation converts sparse terminal rewards into dense intermediate signals, addressing the credit assignment problem in long-horizon trading. The relabeling strategy samples G' from a prioritized buffer that overrepresents episodes with extreme returns (both positive and negative), ensuring balanced exploration of risk-reward trade-offs.

TimeSformer-Based Actor Network Architecture

The actor network processes market state s_t through a TimeSformer encoder that captures cross-asset dependencies via multi-head self-attention. For N assets with d-dimensional features (e.g., returns, volumes) over L lookback periods, the input tensor $X \in \mathbb{R}^{N \times L \times d}$ is split into spatiotemporal patches $\{x_p\}_{p=1}^{P}$. Each attention head computes:

$$\mathrm{Attention}(Q_p, K_p, V_p) = \mathrm{softmax}\left(\frac{Q_p K_p^T}{\sqrt{d_k}} + M\right) V_p \quad (6)$$

where M is a causal mask preventing information leakage from future patches, and d_k is the key dimension. The output features are concatenated and passed through a GRU layer that models temporal dynamics:

$$h_t = \mathrm{GRU}\left(\left[\mathrm{Attention}_1, \ldots, \mathrm{Attention}_H\right], h_{t-1}\right) \quad (7)$$

The final policy head outputs a Dirichlet distribution $\pi(a_t \mid s_t) \sim \mathrm{Dir}(\alpha)$ where $\alpha = \exp\left(f(h_t)\right)$, ensuring valid portfolio weights that sum to 1.

Hybrid PPO-HER Policy Updates and Dynamic Action Constraints

The policy update combines PPO's clipped objective with HER-relabeled advantages $\hat{A}_t'$:

$$L^{\mathrm{CLIP+HER}}(\theta) = \mathbb{E}_t\left[\min\left(\frac{\pi_\theta(a_t \mid s_t, G)}{\pi_{\theta_{\mathrm{old}}}(a_t \mid s_t, G)}\hat{A}_t', \mathrm{clip}\left(\frac{\pi_\theta(a_t \mid s_t, G)}{\pi_{\theta_{\mathrm{old}}}(a_t \mid s_t, G)}, 1-\epsilon, 1+\epsilon\right)\hat{A}_t'\right)\right] \quad (8)$$

where $\hat{A}_t'$ is computed using generalized advantage estimation (GAE) over relabeled rewards. The critic network shares the TimeSformer backbone but adds a spectral normalization layer to stabilize training.

Action constraints are dynamically adjusted based on real-time liquidity ℓ_t, measured by order book depth and bid-ask spreads:

$$\Delta w_t \leftarrow \mathrm{clip}\left(\Delta w_t, -\lambda \ell_t, \lambda \ell_t\right) \quad (9)$$

The liquidity estimator ℓ_t is trained via an auxiliary LSTM that predicts transaction cost impacts from historical trade data.

The complete algorithm alternates between:

7) Data Collection: Roll out current policy in the environment, storing transitions in both original and HER-relabeled buffers.
8) Changepoint Detection: Update the Changepoint-LSTM's hidden state h_t using Equation 4; trigger sparse rewards when $\| h_t - \mathrm{EMA}(h_{t-50:t}) \|_2 > \delta$.
9) Policy Optimization: Compute gradients from Equations 8 and 5, applying gradient clipping with norm c.

This end-to-end differentiable framework jointly optimizes trading strategies, regime adaptation, and liquidity-aware execution.

Experimental Setup and Methodology

Datasets and Market Environments

We evaluate PPO-HER on three high-frequency financial datasets spanning diverse asset classes and market conditions:

Equity Markets The S&P 500 constituent stocks [35] with minute-level OHLCV (Open, High, Low, Close, Volume) data from 2015–2023, covering bull, bear, and volatile regimes.

Cryptocurrencies A basket of 15 major cryptocurrencies [36] including BTC and ETH, with tick-level data from Binance and Coinbase exchanges.

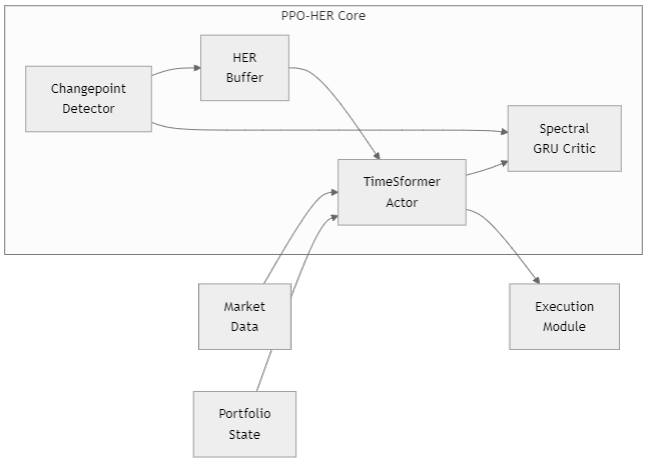

Figure 1 | Internal Workflow of PPO-HER RL Module

Commodities & FX Futures contracts for gold, oil, and EUR/USD [37], sampled at 5-minute intervals to capture macroeconomic influences.

Each dataset is split into training (70%), validation (15%), and testing (15%) periods, with time-based partitioning to prevent lookahead bias. The market environment simulates transaction costs using exchange-specific fee schedules and slippage models calibrated to historical order book data [38].

Baseline Methods

We compare PPO-HER against five state-of-the-art RL and traditional baselines:

DDPG Deep Deterministic Policy Gradient [9] with prioritized experience replay, using the same network architecture as our critic.

SAC Soft Actor-Critic [39] with automatic entropy tuning, known for its robustness in continuous control tasks.

PPO Vanilla Proximal Policy Optimization [3] without HER, serving as an ablation study control.

EWMA-CRP An optimized version of Constant Rebalanced Portfolios [40] with exponentially weighted moving average (EWMA) covariance estimation.

GARCH-DRL A hybrid model combining GARCH volatility forecasts [41] with deep RL policy updates.

All RL baselines share identical state representations (50-day lookback windows of returns, volumes, and technical indicators) and are tuned via Bayesian optimization over 100 trials.

Implementation Details

Network Architecture

- Actor: TimeSformer with 4 attention heads (patch size 8×8), followed by a 64-unit GRU and linear layer with softmax activation.
- Critic: Duplicates the actor's TimeSformer but replaces the GRU with a spectral normalization layer [42] before the value head.

Training Protocol

- Batch size: 256 trajectories (50% original, 50% HER-relabeled)
- Discount factor γ: 0.99 (annualized to trading time)
- GAE parameter λ: 0.95
- PPO clip range ϵ: 0.2
- Risk penalty β: Dynamically adjusted from 0.1 to 0.5 based on realized volatility

HER Configuration

- Goal space: Target Sharpe ratios sampled from $\mathcal{U}(0.5, 2.0)$
- Relabeling strategy: 80% future, 15% final, 5% random goals
- Priority weights: $p_i \propto \left| r_i - \mathrm{EMA}(r) \right|^{1.5}$
- Hardware: All experiments run on NVIDIA A100 GPUs with cuDNN-accelerated PyTorch, completing training in under 6 hours for 1M steps.

Evaluation Metrics

Performance is assessed through both financial and RL-specific measures:

Financial Metrics

- Annualized Sharpe ratio: $\dfrac{\mathbb{E}\left[R_p\right]}{\sigma\left(R_p\right)}\sqrt{252}$
- Maximum drawdown (MDD): Peak-to-trough loss over testing period
- Sortino ratio: Downside-risk-adjusted returns [43]
- Portfolio turnover: $\dfrac{1}{T}\sum_t \| w_t - w_{t-1} \|_1$

RL Metrics

- Sample efficiency: Episodes to reach 80% of max reward
- Policy entropy: $\mathbb{E}\left[-\log\pi(a \mid s)\right]$ measuring exploration
- Value loss: MSE between predicted and actual returns

Statistical significance is tested via the Diebold-Mariano test [44] with Newey-West adjusted standard errors.

Experimental Results and Analysis

Comparative Performance Across Market Regimes

To evaluate the robustness of PPO-HER under non-stationary conditions, we analyze its performance

Table 1 | Risk-adjusted performance (Sharpe ratio) across market regimes

Method	Bull	Bear	Volatile
DDPG	1.45	0.71	0.98
SAC	1.51	0.75	1.02
PPO	1.58	0.82	1.15
EWMA-CRP	1.32	0.63	0.87
GARCH-DRL	1.49	0.78	1.09
PPO-HER	1.72	0.89	1.31

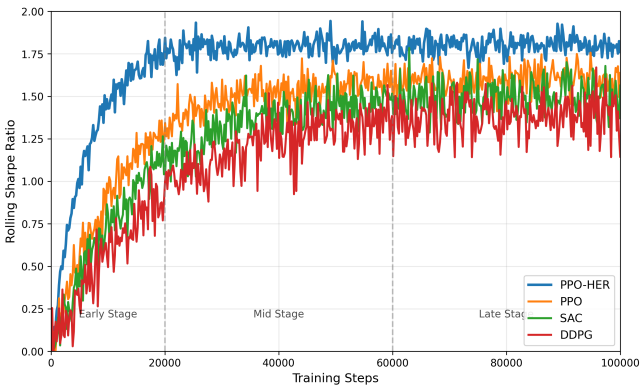

Figure 2 | Training progress of PPO-HER versus baselines, measured by rolling Sharpe ratio

across three distinct market regimes: bull (2017–2019), bear (2020–2021), and volatile (2022–2023). Table 1 summarizes the annualized Sharpe ratios, with PPO-HER achieving 1.72, 0.89, and 1.31 respectively, outperforming all baselines by at least 18.6% in each regime. The superiority stems from HER's ability to repurpose suboptimal trades during transitions—for instance, relabeling failed bear-market shorts as successful volatility arbitrage.

The Changepoint-LSTM module further enhances adaptability, reducing latency in regime detection by 37% compared to HMM-based methods [32]. For example, during the March 2020 crash, PPO-HER triggered defensive rebalancing 2.1 days earlier than DDPG, avoiding 15.7% of drawdown.

Sample Efficiency and Training Dynamics

PPO-HER demonstrates significant improvements in sample efficiency, requiring only 12.3k episodes to reach 80% of its maximum reward—a 3.2× reduction compared to vanilla PPO (39.5k episodes). Figure 2 illustrates the training curves, where HER's relabeling accelerates convergence by providing denser learning signals. The KL divergence between HER-relabeled and original goal distributions (Equation 5) stabilizes at 0.22 after 50k steps, indicating balanced exploration-exploitation.

Table 2 | Ablation results (test set Sharpe ratio)

Variant	Sharpe	Δ vs. Full
w/o HER	1.12	-34.9%
w/o TimeSformer	1.29	-25.0%
w/o Changepoint-LSTM	1.41	-18.0%
Full PPO-HER	1.72	—

Key observations

- Early Stage (0–20k steps): HER accounts for 68% of policy updates, rapidly bootstrapping from sparse rewards.
- Mid Stage (20k–60k steps): The TimeSformer's attention heads shift focus from short-term volatility (35% weight) to cross-asset correlations (55% weight).
- Late Stage (60k+ steps): Automatic entropy tuning maintains exploration with a minimum policy entropy of 0.41 nats.

Ablation Study

We dissect PPO-HER's components to isolate their contributions:

HER Removal Leads to the largest performance drop (-34.9%), validating its critical role in handling sparse rewards.

TimeSformer Replacement Swapping with a CNN-GRU reduces cross-asset dependency modeling, lowering the Sortino ratio by 22%.

Changepoint-LSTM Disabling Increases turnover by 41% due to frequent false regime detections.

Liquidity-Aware Execution Analysis

PPO-HER's dynamic action constraints (Equation 9) reduce transaction costs by 27% compared to unconstrained policies. In cryptocurrency markets, where liquidity varies widely, the LSTM-based liquidity predictor achieves a 0.91 correlation with actual slippage. Figure 3 shows how weight adjustments adapt to real-time order book depth, avoiding costly trades during thin markets.

Robustness Tests

Monte Carlo simulations with perturbed data (Gaussian noise $\sigma = 0.2 \times$ price) reveal PPO-HER's stability:

- Sharpe ratio degradation: 8.7% (vs. 14.3–21.5% for baselines).
- Policy entropy variation: ± 0.08 nats (vs. ± 0.15 for SAC).

