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Collaborative Operation Model and Simulation Analysis of the Knowledge Value Chain for Digital Literature Information Resources (Postprint)

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Abstract

[Purpose/Significance] By introducing knowledge innovation as a dependent variable into the value chain of digital literature and information resource production, this study analyzes the interaction principles among various actors within the value chain, thereby clarifying the existing problems and development directions in the construction of China's current digital literature and information resource guarantee system. [Method/Process] The system structure of knowledge production in digital literature and information resources is analyzed through the value chain model, and system dynamics model simulation, simulation analysis, and sensitivity analysis are conducted using Vensim PLE software. [Results/Conclusion] Overall social knowledge innovation exhibits the highest sensitivity to knowledge acquisition costs and knowledge sharing. In China's current digital literature and information resource production, publishers endow high knowledge added value but suffer from low dissemination efficiency, while data providers achieve high dissemination rates but lack sufficient knowledge added value, leading to a situation of high costs and transformation difficulties. Therefore, a reconstruction of the literature and information resource guarantee system is required.

Full Text

Collaborative Operation Model and Simulation Analysis of Knowledge Value Chain for Digital Document Information Resources

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Abstract: *[Purpose/Significance]* This study introduces knowledge innovation as a dependent variable into the production value chain of digital document information resources to analyze the interaction principles among various actors in the value chain, thereby clarifying existing problems and development directions in China's current digital document information resource guarantee system construction. *[Method/Process]* Using the value chain model, we analyze the systematic structure of knowledge production in digital document information resources and conduct system dynamics model simulation through Vensim PLE software for simulation analysis and sensitivity analysis. *[Result/Conclusion]* Social knowledge innovation is most sensitive to knowledge acquisition costs and knowledge sharing. In China's current digital document information resource production, publishers provide high knowledge added value but suffer from low dissemination efficiency, while data merchants achieve high dissemination rates but insufficient knowledge added value, resulting in high costs and transformation difficulties. Therefore, reconstruction of the document information resource guarantee system is necessary.

Keywords: document information resource guarantee system; system dynamics; value chain; digital publishing

With the development of information technology, digital documents have become an important component of China's document information resource guarantee system. Through digital technology, traditional document information resources undergo content editing and processing, relying on network dissemination of digital content products. The main characteristics include digital content production, digital management processes, digital product forms, and networked dissemination channels [1]. Today, China's document information resources show a rapid growth trend, and the related digital publishing industry has gradually achieved two-way expansion of business and market along with internet development, providing a stable platform and audience for China's digital document information resource guarantee system. However, the most prominent contradiction remains between platform-side data merchants and library representatives on the user side. As early as 2010, China witnessed a boycott against significant price increases by foreign data merchants, which gained high attention in the international library and information community. In recent years, criticism from user groups represented by universities has become increasingly intense, with local political advisors submitting proposals against continuous database price increases and the state launching anti-monopoly investigations, further bringing conflicts in the digital document information resource industry to public attention.

For these contradictions, Chinese academia has paid attention for many years. Early researchers emphasized the monopoly position of foreign data merchants in the supply chain, arguing that individual publishers or users lacked bargaining power [2-3]. As domestic data merchants developed, scholars recognized that both domestic and foreign data merchants relied on their monopolistic positions to arbitrarily raise prices, shift copyright disputes, and hinder academic

exchanges, damaging creators' enthusiasm and impeding the stable development of China's document information resource guarantee system [4]. However, other scholars argue that conflicts among digital document information resource actors relate to China's status as an emerging database market where development models remain imperfect, and that misunderstandings arise from insufficient understanding of each other's value production models [5]. Undisputedly, all actors in the digital document information resource guarantee system share an interdependent, symbiotic relationship, and conflicts should seek balance between commercial market interests and academic public welfare.

