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Knowledge Management in the Digital Economy Era: Challenges and Trends (Postprint)

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Abstract

[Purpose/Significance] To investigate the new challenges that knowledge, as a key strategic resource and core asset, poses to theory and practice in the digital economy era. [Method/Process] Employing literature review and theoretical analysis methods, this study analyzes and elaborates on the challenges and trends of knowledge management in the digital economy era based on Cyber-Physical Systems (CPS). [Results/Conclusion] In the digital economy era, knowledge management imposes higher demands on data acquisition and integration regarding its objects, and requires greater precision, real-time performance, and accuracy in the value-added system from data to information to knowledge; heterogeneous integration and data mining become pivotal to knowledge management, human-computer interaction and artificial intelligence will serve as critical enabling technologies, and data-driven value creation emerges as the core objective. Future knowledge management development will strategically evolve toward real-time dynamic precise decision-making, architecturally transition to holistic knowledge management, organizationally construct efficient innovative organizations through barrier-free knowledge flows, contextually achieve systematic integration of fragmented knowledge, methodologically emphasize tacit knowledge conversion based on human-computer interaction, and technologically develop platform-based knowledge graphs.

Full Text

Preamble

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Knowledge Management in the Age of Digital Economy: Challenges and Trends

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Abstract

[Purpose/Significance] This study analyzes the new challenges that knowledge, as a key strategic resource and core asset, poses to theory and practice in the digital economy era. **[Method/Process]** Using literature research and theoretical analysis methods, this paper examines the challenges and trends of knowledge management in the digital economy based on the structure of Cyber-Physical Systems (CPS). **[Result/Conclusion]** In the digital economy era, knowledge management faces higher demands for data acquisition and integration, and requires greater precision, real-time capability, and accuracy in the transformation from data to information to knowledge. Heterogeneous integration and data mining have become critical to knowledge management, while human-computer interaction and artificial intelligence will play key roles as enabling technologies. Data-driven value creation has become central to knowledge management objectives. Future knowledge management will strategically evolve toward real-time dynamic and precise decision-making, architecturally shift toward global knowledge management, organizationally build efficient innovative organizations through barrier-free knowledge flows, systematically integrate fragmented knowledge in content, emphasize tacit knowledge transformation based on human-computer interaction in methodology, and develop platform-based knowledge graphs in technology.

Keywords: digital economy; knowledge management; Cyber-Physical Systems (CPS); artificial intelligence; challenges and trends

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1 Main Characteristics of the Digital Economy

1.1 Concept and Scope of the Digital Economy

The term “digital economy” was first proposed in 1996 by American consultant D. Tapscott [1], but consensus on its definition remains elusive among governments, industries, and academia. The OECD defines the digital economy as trade in goods and services realized and conducted through e-commerce. Japan’s Ministry of Economy, Trade and Industry defines it as e-commerce in a broad sense. The United States views the digital economy as encompassing e-commerce and the information technology industries that enable it, specifically including infrastructure, e-commerce processes, and e-commerce trade [2]. China first listed the “digital economy” as an important 议题 in the “G20 Digital Economy Development and Cooperation Initiative” in 2016, defining it as “a series of economic activities that use digitalized knowledge and information as key production factors, modern information networks as important carriers, and the effective use of information and communication technology as an important driving force for improving efficiency and optimizing economic structure” [3]. China has a relatively clear understanding of the digital economy’s internal

structure. Based on CPS, Dai Yishu et al. conducted a comparative study of the technical architecture, capability architecture, and application architecture of manufacturing among China, the United States, and Germany [6], which to some extent reveals the internal structure of digital economy development.

1.2 Technical Architecture of the Digital Economy

To understand the challenges that the digital economy poses to knowledge management, we must first examine the development and application of new-generation information technologies such as cloud computing, big data, the Internet of Things, mobile Internet, and artificial intelligence in recent years. In the new form of digital economy, knowledge has become a key strategic resource and core asset. How to effectively produce and manage knowledge in the digital economy era presents new challenges and problems for both theorists and practitioners. The digital economy reduces the costs of information search and sharing in social members' transactional activities through digital factor supply, networked factor connections, and intelligent factor allocation, thereby enhancing output efficiency and becoming a new engine for economic growth.