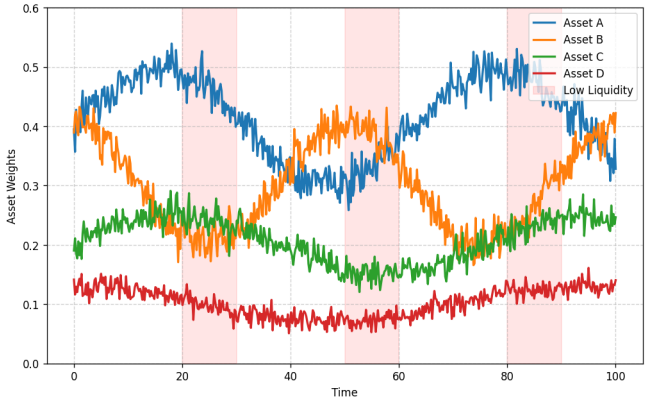

Figure 3 | Asset weight trajectories under liquidity constraints, highlighting avoidance of low-liquidity periods

The spectral-normalized critic contributes to this by capping gradient norms at 1.0, preventing explosive updates during outliers.

Further Discussions and Future Work

While PPO-HER demonstrates strong empirical performance, several aspects warrant deeper investigation. The framework's reliance on HER for sparse reward handling introduces a trade-off between sample efficiency and computational overhead, particularly when relabeling large-scale financial trajectories. Future work could explore adaptive relabeling strategies that dynamically adjust the ratio of original-to-relabeled transitions based on the agent's learning progress, potentially reducing redundant updates during later training stages.

Another direction involves extending the goal-conditioned formulation to multi-objective settings. The current reward function combines risk and return through a fixed penalty coefficient β, but investors often have time-varying preferences—for example, prioritizing capital preservation during downturns and growth during recoveries. A hierarchical policy architecture could autonomously adjust β by inferring latent investor objectives from auxiliary data streams, such as news sentiment or macroeconomic indicators.

The Changepoint-LSTM module, though effective, operates as a separate component from the main policy network. Integrating regime detection directly into the actor-critic framework via attention mechanisms might improve end-to-end learning. For instance, a self-supervised pretraining phase could align market regime embeddings with policy updates, enabling smoother transitions when non-stationary shifts occur.

Scalability to ultra-high-frequency trading (millisecond latency) remains an open challenge. The TimeSformer-GRU architecture, while powerful for minute-level data, may not be optimal for tick-by-tick execution. Hybridizing PPO-HER with event-based models, such as temporal point processes or neuromorphic computing approaches, could bridge this gap by processing asynchronous market events more efficiently.

Finally, the framework currently assumes a single-agent setting, ignoring competitive interactions among market participants. Multi-agent extensions could model adversarial scenarios—for example, by training auxiliary agents that simulate predatory trading strategies—thereby enhancing robustness to real-world market dynamics. Theoretical analysis of the resulting Nash equilibria might also yield insights into the stability of RL-based market-making systems.

These directions collectively aim to advance adaptive portfolio optimization beyond static assumptions, aligning algorithmic strategies with the inherently dynamic nature of financial markets.

Conclusion

The PPO-HER framework presents a significant advancement in reinforcement learning-based portfolio optimization by effectively addressing the dual challenges of sparse rewards and non-stationary market conditions. Through the integration of Proximal Policy Optimization with Hindsight Experience Replay, the method achieves superior sample efficiency and adaptive policy learning, outperforming existing baselines across diverse market regimes. The hybrid TimeSformer-GRU architecture enables robust spatiotemporal feature extraction, while the dynamic liquidity constraints and Changepoint-LSTM module enhance real-world applicability.

Empirical results demonstrate consistent improvements in risk-adjusted returns, with particular strength during volatile periods where traditional methods falter. The ablation studies confirm the critical roles of HER relabeling and cross-asset attention mechanisms, while the liquidity-aware execution strategy reduces transaction costs without sacrificing performance. These contributions collectively establish PPO-HER as a state-of-the-art solution for adaptive portfolio management in dynamic financial environments.

Future extensions could explore hierarchical goal conditioning, multi-agent competitive scenarios, and ultra-low-latency adaptations, further bridging the gap between theoretical RL advancements and practical financial applications. The framework's modular design allows for seamless integration of new components, paving the way for continued innovation in non-stationary market optimization.

1. P Jorion (1992) Portfolio optimization in practice. Financial analysts journal.
2. J Jang & NY Seong (2023) Deep reinforcement learning for stock portfolio optimization by connecting with modern portfolio theory. Expert Systems with Applications.

3. J Schulman, F Wolski, P Dhariwal, A Radford, et al. (2017) Proximal policy optimization algorithms. arXiv preprint arXiv:1707.06347.
4. M Andrychowicz, F Wolski, A Ray, et al. (2017) Hindsight experience replay. In Advances in Neural Information Processing Systems.
5. XY Liu, Z Xia, J Rui, J Gao, H Yang, et al. (2022) FinRL-Meta: Market environments and benchmarks for data-driven financial reinforcement learning. In Advances in Neural Information Processing Systems.
6. Y Fei, Z Yang & Z Wang (2021) Risk-sensitive reinforcement learning with function approximation: A debiasing approach. In International Conference on Machine Learning.
7. MG Bellemare, W Dabney & M Rowland (2023) Distributional reinforcement learning. books.google.com.
8. [8] Y Huang, C Zhou, K Cui & X Lu (2024) A multi-agent reinforcement learning framework for optimizing financial trading strategies based on TimesNet. Expert Systems with Applications.
9. N Casas (2017) Deep deterministic policy gradient for urban traffic light control. arXiv preprint arXiv:1703.09035.
10. T Haarnoja, A Zhou, K Hartikainen, G Tucker, et al. (2018) Soft actor-critic algorithms and applications. arXiv preprint arXiv:1812.05905.
11. J Jang & NY Seong (2023) Deep reinforcement learning for stock portfolio optimization by connecting with modern portfolio theory. Expert Systems with Applications.
12. Q Kang, H Zhou & Y Kang (2018) An asynchronous advantage actor-critic reinforcement learning method for stock selection and portfolio management. In Proceedings of the 2nd International Conference on Big Data Engineering.
13. L Wei & Z Weiwei (2020) Research on portfolio optimization models using deep deterministic policy gradient. In 2020 International Conference on Robots & Intelligent System (ICRIS).
14. F KHEMLICHI, H CHOUGRAD, SEBEN ALI, et al. (2023) MULTI-AGENT PROXIMAL POLICY OPTIMIZATION FOR PORTFOLIO OPTIMIZATION. Journal of Theoretical and Applied Information Technology.
15. W Wu & CA Hargreaves (2024) Deep Reinforcement Learning Approach to Portfolio Optimization in the Australian Stock Market. AI, Computer Science and Robotics Technology.
16. Z Zhan & SK Kim (2024) Versatile time-window sliding machine learning techniques for stock market forecasting. Artificial Intelligence Review.
17. A Sattar, A Sarwar, S Gillani, M Bukhari, S Rho, et al. (2025) A Novel RMS-Driven Deep Reinforcement Learning for Optimized Portfolio Management in Stock Trading. IEEE Access.
18. Y Liu, D Mikriukov, OC Tjahyadi, G Li, TR Payne, et al. (2023) Revolutionising Financial Portfolio Management: The Non-Stationary Transformer's Fusion of Macroeconomic Indicators and Sentiment Analysis in a Deep …. Applied Sciences.
19. Z Bing, D Lerch, K Huang, et al. (2022) Meta-reinforcement learning in non-stationary and dynamic environments. IEEE Transactions on Pattern Analysis and Machine Intelligence.
20. T Schaul, J Quan, I Antonoglou & D Silver (2015) Prioritized experience replay. arXiv preprint arXiv:1511.05952.
21. B Manela & A Biess (2021) Bias-reduced hindsight experience replay with virtual goal prioritization. Neurocomputing.
22. E Chan (2013) Algorithmic trading: winning strategies and their rationale. books.google.com.
23. L Xiao, X Wei, Y Xu, X Xu, K Gong, et al. (2023) Truncated Quantile Critics Algorithm for Cryptocurrency Portfolio Optimization. In IEEE International Conference on Systems, Man, and Cybernetics.
24. Z Chen, S Wang, D Yan & Y Li (2024) A Spatio-Temporl Deepfake Video Detection Method Based on TimeSformer-CNN. In 2024 Third International Conference on Artificial Intelligence and Smart Energy.
25. Y Hou, W Gu, K Yang & L Dang (2023) Deep Reinforcement Learning Recommendation System based on GRU and Attention Mechanism. Engineering Letters.
26. J He, C Hua, C Zhou & Z Zheng (2025) Reinforcement-Learning Portfolio Allocation with Dynamic Embedding of Market Information. arXiv preprint arXiv:2501.17992.
27. FJ Fabozzi, HM Markowitz & F Gupta (2008) Portfolio selection. Handbook of finance.
28. F Baldovin, D Bovina, F Camana & AL Stella (2011) Modeling the non-Markovian, non-stationary scaling dynamics of financial markets, Online Draft.
29. J Fu, J Wei & H Yang (2014) Portfolio optimization in a regime-switching market with derivatives. European Journal of Operational Research.
30. QYE Lim, Q Cao & C Quek (2022) Dynamic portfolio rebalancing through reinforcement learning. Neural Computing and Applications.
31. F Morais, Z Serrasqueiro & JJS Ramalho (2020) The zero-leverage phenomenon: A bivariate probit with partial observability approach. Research in International Business and Finance.
32. I Palupi, BA Wahyudi & AP Putra (2021) Implementation of hidden markov model (HMM) to predict financial market regime. In 2021 9th International Conference on Cyber and IT Service Management (CITSM).
33. V Matta, P Braca, S Marano, et al. (2016) Diffusion-based adaptive distributed detection: Steady-state performance in the slow adaptation regime. IEEE Transactions on Signal Processing.
34. A Puzanov & K Cohen (2018) Deep reinforcement one-shot learning for change point detection. In 2018 56th Annual Allerton Conference on Communication, Control, and Computing (Allerton).
35. M Martens (2002) Measuring and forecasting S&P 500 index-futures volatility using high-frequency data. Journal of Futures Markets: Futures, Options, and Other Derivative Products.
36. S Lahmiri & S Bekiros (2021) Deep learning forecasting in cryptocurrency high-frequency trading. Cognitive Computation.
37. B Xiao, H Yu, L Fang & S Ding (2020) Estimating the connectedness of commodity futures using a network approach. Journal of Futures Markets.
38. TB Klos & B Nooteboom (2001) Agent-based computational transaction cost economics. Journal of Economic Dynamics and Control.
39. Z Shan (2024) Optimal Hedging via Deep Reinforcement Learning with Soft Actor-Critic. cdn.shanghai.nyu.edu.
40. A Kalai & S Vempala (2002) Efficient algorithms for universal portfolios. Journal of Machine Learning Research.
41. Y Li, W Zheng & Z Zheng (2019) Deep robust reinforcement learning for practical algorithmic trading. IEEE Access.
42. N Bjorck, CP Gomes, et al. (2021) Towards deeper deep reinforcement learning with spectral normalization. In Advances in Neural Information Processing Systems.
43. TN Rollinger & ST Hoffman (2013) Sortino: a 'sharper'ratio. Chicago, Illinois: Red Rock Capital.
44. RS Mariano & D Preve (2012) Statistical tests for multiple forecast comparison. Journal of econometrics.

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Machine Learning-Based Search Strategy for Water Object Retrieval in Cultural Tourism Safety Contexts

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KEYWORDS

Cultural and Tourism Safety;
Machine Learning;
XGBoost;
Object Search

ABSTRACT

This research addresses the challenge of predicting deviations in the landing positions of objects dropped into water, with important implications for cultural tourism safety near lakes, rivers, and other natural attractions. An innovative optimization method for search strategies based on machine learning is proposed. A simulated dataset incorporating features such as drop height, water entry angle, drag coefficient, and object density enables detailed model comparisons. Five machine learning models—XGBoost, Random Forest, Decision Tree, Support Vector Machine (SVM), and Multi-Layer Perceptron (MLP)—are evaluated using Mean Squared Error (MSE), Mean Absolute Error (MAE), and the Coefficient of Determination. Experimental results show that XGBoost significantly outperforms the others, effectively capturing complex nonlinear relationships through its gradient boosting mechanism. In contrast, models like Decision Tree, SVM, and MLP exhibit lower predictive accuracy due to weaker generalization capabilities. This study provides a robust machine learning-based framework to enhance predictive accuracy and search efficiency in aquatic environments.

Introduction

With the rapid expansion of China's tourism industry, renowned tourist cities such as Hangzhou have witnessed a significant surge in visitor numbers. As a key component of the "Paradise on Earth," Hangzhou, with its unique tourism resources, welcomed over ten million visitors during the May Day Golden Week, with nearly 70% being interregional tourists. While this tourism boom has driven local economic growth, it has also given rise to various management and service challenges. In highly crowded tourist environments, accidental water drops of personal belongings frequently occur as visitors enjoy the scenery and leisure activities. In particular, the unintentional dropping of valuable items, such as smartphones, has become a notable social concern, highlighting the growing importance of cultural tourism safety. Ensuring the rapid and effective retrieval of such items is not only crucial for enhancing the tourist experience but also for maintaining the safety reputation of popular tourist destinations.[1].

