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REVIEW ARTICLE

Analysis of Grassroots Grid-based Governance in the Context of Big Data

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ABSTRACT

This study evaluates the feasibility and optimization mechanisms of grid-based grassroots governance in China under the influence of big data technologies. By integrating a four-layer governance simulation model—comprising infrastructure, data support, application support, and service layers—with stratified community sampling in Hangzhou, the research adopts a mixed-methods approach combining SPSS, ArcGIS, AnyLogic, and NVivo analyses. Findings reveal that grid-based governance significantly improves infrastructure provision, data accuracy, service responsiveness, and community satisfaction. The model facilitates more efficient policy implementation, enhances party-building integration, and strengthens localized service delivery. This study concludes that grid-based governance, supported by institutional alignment and big data, offers a scalable and human-centered solution for modernizing grassroots administration in China.

Contribution/Originality: This study contributes to the existing literature on grassroots governance by building a hierarchical big data-driven model for grid-based management. The study is one of very few that integrates infrastructure, digital data systems, and real-time analytics to enhance localized public service delivery in China.

1. Introduction

In the current urban development process, most of the grassroots governance is coordinated by the government planning department, but with the continuous development of information technology, more and more contents appear in the governance work, and in the actual governance link often appears inconsistent with the original solution, and the coordination is not synchronized, which makes the grassroots governance disconnected from the development of society (Song et al., 2023). On the one hand, there is a lack of communication between the two, the rapid development of information technology does not give grassroots governance much opportunity to think, and grassroots governance does not feed its own problems well into the big data; on the other hand, the development ideas of the two are different, information technology will consider more the overall coordinated development, focusing on the macro issues of

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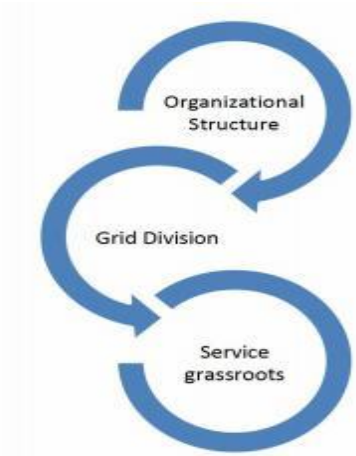
social progress and human development, while grassroots governance is more important to its own "acre of land" (Huang et al., 2020), pursuing the rapid development of grassroots people and highlighting the effectiveness. Therefore, in the actual development process, there will be disconnected phenomena such as slow development of grassroots governance or underutilization of information technology. Specifically, the overall framework of grassroots governance is shown in Figure 1.

Figure 1: Flow chart of grassroots governance



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At the same time, the coordinated development of grassroots governance and economy is a long-term and arduous project, and it is difficult to achieve stable and coordinated development through short-time transformation, thus mature theories are needed for guidance and transformation according to mature programs. But at present, there is no complete unified idea of grassroots governance and urban development in China, often only some regional governments suddenly think of coordinating the development of the two and promulgate relevant laws and regulations, or short-term policies in response to the inspection of higher authorities and feedback from the grassroots, the so-called "face-saving projects" (Heberer & Senz, 2011). These are the concrete manifestations of the lack of maturity of grassroots governance and urban development in the region.

To improve the legal standard of grassroots governance, grid-based governance—as a core national project—should be implemented under the support of relevant laws and regulations (Yue, 2021). At present, there are many relevant laws and regulations in China, both in terms of urban governance and coordinated economic development, and a considerable number of laws and regulations have been promulgated in recent years to provide certain guidance for the coordinated development of both, so as to improve their legal standardization. As shown in Table 1, this paper cites several laws and regulations—many of which are common to both domains—that provide strong legal regulation for the grassroots governance under study.