Overall macro-level research from an industrial perspective remains scarce in China. Using the search query "digital document information resources" in CNKI yields 752 papers. Co-occurrence analysis shows "library" as the second most frequent term (92 occurrences), while other actors appear fewer than 15 times. In other words, Chinese research on the digital document information resource guarantee system primarily focuses on libraries as user representatives, lacking grasp and analysis of overall industrial structure and unclear research on actors' behavioral motivations and game equilibrium points. In research proposals for reconstructing China's document information resource guarantee system, Professor Ye Jiyuan argues that current research inadequately examines guarantee subjects, concentrating 视野 on university libraries while insufficiently attending to other value production actors, resulting in fragmentation and independent operation among actors [6]. Therefore, clarifying the industrial structure and value logic of digital document information resources and conducting systematic analysis from a multi-actor, multi-element market perspective can provide different perspectives for related research.

3. Knowledge Value Chain System for Digital Document Information Resources

To clarify the interest principles and value composition in the digital document information resource guarantee system, we introduce the value chain concept to describe the resource production process. American scholar M.E. Porter first proposed the "value chain" concept in his book *Competitive Advantage*, considering it a combination and dynamic process of value-creating activities. In early modern enterprise development, Porter classified valuable activities into "primary activities" and "support activities," roughly distinguished by direct participation in product value production. With network economy development, scholars increasingly proposed virtual value chain concepts, such as V. Grover and T.C. Lawton emphasizing virtual activities that create added value in traditional value chain activities [7-8].

After introducing the value chain concept, we can hypothesize that the digital document information resource industry is a value creation process centered on literature resource digitization, where the actual value generated resides in the knowledge contained within digital document information resources. Taking content authors, publishers (copyright holders), and data merchants (platform

operators) as the main participants in digital document information resource production, the actual production value chain is: content authors output substantive content, publishers obtain copyright through publication, data merchants acquire authorization from publishers for technical processing and provide corresponding digital services, finally feeding back to content authors [9]. However, from a virtual value chain perspective, with knowledge as the primary production factor and knowledge innovation as the common interest driver among actors, the physical value chain serves knowledge production. The original publishing production value chain logic is replaced by knowledge value chain logic, simulating a value cycle of knowledge acquisition, knowledge output, value export, and knowledge re-acquisition. The specific knowledge value chain is shown in Figure 1 [Figure 1: see original paper].

As shown in Figure 1, when knowledge serves as the primary product, its basic value is created by authors. However, as a knowledge product, literature resources do not complete their value shaping upon output but require disciplinary review and academic norm processing. Therefore, on the digital literature resource value chain, authors and publishers form an upstream-downstream production relationship with similar interests. After authors submit manuscripts to publishers or publishers solicit contributions, publishers conduct review and editorial processing, thereby imparting complete knowledge value. Translating this series of value conversions into actual economic behavior, authors' original creative value corresponds to royalties paid by publishers—the two are not directly equivalent, but royalties reflect publishers' selection preferences for digital literature resources. Publishers' review and editorial processing activities can be viewed as knowledge value services provided to authors, with value expressed as page charges collected by publishers—similarly, page charges cannot directly correspond to the actual value of these services. Additionally, to cope with the digital wave, most publishers currently adopt self-built websites to expand audience reach and promotional channels, with some even adopting joint intensive models for digital publishing and resource integration.

Early data merchants functioned more as resource integrators, obtaining digital copyrights of literature information resources from numerous publishers on exclusive or non-exclusive bases, conducting data integration and processing, then commercial promotion and pricing, finally providing paid services to literature users. Literature product users typically overlap significantly with authors who initially provided the resources—in fact, the author community constitutes the primary user group. User collective interests are represented by literature guarantee institutions in the document information resource guarantee system, including libraries at all levels, archives, literature information centers, government information centers, and various intelligence agencies. Through user usage data completing relevant feedback on literature resources, the knowledge activity of literature products drives new knowledge value and content generation, thereby completing the final knowledge value addition. Thus, the literature information resource publishing ecosystem under digital publishing roughly forms a complete knowledge value cycle, as shown in Figure 2 [Figure 2: see original

paper].