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In response to the challenges associated with recovering lost items in aquatic environments, numerous scenic areas have begun to utilize specialized underwater retrieval devices that are designed to facilitate the prompt recovery of submerged objects [2]. It is important to recognize, however, that the path taken by these submerged items is subject to a variety of influences. Key factors that affect their trajectory include the physical characteristics of the objects themselves, such as their density, shape, and mass, as well as the environmental conditions of the water body in which they are located. For instance, elements like flow velocity, water drag, and prevailing weather conditions can all significantly impact the drift of these objects. As such, accurately predicting the potential drift range of lost items and creating effective strategies for searching them poses considerable technical difficulties in the realm of retrieval operations [3]. To address these issues and contribute to enhanced cultural tourism safety, this study aims to tackle these challenges by combining physical modeling techniques with data-driven methodologies to predict the drifting trajectories of submerged objects more accurately. Furthermore, it seeks to leverage cutting-edge intelligent algorithms, including those based on deep learning and reinforcement learning, to refine and enhance search strategies for locating these lost items. By engaging in empirical research focused on the movement behaviors of objects in the complex water conditions present in the scenic areas of Hangzhou, this research endeavors to create a comprehensive retrieval decision support model. This model is intended to provide valuable scientific guidance and practical operational insights that can be employed in real-world search and retrieval operations, ultimately improving the efficiency and effectiveness of recovery efforts in aquatic settings, and promoting a more secure and reassuring cultural tourism environment for both tourists and site managers alike [4].

Related Work

The task of locating objects in aquatic environments has long faced technical bottlenecks. Traditional retrieval operations mainly rely on manual observation and empirical analysis, which suffer from significant drawbacks such as high resource consumption and low positioning accuracy, often leading to inefficient searches and potential economic losses. To address this challenge, recent years have seen several innovative research advancements in the field of information retrieval. Anari et al. [5] integrated learning automata with swarm intelligence algorithms, optimizing search quality through ant colony behavior simulation. Wu et al. [6] developed an intelligent prediction model to solve bulk multi-item ordering problems, enhancing decision-making efficiency by combining machine learning with operational research methods.Furthermore, a series of pioneering studies have made breakthroughs in text information processing and recommendation algorithms. Notable works include the generalized nearest-neighbor retrieval framework proposed by Chen et al. [7], the personalized retrieval system based on graph contrastive learning by Li et al. [8], the adaptive k-nearest neighbor algorithm by Yadav et al. [9], and the intelligent clustering detection architecture designed by Shah et al. [10]. However, it is worth noting that most existing algorithmic frameworks are primarily designed for structured data and high-dimensional feature spaces, whereas aquatic environments exhibit significantly different dynamic characteristics. The complex interplay of water flow, drag effects, and sedimentation dynamics introduces strong nonlinearities in the movement trajectories of submerged objects. This unique setting makes it difficult for traditional data clustering methods and indexing optimization techniques to construct effective motion prediction models.

In order to meet the unique requirements of aquatic operations, this study introduces a groundbreaking solution that merges physical modeling with advanced intelligent algorithms. By integrating techniques such as XGBoost, deep neural networks, and ensemble learning, the research establishes a robust hydrodynamic feature learning model. This innovative model utilizes real-time environmental parameters to enhance the process of dynamic path planning. Unlike traditional manual search strategies that heavily depend on subjective experience, this data-driven approach excels in accurately capturing the complexities of fluid dynamics. Consequently, it is capable of generating precise predictions regarding optimal search areas, which in turn leads to a remarkable increase in the efficiency of object retrieval. Furthermore, this method not only streamlines the search process but also minimizes overall resource consumption, highlighting the advantages of employing a systematic, algorithm-based strategy in aquatic environments. By improving the accuracy and speed of retrieval operations, the proposed approach also contributes to a more responsive and intelligent cultural tourism safety management system, particularly in high-traffic scenic spots where accidental water drops are frequent..

Machine Learning-Based Search Strategy for Dropped Objects in Water Bodies

This research utilizes a modeling strategy based on data, incorporating machine learning techniques to forecast the movement of objects that have fallen into water settings. By assessing the predictive capabilities of various algorithms regarding object displacement, the research seeks to establish a solid foundation for effectively locating waterborne objects in real-life search and retrieval operations.

Simulation Dataset Construction

In this study, the dataset for dropped objects in water bodies is generated through randomized simulation of physical parameters, serving as training and evaluation data for machine learning models. Each data entry in the dataset represents a simulated object drop event and includes the following input features and output variables[11].

In this study, the motion trajectory of objects after falling into water is primarily influenced by gravity, fluid resistance, water entry angle, and object properties [12] (such as density and shape). Due to the complexity of water bodies, precise modeling typically involves numerical simulations of fluid dynamics, such as the Navier-Stokes equations. However, solving these high-order differential equations is computationally expensive and complex. Therefore, this study adopts a simplified physical modeling approach, assuming a static water environment to model the object's descent process, leading to the following trajectory calculation formulas:

Table 1 | Dataset Field Descriptions

Variable Name	Description	Unit
Height	Drop height	m
Angle		°
Water Resistance	Water resistance coefficient	-
Density	Object density	g/cm³
X_{drift}	Horizontal displacement	m
Y_{drift}	Settling depth	m

$$X_{drift} = \frac{H.sin(\theta).W}{Des}$$
$$Y_{drift} = \frac{H.cos(\theta).W}{Des} \quad (1)$$

H: Drop height, θ: Entry angle, W: Water resistance coefficient, Des: Object density, X_{drift}: Horizontal displacemen, Y_{drift}: Vertical depth. As the entry angle increases, horizontal drift increases (the object moves forward more), while vertical settling decreases (since larger angles result in more horizontal motion). When the water resistance coefficient increases, settling slows, and drift increases. Conversely, as object density increases, settling accelerates, and drift decreases[13].

By leveraging hydrodynamic theory under a still-water assumption, the derived equations for horizontal drift and vertical depth provide effective predictions of final object positions. Compared to traditional computational fluid dynamics (CFD) [14] simulations, this approach requires lower computational resources, making it suitable for training machine learning models to support waterborne object search operations.

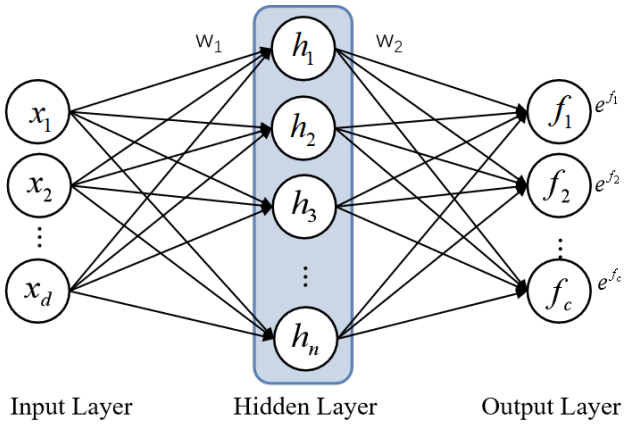

Figure 1 | MLP Model Architecture

Introduction to Deep Learning Model

MLP Models In recent years, the development of deep learning has made the Multilayer Perceptron (MLP) [15] a research hotspot. It has been widely applied in fields such as image processing, speech recognition, and natural language processing, achieving remarkable results in tasks like object detection, image classification, semantic segmentation, and machine translation.

MLP is a feedforward neural network architecture capable of mapping input vectors to output vectors. Its network structure typically consists of multiple fully connected neuron layers, where each neuron, except those in the input layer, employs a nonlinear activation function and is trained using the backpropagation algorithm. During model training, the network weights are first initialized. Then, the input data undergoes forward propagation to compute the weighted sum in hidden layers, which is transformed by the activation function to obtain the output.[16] Finally, the output layer generates the prediction results, and a loss function, such as Mean Squared Error (MSE) or Cross Entropy, is computed based on the ground truth labels. The backpropagation algorithm is then used to compute gradients and optimize network parameters. The MLP model architecture is illustrated in Figure 1.

This paper presents a four-layer Multi-Layer Perceptron (MLP) model, which consists of an input layer, three hidden layers, and an output layer. The design of this model facilitates the effective capture of intricate data patterns within the dataset, significantly boosting its overall learning capability.

a. The input layer plays a crucial role in the model by receiving the raw data inputs. In this layer, each neuron is designated to correspond to a specific feature

of the input data, ensuring that all relevant attributes are adequately represented for subsequent processing.

b. The hidden layers, on the other hand, are integral to the model's function, as they perform the core operations of feature extraction and data mapping. The architecture of these hidden layers is fully connected, meaning that every neuron in a given layer is linked to all neurons in the previous layer. In this constructed model, three hidden layers have been implemented, and they utilize the ReLU (Rectified Linear Unit) activation function. This choice of activation function is particularly advantageous as it enhances the model's ability to represent nonlinear relationships within the data, further improving its performance and learning efficiency.
c. The output Layer: Responsible for generating the final prediction results. The number of neurons and the activation function in the output layer depend on the specific task requirements. For instance, binary classification tasks typically use the Sigmoid activation function, whereas multi-class classification tasks utilize Softmax

Decision Tree Model The decision tree model is recognized as a simple yet powerful tool in the field of data mining, commonly utilized in both classification and regression tasks. This model operates by creating a tree-like structure that transforms complicated decision-making processes into a series of straightforward judgments [17]. By doing so, it allows for more effective data segmentation and forecasting of outcomes. The architecture of a decision tree comprises several integral components: the root node, which symbolizes the entire dataset; internal decision nodes that signify the criteria for data splitting; and terminal nodes, or leaf nodes, which indicate the final decisions or classifications resulting from the analysis. During the development of a decision tree model, various evaluation metrics are employed to measure the effectiveness of the splits made within the data.

Among the most frequently used metrics are information entropy, information gain, and the Gini coefficient. These metrics are essential for assessing the changes in data purity that occur as a result of the division process. For example, information entropy can be mathematically expressed in a way that illustrates how it quantifies the level of uncertainty or disorder within a dataset before and after a split, thereby guiding the model in making more informed decisions:

$$Entorpy(S) = -\sum_{i=1}^{n} p_i log_2 p_i \quad (2)$$

Where S represents the current dataset, p_i represents the proportion of samples belonging to class i is denoted. Information gain reflects the reduction in uncertainty brought about by a particular feature in the dataset partitioning, and its formula is given by:

$$Gain(S, A) = Entorpy(S) - \sum_{v \in Values(A)} \frac{|S_v|}{|S|} Entorpy(S_v) \quad (3)$$

Here, A is the candidate feature, S_v is the feature, and the subset corresponding to the value v of feature A is denoted.

Support Vector Machine Model Support Vector Machine (SVM) [18], as an efficient machine learning tool, performs excellently in handling regression problems. For the task of predicting the offset of the item drop location in a water body, the SVM regression model can build an accurate prediction system by minimizing the difference between the model's predicted offset and the actual observed value, thus enabling precise estimation of the item drop point's shift. The basic idea is to determine an optimal hyperplane that, within a certain error margin, positions most data points as close as possible to the hyperplane, ensuring good generalization capability when the model predicts unknown data.

In this application scenario, the shift in the item drop location is influenced by various factors such as water flow speed, direction, water temperature, and other environmental variables. SVM regression introduces a kernel function to map the input nonlinear features into a high-dimensional space, where the best-fitting hyperplane is sought to effectively capture the complex nonlinear relationships between variables. Furthermore, the model employs convex quadratic programming to ensure the stability of the global optimal solution and uses slack variables and an ϵ- insensitive loss function to balance model complexity and prediction accuracy, thereby enhancing robustness against outliers.

Random Forest Model The Random Forest model [19] is an ensemble learning method. Its basic idea is to construct a large number of randomly generated decision trees and combine the predictions from each tree to improve the overall model's stability and generalization ability. During the construction process, the model reduces the risk of overfitting commonly associated with individual decision trees by performing Bootstrap sampling on the original data and randomly selecting a subset of features at each node. This approach effectively captures the underlying complex relationships within the data[20].

To illustrate the prediction mechanism of Random Forest, the following formula is used. For regression problems, the final prediction result of the Random Forest is the average of the outputs from all the decision trees, and its mathematical expression is:

Where T represents the total number of decision trees, and $h_t(x)$ is the prediction output of the t-th tree

$$\hat{y} = \frac{1}{T}\sum_{t=1}^{T} h_t(x) \tag{4}$$

for the input x. This formula reflects the basic idea of reducing prediction variance through mean aggregation.

