

System Dynamics Analysis of the Implementation Path for Sustainable Development of Government Open Data Ecosystems: Postprint

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Abstract

[Purpose/Significance] Sustainable development of the government open data ecosystem provides sufficient guarantee for data value realization; therefore, exploring its implementation pathways is of great significance. [Method/Process] Grounded in information ecosystem theory, this study identifies the influencing factors of sustainable development of the government open data ecosystem, constructs a theoretical model for sustainable development of the open data ecosystem, and proposes implementation pathways based on Vensim PLE simulation results. [Results/Conclusions] Simulation results reveal that in the sustainable development process of the government open data ecosystem, legal policies exert the greatest impact, while consumer information literacy, the combination of open data platform development level and data innovation capability, organizational management level, and the combination of capital investment and technical support have significant impacts. Finally, specific implementation pathways to promote sustainable development of the government open data ecosystem are proposed.

Full Text

Preamble

System Dynamics Analysis of Sustainable Development Pathways for Government Open Data Ecosystems

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Abstract: [Purpose/Significance] The sustainable development of government open data ecosystems provides essential guarantees for realizing data value, making the exploration of implementation pathways critically important.

[Method/Process] Grounded in information ecosystem theory, this study identifies factors influencing the sustainable development of government open data ecosystems, constructs a theoretical model for sustainable development of open data ecosystems, and proposes implementation pathways based on Vensim PLE simulation results. [Result/Conclusion] Simulation results reveal that legal policies exert the greatest influence on sustainable development, while combinations of consumer information literacy, open data platform development level, data innovation capability, organizational management level, and capital investment with technical support also demonstrate significant impacts. The paper concludes by proposing specific pathways to promote sustainable development of government open data ecosystems.

Keywords: government open data; information ecology; value realization; sustainable development; system dynamics

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The 2009 Open Government Directive marked the U.S. government's initiation of nationwide data openness, sparking a global government data openness movement. While governments aim to promote societal utilization of data resources to create substantial value, they have overlooked how data value realization depends on sustainable development of open data ecosystems. Government data openness is a complex, dynamic process involving multiple stakeholders and stages, where absence of any participant or stage may impede ecosystem development. This study employs system dynamics modeling and simulation to identify key influencing factors and the synergistic advantages of multi-factor combinations, proposing sustainable development pathways to enhance government open data efficiency, value realization, and sustainability.

2 Theoretical Foundation and Related Research

2.1 Information Ecosystem Theory

In ecology, an ecosystem refers to the mutual influence and constraint between organisms and their environment, forming an organic whole through energy transfer within a certain space to achieve a relatively stable state. Ecosystems are open systems that require continuous energy absorption and transfer to maintain virtuous cycles; otherwise, they lose balance. Information ecosystem theory extends ecological concepts to information science, first proposed by Harvard doctoral scholars T.H. Davenport and L. Prusak in the 1990s to analyze information science problems from an ecological perspective. Building on this work, B. Nardi defined information ecology as a system formed by people, practices, values, and technology interacting in specific environments, emphasizing that technology serves human activities rather than being the focus, and noting strong correlations and dependencies among ecosystem components. Chinese scholars simplified the theory, identifying information, information actors,

and information environment as the three fundamental elements of information ecosystems.

Based on domestic and international research, this study defines information ecosystems as relatively stable systems where information actors conduct information transfer within specific information environments, establishing interdependent relationships among the three components. Such systems follow the same energy transfer laws as natural ecosystems. Information ecosystem theory provides a new perspective for government open data ecosystem research and is crucial for model construction.

2.2 Government Open Data Ecosystem

The concept of government open data ecosystems was introduced by Open Knowledge Foundation founder R. Pollack in 2011, who argued that basic data processing models should transform into dynamic data circulation systems. Subsequently, D. Ponte categorized ecosystem actors into data providers, data intermediaries, data enablers, and data consumers according to the data value generation process. M. Mahdi et al. viewed government open data ecosystems as closed-loop systems of interoperable entities forming in open data environments. Shi Yuanyuan proposed that government organizations are core actors in open data ecosystems, working to establish continuous partnership networks among user needs, open data, and application developers. This study operationalizes information actors as data providers, data transmitters, data utilizers, and data consumers, with information environment as the data environment and information as open data. Following the World Bank's interpretation of relationships between data utilizers and intermediaries, this paper replaces Ponte's "data intermediary" with "data utilizer" to better describe actor characteristics.