To enrich the diversity of grassroots governance, it is essential to acknowledge that its planning content shares many similarities with that of urban development (Tu & Long, 2017). Urban development mainly includes the planning of villages and towns within the city, construction of building projects, division of residential land for commercial use, and construction of public facilities, etc. The use of landis part of it, and the use of related landis often regulated when planning for urban development is carried out. Although grid-based governance may seem to refer only to the regional governance of grassroots

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organizations, in fact, when the state carries out the overall planning of grid-based governance, it will clearly count the uses, types and locations of various infrastructures in the region, such as dividing land into agricultural land, construction land and unused land, for which the state will strictly limit the conversion of agricultural land into construction land, control the total amount of construction land, and implement special protection for arable land (Liu et al., 2017). The state will strictly restrict the conversion of agricultural land to construction land, control the total amount of construction land, and implement special protection for farmland. Such similar planning contents make the grid-based governance more close to the development of the city, and this paper can also provide reference and reference for the actual evolution of grassroots governance from more perspectives, complementing each other, improving each other, and increasing the diversity of contents.

Table 1: Laws and regulations related to grass-roots grid-based governance

Classification	Grassroots Governance	Gridding
Name of Laws & Regulations	Law of the People's Republic of China on Land Management	Law of the People's Republic of China on Urban and Rural Planning
	Regulations on the Implementation of the Land Administration Law of the PRC	Regulations on Urban Planning
	Regulations on the Protection of Basic Farmland	Construction Law of the People's Republic of China
	Measures for the Implementation of the Regulations on Land Reclamation	Measures for the Preparation of Urban Planning
	Measures for the Administration of Rural Residential Bases	Measures for the Administration of Grassroots Governance Master Plan

Source: Compiled by the author

In general, the purpose of grassroots governance is to better allocate the resources in the region, to carry out integrated planning according to the system of distribution according to labor in China, to reasonably use the limited resources in various industries such as food, clothing, housing and transportation in the region, and to give priority to the use of land for infrastructure in similar situations to ensure the stable development of society. In this case, this paper provides a better material basis for the development of the region by reasonably arranging all the contents of the region including land, including the location of buildings, the setting of public areas, and the construction of traffic routes, thus realizing the original intention of putting people first, providing a more comfortable environment for people's lives, and promoting the overall pace of grassroots governance in China.

From a comprehensive view, the main writing sequence of this paper is as follows: introduction about grassroots governance and grid-based, to list the research

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contributions of this paper on grassroots governance, followed by the introduction of basic theories and operational methods, the construction of a model related to grassroots governance, with grid-based as its main selling point, and the timely addition of the SaaS model design concept, the description of data sources and validation methods. Finally, the model derivation results are presented and the derivation mechanism is analyzed. At the end, we add a few basic response strategies to the above analysis and provide a small outlook in due course.

This paper aims to evaluate the feasibility and optimization mechanism of grid-based governance under the support of big data at the grassroots level, with a focus on its infrastructure development, data integration, service provision, and institutional adaptability.

As previous studies have pointed out, grid-based governance is increasingly adopted to enhance local responsiveness and administrative efficiency (Gao & Cartier, 2024). This study aims to explore the potential of grid-based governance within the context of China's rapid digital transformation. Specifically, it seeks to assess the impact of big data-enabled grid models on grassroots infrastructure development and service coverage; construct and simulate a modular governance framework based on a four-layer digital architecture; examine data integration, community responsiveness, and institutional adaptability through empirical modeling; and identify optimization mechanisms and governance strategies to enhance grassroots administrative effectiveness. These objectives serve as the foundation for the study's methodological design and guide the interpretation of its findings.

