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Research on Intelligent Agent Technology Empowering ICT Skilled Talent Cultivation for Smart Shipping

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Abstract: Addressing the urgent demand for high-skilled Information and Communications Technology (ICT) talent driven by the agile and digital-smart transformation of smart shipping, this paper explores the mechanisms, architecture, and paths of AI Agent technology and multi-agent matrices in empowering ICT skilled talent cultivation for smart shipping. In conjunction with the requirements of the Opinions of the Ministry of Education on Deepening the Reform of Key Teaching Elements in Vocational Education, this paper analyzes the structural pain points currently faced by higher vocational ICT majors across the "five key teaching elements"—namely, "major, curriculum, textbook, faculty, and practical training"—such as insufficient job adaptability, "offline simulation" in practical training, and lagging industry-education integration. Based on Human-Machine Distributed Cognition theory, a tripartite collaborative educational paradigm involving "Student–Teacher–Agent" is constructed. Taking the interdisciplinary engineering scenarios of "Information + Shipping" in smart shipping as empirical targets, a project-based curriculum system reconstruction plan covering the entire technical chain of "Sensing & Acquisition–Information Transmission–Storage & Processing–Feedback & Control" is proposed, and a skill transfer validation mechanism based on Educational Data Mining (EDM) and Social Network Analysis (SNA) is established. The research demonstrates that constructing a vocational education agent matrix aligned with key teaching elements effectively bridges the mapping channels between industrial engineering scenarios and teaching systems, providing a theoretical basis and practical path for cultivating composite ICT skilled talent equipped with both digital-smart mastery and shipping business logic.

Keywords: Agent Technology (AI Agent); Smart Shipping; ICT Skilled Talents; Key Teaching Elements; Industry-Education Integration; Human-Machine Distributed Cognition.

1. Introduction

1.1. Research Background

Pursuant to the Opinions of the Ministry of Education on Deepening the Reform of Key Teaching Elements in Vocational Education (Document No. 1 [2026] of the Department of Vocational and Adult Education, MOE), vocational education is required to implement systematic reforms addressing the five key teaching elements—specialties, curricula, teaching materials, faculty, and practical training—so as to better align talent cultivation models with industrial technological upgrades and evolving job competency requirements [1]. Currently, the deep application of big data, the Internet of Things (IoT), and artificial intelligence (AI) in the maritime sector is driving the rapid evolution of smart shipping, placing extremely high demands on the interdisciplinary composite capabilities of ICT talents. The 2025 ICT Jobs and Skills White Paper in an Intelligent World released by Huawei and IDC indicates that modern ICT positions, beyond requiring fundamental skills such as code development and system deployment, place greater emphasis on comprehensive qualities including cross-domain synthesis, human-machine collaboration, and engineering cooperation, thereby forcing higher vocational ICT talent cultivation systems to accelerate their transformation [2].

However, traditional higher vocational ICT education exhibits a profound structural mismatch when serving vertical industries like smart shipping: general ICT teaching often leans toward abstract code and generic software development, lacking deep understanding of real-time shipping data flows (e.g., AIS data processing, intelligent vessel sensing) and business rules; practical training relies heavily on "offline simulation" and static cases, with lagging updates of teaching resources that struggle to keep pace with rapid industrial technology iterations. Concurrently, technology applications in the educational field are undergoing a paradigm shift: research focus has transitioned from simple content generation via general generative AI to the deep business and instructional scenario implementation of Large Language Model (LLM) agents (AI Agents) and Multi-Agent Systems [3].

1.2. Domestic and Foreign Research Status

Although extensive exploration has been conducted by academia and industry globally, systematic research specifically tailored to higher vocational ICT majors and aligned with the "five key teaching elements" of vocational education still leaves a distinct gap.

1.2.1. Overseas Research Status

Overseas institutions started research on underlying agent technologies relatively early. Teams from OpenAI, Stanford University, and other organizations have focused on core technologies such as Retrieval-Augmented Generation (RAG), memory mechanisms, and tool calling to explore autonomous task planning and logical reasoning mechanisms for agents (such as the ReAct framework) [4]. In educational scenarios, mainstream overseas research centers on personalized intelligent tutoring systems, with Khan Academys AI Tutor (e.g., ChatGPT Study Mode) serving as a typical application, primarily serving general education and higher education through core functions like Q&A and adaptive learning path recommendation [5]. In recent years,

multi-agent collaboration has become a research hotspot, with scholars assigning specific roles to agents to simulate group collaboration and decision-making behaviors in educational settings.