Synthesizing these perspectives, this study defines government open data ecosystems as stable, sustainable dynamic circulation systems centered on open data and carried by data transmitters, formed through interactions among data providers, data utilizers, data consumers, and the data environment during processes of data opening, utilization, consumption, feedback, and value realization.

2.3 Related Research

2.3.1 Government Open Data Research International research on government open data began earlier with more theoretical achievements, focusing on impacts on knowledge economies, case studies, value research, and policy analysis. Building on this foundation, domestic scholars have advanced research on platform construction, utilization effects, value realization, security and privacy, and legal frameworks. Research methods show diversification trends, employing comparative analysis, empirical analysis, statistical analysis, and literature review methods. S. Stuti compared open government data frameworks across six Middle Eastern countries, identifying obstacles in dataset utilization. Xiang

Liling et al. analyzed operational mechanisms and openness levels of platforms in the U.S., EU, and Australia, comparing domestic and international platform construction differences. M. Yi conducted statistical analysis of different data formats and completeness to explore key data quality issues. Gu Jiaqi et al. examined connections between service quality and public demand, constructing a “quality house” model for open data services to identify optimal solutions for service quality improvement.

System dynamics methods, widely used in natural sciences, have been increasingly applied to government open data research, aligning with the field’s interdisciplinary development trend. Li Xiaoyan et al. used system dynamics to explore key factors affecting government information disclosure. Duan Yaoqing et al. analyzed main influencing factors across the entire lifecycle of government open data from a systems perspective, constructing a lifecycle system dynamics model. Ma Haiqun et al. analyzed factors affecting government data openness and security from a COVID-19 perspective, establishing a system dynamics model based on a “goal-user” two-dimensional framework. System dynamics provides new research tools for investigating complex mechanisms in government open data research.

2.3.2 Government Open Data Research Based on Information Ecosystem Theory Applying information ecosystem theory to government open data represents a novel approach. Tong Linjie et al. constructed a government data openness information ecosystem, analyzing dilemmas and causes of data security and privacy protection and proposing corresponding safeguards. Xia Yiqian summarized requirements and characteristics of grassroots government data and designed governance architecture. Zhao Xuyao et al. proposed the concept of government open data information chains based on information ecology chains, elaborating their essence and types. Chen Hongmei et al. established libraries’ functional positioning in government open data chains by examining concepts, structures, and dynamic mechanisms. Although these achievements did not specifically introduce information ecosystem theory into dedicated government open data research, they laid foundations for deeper development.

In summary, government open data has become a research hotspot with rich methodological and outcome diversity. However, ecosystem research remains limited to influencing factors without deep exploration of mechanisms, particularly the interactive effects of various factors on the system. Information ecology perspective-based research is also scarce, and no studies have applied system dynamics to government open data ecosystems. This research aims to explore relationships and influence degrees among factors in government open data ecosystems and propose sustainable development pathways.

3 Model and Influencing Factors for Sustainable Development of Government Open Data Ecosystems

Based on ecosystem components and their interactions, this study constructed a sustainable development structural model for government open data ecosystems, shown in Figure 1 [Figure 1: see original paper]:

The model follows information ecosystem theory's three components: information (open data), information actors, and information environment. Open data serves as the “energy” sustaining model operation, determining ecosystem sustainability through data circulation. Information actors include data providers, transmitters, utilizers, and consumers—not specifically individuals but all entities involved in information activities—representing the model's core that determines behavioral patterns. The information environment comprises internal and external environments including legal, economic, organizational, and technical environments, providing objective conditions for normal operation.

This study identifies sustainable development influencing factors by explaining how model elements participate in processes from data opening through value realization.

3.1 Information Actors

3.1.1 Data Providers Government departments, managing massive data resources in public affairs, are the primary data holders and providers. Data providers are defined as provincial, municipal, and local government departments. During open data processes, government departments desensitize raw data, prioritize data in livelihood areas such as education, housing, and health-care, ensure data security and quality, and reduce data dormancy. Additionally, data utilizers and consumers express data needs through open platforms, significantly influencing government departments' openness enthusiasm. As demands increase, so does data volume. Therefore, government willingness to open data is a key factor affecting the entire system.

3.1.2 Data Transmitters Data transmitters bridge data providers with data utilizers and consumers, substituting for D. Ponte's “data enablers” and serving infrastructure functions. Government open data platforms provide data retrieval, acquisition, and interactive feedback services to participants through user-friendly interfaces, demand-oriented transferring open data from government to utilizers or consumers. Their interactive nature better reflects transmission characteristics. According to the 2020 Government Open Data Utilization Research Report, as of December 2019, 82.41% of China's government open data platforms were highly developed, more professional, and offered better user experience, representing the future development direction. Therefore, platform development level becomes an important factor influencing sustainable ecosystem development.