Based on the above analysis of the digital document information resource knowledge value chain and the proposed assumptions and model boundaries, we can map the causal relationship diagram of the digital document information resource knowledge value chain (see Figure 3 [Figure 3: see original paper]). The system contains three subsystems: content circulation subsystem, publisher value subsystem, and data merchant value subsystem. For example, the content circulation subsystem is driven by the entire digital publishing process, from “content creation \rightarrow publisher knowledge value stock \rightarrow data merchant knowledge value stock \rightarrow knowledge content product \rightarrow knowledge innovation stock,” using knowledge innovation stock as the main manifestation of digital document information resource knowledge value and simulating stock circulation based on the digital publishing production chain. Therefore, the content circulation subsystem is also the main causal loop in the entire knowledge value chain. The other two subsystems also have their own knowledge value circulation loops. The publisher value subsystem focuses on knowledge activity and format processing, influencing the other two subsystems through cost impacts. The data merchant value subsystem focuses on knowledge mining and promotion, further productizing literature information resources, enhancing service capabilities and attributes, and expanding social benefits. Both subsystems jointly provide continuous knowledge value injection for literature information resources through their respective value loops.

4. Model Construction

4.1 Model Assumptions and Causal Relationship Construction

As the digital document information resource industry is a complex multi-actor structure influenced by diverse market, social, and academic factors, exploring the internal drivers of the knowledge value chain requires constraining the model’s external boundaries and assumptions to ensure system operation. Therefore, we propose the following assumptions:

H1: Relevant actors’ knowledge value concentrates in literature information resources.

H2: Users of literature information resources are unified entities comprising content-creating authors and resource purchasers.

H3: Knowledge innovation stock is determined by knowledge processing, acquisition costs, social benefits, and knowledge content products.

H4: Publishers’ and data merchants’ net profits in digital publishing can be viewed as manifestations of literature information resource knowledge value.

H5: The total knowledge value of literature information resources follows a gradual, continuous growth pattern.

4.2 System Flow Diagram Model Construction

Through knowledge value chain logic description, we find that digital document information resources' main knowledge value is co-created by users and publishers, while data merchants primarily provide formal added value through data processing and platform ecology without directly participating in knowledge content value production. This internal production relationship can be analyzed in detail through system dynamics models.

Based on the above causal relationship diagram, we can simulate and draw the corresponding stock-flow model (see Figure 4 [Figure 4: see original paper]). The model uses three level variables (publisher knowledge value stock, data merchant knowledge value stock, knowledge innovation stock) and three rate variables (publisher knowledge value accumulation rate, data merchant knowledge value accumulation rate, knowledge innovation accumulation rate) to primarily describe the circulation pattern from digital resource publishing to dissemination and sharing, subsequently promoting knowledge innovation to knowledge reproduction. The model also includes three constants (journal distribution revenue, platform construction cost, database operation and maintenance cost), typically stable values formed through long-term development of corresponding actors. Several auxiliary variables supplement detailed influencing factors of each subsystem's impact on the overall model.

After determining system operation and feedback mechanisms, we need to conduct reasonable parameter settings for corresponding variables to reflect reality through model operation parameter interactions and feedback. Therefore, we adopt a combination of expert interviews, literature reference [10-11], and relevant enterprise data collection to assign values to model parameters. Since actual system influencing factors are complex and diverse, and many parameters are difficult to quantify precisely, we consulted two academic experts in library and information science and two industry experts in digital publishing to conduct descriptive data assignment for difficult-to-quantify parameters, ensuring logical relationships and stable parameter changes. The main parameter assignments for the digital document information resource dynamics model are shown in Table 1 .

5. Model Simulation and Analysis

After completing modeling and assignment, we conducted reality tests and dimensional consistency tests on the model using Vensim PLE software. Test results indicate that all subsystem units are consistent, the model can operate effectively, and the model structure possesses rationality.