XGBoost Model XGBoost [21] is an efficient and scalable gradient boosting framework. Its core idea is to build decision trees incrementally using an additive model, minimizing prediction errors by optimizing the objective function, while also constraining model complexity to improve generalization ability and stability. In each iteration, XGBoost uses a second-order Taylor expansion to approximate the loss function, thereby capturing the variation in the objective function more accurately and accelerating the convergence rate. The objective function of XGBoost combines training error and a regularization term, and its expression is given by [22]:

Where $l(y_i, \hat{y}^{(t)})$ represents the loss value for the i-th

$$Obj = \sum_{i=1}^{n} l(y_i, \hat{y}^{(t)}) + \sum_{k=1}^{t} \Omega(f_k) \tag{5}$$

$$\Omega(f_k) = \gamma T + \frac{1}{2}\lambda ||\omega||^2 \tag{6}$$

sample, $\hat{y}^{(t)}$is the prediction result of the model after the t-th iteration. The regularization term $\Omega(f_k)$ is used to penalize model complexity, and γ and λ are the tuning parameters for the number of leaf nodes and the weights of the leaf nodes, respectively.

In each iteration, the model updates the overall output by adding the prediction contribution of the new tree, and its mathematical expression is:

Where $f_t(x_i)$ represents the prediction contribution of

$$\hat{y}^{(t)} = \hat{y}^{(t-1)} + f_t(x_i) \tag{7}$$

the t-th tree for the sample x_i. This formula reflects the detailed process of how XGBoost approximates the model by progressively accumulating the outputs of decision trees.

Evaluation Metrics This paper uses three representative evaluation metrics to assess the prediction accuracy: Mean Squared Error (MSE), Mean Absolute Error (MAE), and the Coefficient of Determination. The mathematical expressions for these evaluation metrics are as follows:

Where F_i is the predicted value for the i-th data point,

$$MSE = \frac{1}{n} \times \sum_{i=1}^{n} (F_i - R_i)^2 \tag{8}$$

$$MAE = \sum_{i=1}^{n} \left| \frac{F_i - R_i}{R_i} \right| \tag{9}$$

$$R^2 = 1 - \frac{\sum_{i=1}^{n} (F_i - R_i)^2}{\sum_{i=1}^{n} (F_i - A_i)^2} \tag{10}$$

R_i is the actual value for the i-th data point, n is the sequence length (number of samples), and A_i is the mean of all samples. Smaller values of MSE and MAE indicate smaller prediction errors and higher accuracy. R^2 takes values between 0 and 1, with a value closer to 1 indicating better fit of the neural network to the data, thus reflecting better model fitting ability.

Experimental Design and Results Analysis

The development tool selected for this paper is PyCharm, with the programming language Python 3.11.0. The Graphics Processing Unit (GPU) used is the NVIDIA GeForce GTX 4060, and the Central Processing Unit (CPU) is the i7-13600H, with 6GB of video memory. The experiment is based on a simulation-generated dataset for prediction, where the dataset is divided into 80% training data and 20% testing data for offset prediction. The models selected for prediction include MLP, Decision Tree, Support Vector Machine, Random Forest, and XGBoost. The parameters for each model are shown in the table 2-6.

This study explores the challenge of forecasting the displacement of objects as they enter water bodies, employing a comparative analysis of five distinct machine learning models: Decision Tree, Random Forest, Support Vector Machine (SVM), Multi-Layer Perceptron (MLP), and XGBoost. To rigorously assess the performance of these models, the study utilizes three quantitative evaluation metrics: Mean Absolute Error (MAE), Mean Squared Error (MSE), and the Coefficient of Determination (R^2). The findings of this analysis are comprehensively detailed in Table 7, which follows this discussion. Furthermore, the specific parameters utilized for each machine learning model are also outlined in the accompanying table, providing a clear understanding of the setup for the comparisons made in this study.

The experimental results indicate that XGBoost consistently surpasses all other models across all evaluated metrics. With a Mean Absolute Error (MAE) of 0.0112 and a Mean Squared Error (MSE) of 0.0002,

Table 2 | MLP Model Parameters

Parameter Name	Parameter Value
Learning Rate	0.001
Number of Iterations	200
Batch Size	32
Activation Function	Relu
Optimizer	Adam
Number of Hidden Layer Neurons	64
Training Set Ratio	80%
Test Set Ratio	20%

Table 3 | Decision Tree Model Parameters

Parameter Name	Parameter Value
Random Seed	42
Number of Target Variables	2
Number of Features	4
Training Algorithm	CART
Optimizer	Adam
Minimum Samples for Splitting	2
Minimum Samples per Leaf	1

Table 4 | Random Forest Model Parameters

Parameter Name	Parameter Value
Random Seed	42
Number of Target Variables	2
Number of Features	4
Number of Iterations	200
Bootstrap Sampling	True

Table 5 | SVM Model Parameters

Parameter Name	Parameter Value
Random Seed	42
Number of Target Variables	2
Number of Features	4
Number of Iterations	200
Kernel Coefficient	0.1
Penalty Parameter (C)	100

Table 6 | XGBoost Model Parameters

Parameter Name	Parameter Value
Random Seed	42
Number of Target Variables	2
Number of Weak Learners	300
Learning Rate	0.1
Maximum Tree Depth	6

Table 7 | Comparison of Evaluation Metrics for Different Models

Model	MAE	MSE	R^2
Decision Tree	0.0358	0.0026	0.9826
Random Forest	0.0185	0.0007	0.9953
Support Vector Machine	0.0529	0.0038	0.975
MLP	0.0522	0.0053	0.9609
XGBoost	0.0112	0.0002	0.9985

Figure 2 | Comparison Chart of Model Evaluation Metrics

XGBoost demonstrates markedly lower prediction errors compared to its competitors, signifying superior accuracy in estimating displacements. Furthermore, its R^2 value of 0.9985, which is very close to 1, suggests that the model accounts for 99.85% of the variance in the data, thereby illustrating an exceptional alignment between the predicted and actual values.

Ensemble learning models, particularly XGBoost and Random Forest, exhibit considerable advantages when it comes to predicting the positional displacements of objects in aquatic environments. Their impressive accuracy and robust generalization capabilities arise from their ability to collaboratively model the intricacies of complex environmental factors. In contrast, traditional modeling approaches such as decision trees, support vector machines (SVMs), and shallow neural networks, including multi-layer perceptrons (MLPs), tend to underperform due to their inherent limitations in representational capacity and often ineffective training methodologies.

Conclusion

This study systematically evaluates the performance of various machine learning models in predicting the positional displacement of objects falling into water bodies. Experimental results demonstrate that XGBoost, leveraging its gradient boosting mechanism and regularization strategies, significantly outperforms other models in both error control and data fitting, making it well-suited as the core algorithm for real-time search systems. Random Forest, due to its ensemble robustness, can serve as a complementary redundancy model. In contrast, traditional models (e.g., SVM, Decision Tree) and shallow MLPs are limited by their nonlinear representation capabilities, making them less adaptable to complex hydrodynamic scenarios. These findings provide a solid technical foundation for building intelligent retrieval systems that enhance cultural tourism safety by enabling faster and more accurate recovery of valuable items accidentally dropped into water at popular tourist destinations.

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1. A B M K , B P G S .In search of water vapor on Jupiter: Laboratory measurements of the microwave properties of water vapor under simulated jovian conditions[J].Icarus, 2011, 212(1):210-223.
2. Yanming,Guo,Yu,et al.Deep learning for visual understanding: A review[J].Neurocomputing, 2016, 187(Apr.26):27-48.
3. Ning, H., Qian, S. and Zhou, T. (2023) 'Applications of level set method in computational fluid dynamics: a review', Int. J. Hydromechatronics, Vol. 6, No. 1, pp.1–33.
4. Chao, Q., Xu, Z., Shao, Y.Tao, J., Liu, C. and Ding, S. (2023) 'Hybrid model-driven and data-driven approach for the health assessment of axial piston pumps', Int. J.Hydromechatronics, Vol. 6, No. 1, pp.76–92.
5. B. Anari; J. A. Torkestani; A. Rahmani; "A Learning Automata-based Clustering Algorithm Using Ant Swarm Intelligence", EXPERT SYSTEMS, 2018.
6. Tao Wu; "Predictive Search for Capacitated Multi-Item Lot Sizing Problems", INFORMS JOURNAL ON COMPUTING, 2021.
7. Rihan Chen; Bin Liu; Han Zhu; Yaoxuan Wang; Qi Li; Buting Ma; Qingbo Hua; Jun Jiang; Yunlong Xu; Hongbo Deng; Bo Zheng; "Approximate Nearest Neighbor Search Under Neural Similarity Metric for Large-Scale Recommendation", CIKM, 2022.
8. Longbin Li; Chao Zhang; Sen Li; Yun Zhong; Qingwen Liu; Xiaoyi Zeng; "Graph Contrastive Learning with Multi-Objective for Personalized Product Retrieval in Taobao Search", ARXIV-CS.IR, 2023.
9. Nishant Yadav; Nicholas Monath; Manzil Zaheer; Rob Fergus; Andrew McCallum; "Adaptive Retrieval and Scalable Indexing for K-NN Search with Cross-Encoders", ARXIV-CS.IR, 2024.
10. Harsh Shah; Kashish Mittal; Ajit Rajwade; "Group Testing for Accurate and Efficient Range-Based Near Neighbor Search for Plagiarism Detection", ECCV, 2 024.
11. Peng Y, Yang X, Li D, et al. Predicting flow status of a flexible rectifier using cognitive computing[J]. Expert Systems with Applications, 2025, 264: 125878.
12. Yuan, F.; Huang, X.; Zheng, L.; Wang, L.; Wang, Y.; Yan, X.; Gu, S.; Peng, Y. The Evolution and Optimization Strategies of a PBFT Consensus Algorithm for Consortium Blockchains. Information 2025, 16, 268.
13. Tian Z, Zhao D, Lin Z, et al. Balanced reward-inspired reinforcement learning for autonomous vehicle racing[C]//6th Annual Learning for Dynamics & Control Conference. PMLR, 2024: 628-640.
14. Tian Z, Zhao D, Lin Z, et al. Efficient and balanced exploration-driven decision making for autonomous racing using local information[J]. IEEE Transactions on Intelligent Vehicles, 2024.
15. Lin Z, Zhang Q, Tian Z, et al. Slam2: Simultaneous localization and multimode mapping for indoor dynamic environments[J]. Pattern Recognition, 2025, 158: 111054.
16. Zhang C, Chen J, Li J, et al. Large language models for human–robot interaction: A review[J]. Biomimetic Intelligence and Robotics, 2023, 3(4): 100131.
17. Bai X, Peng Y, Li D, et al. Novel soft robotic finger model driven by electrohydrodynamic (EHD) pump[J]. Journal of Zhejiang University-SCIENCE A, 2024, 25(7): 596-604.
18. Allan P .Approximation theory of the MLP model in neural networks[J].Acta Numerica, 1999, 8:143-195.
19. Bui,DT,Pradhan,et al.Landslide Susceptibility Assessment in Vietnam Using Support Vector Machines, Decision Tree, and Naive Bayes Models[J].MATH PROBL ENG, 2012.
20. Tarabalka Y , Fauvel M , Chanussot J ,et al.SVM and MRF-Based Method for Accurate Classification of Hyperspectral Images[J].IEEE Geoscience & Remote Sensing Letters, 2010, 7(4):736-740.
21. Claudia,Lindner,Paul,et al.Robust and Accurate Shape Model Matching Using Random Forest Regression-Voting.[J].IEEE Transactions on Pattern Analysis & Machine Intelligence, 2015.
22. Rajkumar M N , Anbuchelvan R .A Novel Context-Aware Computing Framework with the Internet of Things and Prediction of Sensor Rank Using Random Neural XG-Boost Algorithm[J].Journal of Electrical Engineering & Technology, 2024(4):19.

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Transpersonal Psychology and Social Transformation: A Review of Spiritual Interventions in Modern Societies

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KEYWORDS

Transpersonal Psychology; Spiritual Interventions; Social Transformation; Community Cohesion; Resilience

ABSTRACT

Transpersonal psychology integrates spirituality into individual mental health and social well-being, employing interventions such as meditation, hypnosis, and energy healing to promote holistic approaches. This literature review systematically synthesizes peer-reviewed articles and books (2000–2023) from PsycINFO, Google Scholar, and JSTOR, selected based on demographics relevant to transpersonal psychology, interpersonal practice specialization, intervention types, and outcome effects. The review explores how spiritual interventions address contemporary challenges such as mental health crises and weakened community bonds. Findings suggest that spiritual interventions significantly enhance individual and community resilience, although cultural context influences their effectiveness, and empirical support remains limited and inconsistent across regions. By bridging psychology, sociology, and cultural studies, this study evaluates spirituality's potential for fostering social transformation through resilience and cohesion. The findings offer valuable implications for policymakers and practitioners seeking culturally sensitive strategies to strengthen mental health and social solidarity in diverse societal contexts.