3.1.3 Data Utilizers Data utilizers develop various APP applications using government open data, including social livelihood, economic and commercial applications, research reports, and media products. Multiple types exist, such as data developers, enterprises, and technical groups, with enterprises representing the most important actors due to their strong data utilization and innovation capabilities. After data opening, ordinary citizens cannot directly use complex data obtained from platforms, particularly data-vulnerable groups, requiring enterprises to continuously improve utilization and innovation capabilities to process complex data, develop high-quality applications, and meet government and public needs, thereby achieving data value-added. Thus, utilizers' data utilization and innovation capabilities positively promote virtuous ecosystem operation.

3.1.4 Data Consumers The public represents the largest data consumers and the most important subject affecting value realization—the ultimate purpose of government data openness. Daily life shows growing public demand for livelihood data. The 47th China Internet Development Statistics Report indicates that as of December 2020, China's online government service users reached 843 million, accounting for 85.3% of all internet users, demonstrating massive demand for public services and online entertainment data. Public usage demand drives participation in open data processes, feeding usage opinions back to utilizers to prompt development of more consumer-oriented products. Utilizers then feed consumer demands back to providers, encouraging more data openness. Consumers can also interact directly with providers to promote demand-aligned data opening. Throughout this process, feedback drives data value realization and ecosystem virtuous cycles. Additionally, public data sensitivity significantly affects utilization efficiency. Therefore, consumer usage demand, participation, feedback, and information literacy are non-negligible factors for sustainable development.

3.2 Information Environment

3.2.1 Internal Environment The internal environment significantly influences sustainable development, including economic and organizational environments. In the economic environment, capital investment ensures open data platform establishment and incentivizes data utilizers, thereby affecting government data openness and forming the material foundation for sustainability. Good organizational management provides effective data governance, fosters strong organizational culture, and offers lasting motivation for members. Therefore, capital investment and organizational management level support orderly government open data work, facilitate value realization, and guide sustainable ecosystem development.

3.2.2 External Environment Technical support and legal policies provide guarantees for sustainable development. Legal policy gaps affect government willingness to open data and societal demand. Although China has issued

regulations like the Government Information Disclosure Regulations and Big Data Development Action Outline, legislation on privacy security and data sharing requires further improvement, and no national-level laws specifically target government data openness. The technical environment significantly impacts ecosystems—advanced data technologies such as big data and AI provide technical support for government data collection, publication, and maintenance, ensuring higher-quality data openness. Similarly, in data utilization and consumption stages, technological development drives emerging businesses and industries, stimulates social demand, and prompts further government data openness, benefiting ecosystem sustainability.

3.3 Information

Information refers to open data that can be freely accessed, obtained, utilized, and shared by anyone, following eight principles including completeness, originality, and accessibility. In government open data ecosystems, open data is the crucial object and energy sustaining system operation. Data circulation is essential from publication to value realization, ensuring system operation and interconnections among components. During publication stages, effective data capacity determines data quality provided to utilizers; during utilization stages, data acquisition and usage volumes affect application development quantity, influencing consumer usage and value realization. Therefore, effective data capacity, utilizer data acquisition volume, and utilizer data usage volume all significantly impact ecosystem virtuous cycles.

Through further quantification of model elements and the influencing factors discussed above, the final influencing factors are identified in Table 1 .

4 System Dynamics Model for Sustainable Development of Government Open Data Ecosystems

Government open data ecosystems contain multiple variables and dynamic feedback loops with complex causal relationships. System dynamics studies information feedback systems and represents an interdisciplinary approach to understanding and solving systemic problems, making it suitable for investigating complex system structures and dynamic relationships. Therefore, system dynamics modeling is appropriate for this research.

4.1 Causal Loop Diagram Construction

Based on Table 1 factors, a causal loop diagram for sustainable development of government open data ecosystems was constructed (Figure 2 [Figure 2: see original paper]) to present logical relationships and feedback loops among influencing factors. In causal diagrams, positive relationships (where one variable's increase causes another's increase) are marked with “+” arrows, while negative relationships use “-” arrows.