1.2.2. Domestic Research Status

China has closely followed global intelligent technology trends, achieving fruitful results in generative AI-assisted teaching and intelligent instructional design. Alongside the continuous advancement of reforms in key vocational education teaching elements, scholars have begun reflecting on drawbacks such as single-point AI applications, data silos, and element fragmentation, gradually shifting research perspectives toward the systematic reconstruction of multi-agent matrices. The "Penguin Teacher Assistant," jointly developed by Northwest Normal University and Tencent, explores new models such as AI study companionship and data-driven teaching evaluation, injecting "digital-smart momentum" into teacher education classrooms. Zhejiang University, leveraging the "Zhedaxiansen" platform, built an integrated intelligent agent matrix spanning research, teaching, and administration [6].

In vocational education, relevant CNKI literature analysis shows research advancing into deeper domains: Bi et al. constructed a vocational education agent matrix crossing three layers (decision, collaboration, execution) with three categories (industry-education integration, school governance, teaching reform), clarifying the core value of agents in bridging the industry-education divide [7]. Liu et al. proposed the mechanism and implementation paths for AI agents empowering vocational education job training symbiosis spaces [8]. Focusing on higher vocational ICT and computer majors, Ren et al. conducted targeted research on teaching agents empowering vocational computer project-based instruction, exploring application paths in task deconstruction, classroom implementation, and resource matching [9].

1.2.3. Research Development Trends

Artificial intelligence is transitioning from a mere auxiliary tool into an endogenous core force reshaping the educational ecosystem. Agents are accelerating their evolution from "standalone autonomous operation" to "swarm intelligence matrices," becoming the mainstream trend driving the intelligent reshaping of educational scenarios.Human-Machine Distributed Cognition Theory

This study introduces the theory of Human-Machine Distributed Cognition. Cognitive processes no longer occur solely within a students brain but are distributed across a composite network formed by "Student–Teacher–AI Agent–Smart Shipping Engineering Environment". As cognitive proxies possessing autonomous planning and external tool-calling capabilities, agents undertake high-load cognitive tasks such as heterogeneous data cleaning, basic code generation, and engineering simulation, enabling learners to focus on developing cross-domain transfer thinking, understanding shipping business logic, and solving higher-order engineering problems.

2. Mechanism of Agents Empowering ICT Talent Cultivation for Smart Shipping

The core of agent technology empowering ICT talent cultivation for smart shipping lies in achieving dynamic coupling between the "ICT Skill Chain" and the "Smart Shipping Industry Chain" through digital-smart media. The mechanism is shown in Figure 1.

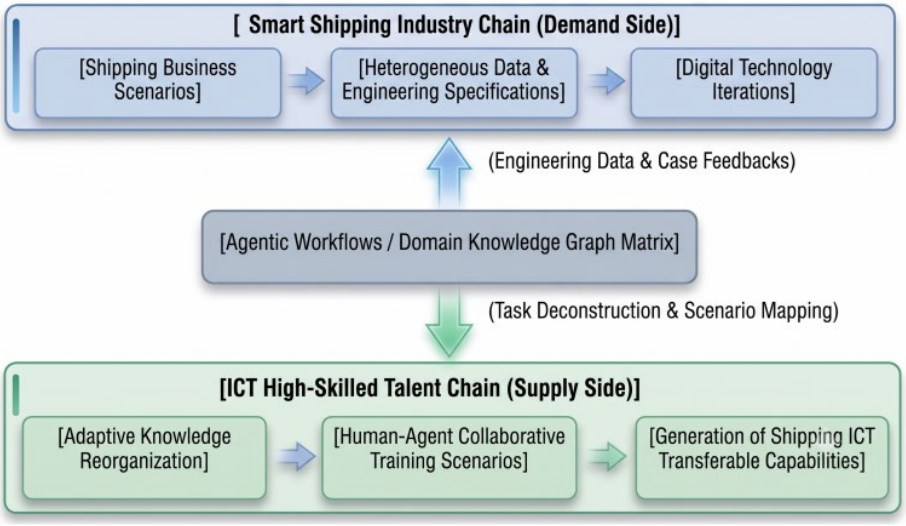


Figure 1. Mechanism of Agent-Driven "ICT Skill Chain – Smart Shipping Industry Chain" Collaborative Evolution