In this five-layer architecture: 1) The **connection layer** digitizes elements in physical space (such as equipment, factories, processes, services, and all elements and links in the supply chain), driving the digitization of physical space elements and processes to enable them to flow and exchange freely in interconnected cyberspace. This layer's development is closely related to the Internet of Things. 2) The **conversion layer** further realizes data value-added on the basis of massive data from the connection layer. Data value-added refers to using computing tools and algorithms to integrate, process, analyze, and mine data collected by the connection layer, achieving the transformation from data to information. Therefore, this layer is closely related to data mining and knowledge discovery. 3) The **network layer** uses cloud computing, mobile Internet, and other technologies to aggregate and integrate massive data of multiple types and sources in cyberspace. Heterogeneous digital resources interact through standardized connections and heterogeneous computing methods, forming a wide-area foundation for e-commerce processes and trade. 4) The **cognition layer** utilizes artificial intelligence and other technologies to develop intelligent machines that can respond similarly to human intelligence, including language recognition, image recognition, natural language processing, expert systems, and deep learning. It processes massive, complex, and heterogeneous data aggregated at the network layer, providing highly personalized services to users through high-value knowledge resources such as user profiles, model libraries, experience libraries, solution libraries, algorithm libraries, and tool libraries [7][8]. 5) The **configuration layer** refers to feeding information from cyberspace back to physical space and conducting guiding control of the system for two-way interaction with markets, customers, and real-world contexts. The configuration layer acts as an elastic control system, using preset rules and semantic specifications to apply corrective and preventive decisions made by the cognition layer to the

supervised system, enabling knowledge resources to be flexibly and dynamically allocated and controlled to drive underlying industrial equipment and machine components, giving machines adaptive and self-configuring capabilities.

2 Challenges to Traditional Knowledge Management in the Digital Economy Era

Fundamentally, the traditional knowledge management process of value addition from data to information to knowledge has not changed in the digital economy era, nor have the main activities of data acquisition, processing, integration, analysis, application, and sharing. However, significant changes have occurred in knowledge management strategy, focus, objects, value-added activities, and core knowledge types. Traditional knowledge management, centered on organizations or individuals, focused on solving organizational knowledge acquisition, integration, application, sharing, and creation, with the core strategic goal of transforming individual tacit knowledge into team and organizational tacit and explicit knowledge to enhance organizational knowledge creation capabilities. Traditional knowledge management emphasized the influence of leadership, strategy, culture, and incentive mechanisms on knowledge management effectiveness, with computer technology playing a supporting role. However, new technology applications and massive heterogeneous data have posed five major challenges to traditional knowledge management:

2.1 Strategic Challenge: Data-Driven Value Creation as the Core Objective

In the product-dominant logic of traditional models, enterprises embed value into goods through production activities and then trade with consumers in the market to achieve value creation, with knowledge management strategy focusing on production processes and internal organization. In the digital economy era, value creation occurs during interaction between manufacturers and consumers, with responsibilities from product design to market transaction crossing traditional enterprise boundaries. Relationships between enterprises and between enterprises and consumers present as equal network structures. Mining knowledge from consumer data and using it as a foundation for manufacturer innovation has become an important resource for enterprise value creation. Therefore, using data-driven approaches to dynamically meet user needs in specific contexts in real time [9] has become the core problem that knowledge management strategy must solve.

2.2 Focus Challenge: Heterogeneous Integration and Data Mining as Key Priorities

In cyberspace, integrating knowledge from different sources, structures, and characteristics will become the focus of knowledge management. At the network layer, as massive physical assets are mapped into digital twins, those who can

efficiently integrate and utilize these resources in cyberspace may become leaders of cyberspace. The key capability required is resource integration capability. According to service-dominant logic theory, resource density represents the total amount of resources a subject can obtain in a certain context [10]. The stronger the resource integration capability, the greater the breadth, depth, and speed of integrated resources, and the higher the resource density, ultimately creating more opportunities for value co-creation between supply and demand sides [11]. At this layer, resources feature massive volume, diversity, high velocity, and heterogeneity. Traditional reliance on manual and internal organizational software systems is clearly inadequate. In this context, artificial intelligence and machine learning technologies based on big data become particularly important.

2.3 Object Challenge: Massive Data Analysis as a Critical Capability

With the fusion and rapid growth of data at the network layer, knowledge management activities require higher capabilities for dynamic acquisition, integration, and analysis of data. At the connection layer, technology enables full connectivity: person-to-person (social media), person-to-thing (e-commerce platforms), thing-to-thing (Internet of Things, vehicle networks, aero-engine data networks), and person-to-process (logistics platforms). Sensors installed on physical objects can collect massive data during product and production processes, mapping physical assets into cyberspace to form digital twins that present real-time and accurate mirrors of physical objects' attributes and states, including shape, position, status, and motion. In other words, digital twins are digital representations of physical assets that, based on changes in physical assets, organically combine artificial intelligence, machine learning, and data mining technologies in cyberspace to create dynamically updated digital simulation models of reality.

2.4 Value-Added System Challenge: Data-Based Decision Making with Higher Requirements

In the value-added process from data to information to knowledge, people have higher requirements for knowledge precision, real-time capability, and accuracy. Traditional digital assets include various materials such as text, images, and audio. With the widespread use of mobile Internet, people's locations and behaviors are stored in digital form. Analyzing and interpreting digital assets can help people understand, analyze, and predict, thereby making more forward-looking and precise decisions. Therefore, at the conversion layer, how to conduct multi-dimensional analysis and mining of more extensive and finer-grained data to generate valuable suggestions for managers and decision-makers has become an essential core capability for organizations.