Figure 2 reveals an important causal feedback loop: Government Data Openness → Effective Data Capacity → Utilizer Data Acquisition Volume → Utilizer Data Usage Volume → Application Development Quantity → Consumer Data Application Usage Volume → Consumer Usage Feedback → Open Data Value Realization → Government Willingness to Open Data → Government Data Openness. This loop clearly describes each link in sustainable development and demonstrates value realization's central position in the system.

4.2 System Flow Diagram Construction

Causal diagrams emphasize logical relationships and feedback loops but cannot comprehensively display system elements and internal structures. Therefore, a system flow diagram was constructed (Figure 3 [Figure 3: see original paper]), containing 2 state variables, 3 rate variables, 13 auxiliary variables, and 7 constants (25 variables total). State variables (level/flow variables) represent accumulations, shown as rectangles; rate variables represent change rates, shown as valve symbols.

According to system dynamics principles, models emphasize structure over parameter estimation, as structure fundamentally reflects element interconnections. A causally correct model can produce realistic behavior as long as parameters fall within appropriate ranges. Following common research practices, initial parameters were adjusted through multiple simulation runs to finalize the model. Main equations and parameters, following open data transfer feedback sequence, are:

- (1) Government Data Openness = INTEG(Open Data Increase - Open Data Dormancy, 400), with initial value set at 400.
- (2) Open Data Increase = Government Willingness to Open Data × Guarantee Mechanism.
- (3) Open Data Dormancy = STEP(Government Data Openness × Open Data Dormancy Rate, 5). Dormancy occurs due to individual or other factors, simulated using STEP function beginning at time 5.
- (4) Government Willingness to Open Data = Open Data Value Realization × (1 - Data Security Risk) × Consumer Usage Demand. Willingness is determined by value realization, security risk (negatively correlated), and consumer demand (positively correlated).
- (5) Guarantee Mechanism = Technical Support × Legal Policy × Organizational Management Level × Capital Investment.
- (6) Open Data Value Realization = INTEG(Value Generation, 0), with initial value 0.
- (7) Data Security Risk = (1 - Technical Support) × (1 - Legal Policy). Technical support and legal policy are negatively correlated with security risk.

- (8) Consumer Usage Demand = DELAY1(Legal Policy \times Consumer Information Literacy, 15, 0). Demand formation requires time, simulated with material delay function DELAY1 for 15 time units.
- (9) Value Generation = SMOOTHI(Consumer Data Application Usage \times Consumer Usage Demand \times Consumer Usage Feedback, 2). Consumer feedback involves delays, simulated with information delay function SMOOTHI for 2 time units.
- (10) Consumer Data Application Usage = SMOOTHI(Application Development Quantity \times Consumer Participation, 2).
- (11) Consumer Usage Feedback = Consumer Application Usage \times 0.6.
- (12) Application Development Quantity = SMOOTHI(Utilizer Data Usage \times Data Innovation Capability, 5, 0).
- (13) Consumer Participation = Consumer Usage Demand \times 0.3.
- (14) Utilizer Data Usage = SMOOTHI(Utilizer Data Acquisition \times Data Utilization Capability, 5, 0).
- (15) Data Utilization Capability = WITH LOOKUP(TIME([(0,0)-(60,1)], (0,0.6), (60,0.9))). Capability improves over system operation, captured with lookup function showing 30% linear growth over 60 time units.
- (16) Utilizer Data Acquisition = SMOOTHI(Effective Data Capacity \times Platform Development Level, 1, 0). Data acquisition involves screening, simulated with first-order information delay.
- (17) Effective Data Capacity = SMOOTHI(Government Data Openness \times (1 - Open Data Dormancy Rate), 2).

Since system dynamics simulation focuses on collaborative trend evolution rather than precise values, data processing does not affect overall results. However, to realistically simulate reality, utilizer data innovation capability index was substituted with 0.75 from Shanghai Open Data Innovation Competition's data fusion utilization degree. Open data dormancy rate was set at 0.02 based on open data reports and academic research. Other data sources are not enumerated due to space limitations. Technical support, legal policy, organizational management level, capital investment, and platform development level use RANDOM UNIFORM distribution functions between [0,1]. Given numerous information flows with inevitable delays, information delay function SMOOTHI is uniformly applied.

5 System Dynamics Simulation and Analysis

5.1 Model Validity Testing

Following the criterion of easily observable variables with readily comparable simulation and reality results, Government Data Openness, Utilizer Data Acqui-

sition, Application Development Quantity, and Open Data Value Realization were selected as observation objects. The system flow diagram model (Figure 3) was simulated using Vensim PLE with 60-month duration and 1-month time steps. Main variable simulation results under 既定 parameters are shown in Figure 4 [Figure 4: see original paper].