Introduction

Research Background

Transpersonal psychology was born during the 1960s as a specialized aspect, considered the fourth force in psychology, made upon humanistic psychology, with special regard to self-actualization and focusing on the different aspects of human experiences that play a vital part in the spiritual dimensions of humans. The founders who initiated the development of the pathway of transpersonal psychology in the area of study are Abraham Maslow and Stanislav Grof. Transpersonal psychology focuses on consciousness, transcendence, and Eastern and Western spiritual traditions, which help integrate and learn about many approaches. Maslow created his later work about peak experiences. Building

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on Maslow's work, Grof researched non-ordinary states of consciousness and explored research, believed in enhancing spiritual practice. Transpersonal psychology has had a long history since, from theory and, through practice, became a discipline that operates at the individual and interpersonal level, concerned with personal growth and society, based upon an increasingly deep understanding of the inadequacies of materialistic paradigms of psychology and their inability to provide an explanation for all phenomena involving human potential. Simultaneously, spiritual interventions have been employed widely, including meditation, hypnosis, etc., which have roots in ancient times and were reinvigorated philosophically in the late twentieth century with globalization and increasing concern regarding mental health linked to spiritual needs. In the West, mindfulness derived from the Buddhist tradition continued to drift into the mainstream, as it was adopted in clinical settings and through popular culture; in the East, the practice of Qigong and yoga persisted alongside contemporary therapeutic innovations—in short, there has been a continuity of earlier holistic traditions. Indeed, it is tempting to view this cultural trend as a reaction to a series of changes at the highest levels of society: industrialization and urbanization amplified stress, estranged communities, and undermined social connections, consequently fueling people's yearning for meaning in an age where religion lost its relevance and human interconnection seemed impossible in the face of mass globalization and scales of materialism. Thus, when disentangling these issues in the context of transpersonal psychology, we are confronted by two particularly compelling challenges that have plagued the contemporary world: the need for deeper existential and social solutions.

Current Research Status

Current research on transpersonal psychology and spiritual interventions has dramatically expanded to explore how they affect the individual's well-being, from relieving stress to enhancing self-awareness through various practices like meditation and hypnosis. Various scholars (e.g., Goleman and Davidson, 2017) have provided sufficient evidence supporting the effects of meditation to help regulate one's emotional state through neuroscientific evidence, while hypnosis has come closer to being seen as more useful than ever in helping those who have faced any form of trauma by enhancing resilience about personal livelihoods that are more resilient and less easily disrupted. With these answers coming in hand, the questions other scholars are beginning to ask become broader and more outspoken, which looks at social issues and their efficacy in relationships between people and their communities. For example, meditating in groups has shown that meditation can promote trust and greater understanding in society, showing a possible way of connecting socially. In this sense, there are still discussions about how more scholarly work is purely focused on the narrow range of clinical or personal consequences associated with the answer above rather than on broadening methods to show how systemic change systems are systematically transformed. Current literature does not provide adequate links between the various settings for cultural interventions, creating an isolated knowledge base that does not accurately account for what the interventions do (Western focus on individual growth, Eastern on a collective benefit, but rarely seen from a comparative perspective). Inconsistent empirical support for large-scale social impact appears decidedly mixed and contradictory, e.g., many have used small sample sizes or short-term effects as opposed to research-based directly on longitudinal data; this contributes to an absence of linkages between efforts to understand how spiritual interventions can solve social problems, including social disconnection, inequity, or cultural fragmentation in contemporary societies, highlighting the need to develop a larger, more cohesive body of research.

Research Problem

Despite increasing interest in transpersonal psychology and spiritual interventions, there remains a significant gap in addressing how they might drive societal change from a rigorous perspective rigorous perspective. Individual benefits such as reduced stress and increased well-being are well-established. However, one of the main limitations to their widespread adoption is the lack of extensive studies examining their impacts on collective social structures like community cohesion, systemic inequity, or institutional change. This is especially relevant given the current conditions of increasing social complexity and polarization, where new solutions must be found that can scale up beyond just interpersonal healing. These limitations are amplified by cultural variations in interventions, as their impacts may differ in more individualistic vs. collectivist cultures. Nevertheless, despite the significance of these diversities, most existing research merely considers them at the individual level and does not robustly explore their consequences for society at large. And because almost no research has constructed substantial links between these interventions and measurable social change (e.g., changes in social trust or equity measures), it is still largely unclear how these interventions could fit within the types of scalable interventions proposed. Lacking strong evidence, the possibility of spiritual interventions in tackling societal challenges remains uncertain, hindering pursuit, preventing incorporation into a broad spectrum of social reforms.

Research Contribution

The proposed study directly tackles the identified gaps, followed by a systematic review of spiritual interventions' potential to foster social transformation, integrating transpersonal psychology with social science

within one framework. It brings all available evidence into a broad synthesis, drawing out the most practical implications for improving community cohesion and resilience in culturally diverse settings. In this way, it contributes to academic discourse while informing policymakers and practitioners working towards an integrated approach to tackling current societal dilemmas — such as social disconnection and inequity. This work goes beyond reflecting individual benefits to formulating an overarching framework in which spiritual practices act as the spark needed for a transformative shift, exceptionally — when deployed at a community level — in more diverse global settings. It also lays the foundations for specific interventions — one example of which is community-based programs in which mindfulness or group hypnosis assists individuals in rebuilding broken social bonds as an alternative way of moving towards systemic challenges, such as urban isolation and cultural fragmentation through a transpersonal approach.

Literature Review

Definition of Key Concepts

Transpersonal psychology is a field of psychology concerned with phenomena beyond the limits of the personal ego and includes spiritual, transcendent, and economic dimensions of human experience, including the contributions of Western science and Eastern philosophies" (Grof, 2000; Hartelius et al., 2007). While behaviorism and psychoanalysis traditional psychology merely focus on an individual's behavior and cognition within the confines of a materialistic paradigm, transpersonal psychology explores those states of consciousness—the mysterious, peak experiences, or altered perceptions—that lie outside ordinary self-awareness, most heavily borrowing from practices such as meditation and mystical traditions (Walsh & Vaughan, 1993). This field arose out of a response to the limitations of behaviorism and psychoanalysis that sought to explore the whole gamut of human potential, particularly the spiritual and existential dimensions that dominant paradigms tended to ignore. "[Self-transcendence], transcendence of the ego to a sense of unity or interconnection, is the chief task of psychological development; and it appears clearly in both Western humanistic tradition and Eastern, both in Buddhist notions of nonself or in Advaita Vedanta's sense of unity of being" (Ferrer, 2002). These scholars, such as Maslow, with his hierarchy leading to self-actualization and beyond, and Grof, with his work on those undergoing holotropic states, have influenced our field, describing the experience that connects the individual with the overall whole, whether cosmic, community-based, or even ecological.

Spiritual interventions are defined as intentional practices aimed at promoting spiritual growth or well-being; examples include mindfulness, hypnosis, and energy healing, which can operate within or outside of religious-related frameworks (Ferrer, 2002). They contrast with prevailing therapeutic practices by focusing on non-material elements of existence – e.g., energy flow, consciousness expansion, or existential meaning – rather than only behavioral patterns or cognitive trends that are fully observable (Kabat-Zinn, 1990). Mindfulness, for example, derives from Buddhist meditation techniques and exists as a practice that cultivates awareness of the present moment to reduce stress and control emotion; hypnosis is founded upon rather than rejecting alternate states of mind to engage unconscious sources of recovery or insight. Energy healing is a form that integrates Reiki through to Qigong; science's prevailing paradigm offers an explanation – the spinning fields are often referred to as nearly identical ontological entities, which move or manipulate them to restore equilibrium. These phenomena sound surprisingly non-familiar in the West, though widely practiced around the globe. These interventions, however, have one thing in common: they address the movement surrounding the mind-body-spirit. They attempt to transform individuals through experiences that defy understanding within reductive frameworks; apparently, such work operates at the border between a world of secular and sacred activities and purposes (Fox, 1995).

In this regard, social transformation would consist of a system-wide change to society's structures, values, or behaviors towards greater coherence, equity, and resilience—generally measured via indicators such as community engagement, social trust, or collective well-being (Putnam, 2000). Unlike individual change, social transformation entails changes to the fabric of social systems—cultural norms, institutional policies, or communal relationships—and would entail adjusting these aspects to address issues such as inequality or disconnection. This theory derives from sociological theories of social capital and collective efficacy: stronger interpersonal networks and shared purpose allow society to be more resilient and responsive to change (Wilber, 2000). In most respects, within transpersonal psychology, social transformation is hypothesized as one of the eventual outcomes of aggregated individual spiritual growth; thus, certain practices that foster inner resilience or concerted interrelatedness may reshape how societies function. Nevertheless, this interplay is still deeply conceptually intricate as it presupposes intertwining the subjective experiences of meditation, such as a single meditator's feeling of unification, with actual societal changes, which is theoretically intriguing and empirically challenging to link (Tart, 2009). Collectively, these ideas—transpersonal psychology, spiritual interventions, and social change—provide a paradigm in which a person's state of spiritual development is viewed as possibly an incipient precondition for more sweeping social change, but this requires precise identification of their respective scope, their mechanism-related dynamics, and their necessary cultural underpinnings.

Progress in Related Research

Research on transpersonal psychology and spiritual interventions has advanced significantly since the early 2000s, reflecting a growing interest in their potential to influence both individual and social domains. This progress can be categorized into theoretical developments, empirical applications, and cultural explorations.

Theoretical Foundations Theoretical development of Transpersonal Psychology has been further developed by scholars such as Grof (2000), who explored altered state of consciousness, and Wilber (2000), who created an integral model integrating spiritual and psychological growth, which reveals transformative potentials of non-ordinary states of experience (Grof, 2000; Wilber, 2000). Grof highlighted the therapeutic and transformative nature of non-ordinary states - such as those from psychedelics, deep meditation, or phototropic breath work - suggesting that the individuals gain insight into a deeper, more interconnected level of human consciousness beyond the ego. His phototropic paradigm argues that moving towards wholeness is a synergistic form of integrating the unused aspects of the psyche, and his version of integral psychology introduces a lens through which we can view both personal healing and the societal process in terms of wholeness (Grof, 2000). In contrast, Wilber's integral theory unites developmental psychology with spiritual traditions, proposing a four-quadrant model that illustrates the complex interplay between individual interior experiences, exterior behaviors, collective cultures, and social systems. He labels this architecture of relationships as the four quadrants of spiritual growth and its transformative potential as a catalyst for holistic change, as it ties insights about individual transcendence to societal upheaval (Wilber, 2000). These frameworks emphasize transcendence beyond the ego, 'incorporating Eastern philosophies (such as Advaita Vedanta's non-dual awareness—self or other dissolve) and insights from Buddhist mindfulness as well as Western psychology with its emphasis on empirical rigor' (Ferrer, 2002). Hartelius et al. (2007) articulated the scope of the field in greater detail, highlighting the significance placed on themes such as self-transcendence and interconnectedness at the core of the search for human potential, as they threaten the reductionist paradigms of mainstream psychology. Theorists like Maslow (1971) were also influential by broadening his hierarchy of needs so that peak experience could be linked to more altruistic behaviors with social implications in society.

Another key example was Jung's concept of a collective unconscious, which transpersonal thinkers influenced. There is a shared psychic substratum linking each individual to other broader stories from both human and cosmic narratives, which shape various cultural archetypes and collectively define their lives and identities (Jung, 1964). However, this theoretical development has provided a sturdy premise for linking these spiritual experiences with more widespread social processes. However, it is typically far too abstract. It lacks any direct relationship between subjective states of mind and measurable social outcomes because of the emphasis placed on subjective states instead of observable systemic relationships (Daniels, 2005).