2. Research Background

Some scholars focus on rural areas and summarize patterns from many successful cases in China, finding that most of the typical cases in China are economically developed coastal areas that are prone to successful grassroots governance outcomes, and concluding that economic strength is an important support for successful grassroots governance (Kruks-Wisner, 2022). Some scholars also look at the whole region, starting from the new situation development in China, implement fixed observation, notice the energy efficiency of governance brought by the rapid development of information technology to these regions, and conclude the relevant valuable governance experience (Verhoeven et al., 2022). Other scholars have a clear perspective, focusing on the negative impacts in grassroots governance, exploring whether some regions have adopted reasonable policies in implementing grassroots governance from the perspective of innovation, and analyzing the internal logic and mechanism of action of regional grassroots governance from actual cases. Some scholars start from urban communities, divest the state functions in grid-based management and compare it with the model of residents' self-governance, and propose to combine government participation with residents' self-governance to better utilize the advantages of grid-based as a governance model (Schrage & Kjærås, 2022). Some scholars also combine gridization with current events and reflect the relevance of gridized governance by concretizing the significance of gridization application through data such as health implementation rate, reduction in the number of infections, and recovery rate through the construction case of Fang Cabin Hospital (Jackson et al., 2023). Other scholars have directly studied the logic and limits of grid-based governance, focusing on its "simplicity" and "compounding" characteristics, highlighting the important role of grid-based governance in bringing synergy on the one hand; on the other hand, emphasizing

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that grid-based governance is not a panacea and needs to be On the other hand, it also emphasizes that grid-based governance is not a panacea and that there is a need to guard against the dangers of over-administration.

Many Chinese scholars take the approach from big data technology and grassroots governance in China to argue grid-based grassroots governance in line with Party grassroots governance strategy, and improve grassroots governance systems and modernization capabilities. Some scholars take local development as an example nearby and explore different models of grassroots grid-based governance based on different degrees of grassroots development from a modernization perspective, adapting to local conditions (Marks-Krzyszkowska et al., 2022). Some scholars can go further and compare the effectiveness of grassroots grid-based governance in different regions and summarize the "composite" and "embedded" regional governance models, and analyze the paths from different dimensions to highlight the ideal situation that grassroots grid-based governance can create In order to highlight the different dimensional analysis paths, the grassroots grid-based governance can ideally create a situation where multiple subjects can participate in social governance together (Zhu et al., 2022).

In summary, China's research on grassroots grid-based governance is relatively diverse, and has maintained an overall upward trend under the leadership of the Party, with more comprehensive and in-depth research, especially in the area of grassroots grid-based governance, many scholars have realized the significance of the combination of the two, and are constantly studying its superiority, and also put forward some effective countermeasures for improvement (Yang et al., 2022). However, there are still few cases that can integrate modern information technology into grassroots governance, which cannot well reflect the changes brought by the information technology era for grassroots governance, and further combination and analysis are needed (Qi & Han, 2022).

3. Materials and methods

To comprehensively address the objectives outlined in the Introduction section, this study adopts a mixed-methods research design, integrating both quantitative system simulation and qualitative document analysis (Plano Clark, 2017). This approach allows simultaneous measurement of model performance (e.g., infrastructure growth, database optimization) and contextual interpretation of institutional mechanisms enabling such performance.

3.1. Basic theory

Combined with the previous article, the current use of big data is becoming more and more widespread, and the process of grassroots governance needs the continuous support of big data. It can help governance subjects get rid of the traditional grassroots governance problems and use the advanced nature of information technology to realize the wisdom, ecology and humanization of grassroots governance. Overall, the current features of grid-based application in grassroots governance are mainly as follows.

3.1.1. Wisdom of Gridded Governance at the Grassroots Level

In wisdom, the difference between grid-based governance and traditional governance mode lies first in the statistics of data. For example, in the classification of land types, as shown in Table 2, the data statistics of grid-based governance will generally focus on the

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concept of "land", dividing the land into agricultural land, forest land, water areas, etc. according to the way of use, and also roughly dividing the land into applied land and unapplied land according to the usage. The traditional land type only considers the overall function and regional coordination, and generally divides urban land into residential land, business land, commercial land, public facilities land, and other special land, etc. The data statistics of this will be very different. In addition, the data statistics of grid-based governance are generally realistic, using the most accurate and direct method to measure, taking the data as the standard, without considering other factors; whereas the data statistics of traditional governance mode are not so accurate and will have certain deviation from the actual results, which will easily produce omissions in the subsequent application.