5.1.1 Static Validity Testing Through Four Main Variable Simulations

- (1) Figure 4(a) shows slow growth in government data openness during the first 30 months, maintaining relatively stable trends before rapid growth after month 30. This reflects conservative government attitudes during initial stages, with rapid growth later driven by enhanced awareness and supportive measures.
- (2) Figure 4(b) shows rapid growth in utilizer data acquisition during the first 12 months, then stabilization until month 30, followed by rapid growth. Early growth stems from enterprises utilizing abundant raw data; after multiple utilization rounds, acquisition entered a “dormancy period” before accelerating again due to improved overall environment.
- (3) Figure 4(c) shows rapid application development growth in early stages, stabilizing around month 21, then accelerating after month 36. Initial applications flooded the market but maintenance issues and immature smart tools caused stagnation; later, maturing technology and more participants drove rapid growth.
- (4) Figure 4(d) shows rapid value realization growth after month 18, indicating that more government data openness enables more acquisition, increasing application development and satisfying public demand, thereby facilitating value realization.

5.1.2 Dynamic Validity Testing Through Adjacent Variable Simulation Analysis

- (1) Figures 4(a) and 4(b) show early smooth government data openness growth corresponding to sharp acquisition increases, followed by similar trends. Early raw data consumption by enterprises caused acquisition spikes while openness increments remained modest; after 30 months, feedback from utilizers stimulated more openness, further driving acquisition.
- (2) Figures 4(b) and 4(c) show similar overall trends, but early application development growth points lag acquisition growth. This occurs because application development requires time for requirement confirmation, design, coding, and testing. After month 30, improved economic benefits and innovation capabilities drove acquisition growth, 同步推动 application development.

- (3) Figures 4(c) and 4(d) show application development surging early while value realization remained low until after month 20. Value realization requires time for awareness, atmosphere, and culture formation. Once public utilization reached critical mass, positive externalities emerged, driving a second boom in application development and value realization.
- (4) Figures 4(d) and 4(a) show similar trends, but smooth early openness did not immediately yield value realization due to weak awareness and insufficient environmental preparation. Over time, economic and social benefit feedback from value realization drove openness upward, accelerating value realization.

Simulation results demonstrate that main observation variables follow realistic patterns, confirming the structural model accurately depicts sustainable development evolution.

5.2 Scenario Simulation Analysis

Following ecosystem operation sequence, this study adjusted parameters for seven main variables (organizational management level, capital investment, technical support, legal policy, platform development level, data innovation capability, consumer information literacy) to analyze individual and combined impacts. Value realization serves as the internal driving force for sustainability, with all links working toward it while being influenced by it, maintaining ecosystem circulation. Therefore, Open Data Value Realization was selected as the core observation variable.

5.2.1 Single Variable Parameter Adjustment Simulation Results

In Figure 5, the “current” curve represents initial status, “current-” curves show results after 20% reduction, and “current+” curves show 20% increase results. Organizational management level, capital investment, and technical support show minimal changes, indicating weak individual influence. In contrast, legal policy, platform development level, data innovation capability, and consumer information literacy show substantial changes, indicating strong influence.

Figure 5 shows minimal parameter impact during the first 24 months; after 24 months, all “current-” curves weaken system effects similarly. However, “current+” curves diverge significantly. To analyze influence degrees, key point data from Figure 5 were compiled into Table 2 .

Table 2 comparisons reveal that at month 24, value realization quantities begin diverging, with Figure 5(d) increasingly surpassing Figure 5(g) in both value and growth rate, indicating legal policy’s stronger and deeper influence than consumer information literacy, especially in later stages.

Table 2 shows Figures 5(e) and 5(f) values are lower than Figures 5(d) and 5(g), indicating weaker influence. Figure 5(e) slightly exceeds 5(f) after month 24, suggesting platform development influence surpasses data innovation capability.

Thus, among four significant variables, legal policy exerts the greatest influence, followed by consumer information literacy, platform development level, and data innovation capability.

5.2.2 Combined Variable Parameter Adjustment Simulation Results

Given that some variables may not be significant individually but could be in combination, this study tested representative combinations: weak-weak (organizational management, capital investment, technical support), strong-strong (platform development, data innovation capability), and strong-weak (data innovation capability, capital investment).