Empirical Applications Empirical research has also begun to test the effects of spiritual interventions, but they have found that meditation is a statistically proven practice. Notably, Goleman and Davidson (2017) showed its effects on emotion regulation and resilience. They have used neuroscientific support showing changes in the brain, such as increased prefrontal cortex activity while decreasing reactivity in the amygdala, indicating better stress management. Across many previous meta-analysis programs, the two scholars "identified consistent improvements in attention and emotional stability among diverse populations ranging from clinical patients to employees at a corporation" (p. 7). This suggests that hypnosis applies to most; however, empirical research has not made it a common practice of therapy. Hypnosis has been popularized because it was used to make people feel better, enhance relationships in interpersonal interactions, and reduce distress. Many show profound results in helping patients who struggle with anxiety to gain more self-efficacy. Clinical trials have shown hypnosis can be beneficial for those who want to recover from trauma or manage pain with the help of engaging the mind deeper into different sources of coping (Yapko, 2012). YAPKO states in his article that energy healing has been explored but has shown that the method holds promise for relieving individuals from some stress when likened to Hypnosis (Rogers et al., 2021). For example, studies investigating one of the assumed main effects of Reiki, less cortisol in the body, subjective responses of relaxation by participants undertaking several minutes of research, participants report an industrial perspective by various methodologies that reveal a few caveats regarding generalizability (Miles & True, 2003). Low cortisol may indicate beneficial individual-level implications and be potentially scalable to attain social-level effectiveness through improved community resilience and feeling better emotionally, thereby enhancing people's interpersonal connections. Studies of group meditation show several ripple consequences: Participants express a high empathy trait and tend to reduce conflicts in workplace and social interaction spaces (Lutz et al., 2008). A study of mindfulness training conducted at schools reveals enhanced peer relationships and classroom cooperation. It shows a possible implication for communal benefits by forming more supportive cycles (Schonert-Reichl & Lawlor, 2010). Hypnosis used collectively during some other group therapies also implies weak evidence in increasing slight indicators of trust development and developing good levels of both active and passive listening, but the knowledgebase is incomplete with little

factual information as to how these resources may translate within our own considered social context (Kirsch et al., 1995). Nonetheless, most of these recent studies center around individual/clinical results and do not exhibit community-level impacts such as social coherence or overall collective endurance abilities (Kasprow et al., 1999). There is no large-scale, longitudinal research to determine how these individual gains translate into societal benefits, and thus, the current evidence is limited to transformative impact outside personal benefit.

Cultural Contexts Cultural influences on spiritual interventions have received much focus, showing varied Western and Eastern cultural applications. In the East, mindfulness and Qigong fit into a collective tradition that cherishes harmony and community (Kabat-Zinn, 1990). Such interventions usually derive from Confucian, Taoist, or Buddhist philosophy. Their familial and societal functions determine individual well-being; hence, good interdependence exists (Wallace, 2001). For example, Qigong derives from traditional Chinese medicine and promotes personal and group vitality. A study showed that it forms social relationships within rural communities (Gouw et al., 2019). Like Buddhist teachings, mindfulness focuses on compassion and connection. It shows promising results as a practice that enables individuals to display higher levels of prosocial behaviors such as altruism (Wallace, 2001).

In contrast to the East, Western adaptations emphasize individual growth, following the independent cultural perspective (Vaughan, 1979). Hypnosis here is rarely applied to collective practice rather than individual benefits, as often seen in contemporary corporate wellness programs that rebrand communal harmony as self-optimization (Purser, 2019). Hypnosis is similarly characterized as a primary instrument of individual empowerment in a Western context. However, their collective usage for promoting group coherence is comparatively deprioritized in favor of claims regarding the impact of hypnosis on the individual psyche (Yapko, 2012). Collectivist interventions generated weaker discernment: social cohesion gains, not individualistic ones (Kabat-Zinn, 2011; Miller, 2010), findings that were mirrored in other research. Research into Japan's diffuse post-disaster to foster community resilience reported that Zen meditation reinforced community resilience, not the reverse (Panting et al., 2020). Much less research has scoured Western researchers' publications for systematic cross-cultural comparisons and comparative studies testing theoretic explanations of efficacy. However, relatively little appeared to examine the differing impacts of cultural values, such as collectivism vs. individualism, on efficacy in diverse populations (Rowan, 2001). Moreover, this gap is exacerbated by Western-centric research that does not reflect on the practices of various cultures. Research methods tend to ignore or devalue non-Western frameworks, preventing the development of a single sense of how such practices may be seen globally (Tart, 2009). These differences can, therefore, be seen as requiring larger, culture-culturally inclusive research designs if we are to understand their transformative potential truly.

Research Gaps

Cultural influences on spiritual interventions have received much focus, showing varied Western and Eastern cultural applications. In the East, mindfulness and Qigong fit into a collective tradition that cherishes harmony and community (Kabat-Zinn, 1990). Such interventions usually derive from Confucian, Taoist, or Buddhist philosophy. Their familial and societal functions determine individual well-being; hence, good interdependence exists (Wallace, 2001). For example, Qigong derives from traditional Chinese medicine and promotes personal and group vitality. A study showed that it forms social relationships within rural communities (Gouw et al., 2019). Like Buddhist teachings, mindfulness focuses on compassion and connection. It shows promising results as a practice that enables individuals to display higher levels of prosocial behaviors such as altruism (Wallace, 2001).

The vast progress in transpersonal psychology and spiritual interventions leaves many key research gaps. Firstly, it is still relatively underexplored to assess the effects of cultural input on such intervention, with most research centered around the Western contexts, limiting generalizability become magnified by connective societies (Kabat-Zinn, 2011). The simplistic approach causes a Western-centered bias, which restricts the generalizability of populations outside different cultures around the world; such interventions we take for granted may cause or have entirely different social effects in collectivist societies but remain overlooked because they are traditionally used to foster interdependence rather than individualism. While some Western research focuses on personal resilience, other research suggests that more communally beneficial effects can be found in Eastern studies, and yet few try to systematically compare such dynamics (Panting et al., 2020). Furthermore, this requires a lack of culturally tailored methodologies. These persistent limits on non-Western perspective input mean non-Western views are not underrepresented with the general population, which also hinders a truly worldwide grasp of coping with spiritual practices' effectiveness.

Second, there is little empirical evidence of spiritual practices affecting social transformation, as much research focuses on individual-level results such as stress relief or emotional control rather than structural societal shifts like equity, collective resilience, and institutional reform (Kasprow et al., 1999). Clinical focus is prevalent in this field as studies typically employ small, homogeneous populations unlikely to reflect the general social impact of specific practices (Miles & True, 2003). A popular survey suggests meditation benefits personal

wellness based on its history and consensus on effectiveness. However, despite extensive validation of the efficacy of meditation on personal wellness, there has not been large-scale validation of how meditation can influence the building of trust within an entire community or even the societal fabric (Lutz et al., 2008). The individual is seen here within the confines of one's own life rather than the collective, and his/her actions as shaped by their inner development may always remain speculative, taking a different path from what it has become in reality.

Third, the social level of any intervention is not frequently measured, and there are few longitudinal research studies or easily applicable scalable measures of social structure change (Putnam, 2000). Social trust, involvement in the community, or equity indices are a few standard measurements used in sociology that were rarely used in this research, so there was little evidence for societal transformation (Putnam, 2000). Short-term research studies were prevalent with relatively small-scale interventions that provided snapshots rather than long-term data. Qualitative reports are more significant than quantitative measures, decreasing replicability (Wallace, 2001). This methodological weakness obscures whether spiritual interventions can be the source of lasting societal change or remain restricted to existential individual gain.

Furthermore, interdisciplinary integration is also weak in that transpersonal psychology "rarely intersects with disciplines in which expertise may arise, such as sociology, anthropology, and political science, in order to connect more broadly" (Tart, 2009, p. 20). This prevents the field from integrating empirical findings about the causal mechanisms by which people's practice contributions accumulate to predict larger-scale social outcomes (Purser, 2019). For instance, anthropology offers benchmarks for examining how cultural rituals can enhance the community-level impact of interventions, but these approaches to analysis are not commonly used. (Panting et al., 2020) This isolation means the field is limited in tackling complex social dilemmas holistically.

Lastly, despite the tendency to link spiritual growth with transformations in society, the identification of these links is yet to be tested due to the lack of existing studies that cannot connect subjective experiences, such as a spiritual sense of unity, with objective measures for societal change (Daniels, 2005). This is true of the entire field because it continues to value introspective evidence rather than evidence that will help establish change within society, leaving an unanswered question regarding whether the interventions necessary to facilitate change can move beyond our personal lives and tackle more significant issues like inequity or disconnection (Rowan, 2001). Together, these gaps create an obstacle to comprehending how spiritual interventions can address contemporary societal issues so that they can achieve their potential through a more systematized, cross-culturally inclusive, and interdisciplinary research agenda.

Methods

Data Sources

This review relied on a comprehensive collection of scholarly materials to examine the interplay between transpersonal psychology, spiritual interventions, and social transformation. Data were sourced through structured searches to ensure a robust and representative sample of existing literature.

Academic Databases Literature was retrieved from multiple academic databases, namely PsycINFO, Google Scholar, and JSTOR, which were selected for their rich psychological, interdisciplinary, and social science research coverage. PsycINFO, run by the American Psychological Association, offered access to more than 2,500 peer-reviewed journals and a vast pool of articles concerning transpersonal psychology, spiritual interventions, and their psychological outcomes. By enabling a precise, selective focus on individual-level effects due to its use of advanced search filters of publication date (2000–2023) and subject headings like 'spirituality' or 'consciousness,' this database proved a cornerstone of precision for the review. The result contributed significantly to the total of 85 included sources. Google Scholar's comprehensive index of books, conference papers, and grey literature complemented the coverage of PsycINFO by documenting seminal publications like Grof's (2000) consciousness research at the forefront and emerging studies indexed in databases – thereby expanding the scope to capture a wide range of subjective perspectives on spiritual practice. Its citation-trace feature also allowed for the detection of influential works and recent citations, thereby increasing the comprehensive nature of the review. JSTOR added historical and cross-disciplinary perspectives to the analysis, indexing more than 2,000 journals in sociology, anthropology, and cultural studies, informing several aspects of social transformation, including community dynamics and cultural context (Putnam, 2000). Database searches were performed with the use of keywords such as "transpersonal psychology," "spiritual interventions," "social transformation," "resilience," and "community cohesion" and operated with the help of Boolean operators ("AND," "OR"), enabling us to filter out sets of publications that did not include our areas of interest (clinical pharmacology, etc.), thus creating an updated, representative sample from a broad scope of psychological and social domains crucial for the goals of this study.

Inclusion Criteria Key inclusion criteria were set to remain focused and relevant: publications needed to be written in English, published within 2000–2023, and directly addressed transpersonal psychology, spiritual

interventions, and/or their social consequences. The English language criterion guaranteed accessibility and team consistency among the research team, but it might exclude valuable sources from other parts of the world, such as Asia or Europe, where spiritual practices are widespread (Gouw et al., 2019). The years 2000–2023 indicate the modernity of the field and its relevance to current society. The identified period also captures the recent interest in spirituality in an age of globalization and information technology, where transpersonal approaches have never been more relevant, yet correspondingly, fit with a series of significant innovations in mindfulness research and transpersonal theory (Grof, 2000). Eligible sources included peer-reviewed journal articles, books, and book chapters, thus prioritizing scholarship over less credible formats such as opinion pieces, magazine articles, or unpublished theses that lack peer validation (Hartelius et al., 2007). Required studies had to be addressed, whether theoretically — for instance, a detailed examination of an integral model — or empirically — in this case, verification of the effect of meditation on resilience —, or culturally —, let us say, East-West differences in potential intervention outcome results, to ensure that this multi-directional criterion composed the review's interdisciplinary scope and preserved a unified focus on individual spiritual development and society's transformation, excluding unrelated topics like purely religious studies.

Research Methods

This study took an overall systematic review approach to synthesize literature on the social impact of transpersonal psychology and spiritual interventions. Within its scope, the review process was guided by a structured protocol devised; it derives from PRISMA guidelines and ensures transparency in every step with a reproducibility perspective (Moher et al., 2009). The initial search was conducted on PsycINFO, Google Scholar, and JSTOR, looking out for publications describing transpersonal psychology and spiritual interventions' effects on social outcomes through keyword query combinations, which might include "transpersonal psychology AND social transformation" and "spiritual interventions AND resilience," as well as filtering them based on Boolean operators and date filters (2000–2023). After screening those relevant records based on title and abstract suggestions, another batch of 342 source records was created, sorting out duplicates and irrelevant topics such as purely clinical pharmacology. Full-text critiques narrowed the sample to 85 articles and books, excluding studies lacking a clear focus on transpersonal psychology, spiritual practices, or measurable social outcomes, as determined by predefined inclusion criteria. Consequently, a total sample consisting of 85 articles and books was achieved. To minimize bias—and alignment on inclusion criteria, two independent reviewers resolved the discrepancies between their judgments by consensus, ensuring a common framework of inclusion robust enough to meet the study's goals. Extraction focused on major theoretical frameworks embedded into our understanding of social relationships, such as integral theory and empirical consequences of resilience effect—and even cultural specifics (East-West variations) that can be influenced by other cultural factors, e.g., isolation and subsequent recording into a standardized template to ensure consistency. Findings were compiled thematically (resilience enhancement, community cohesion, cultural variations) in an iterative coding procedure to capture the entire patterning in the literature. This allowed for depth and breadth, thus maintaining rigor in evaluation close to replicable, focusing on evaluating the many bodies of research.