2.5 Core Knowledge Type Challenge: Artificial Intelligence as a Strategic Resource

In cyberspace, operant resources have become the commanding heights of international competition. According to service-dominant logic theory, humans can utilize two major types of resources: operand resources and operant resources. Operand resources (such as land and minerals) are tangible, static, and finite resources that humans utilize to generate utility. Operant resources (such as artificial intelligence, algorithms, big data analytics capabilities, and machine deep learning) are intangible, dynamic, and infinite resources generated during the utilization of operand resources [11]. Traditional economic models emphasize the development of natural resources like land and minerals. In the digital economy era, the ability to process massive data in cyberspace through core technologies such as artificial intelligence has become core knowledge. In other words, the development of operant resources occupies the strategic core position in the value network [11-13], serving as the fundamental source of strategic benefits and a key element in service provision and value creation processes [13-14].

3 Development Trends of Knowledge Management in the Digital Economy Era

In the digital economy era, the importance and strategic significance of knowledge management have increased substantially, and the number of knowledge-intensive organizations has grown significantly. The development trends of knowledge management are as follows:

3.1 Strategic Trend: From Data Mining to Real-Time Dynamic and Precise Decision-Making

The core objective of knowledge management in the digital economy era is to achieve data-driven value creation. Internally, the main value of knowledge management lies in decision support for all organizational links and positions, assisting employees in judging, decision-making, and responding to real-world phenomena through visualization tools such as real-time, dynamic digital dashboards. Externally, knowledge management must help organizations achieve their strategic goals and better serve society: governments can effectively provide public services, crisis management, and social resource coordination through e-government and smart city systems; enterprises can accurately provide customized products and services according to customer needs [15]. To achieve these objectives, leaders at all levels must treat the data-information-knowledge-decision support system as a core strategic tool to enhance overall management and decision-making capabilities.

3.2 Architectural Trend: From Local to Global Knowledge Management

As the digital granularity of people, equipment, processes, and activities becomes increasingly fine and extensive, knowledge management activities previously focused on enterprise strategy, R&D, marketing, or production will expand to full processes, full value chains, and full processes. Therefore, organizations need to update their existing knowledge ontologies and place them in cyberspace to collect and integrate knowledge from both inside and outside the organization. As a system that displays the attributes and relationships of various independent elements, knowledge ontology has important value for knowledge management blueprint design and implementation.

3.3 Organizational Trend: Building Efficient Innovative Organizations Through Barrier-Free Knowledge Flows

Traditional enterprises' vertical and horizontal divisions have created numerous information silos, raising barriers to knowledge dissemination and exchange, reducing knowledge sharing efficiency, and affecting corporate creativity and environmental adaptability. For new platform enterprises, the digital connections they build in cyberspace provide unprecedented pathways for barrier-free knowledge flow and sharing, creating a solid foundation for stimulating corporate creativity. Business insights formed through data mining and scenario tracking can help enterprises rapidly test, iterate, and summarize creative ideas, transforming them into commercial value and thereby continuously stimulating organizational adaptability through creativity [16]. Particularly for companies like Alibaba, NetEase, and Toutiao, which can tightly focus creativity on consumer data mining and knowledge discovery, they can aggregate product manufacturers, service providers, financial institutions, information providers, and other relevant stakeholders according to market demand. Through the "network effects" formed by connecting, interacting, and matching supply and demand between consumers and stakeholders, they continuously seek opportunities and space for value co-creation.

3.4 Content Trend: From Fragmented Generation to Systematic Integration

The development of IoT, mobile Internet, and artificial intelligence has not only brought explosive growth in data volume but also increased data complexity, weakened information reliability, and made valuable knowledge extraction more difficult. The arrival of the knowledge fragmentation era has placed higher demands on knowledge management [17]. Traditional knowledge acquisition was relatively complete and systematic, with close connections between knowledge elements forming stable knowledge systems. In contrast, fragmented knowledge features multi-source distribution, social propagation, and redundancy. Fragmented knowledge is scattered, with diverse information sources, hiding knowledge within fragmented information data pieces that transfer between different

sources and receivers. The social nature of fragmented knowledge propagation manifests in knowledge about the same theme spreading across various platforms, with different groups focusing on different aspects, resulting in different social forms of fragmented knowledge [18]. Additionally, only valuable data can be called information. While fragmentation increases the total amount of information, it also greatly increases the amount of non-information data, which can be considered “noise” in knowledge management processes. This noise pollution creates obstacles to knowledge acquisition. In this context, the value of knowledge search becomes more important, serving not only as a supplement and extension to search engines but also helping to externalize tacit knowledge [19]. Current Q&A platforms like Wolfram Alpha and Zhihu are knowledge provision and search platforms based on user needs, transforming many people’s professional knowledge and insights into explicit knowledge and effectively supplementing traditional knowledge providers like libraries.