2.1. Knowledge Graphing of Shipping Engineering Scenarios

In the context of the rapid evolution of smart shipping, key skills such as dynamic electronic fence construction, shipping data security warning, vessel AIS stream data cleaning, and risk deduction exhibit high engineering complexity and situational dependence. These skills contain rich industry tacit knowledge, which is typically scattered across frontline engineers practical experience, unstructured maintenance logs, and specific engineering contexts, making them difficult to impart in a standardized and explicit manner through traditional static textbooks—a fundamental pain point restricting the cultivation of composite shipping ICT talent.

To break through this bottleneck, this study relies closely on the Jiangsu Shipping Big Data Engineering Research Center, fully leveraging the results of dozens of representative national, provincial, and corporate smart shipping projects undertaken over the past five years. Adhering to the core philosophy of "integrating science and education, promoting teaching through research," the study adopts autonomous AI Agent technology as the core driving engine to establish a multi-source heterogeneous data collection and knowledge mining mechanism covering the entire project lifecycle.

Agents seamlessly penetrate engineering logs, algorithm codebases, maritime business specifications, and real-time vessel perception data. Utilizing LLMs powerful semantic understanding, knowledge extraction, and deep association capabilities, agents perform structural organization and logical reasoning on fragmented, empirical industry knowledge.

Through this integration process, tacit skills in the industry chain are deconstructed and internalized into explicit, standardized, and dynamically expandable smart shipping cross-domain skill graphs. The graph clarifies derivative relationships and capability requirements among knowledge nodes across the complete technical chain of "Sensing & Acquisition–Information Transmission–Storage & Processing–Feedback & Control," providing solid academic support for the organic integration of ICT professional knowledge and shipping business logic. On this basis, Retrieval-Augmented Generation (RAG) technology is further introduced, empowering agents to accurately retrieve and reason over the skill graph based on specific instructional goals. Agents deeply associate real engineering contexts, automatically deconstructing and recombining complex industrial engineering projects into modular project case libraries that conform to cognitive laws and feature tiered difficulty, thus bridging the complete pathway of "Engineering Research Achievements → Skill Graph Deconstruction → Adaptive Instructional Case Generation" and achieving efficient transformation from high-level research practice to high-quality instructional resources.

2.2. "Student–Teacher–Agent" Tripartite Collaborative Evolution Mechanism

The instructional relationship profoundly evolves from a traditional two-dimensional "Teacher–Student" structure into a digital-smart collaborative ecosystem involving "Student–Teacher–Agent" tripartite linkage. Agents play dual roles as "Virtual Tutors" and "Teaching Assistants" in this ecosystem, greatly reshaping the form of teaching and learning interactions: At the Student Level: Agents transform into 24/7 collaborative learners and engineering coaches. Relying on LLMs and knowledge graph technologies, agents accurately profile students cognitive levels and skill shortcomings, tailoring adaptive learning paths and resource pushes. Meanwhile, agents connect to real shipping ICT engineering scenarios (e.g., real-time AIS data cleaning, electronic fence warning deduction) to build highly interactive, low-risk virtual training environments. Through multi-turn interactions and human-agent collaborative problem-solving, students transform abstract ICT theories into capabilities for solving actual engineering problems, achieving a leap from "passive reception" to "embodied practice"—truly unifying knowledge and action. At the Teacher Level: Agents serve as high-efficiency teaching decision-making brains. By seamlessly capturing students code debugging trajectories and cognitive obstacle nodes when solving complex shipping ICT engineering problems, agents generate real-time diagnostic reports to help teachers precisely grasp learning pain points. Based on data feedback, teachers dynamically reconstruct teaching strategies and leverage agents to efficiently transform the latest industry research achievements and engineering projects into instructional cases. This mechanism prompts teachers to transition from traditional "knowledge deliverers" to "engineering guides" and "instructional designers," comprehensively driving the faculty team toward upgrading into cross-domain "dual-qualified" teachers proficient in both ICT technology and shipping business logic.