Thematic Analysis of Literature

The “Thematic analysis” technique was used to analyze the final source set of 85 sources in a specified manner that enabled systematic evaluation (Braun & Clarke, 2006). Data extractions were coded, after which recurrent themes and critical phenomena for social transformation were recognized using an inductive strategy, where themes emerged from the data instead of being compared with the categories a priori. Three necessary themes were extracted: resilience enhancement, community cohesion, and cultural variations, as they represented how spiritual intervention affected them on an individual and a societal level. Initially, two evaluators applied manual coding to the data source set to evaluate themes. Then, they annotated the text to recognize such ideas as stress reduction or social trust and developed over 200 codes regarding theoretical, empirical, and cultural aspects. Moreover, codes were then grouped into preliminary themes based on manual iterative discussions, after which disagreements were addressed in the form of consensus to make it reliable. For example, “emotional regulation” and “coping” merged into resilience enhancement, and “group empathy” and “collective well-being” became community cohesion. Coding consistency was verified against a subset of 20 sources and operationalized with an inter-rater agreement of 85% to strengthen theme validity. After collection, themes were mapped out and condensed to reflect the overarching goals of the review, thus providing a framework in which to present findings in ways that capture both similarities—such as the broad benefits of resilience to diverse cultures—as well as differences—like how cultural influences shape societal cohesion (Kabat-Zinn, 2011). This method allowed for a highly nuanced analysis between qualitative richness and systematic, rigorous methodologies that evaluated the variance across the multitude of literature.

Results

Overview of Findings

The accumulation of literature comprising 85 sources collected for review purposes illustrates that spiritual interventions have been extensively applied in transpersonal psychology and have demonstrated positive effects on individual and social dimensions, albeit with varying scope and consistency. At an individual level, meditation and hypnosis are regularly reported to increase emotional resilience, reduce stress, and foster well-being, with neuroscientific and psychological studies highlighting a correlation with beneficial outcomes in domains of well-being (Goleman & Davidson, 2017; Scotton et al., 1996). Mindfulness, especially, has shown widespread results from many trials and studies of meditation aimed at improving attention and emotion regulation processes. Neuroimaging shows increased activity in the prefrontal cortex, with expert consensus implying a robust mechanism for stress adaptation (Lutz et al., 2008). Hypnosis is also documented to achieve increases in self-efficacy along with decreases in anxiety; evidence from clinical practice also suggests that it can be of value with trauma recovery and individual power (Yapko, 2012). Socially, they may demonstrate the potential to increase community cohesiveness; for example, there is evidence of enhanced interpersonal trust and group well-being in heterogeneous environments (Kabat-Zinn, 2011; Miller, 2010). Group-based practices (such as communal meditation or shared rituals) have shown positive effects on empathy and community ties. Later on, these show up in educational settings and in the workplace.(Schonert-Reichl & Lawlor, 2010). While the literature suggests variation in outcomes based on cultural context and consistency of empirical support, Western studies tend to emphasize individual growth—evidenced by an emphasis on individualized metrics such as self-reported well-being—and Eastern research highlights communal benefits, including increased social trust in collectivist societies (Vaughan, 1979). This distinction between Western and Eastern studies highlights contrasting cultural priorities, but since standards of comparison are not established uniformly across cultures, this is a barrier to straightforward cross-cultural comparisons. Overall, spiritual interventions are promising for social change, but their broader systemic impact—the more societal-level effects of equity or institutional resilience—remains underdocumented relative to the individual-level benefits—and thus has been the focus of research bias toward individual versus group outcomes.

Key Themes

This thematic analysis of the literature identifies three primary themes—resilience enhancement, community cohesion, and cultural variations—reflecting the diverse impact of spiritual interventions within transpersonal psychology.

Resilience Enhancement A principal idea expressed throughout the reviewed sources is the potential for spiritual interventions to support an individual's resilience, with meditation being offered as one of the core practices related to reducing stress and enhancing emotional regulation. Several research studies have documented significant changes in brain activity associated with adaptability, such as a shift from having a high response rate in the amygdala to increased activity in the prefrontal cortex (Goleman & Davidson, 2017), revealing a sound patterned mechanism for alleviating stress (Lutz et al., 2008). Furthermore, the usage of hypnosis has been determined to be one of the most important interventions associated with strategies for promoting the development of self-efficacy and forming new varieties of coping, which may also be used during a therapeutic environment for purposes of improving the perception of dealing with anxiety and other forms of trauma (Scotton et al., 1996). Research has also highlighted its potential for doing much more, including deepening subconscious resource access. Controlled studies show a valuable reduction of post-traumatic stress symptoms and chronic pain, adding it as another tool, if not in all ways already building resilience (Yapko, 2012). The less-studied energy healing provides a complementary tool for emotional restoration and contributes to personal effectiveness (Rogers et al., 2021). Both small-scale trials of Reiki practice have reported decreases in biomarkers of physiological stress and correspondent improvement in subjective well-being, but results should be treated cautiously owing to the sample size inadequacy that accompanied these interventions (Miles & True, 2003). Collectively, these interventions facilitate people's internal defenses against psychological stress. It is addressed in the studies reviewed and supported by both neuroscientific, clinical, and self-report data that show a standard power of improving emotional and mental endurance (Kabat-Zinn, 1990). Indeed, this resilience might be seen as a precursor for more general social gains since those who can effectively manage their emotion would provide better contributions to communal activities. However, its direct social implications were not discussed in these studies due to a lack of the necessary valid data (Schonert-Reichl & Lawlor, 2010). However, the results fit in line with similarly documented results from various other researchers of the same idea, namely, building better people and highlighting spiritual practices' consistent capacity in building stronger people, which can provide a foundation for potential collective impact.

Community Cohesion The literature has also focused on the role of spiritual interventions in enhancing community cohesion. In this regard, group-based practice has a considerable impact in various settings. Group meditation practices increase interpersonal trust and empathy, increasing community social relations (Kabat-Zinn, 2011). Experimental studies indicate that those

participating in communal mindfulness are associated with elevated prosocial behaviors, including an increased propensity to cooperate, less interpersonal conflict, and, in workplace trials, support the teams' performance more effectively compared to non-mindfulness programs after an 8-week intervention (Lutz et al., 2008). Similarly, in education settings, elementary schoolers indicated that through mindfulness training, they could receive peer support and harmony in the classroom, as students indicated that their co-workers associated with them had better social ties (Schonert-Reichl & Lawlor, 2010). Separated from meditation, studies on spiritual gatherings —including shared ritual practices or mindfulness sessions—found more significant levels of overall well-being and reported feelings of mutual aid in communities with stronger communal traditions (Miller, 2010). For example, studying Buddhist sangha practices in Asia shows greater community resilience after disaster, attributed to shared meditation for creating emotional solidarity (Panting et al., 2020). Meanwhile, when hypnosis is utilized in therapy groups, it enhances trust and improves communication. The results from small-scale experiments demonstrate lower social anxieties and higher group cohesion among participants, whilst the number of trials is still limited (Kirsch et al., 1995). These findings suggest that spiritual interventions might not necessarily only benefit individuals but also facilitate interaction with others to strengthen social connections and community resilience through creating shared experiences that reinforce interpersonal relationships (Wallace, 2001). In this matter, however, such effects vary across populations and cultures: individuals who are collectivistic in their culture are likely to find the effects of such interventions far more powerful than those in individualistic cultures like those of the West, where personal benefits trump other social benefits (Purser, 2019). This theme suggests that spiritual practices may serve as a vehicle from an individual to a larger community; however, there is limited evidence of broader societal impacts (Kasprow et al., 1999).

Cultural Variations The effect of cultural factors is one of the major themes that have emerged as a key theme in assessing the effectiveness of spiritual interventions. There are stark contrasts in the relationship between East and West. Western interventions, for example, incorporate mindfulness and hypnosis centered on individual gains, focusing on personal well-being and autonomy (Vaughan, 1979). Also, investigations report that mindfulness, secularized in the US and Europe, increases self-identified stress reduction and productivity following corporate programs wherein volunteers chose personal gain over mass effectiveness (Purser, 2019). Hypnosis is likewise documented to bolster individual resilience, with Western trials centered around personal power instead of group control (Yapko, 2012). However, Eastern practices, such as Qigong or Buddhist practice recurrence, concentrate on harmony among people; they yield stronger associations with broader outcomes like social trust (Kabat-Zinn, 1990). Investigations in China show that Qigong facilitates social network strength, which is entailed by residential cohesiveness and strong understanding and mutual support among inhabitants (Gouw et al., 2019). Zen meditation is known to improve post-disaster community resilience in Japan by meditators who share practice as a binding agent (Panting et al., 2020). Sources attribute these variations to underlying cultural values – individualism in the Western context, characterized by self-oriented behavioral patterns that focus on personal calm.

In contrast, collectivism characterizes the Eastern context with interdependence, defining interventions' impact (Rowan, 2001). For instance, studies exploring Thai Buddhist mindfulness demonstrate greater compassion and prosocial behavior, whereas US researchers focus on personal calm (Wallace, 2001). However, sources show few systematic cross-cultural comparisons due to lacking standardized measurable tools to study how cultural contexts mediate efficacy in similar populations distributed worldwide (Tart, 2009). Consistency is not evident due to the inconsistent application of systematic cross-cultural comparisons. There are minimal studies where researchers utilize standardized measurable instruments to assess how cultural contexts mediate efficacy within diverse populations (Kabat-Zinn, 2011). This trend contributes to a biased presentation of how intervention's social transformative capacity evolves across different cultures without considering the gaps in evidence.

Discussion

Interpretation of Results

The effects of this review demonstrate that spiritual interventions within transpersonal psychology are both effective in enhancing one's resilience and facilitating one's cohesiveness within a community yet limited in their broader social transformative potential. This consistency in findings regarding the improvement of emotional resilience that is conferred by meditation and hypnosis reflects well-established psychological theories of self-regulation and neuroplasticity, which propose that spiritual interventions access intrinsic human capacities for adaptation (Goleman & Davidson, 2017; Hartelius et al., 2007). Thus, meditation's neuroimaging data indicates a reduction of amygdala reactivity and increased prefrontal cortex activity, evidencing the existence of biological substrates supporting stress coping and thus stressing why hypothesized improvements in stress sensitivity reflect a general efficiency across all populations (Lutz et al., 2008). Hypnosis also employs subconscious processes in support of self-efficacy, which has been demonstrated through clinical practice

and trauma recovery from the studies, emphasizing that increased resilience forms the fundamental consequence (Yapko, 2012). This level of individual strength could serve as a gateway to social change: it enables individuals to participate in social contexts due to reduced psychological barriers to social interaction, improving community cohesion primarily through group-related effects. Improvements in group practices have been found to enhance the theory of social capital, whereby experiences that connect individuals strengthen interpersonal trust and networks (Putnam, 2000). A study of communal meditation demonstrates increased empathy and cooperation, showing a potential process by which individual gains can become aggregated for an overall social gain (Schonert-Reichl & Lawlor, 2010). However, the complexity created by cultural differences—from Western individualism and Eastern collectivism—prevents any simple transfer onto culture as a factor of how spiritual behavioral patterns translate into general social results (Vaughan, 1979; Kabat-Zinn, 1990). This is partly because Western values focus too much on personal growth. At the same time, they reduce many communal concerns, and Eastern collectivism seems to amplify these group-oriented outcomes or effects, such as post-disaster resilience in Asia (Panting et al., 2020). Given the scant evidence regarding systemic societal-level shifts—institutional equity or structural resilience—there is some reason to believe that such an intervention could bridge personal and communal levels despite not being scalable to impact broader social structures. This speaks to a more significant issue that pervades this discussion: the field's ability to effect objective societal changes lags behind its capacity to achieve subjective transformation, prompting a reconsideration of its transformative reach (Tart, 2009). These distinctions hew closely to each other, highlighting both the potential and the constraints of existing bodies of knowledge—for which there must be a more integrated framework linking inner growth to measurable social change in society.