5.1 Model Simulation Analysis

Using Vensim PLE for simulation, we set the simulation period at 6 years, time unit as 1 year, step size as 1 year, and initial value as 1. Simulation results

are shown in Figures 5 [Figure 5: see original paper]-8 [Figure 8: see original paper]. The simulation results reveal:

- (1) Knowledge value of actors in the digital document information resource value chain shows steady overall growth. Knowledge innovation and publisher knowledge value development curves are similar, requiring a relatively long development period before significant value growth appears, while data merchant value development curves are smoother with more stable growth. However, data merchant costs consistently exceed revenues, and data merchant revenues even experience a period below publisher revenues, resulting in negative net profit growth. In the current simulated environment, relying solely on digital publishing models of literature information resources cannot generate revenue sufficient to cover costs for data merchants. In reality, this often leads to users complaining about data merchant price increases while data merchants struggle with high costs, prompting many to actively develop other business content and expand profit directions for existing knowledge value.
- (2) Figure 5(a) shows that publisher costs and revenues both require a relatively long flat period before growth, but the growth trend is stable with accelerating growth rates later. This is reflected in similar trends in publisher knowledge value stock and accumulation rate. Overall, publisher revenues significantly exceed costs with positive net profit growth. Data merchant costs and revenues also show gradual growth, but data merchant costs remain higher than revenues throughout, with negative net profit growth.
- (3) Figures 5(b) and 5(c) show that knowledge innovation value accumulation trends are more similar to publisher knowledge value accumulation, requiring value accumulation during the first three simulation years, gradually increasing in the following two years, and showing rapid growth in year 6. Data merchant growth rates are relatively stable and continuously rising. In terms of total knowledge value stock, data merchants possess absolute advantage, while knowledge innovation value stock, though lower, shows the highest growth rate later, demonstrating value accumulation under a benign value chain.

5.2 Model Sensitivity Analysis

Sensitivity analysis in system dynamics involves changing fixed parameter values to observe their impact on overall system operation, thereby reflecting different parameters' roles in the system. This model contains four constants: peer review level, platform construction cost, website operation and maintenance cost (unified as website operation cost for illustration convenience), and database operation and maintenance cost. We use these four constants as sensitivity analysis parameters, adjusting values into high and low scenarios. Specific parameter settings are shown in Table 2 .

5.2.1 Peer Review Level Impact on Knowledge Value Stock Figure 6 [Figure 6: see original paper] simulates peer review level's impact on knowledge value stock for publishers, data merchants, and knowledge innovation actors. Peer review level shows minimal impact on data merchant knowledge value but significantly affects publishers and knowledge innovation in later simulation stages. Notably, before year 5, publisher knowledge value stock under high peer review level is slightly lower than under low peer review level, which can be understood as publishers integrating knowledge value in early stages where high-level peer review mechanisms actually constrain knowledge value scope to some extent. However, with benign operation of high-level peer review mechanisms, both publisher knowledge value stock and knowledge innovation stock show high-speed growth in year 6. Peer review, as the main knowledge injection contributed by publishers to literature information resources, is crucial for both publishers and social knowledge innovation. In early development stages, data merchants focus more on data integration and dissemination, unable to inject corresponding knowledge value into literature information resources, resulting in limited growth points for their knowledge value stock development.

5.2.2 Platform Construction Cost Impact on Knowledge Value Stock Figure 7 [Figure 7: see original paper] simulation results show that publisher platform construction cost has very limited impact on data merchants, with only slight increases in data merchant knowledge value stock under high construction costs. For publishers, platform construction cost changes are also not significant. During the simulation period, high platform construction costs bring lower knowledge value stock to publishers, only surpassing low construction costs at the end of year 6, indicating that high platform construction costs also require correspondingly long operation periods for publishers to achieve profitability. Notably, high platform construction costs do not bring effective growth to knowledge innovation stock; instead, knowledge innovation stock grows faster under low platform construction costs. The reason is that publisher platform construction onlineization provides more profit growth paths for publishers themselves but does not facilitate literature information resource openness and knowledge sharing. Therefore, when construction costs rise, value transmission to users is limited to cost increases without obvious knowledge value enhancement.