3. Paths of Agents Empowering ICT Talent Cultivation for Smart Shipping

3.1. Layered Architecture of Vocational Education Agent Matrix

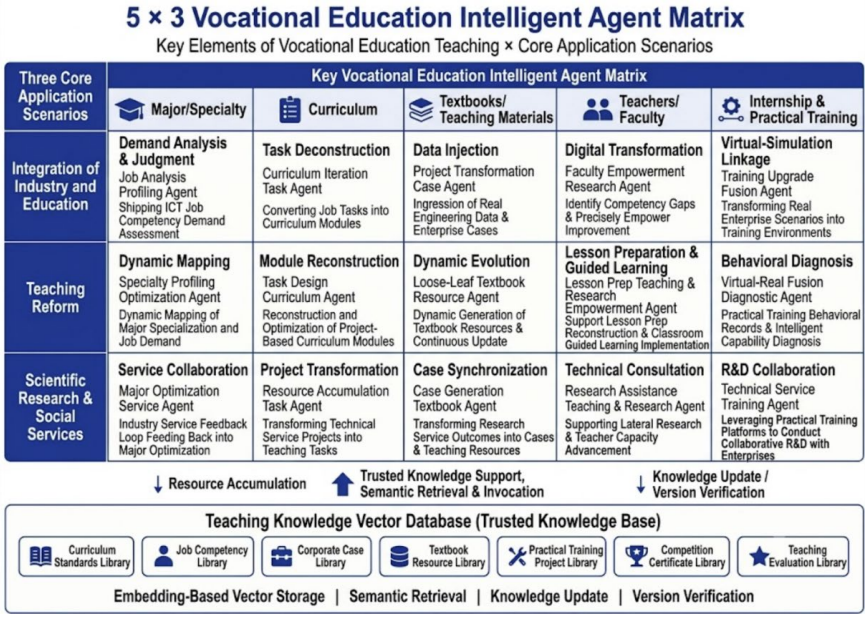


Figure 2. Smart Shipping ICT Smart Education System Architecture Aligned with Five Key Elements

In accordance with Document No. 1 [2026] of the Department of Vocational and Adult Education, this study references vocational education agent layering concepts, aligning with the five key teaching elements ("major, curriculum, textbook, faculty, practical training") to construct a "5×3" vocational education agent matrix layered architecture tailored to smart shipping ICT majors, as shown in Figure 2. This architecture horizontally spans the five key

teaching elements and vertically connects three core application scenarios ("industry-education integration, teaching reform, research and social service"), forming an intelligent service system operating across three collaborative layers: "Decision & Management—Teaching Collaboration—Training & Service Execution".

3.1.1. Decision & Management Agents: Industry-Driven Dynamic Updating of Five Elements

Decision & management agents focus on industry-education integration scenarios, prioritizing alignment with dynamic adjustments in the "Major" element. Centered on maritime characteristics, agents continuously aggregate cutting-edge technical standards and job capability models from smart shipping enterprises and the ICT industry, monitoring real-time skill demand changes in maritime information technology positions. Through deep deconstruction of real corporate engineering projects and technical workflows, agents losslessly transform the latest industrial technical systems into teaching resources, adaptively generating fine-tuning recommendations for professional talent cultivation programs. On this basis, decision agents orchestrate dynamic major adjustments, curriculum content iterations, practical training project updates, intelligent textbook upgrades, and faculty industrial technology capacity enhancements, overcoming the pain points of traditional teaching elements lagging behind industry development and disconnecting from actual job roles, thereby achieving precise alignment between industrial demand and talent supply.

3.1.2. Teaching Collaboration Agents: Teaching Implementation Five-Element Collaborative Quality Improvement

Teaching collaboration agents are grounded in teaching reform scenarios, aligning with the reconstruction and upgrade of "Curriculum" and "Textbook" elements. Agents act as intelligent tutors and teaching assistance cores, forming dedicated teaching service systems. During teaching implementation, agents achieve adaptive transformation and reorganization of job tasks into project-based curriculum modules, driving the dynamic evolution of loose-leaf digital textbooks. Through multi-agent collaborative dispatch mechanisms, agents coordinate the reform rhythm and joint construction of the five elements, forming a closed loop of collaborative quality improvement: "major adjustment drives curriculum update → curriculum update pulls textbook iteration → textbook iteration compels faculty enhancement → faculty upgrade supports training optimization".