Figure 6 [Figure 6: see original paper] shows simulation results. Figure 6(a) demonstrates that after month 45, combined adjustments produce significant impacts, with the three-variable combination (organizational management, capital investment, technical support) showing accelerating growth, indicating that combined elements more effectively increase value realization than single variables.

Figure 6(b) shows significant impacts emerging after month 24, with the platform development and data innovation combination (current2) performing most prominently, demonstrating synergistic effects when strong variables combine.

Figure 6(c) shows the strong-weak combination (data innovation capability, capital investment) exceeding strong individual variables after month 45, with widening gaps over time, indicating that strong-weak combinations produce positive effects and better achieve value growth.

In summary, combined variables promote data value growth more than single variables, with more elements producing stronger effects. Even weak-weak combinations show impact, and strong-strong or strong-weak combinations naturally produce more pronounced synergistic governance effects.

5.2.3 Simulation Results Summary

- (1) Legal policy has the greatest impact on sustainable development; consumer information literacy also significantly influences sustainability. Legal policies guarantee 良性 interaction among providers, transmitters, utilizers, and consumers, supporting participation and operation across ecosystem stages and determining value realization. Therefore, sound legal policies are the most effective implementation pathway. Higher consumer information literacy increases participation, intensifies government-public interaction, satisfies public needs, and facilitates value transformation.
- (2) The synergistic governance strategy of enhancing platform development and data innovation capability significantly impacts sustainability. As openness progresses, value realization feedback creates societal recognition of open data importance while factor maturity improves. Once ecosystems

sensitive to platform development perceive another strong variable's addition, synergistic effects accelerate value realization, forming an effective pathway.

- (3) Individual factors of organizational management, capital investment, and technical support have insignificant impacts because sustainability requires combined environmental factors. Only internal-external environment combinations produce significant value realization changes. These factors become significant when forming guarantee mechanisms for initial openness stages.
- (4) Internal environmental factors must combine with actor factors to function—for example, improving data innovation capability combined with capital investment produces significant impact. Therefore, pathway development should emphasize important factors while adopting “synergistic governance” concepts to leverage multiple factors' combined advantages.

6 Implementation Pathways

Based on simulation results and China's government open data practices, this study proposes the following pathways:

6.1 Accelerate Legal Policy Improvement for Open Data

Sound legal policies are crucial for value realization—successful open data in developed countries relies on comprehensive legal frameworks. Perfecting legal policies ensures smooth operation across all ecosystem stages and guarantees other factors' effectiveness. Governments should: (1) Clarify open data principles covering both opening and reuse stages, drawing on international experience to develop principles suited to China's context; (2) Enact data security and privacy protection laws focusing on national/social security and personal privacy, severely punishing crimes using open data; (3) Explicitly define open data scope, standards, quality, and objectives to guide implementation and ensure sound legal policy environments.

6.2 Enhance Data Consumer Information Literacy

Consumer information literacy affects public participation, which is essential for value realization. To improve literacy: (1) Increase publicity through WeChat, Weibo, and government websites to raise public awareness and participation; (2) Establish differentiated demand guarantee mechanisms considering age, education, and occupation differences, emphasizing platform-public interaction and providing personalized services like Shanghai's interactive management functions and human customer service.

6.3 Construct Government Open Data Innovation Mechanisms

Sustainable development requires innovation—macro-level innovation in capability and micro-level innovation in platform construction. Governments should: (1) Leverage multi-factor synergy, increase technology funding, guide innovation elements toward enterprises, ensure sustainable corporate investment, attract global talent, and support enterprise-university-research institution collaborations to establish innovation platforms and incubators; (2) Innovate platform functions and enhance user experience by providing prominent, convenient data guidance, platform interconnectivity, and inclusive functions such as application scenario guidance, cross-city platform links, and humanized interfaces for special groups; (3) Accelerate platform innovation by establishing national-level platforms to coordinate local portals and avoid fragmentation.

6.4 Improve Government Open Data Guarantee Mechanisms

Value realization requires multi-factor synergy. Organizational management, capital investment, and technical support form guarantee mechanisms that play coordinative, financial, and technical roles. Improvement measures include: (1) Organizational guarantees: Establish specialized data management agencies to coordinate multiple departments, clarify divisions, and cooperate with third parties for supervision; (2) Financial guarantees: Increase funding for platform construction and mobile technology, sustain investment in big data, AI, and cloud computing, and provide financial support to encourage enterprise product development; (3) Technical guarantees: Cultivate data talent, utilize new information technologies like WeChat and Weibo for promotion, and establish government-enterprise collaboration mechanisms for technical complementarity.

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

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