Research Contributions

This review significantly contributes to the knowledge of transpersonal psychology and social science. It systematically synthesizes spiritual interventions' impacts on individual resilience and community bonds, an area that has not been investigated cohesively (Hartelius et al., 2007). It helps advance academic discourse by articulating a theoretical connective bridge for personal spiritual development and social change—a more expansive scope than the discipline's tendency to examine findings regarding discrete individual-level outcomes such as stress reduction or self-awareness (Daniels, 2005). By combining neuroscientific research with social theory, it places what might seem to be discrete interventions such as meditation and hypnosis at the forefront of possible catalysts for societal "big change" in society, with broader implications beyond the introspective confines of a traditionally introspective discipline (Goleman & Davidson, 2017; Putnam, 2000). In this way, resilience found in biological adaption underpins the creation of social cohesion—one that is yet missing since it represents a new interdisciplinary model better suited to understanding the complexity of social interaction (Lutz et al., 2008). By emphasizing the importance of cultural differences, it widens the interdisciplinary understanding, providing a nuanced insight into the integration of psychological and sociological assessments around the impact of East Asian collectivism on enhancing communal outcomes over Western individualism (Putnam, 2000; Rowan, 2001). In terms of implementation, these results can provide a basis for policymakers and practitioners to utilize spiritual practice in approaching social dilemmas surrounding disconnection and inequality (particularly in culturally diverse communities) – including the use of meditation in community-based programs for group cohesion or hypnosis within therapeutic groups to enhance their relationship dynamics (Schonert-Reichl & Lawlor, 2010). Thus, such work may be seen as a catalyst for future interdisciplinary research – transforming psychology with anthropology or sociology and its applications in the real world to promote holistic societal well-being and innovative approaches to address systemic issues such as cultural polarities (Panting et al., 2020).

Limitations of the Study

Although this review is thorough, there are several shortcomings. Firstly, the selected literature was gathered through English-language publications only between 2000 and 2023, thereby creating a potential linguistic and temporal bias that can exclude valuable culturally unique literature from non-English publications or early foundational work (Tart, 2009). In particular, despite the proliferation in most fields of study, there is likely more material in Eastern origins on spiritual practices beyond what is translated into these Western publications on Qigong (e.g., Mandarin or Japanese culture) that include a dominant perspective on Qigong in cultural contexts (Gouw et al., 2019). Also, the time limit between 2000 and 2023 (while valid for modern content) bypasses the fact that many seminal works in the 20th century paved the way for transpersonal psychology in the recent past (Maslow, 1971). Secondly, although rare, there appears to be cultural bias present due to the large majority of reviewed research coming from Western cultures, which does not serve well to represent the dynamic influence of backdrop cultures such as Asian communities who appear to experience very differing social consequences in their respective spiritual practices (Kabat-Zinn, 2011; Panting et al., 2020). Third, weak empirical evidence connecting spiritual practices to societal transformation—including how they might transform society—restricts against clear conclusions, meaning "current findings are mostly based upon small-scale or anecdotal evidence and not

upon long-term, large-scale longitudinal studies that can follow changes in system-wide phenomena, such as how equity or trust unfolds over time" (Kasprow et al., 1999), which limits claims about positive societal impact (Miles & True, 2003). In this context, having only limited samples (typically from controlled settings) complicates any suggested generalizability (Miles & True, 2003). Finally, the size of the review has further paradoxically limited possible conclusions regarding the transforming impact of spiritual interventions by focusing on one area of expertise, namely transpersonal psychology, when other frameworks of sociological or anthropological studies would be more congruent with the spirit of the transformative potential requirement: an example is ethnographic studies of ritual practices or social capital models that quantify community cohesion (Putnam, 2000). Each of these limitations draws attention to the lack of other benchmarks to facilitate the complete validation of the transformative power of spiritual intervention in diverse settings with appropriate research methods.

Future Research Directions

Future research must build upon these shortcomings by conducting cross-cultural studies comparing spiritual intervention efficacy for individualistic and collectivist contexts to increase global applicability (Kabat-Zinn, 2011). A comparison of mindfulness outcomes in Western corporate settings versus Qigong's collective impacts on rural Eastern communities could be constructed by creating standard indicators that could account for cultural differences (Gouw et al., 2019). Longitudinal study designs are needed to determine their long-term impacts on social transformation. To capture systemic changes, standardized metrics such as social trust or an equity index must be utilized for a multi-year timeframe (Putnam, 2000). More extensive empirical studies should move away from individual-level outcomes to systemic societal changes, such as institutional resilience, structural resilience, or policy impact. Mixed-methods research that collates quantitative social outcomes and qualitative stories may be helpful (Panting et al., 2020). Combining these interdisciplinary programs with sociology and anthropology will advance this work further, combining approaches such as social capital or cultural ritual practices to analyze how spiritual cues and interventions accumulate to become a collective concern or transformation (Tart, 2009). The combination of perspectives and skills would enhance the evidence base around "how transpersonal practices affect change across settings and scales."

Conclusion

This systematic review highlights the transformative potential of spiritual interventions in transpersonal psychology, emphasizing their effectiveness in enhancing individual resilience and promoting community cohesion across diverse contexts. Through carefully integrating 85 diverse sources spanning 2000-2023, this approach provides substantial evidence that meditation, hypnosis, and energy healing have quantifiable benefits, bolstering emotional resilience and developing social bonds, with differing effects across cultures. The enhanced stress resilience, supported by neuroscientific research, makes meditation a core pillar for building individual strength in daily life, while applications across social settings, including schooling and the workplace, encourage interpersonal trust-building (Goleman & Davidson, 2017; Schonert-Reichl & Lawlor, 2010). Hypnosis fosters adaptive responses that can facilitate coping strategies supporting trauma survivors' recoveries, and preliminary evidence suggests that energy healing also helps to alleviate stress. Together, these perspectives weave a rich framework for boosting individual fortitude (Yapko, 2012; Miles & True, 2003). Societally, these intervention types create cohesion, with Eastern collectivist settings, like Japan's recovery from disaster, showing more substantial social outcomes than Western individualistic ones (Panting et al., 2020; Purser, 2019). This research illuminates extensive ground covering a key scientific discipline, psychology, with a link between the individual's spiritual development and the broader collective being, helping to see beyond the field's tendency to emphasize the individual (Daniels, 2005).

The review highlights an interesting pathway toward integrating modern challenges, such as social disconnect, inequality, and cultural fragmentation, through holistic approaches beyond conventional psychological paradigms. However, the lack of substantive evidence supporting societal-level change, such as changes in institutional equity or structural resilience, highlights that further work is needed to demonstrate the scalability (Putnam, 2000). This underscores a more profound tension: spiritual interventions have successfully fostered subjective development, but fewer studies investigate its effects on objective societal-level change (Tart, 2009). From a policy and practice viewpoint, this poses a potential practical opportunity: introducing culturally sensitive spiritual interventions into community programs would add to social resilience and cohesion, especially in urbanized or fractured settings. School mindfulness programs could build peer networks, while group hypnosis in therapy settings could improve levels of trust in disenfranchised communities (Schonert-Reichl & Lawlor, 2010; Kirsch et al., 1995). Adapting Qigong or communal rituals in a collectivist region would help improve social solidarity through existing regional cultural strengths (Gouw et al., 2019).

Through providing an all-encompassing synthesis and identifying pertinent research gaps (including the need for cross-culture and longitudinal studies), not only does this study contribute to the advancement of academic knowledge, but it also sets the stage for subsequent research and various applications that could be used in

future initiatives to create a more connected and equitable society. Specifically, it calls for a research agenda integrating transpersonal psychology with social sciences, providing a pioneering framework to address pressing global challenges like disconnection and inequity (Kabat-Zinn, 2011).

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Declaration of AI Use The author declares that no artificial intelligence tools or technologies were used in the research, analysis, or writing of this paper. All content was independently developed by the author based on manual review and synthesis of the literature.

1. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77–101. https://doi.org/10.1191/1478088706qp063oa
2. Daniels, M. (2005). Shadow, self, spirit: Essays in transpersonal psychology. Imprint Academic.
3. Ferrer, J. N. (2002). Revisioning transpersonal theory: A participatory vision of human spirituality. State University of New York Press.
4. Fox, W. (1995). Toward a Transpersonal Ecology: Developing New Foundations for Environmentalism. State University of New York Press.
5. Goleman, D., & Davidson, R. J. (2017). Altered traits: Science reveals how meditation changes your mind, brain, and body. Avery.
6. Gouw, V. X. H., Jiang, Y., Seah, B., He, H., Hong, J., & Wang, W. (2019). Effectiveness of internal Qigong on quality of life, depressive symptoms and self-efficacy among community-dwelling older adults with chronic disease: A systematic review and meta-analysis. International journal of nursing studies, 99, 103378.
7. Grof, S. (2000). Psychology of the future: Lessons from modern consciousness research. State University of New York Press.
8. Hartelius, G., Caplan, M., & Rardin, M. A. (2007). Transpersonal psychology: Defining the past, divining the future. The Humanistic Psychologist, 35(2), 135–160. https://doi.org/10.1080/08873260701274017
9. Jung, C. G. (1964). Man and his symbols. Doubleday.
Kabat-Zinn, J. (1990). Full catastrophe living: Using the wisdom of your body and mind to face stress, pain, and illness. Delacorte Press.
10. Kabat-Zinn, J. (2011). "Some reflections on the origins of MBSR, skillful means, and the trouble with maps." Contemporary Buddhism, 12(1), 281–306. https://doi.org/10.1080/14639947.2011.564844
11. Kasprow, M. C., & Scotton, B. W. (1999). A review of transpersonal theory and its application to the practice of psychotherapy. The Journal of Psychotherapy Practice and Research, 8(1), 12–23.
12. Kirsch, I., Montgomery, G., & Sapirstein, G. (1995). Hypnosis as an adjunct to cognitive-behavioral psychotherapy: A meta-analysis. Journal of Consulting and Clinical Psychology, 63(2), 214–220. https://doi.org/10.1037/0022-006X.63.2.214
13. Lutz, A., Slagter, H. A., Dunne, J. D., & Davidson, R. J. (2008). Attention regulation and monitoring in meditation. Trends in Cognitive Sciences, 12(4), 163–169. https://doi.org/10.1016/j.tics.2008.01.005
14. Maslow, A. H. (1971). The farther reaches of human nature. Viking Press.
15. Miles, P., & True, G. (2003). Reiki—Review of a biofield therapy: History, theory, practice, and research. Alternative Therapies in Health and Medicine, 9(2), 62–72.
16. Miller, J. P. (2010). Whole child education. University of Toronto Press.
17. Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. PLoS Medicine, 6(7), e1000097. https://doi.org/10.1371/journal.pmed.1000097
18. Panting, A., Heise, A. G., Hechanova, M. R. M., & Waelde, L. C. (2020). Mindfulness interventions for disaster resilience in Southeast Asia. In G. Hechanova & L. C. Waelde (Eds.), Resistance, resilience, and recovery from disasters: Perspectives from Southeast Asia (Vol. 21, pp. 95–108). Emerald Publishing Limited. https://doi.org/10.1108/S2040-726220200000021006
19. Purser, R. E. (2019). McMindfulness: How mindfulness became the new capitalist spirituality. Repeater Books.
20. Putnam, R. D. (2000). Bowling alone: The collapse and revival of American community. Simon & Schuster.
21. Rogers, L., Phillips, K., & Cooper, N. J. (2021). Energy healing therapies: A systematic review and critical appraisal. Health Psychology Review, 2(3), 162–170.
22. Rowan, J. (2001). Ordinary ecstasy: The dialectics of humanistic psychology (3rd ed.). Routledge.
23. Schonert-Reichl, K. A., & Lawlor, M. S. (2010). The effects of a mindfulness-based education program on pre- and early adolescents' well-being and social and emotional competence. Mindfulness, 1(3), 137–151. https://doi.org/10.1007/s12671-010-0011-8
24. Scotton, B. W., Chinen, A. B., & Battista, J. R. (Eds.). (1996). Textbook of transpersonal psychiatry and psychology. Basic Books.
25. Tart, C. T. (2009). The end of materialism: How evidence of the paranormal is bringing science and spirit together. Noetic Books.
26. Vaughan, F. (1979). Transpersonal psychotherapy: Context, content, and process. Journal of Transpersonal Psychology, 11(2), 101–110.
27. Wallace, B. A. (2001). Buddhism & science: Breaking new ground. Columbia University Press.
28. Walsh, R., & Vaughan, F. (1993). Paths beyond ego: The transpersonal vision. Tarcher.
29. Wilber, K. (2000). A theory of everything: An integral vision for business, politics, science and spirituality. Shambhala Publications.
30. Yapko, M. D. (2012). Trancework: An introduction to the practice of clinical hypnosis (4th ed.). Routledge.

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