Table 2: Laws and regulations related to grid-based governance and urban development

	Grid-based Governance		**Traditional Governance**
Specific classification	Agricultural Land	Arable Land	Residential Land
		Forest Land	Land for Public Administration & Public Services
		Grassland	Commercial Service Facilities
		Farming Land	
		Agricultural Land & Water Conservancy Land	Industrial Land
	Construction Land	Land for Urban/Rural Residential & Public Facilities	Logistics & Warehousing Land
		Industrial & Mining Land	Land for Roads & Transportation Facilities
		Land for Transportation & Water Conservancy Facilities	
		Tourism Land	Land for Public Facilities
		Military Land	
	Unused Land		Green Space & Square Land

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3.1.2. Ecological nature of grassroots grid-based governance

In ecology, the advantage of grid-based governance lies in the fact that data can be constantly replenished in real time, forming a virtuous ecological cycle (Krick, 2022). Thisecological cycle will connect residents to the database, and through the field visits of grassroots staff, the data of each part will be transmitted to the back-end in real time in the grid, and a certain update frequency will be maintained. Compared with the traditional governance model, the planning of different areas is usually handled by different departments, so the guiding ideology of these two departments will be different, and the phenomenon of oversupply or undersupply can easily occur. In contrast, grid-based governance adopts the guiding ideology of "supply and demand", which means that all regional resources are first integrated by national coercive force, and then allocated according to actual demand and other factors, so that the overall development of the areas under its jurisdiction can be better understood, and the continuous updating of data through the cloud platform makes grassroots governance more flexible. forming a green ecological cycle (Awasthi & Walumbwa, 2022).

3.1.3. Social nature of grassroots grid-based governance

In addition, the social nature of grid-based governance in China differs from that of traditional governance, as grid-based governance can better serve the specific masses and use accurate data to support the "last mile" from the government to the masses, which is more humane. In contrast, traditional governance is not as rapid as grid-based, and most of them need a long response time to implement to the specific masses, which cannot achieve the important goal of "implementing to every household" of grassroots governance (Sahamies et al., 2022).

3.2. The basic functions of grassroots grid-based governance

Combined with the characteristics of the basic theory of grid-based grassroots governance, the grassroots grid-based governance of big data is mainly reflected in wisdom, ecology and sociality. As shown in Figure 2, a wise, social, grassroots governance ecosystem contains the following functions: “sense, remember, think, know, and act.”

Combined with the Figure 2, "sense" refers to the governance system's awareness and feeling of various information in the society, laying a certain foundation for subsequent processing; and "remember" refers to recording all kinds of data in the system and synchronizing them to various storage platforms such as cloud platforms, providing data support. "thinking", as the name implies, is to carry out various "thinking activities", involving grassroots grid-based governance is to understand, analyze, judge and decide on the previously stored data. "Know" means to summarize the results of all kinds of thinking and other ways, and further organize them according to the unique or common, concrete or abstract, explicit or implicit characteristics; "Do" means to finally take action to put the previously obtained data and information into practice and To obtain the desired result.

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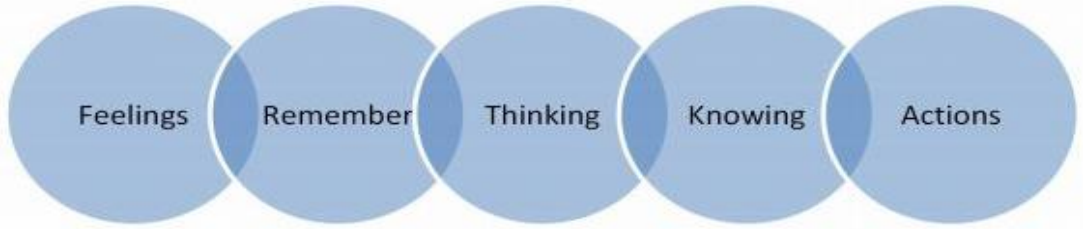
Figure 2: The functions of a wisdom-based grassroots governance ecosystem