3.1.3. Training & Service Execution Agents: Social Service Feedback for Long-Term Five-Element Iteration

Training & service execution agents connect "practical training" with "research and social service" scenarios, focusing on alignment with "Practical Training" and "Faculty" elements. In job training symbiosis spaces, agents act as "virtual engineers" and practical training coaches, recording students training operations in real time and intelligently diagnosing code bugs and engineering decision errors. In the dimension of social services, service-oriented agents for technical consultation assistance, research project collaboration, and scientific achievement transformation are developed to support teachers in providing intelligent technical services and horizontal research for smart ports/shipping and the ICT industry. New industrial technologies, demands, and engineering pain points captured by teachers during technical services are fed back through the agent matrix to revise talent cultivation plans, update curriculum contents, upgrade practical training systems, and optimize teaching resources, building a long-term self-evolving iterative mechanism of "Industry Service → Technology Accumulation → Instructional Feedback → Element Upgrade".

3.2. Reconstruction of "Information + Shipping" Project-Based Curriculum System

Focusing on real engineering scenarios in the smart shipping industry and relying on the agent matrix, the traditional information major curriculum system is modularly reconstructed and intelligently deconstructed along the ICT technical chain of "Sensing & Acquisition–Information Transmission–Storage & Processing–Feedback & Control":

3.2.1. Sensing & Acquisition Module: Multi-Source Perception and Data Fusion Practice

Combining Vessel Automatic Identification Systems (AIS), maritime IoT sensors, and computer vision technologies, agents deconstruct typical tasks such as "Multi-Source Data Perception for Smart Vessels/Ports". Project training covering maritime perception device access, multi-source heterogeneous data cleaning, and spatiotemporal alignment is constructed, guiding students under agent assistance to complete the entire process from physical world signal collection to digital world data extraction, enhancing students underlying hardware interaction and intelligent perception development skills.

3.2.2. Information Transmission Module: Vessel IoT Communication and Security Protocol Practice

Addressing communication challenges in highly dynamic maritime environments, Internet of Vessels/Ships (IoV/IoS), 5G sea-coverage technology, and Software-Defined Networking (SDN) are introduced. Relying on agent workflows, curriculum modules design "Ship–Shore–Cloud" highly reliable transmission protocol analysis, multi-agent deep reinforcement learning spectrum sharing algorithm simulation, and SDN DDoS attack detection and defense drills. Students debug network transmission code via human-machine collaboration, strengthening their network protocol design and maritime information security protection capabilities.

3.2.3. Storage & Processing Module: Stream Computing and Data Warehouse Hands-on Practice

Relying on stream computing and maritime data warehouse technologies, real engineering topics such as "Real-Time AIS Data Cleaning," "Shipping Data Indicator Analysis," and "Data Warehouse-Based Vessel Manning Analysis" are dimensionally reduced and reconstructed into instructional projects. Agents automatically generate standardized code templates and test datasets, guiding students to build real-time big data processing pipelines to achieve millisecond-level cleaning and intelligent analysis of massive shipping spatiotemporal trajectory stream data, cultivating students high-concurrency big data architecture and algorithm implementation skills.

3.2.4. Feedback & Control Module: Risk Warning and Smart Maritime Control Training

Focusing on core operations such as smart maritime supervision and collision avoidance, deep learning algorithms,

virtual electronic fences, and spatial clustering analysis (e.g., ConDPC/DPC algorithms) are integrated. Agents provide interactive 3D maritime simulation environments where students write warning logic and control strategies to complete vessel boundary-crossing warning, water pollution monitoring, and dynamic navigation risk deduction projects. This module completes the closed loop from "data perception" to "intelligent decision-making," cultivating students comprehensive decision -making abilities in solving complex maritime ICT engineering problems.

3.3. Paths for Enhancing Teachers Digital - Smart Dual-Qualified Capabilities

Faculty forms the core support for reforms in key teaching elements. Addressing pain points commonly found among higher vocational ICT teachers—such as shallow understanding of industry business logic and weak digital-smart teaching capabilities—this study relies on the vocational education agent matrix to explore a three-dimensional capability enhancement path of "Digital-Smart Empowerment–Science/Education Integration–Diverse Collaboration," driving the faculty team toward upgrading into cross-domain "digital-smart dual-qualified" teachers proficient in both ICT technology and shipping business logic.