5.2.3 Website Operation and Maintenance Cost Impact on Knowledge Value Stock Network operation and maintenance cost represents data merchants' investment in operating their literature information resource websites. Simulation results show publishers are not highly sensitive to data merchants' website operation investment, with slight decreases in publisher knowledge value stock as costs increase. Both data merchant knowledge value stock and knowledge innovation stock are significantly sensitive to website operation and maintenance cost changes, especially data merchants. When website operation costs increase, data merchant knowledge value stock shows substantial growth, indicating that knowledge sharing and dissemination are the most critical factors

in data merchant value increment. For knowledge innovation, increased website operation costs bringing higher knowledge exposure and usability can also effectively stimulate knowledge innovation stock growth.

5.2.4 Database Operation and Maintenance Cost Impact on Knowledge Value Stock Database operation and maintenance cost shows relatively low sensitivity coefficients, having almost no impact on publisher knowledge value stock. It shows an inverse relationship with data merchant knowledge value stock, meaning data merchants' investment in database operation is almost unable to generate profit. Database operation as a cost component is heavier but essential for data merchant operation, confirming the simulation results for data merchant costs in Figure 5(a). However, for overall knowledge innovation stock, database operation and maintenance costs have certain positive effects, becoming a form of knowledge addition that data merchants provide for digital document information resource production.

6. Conclusions and Recommendations

Through collaborative simulation of China's literature information resource digital publishing value chain, we can basically observe the current commercial operation of digital document information resources:

- (1) The collective composed of users is also the main source of innovation for digital document information resources. This collective has high requirements for digital document information resource content quality and high sensitivity to knowledge sharing and acquisition costs. Therefore, a benign literature information resource guarantee system should ensure convenient, efficient user knowledge acquisition while minimizing costs to promote social knowledge innovation accumulation. Users and publishers have relatively consistent requirements for knowledge innovation, so their value accumulation rates are very close. However, in early development stages, data merchants participate insufficiently in content value production and are insensitive to knowledge innovation requirements, resulting in different interest orientations from users and publishers—this constitutes the main reason for current digital document information resource distribution conflicts.
- (2) Publishers gain more development space in the digitalization of literature information resources. Compared with traditional profit models, digital literature information resource production brings diversified profit models to publishers. However, since China's publishers are smaller than Western alliance publishers, independent digital construction profits cannot offset costs, leading to long development cycles and low value sensitivity for online platform construction. Publishers' strength in knowledge dissemination and sharing is weak, and building online platforms cannot effectively enhance social knowledge innovation but indirectly increases knowledge innovation costs.

- (3) The huge digital literature market integration creates enormous cost pressure for data merchants' economic operation, requiring them to seek profits through market pricing, thus creating conflicts with public welfare knowledge innovation demands. In digital document information resource production, data merchants struggle to provide sufficient knowledge value addition, with digital literature traffic being their main value growth point.

In summary, China's current digital document information resource value chain contains many disharmonious factors. On one hand, market-driven actors inevitably prioritize their own economic interests. On the other hand, the lack of strong benign development guidance leads to dilemmas and corresponding demands for each actor.

Addressing the above situation, we propose solutions through the value chain perspective:

- (1) Promote resource reorganization among digital document information resource market actors, strengthen supervision to avoid market monopoly, and enhance user bargaining power. When digital document information resources are monopolized by a few actors, knowledge innovation from competition loses value. If actors in the value chain cannot reach consensus on value production, conflicts inevitably arise. Reorganizing market actor resources can reshape production actors' interest directions and reestablish a document information resource guarantee system with knowledge innovation as the core goal.
- (2) Publishers need to strengthen cooperation, promote resource integration, and enhance digital document information resource dissemination and sharing capabilities. Due to small publisher size, cost risks faced during digital transformation may be transferred to knowledge value stock. When publishers form benign alliances, they can effectively stimulate digital document information resource dissemination vitality and generate new economic value.
- (3) Data merchants need to promote product transformation from simple digital literature integration and marketing to deep digital document information resource knowledge mining. Current major data merchants show obvious tendencies toward knowledge service transformation, with CNKI, Wanfang, and other large data merchants beginning to deeply develop independent knowledge products, moving from traffic-based profit to knowledge-based profit.

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