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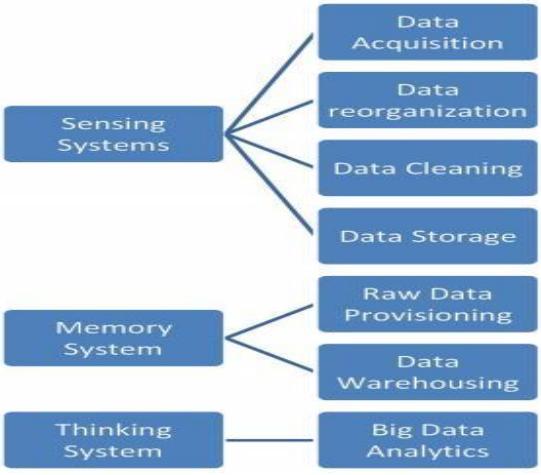
For example, in a grassroots grid-based governance process, the data collection process starts with a self-built database, and the data from the original files are reorganized, cleaned and stored in the process of collection and analysis. And the grassroots authorities will participate in the main process, for the community and residents to collect data activities. At the same time, data archives were created to be able to provide a place to store a large amount of data, from the original to the collected and to the actively reported ones. The applications of the thinking system are currently learning robots that can actively analyze relevant data and derive appropriate application solutions through statistics, reasoning, classification and other logic (Johnson et al., 2022). The next stage of "knowledge" also requires some processing of data, the original data collected, computer-generated professional data, together with the transformation of the people into easily understood and absorbed knowledge. The final act should be put into practice, which can be applied to the service applications for residents such as pension, education, party building and medical care. Finally, the already processed data information is displayed through applications by means of big data visualization center and centralized dispatch center (Muenratch & Nguyen, 2022). As shown in Figure 3, the specific application ideas of five of these processes are presented.

Figure 3: Specific application ideas of the ecological function of intelligent social grassroots governance



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3.3. Model setting and data

3.3.1. Research Design

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This study employs a mixed-methods approach to evaluate the efficacy of big data-enabled grid-based grassroots governance, integrating quantitative system dynamics simulation of the four-tier governance framework with qualitative analysis through policy document review (Table 1) and assessment of institutional adaptation. This dual approach is justified by the need to empirically measure governance outcomes while simultaneously interpreting the socio-political implementation mechanisms within China's unique governance context.

3.3.2. Research Setting and Population

This study is conducted in Hangzhou City, Zhejiang Province, one of China's national pilot zones for digital governance. As a leading example of the integration of big data technologies—most notably the "City Brain" platform—with grassroots governance systems, Hangzhou offers a mature policy environment and well-developed infrastructure, making it an ideal case for model validation.

The research focuses on 112 urban communities operating under grid-based governance. The target population includes approximately 85,000 residents, 320 grid administrators, and 42 government staff members involved in local governance and digital service delivery.

3.3.3. Sampling Strategy

A stratified random sampling method was employed to ensure representative coverage of diverse community contexts and technological readiness levels. The stratified sampling strategy yielded a final sample of 460 participants, distributed across community types and digital maturity levels as detailed in Table 3.

Table 3: Sample Composition

Stratum	Residential	Commercial	Mixed	Total
High Maturity	78	52	45	175
Medium Maturity	92	64	53	209
Low Maturity	48	18	10	76
Total	218	134	108	460

Source: Compiled by the author

This sampling strategy ensures ±4.5% sampling error at 95% confidence level while maintaining proportional representation of key governance contexts. The stratified sampling strategy yielded 460 participants distributed across digital maturity tiers as follows:

i. High-digital-maturity communities: 175 participants (78 residential, 52 commercial, 45 mixed-use)
ii. Medium-digital-maturity communities: 209 participants (92 residential, 64 commercial, 53 mixed-use)
iii. Low-digital-maturity communities: 76 participants (48 residential, 18 commercial, 10 mixed-use)

Sample Size Determination:

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The target sample size of n = 460 was calculated using Cochran's formula for finite populations at 95% confidence level (Z = 1.96) with 5% margin of error:

$$n = \frac{N \cdot Z^2 \cdot p(1-p)}{e^2(N-1) + Z^2 \cdot p(1-p)} = \frac{85{,}000 \times (1.96)^2 \times 0.5(1-0.5)}{(0.05)^2 \times 84{,}999 + (1.96)^2 \times 0.25} = 460$$

Where:
• Population size (85,000 residents)
• 1.96 (Z-value for 95% CI)
• 0.5 (conservative proportion)
• 0.05 (margin of error)

Implementation Procedure:

a) Community registry databases were stratified using the dual-category matrix
b) Probability-proportional-to-size (PPS) sampling allocated participants across strata
c) Random number generation selected specific residents within each stratum
d) Oversampling (+15%) accounted for potential non-response bias

3.3.4. Model setting

The main research object of this paper is grassroots grid-based governance, dedicated to the use of big data to grid-based governance, better service and the masses, the following will build a model related to grassroots grid-based governance, will be a hierarchical way to separate the distribution of the various layers of the model, a total of four major layers, respectively, the infrastructure layer, data support layer, application support layer, application services layer, and supplemented by the corresponding descriptions, the specific model architecture is as follows.

As the foundation of the whole model, IaaS needs to achieve solid support and the best quality of hardware to help the upstream layers to be effective. Implemented into practice, it is equivalent to building sufficient infrastructure in the grassroots level to pave the way for the subsequent grid-based governance.

For this level, a base coordinate system (x1,x2,x3) can be set down as the spatial background of grassroots governance. Assuming the existence of variable a, the location of infrastructure in the grassroots level, the coordinates in the base coordinate system would be (a1,a2,a3)T, which is obtained after the vector conversion and calculation as

$$R = \begin{matrix} x_1 a_1 & x_1 a_2 & x_1 a_3 \\ x_2 a_1 & x_2 a_2 & x_3 a_3 \\ x_3 a_1 & x_3 a_2 & x_3 a_3 \end{matrix} \quad \text{(Eq. 1)}$$

Infrastructure location mapping was performed in ArcGIS Pro by projecting all facility points and administrative layers into the model's base coordinate system defined in Eq. 1. In this system, the study area is represented by a right-handed Cartesian frame (x1,x2,x3); each infrastructure object a is described by the column vector $(a1,a2,a3)^{\top}$. The linear transform R in Eq. 1 maps observed facility coordinates into the base frame, ensuring spatial comparability across governance layers for subsequent overlay, distance calculation, and aggregation. As specified in Model setting section and Eq. 1, all mapped points were validated against civil-affairs GIS layers prior to analysis.

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Spatial coordinate extraction follows Eq. 1: starting from field/GIS observations (longitude–latitude and, where available, elevation), facility points are converted to the model's base coordinate frame (x1,x2,x3) using the transformation matrix R. Given an infrastructure object a with local measurements, we compute its base-frame coordinates x=R a; where elevation was unavailable, we set a3=0 and document the assumption. This procedure standardizes locations across heterogeneous data sources and enables consistent spatial queries and overlays used throughout the analysis. Eq. 1 and its surrounding text define the frame and transformation used for all spatial operations in this study.

With the support of hardware, the model needs to store the collected data in these hardware and use current advanced information technology methods such as data chains and block domains to reduce the whole to zero and build the grassroots governance information base needed by the model and maintain timely supervision and guidance (Zhou, 2022).

The data needs to be implemented into applications, and after absorbing the front-end data, this tier will provide application support, including application status supervision, application automation deployment, and application unified operation and maintenance. At the same time, a complete set of service access framework will be constructed according to the existing grid-based distribution, including service registration, service access control, and service routing. Moreover, services such as data sharing and exchange between various business systems will be arranged for unified management. So that the business systems required for grid-based governance are registered and released through this system, and the model monitors the operation of these services.