3.3.1. Digital-Smart Empowerment: Adaptive Extraction of Cutting-Edge Professional Knowledge

Teachers utilize empowerment and research-assistant agents to track and deeply extract industry frontiers in smart shipping and ICT. Agents condense complex new industrial technologies into concise knowledge briefs and micro-teaching modules, precisely filling teachers cognitive gaps in specific industry operations and cutting-edge technologies. With agent workstations, teachers efficiently complete lesson preparation reconstruction and knowledge updating, significantly broadening their technical horizons and academic frontier insight.

3.3.2. Integration of Science and Education: Efficient Transformation of Research Output into Instructional Resources

Leveraging agents technical advantages in "knowledge reorganization and case generation," a regularized mechanism for research feeding back into teaching is established. Research teams input smart shipping-related invention patents, high-level papers, and corporate research achievements into the agent knowledge base (RAG). Agents automatically deconstruct, desensitize, and reconstruct these assets into standardized instructional cases, training projects, and competition problems. In hosting or participating in research transformation, teachers deepen their understanding of engineering practice, achieving a positive capability cycle of "Research Innovation → Instructional Transformation → Practical Guidance".

3.3.3. Diverse Collaboration: Creating a "Teacher–Industry Expert–Agent" Teaching and Research Ecosystem

Relying on agent collaborative networks, a diverse teaching and research community composed of full-time vocational teachers, smart shipping industry experts, and AI agents is established. Agents assist teachers in horizontal research and technical consulting in social service scenarios, seamlessly recording engineering practice data during corporate services. Meanwhile, agents handle tedious routine work such as basic lesson plan writing and code diagnosis, freeing teachers from repetitive labor and enabling them to collaborate deeply with industry experts on high-order project-based instructional design and engineering problem-solving, comprehensively enhancing teachers engineering practical instruction and industry-university-research collaborative innovation capabilities.

3.4. Empirical Data Collection and Capability Confirmation Model

To objectively evaluate cultivation effectiveness, a data-driven empirical analysis framework is established, collecting full-process "Human–Machine–Environment" interaction data during teaching:

Interaction Log Data: Prompt evolution trajectories, API call chains, code modification frequencies, and agent debugging records.

Cognitive Behavioral Data: Task deconstruction logic and decision latency when facing complex shipping ICT problems.

Comprehensive Capability Metrics: Engineering project completion rate, shipping business understanding scores, and innovation competition performance.

A Social Network Analysis (SNA) model is constructed for the interaction network:

$$G=（V, E, W） \quad (1)$$

Where $V = V_s \cup V_\alpha \cup V_\kappa$ represents node sets for students, agents, and shipping ICT knowledge points, respectively. E represents interaction edges, and W represents interaction weights. By calculating betweenness centrality and clustering coefficients of student nodes, their cross-domain skill transfer capabilities and new quality job adaptability are quantitatively evaluated.

4. Conclusion

In close alignment with the spirit of the Opinions of the Ministry of Education on Deepening the Reform of Key Teaching Elements in Vocational Education (Jiao Zhi Cheng [2026] No. 1), this paper systematically explicates the internal mechanisms and implementation paths of agent technology and multi-agent matrices in empowering ICT skilled talent cultivation for smart shipping. The study shows that agent technology can effectively bridge the deep chasm between generic ICT technologies and vertical industry business logic in traditional vocational education. By creating a "Student–Teacher–Agent" tripartite collaborative cognitive ecological network, dynamic coupling and resonance between the "ICT Skill Chain" and the "Smart Shipping Industry Chain" are successfully achieved. On this foundation, this study comprehensively aligns with the "five key teaching elements"—major, curriculum, textbook, faculty, and practical training—constructing a multi-agent matrix and project-based teaching system that significantly enhances students cross -domain engineering practical capabilities and job adaptability. Future research will further explore the instructional applications of multi-agent systems in complex maritime game-theoretic and dynamic decision-making scenarios, continuously enhancing the promotion and extension value of this cultivation paradigm and evaluation model in ICT talent cultivation across more industries.

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