3.5 Methodological Trend: From Human-Based Tacit Knowledge Conversion to Human-Computer Interaction-Based Knowledge Creation

Tacit knowledge management has always been a difficult and key aspect of knowledge management. The digital economy era provides new methods and technical support for tacit knowledge management, significantly improving efficiency compared to traditional direct human-to-human interaction and avoiding knowledge distortion during sharing to some extent. Methods such as knowledge search, knowledge maps, and virtual learning communities have emerged for tacit knowledge externalization. Traditional knowledge management scholar Ikujiro Nonaka’s SECI model (Socialization, Externalization, Combination, Internalization) emphasizes that knowledge creation is driven by the spiral transformation between tacit and explicit knowledge in groups and contexts of social interaction. In Nonaka’s model, tacit knowledge mainly comes from frontline employees’ production experience, professional insights, mutual exchanges and collisions, and leaders’ practical wisdom [20], focusing on environmental change prediction, interpretation, and decision-making. In the digital economy era, the sources of tacit knowledge have further expanded, with human-computer interaction becoming an important source. Based on the automatic monitoring, diagnosis, and prediction functions of digital twins or big data centers, as well as their data mining algorithm models, historical information continuously generated and archived during physical asset usage can be compared across machine groups in different geographical distributions to automatically identify problems and obstacles, enabling remote monitoring and management of individual devices or even entire networks with minimal human input. In this process, AI can handle relatively simple, repetitive, and primary data collection and analysis tasks, freeing employees’ time and energy for more complex and creative activities. Therefore, to maintain competitive advantages under the wave of disruptive technologies like AI, enterprises must enhance human-computer interaction and data mining capabilities and increase investment in knowledge

management of data and operational processes [21].

3.6 Technological Trend: From Organization-Based Knowledge Maps to Platform-Based Knowledge Graphs

Knowledge maps are a tacit knowledge acquisition technology that establishes dynamic connections between knowledge in different domains, externalizing experts' tacit knowledge and internalizing it as organizational knowledge resources to help organizations discover the value of their intellectual assets [22]. Traditional knowledge management emphasizes the externalization and management of organizational knowledge assets, identifying the entire organization's knowledge system through systematic auditing. Knowledge maps serve as a navigation system displaying market capital, structural capital, innovation capital, and human capital in knowledge assets, showing the location, ownership, usage methods, and value of different knowledge and revealing their internal structures and dynamic connections, thereby guiding and leveraging the maximization of organizational knowledge asset value. However, traditional knowledge maps, centered on people and documents, have limitations in revealing the breadth and depth of knowledge assets. In the digital economy era, the scope, scale, and types of knowledge assets for platform-based enterprises and their stakeholder groups continue to expand, making knowledge map methods unable to cover all knowledge elements. Knowledge graphs, by contrast, use algorithms, machine learning, graphics, information visualization, information retrieval, image recognition, and speech recognition to visually display the core structure, evolution, and overall architecture of people, equipment, products, and processes, providing a basis for systematic management and decision support of network platforms. The concept of knowledge graphs was first proposed in 2000 and developed and used by Google in 2012 as a large-scale semantic network. While traditional knowledge maps rely more on expert experience rules and are limited to domain-specific data, knowledge graphs expand with massive entity data and relationship data from the Internet. In the digital economy era, benefiting from massive data, powerful computing capabilities, and cloud computing technologies, large-scale, high-quality knowledge bases can now be automatically constructed to meet the needs of large-scale open applications in the Internet era.

In the digital economy era, knowledge as the most important operant resource has become the core asset for organizations to build competitive advantages. However, our understanding of the challenges in concepts, systems, technologies, and methods for knowledge management in this era remains at a preliminary stage. On one hand, knowledge management is becoming more difficult, with higher user requirements. The growth and dynamic changes of massive data pose higher demands on data acquisition and integration, making heterogeneous integration and data mining critical and requiring higher precision, real-time capability, and accuracy in the transformation from data to information to knowledge. On the other hand, existing knowledge management needs

continuous technological updates and active exploration of the roles of human-computer interaction and artificial intelligence. To address these challenges, greater investment in human and material resources is needed, along with multidisciplinary expert collaboration to jointly build a knowledge management system adapted to the digital economy era.

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Author Contributions

Dong Xiaoying: Responsible for research framework, core ideas, and writing revision.

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Cao Tuantuan: Responsible for writing Parts 3 and 4.

Note: Figure translations are in progress. See original paper for figures.

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