After confirming the cited data, 10 points can be randomly selected from the model to form a survey sample, and then the application efficacy between each point will be reflected in the following formula.

$$y = \frac{\ln\ (1-p\ )}{\ln\ (1-Q^n\ )} (2)$$

After the completion of the basic work at the above-mentioned level, personnel will be arranged to return to the lower level to handle various needs according to actual needs, including feedback and opinions from the grassroots level on the rules promulgated by the upstream platform, as well as platform updates and maintenance required to meet the frequent visits of the lower level. And after reaching the lowest level there will be a complex situation where various tasks affect each other, thus requiring constant consideration of updates (Sibbing et al., 2022).

The overall design of this model adopts the design idea of low coupling, and the principle of layered independence is clearly defined, and various applications are presented in modules, which are independent of each other and have low coupling, and can be customized and combined according to the business characteristics of the unit, and then services can be purchased on demand, as shown in Table 3. Compared with the traditional construction model, the response time is faster, and the switching is more rapid and convenient. The general flowchart is shown in Figure 4.

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Figure 4: The general flow chart of the grassroots grid-based governance model
Source: Compiled by the author

The four-layer governance model dynamics were implemented in AnyLogic 8.7 as a modular system-dynamics/agent-based hybrid. Stocks include the number of infrastructure units (infrastructure layer), records in the governance database (data-support layer), active applications and service gateways (application-support layer), and fulfilled public-service requests (service layer). Flows represent (i) infrastructure investment and commissioning, (ii) data capture/cleaning and record integration, (iii) application deployment and inter-service routing, and (iv) service delivery and citizen feedback. Exogenous policy levers (e.g., infrastructure funding rate, data refresh cycle, automation level) drive transitions among layers at monthly time-steps over the evaluation horizon. Figure 4 visualizes this pipeline from infrastructure inputs to service outcomes and the feedback paths used to update upstream layers.

3.3.5. Data source and Collection

To support the modeling of grassroots governance, the study draws on diverse data sources as detailed in the Table 3, ensuring comprehensive and accurate simulation inputs. Given the hierarchical structure of grid-based governance, survey subjects are systematically extracted from actual street offices, community centers, and affiliated service organizations, including groups managed by key personnel and those listed in specialized databases. These sources enable standardized data exchange essential for grassroots-level operations. Furthermore, the model integrates data from enterprise information systems, store registries, population databases, street-level directories, and public security records. This multidimensional data foundation not only addresses the varied informational needs of the governance model but also enhances the reliability and precision of simulation outcomes Table 4.

Table 4: Data Sources and Collection

Data Type	Sources	Collection Protocol
Infrastructure data	Hangzhou Civil Affairs Bureau GIS	Spatial coordinate extraction (Eq. 1)
Service feedback	"Zheli Ban" community service app	Structured ratings (1–5 scale)
Policy compliance	Laws/regulations in Table 1	Content analysis
Database metrics	Ali Government Cloud repositories	API-based real-time extraction

Source: Compiled by the author

3.3.6. Data Analysis

Quantitative and qualitative analyses were conducted using specialized software tools, as shown in Table 5. We conducted descriptive frequency analysis in SPSS v28 to

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quantify counts and proportions for each outcome: the number of infrastructures by type before vs. after grid-based governance (Figure 5), the distribution of data time periods used in governance work (Figure 6), changes in the volume and categories of the comprehensive community information database (Figure 7), and the percentage distribution of community service evaluation scores after gridding (Figure 8).

Table 5: Date Analytical Tools and Techniques

Analysis Type	Software/Tool	Specific Application
Descriptive	SPSS v28	Frequency analysis (Figure 5, Figure 6, Figure 7 and Figure 8), cross-tabulation
Spatial	ArcGIS Pro	Infrastructure location mapping (Eq. 1)
Model Simulation	AnyLogic 8.7	Four-layer governance model dynamics (Figure 4)
Qualitative	NVivo 12	Thematic analysis of policy documents

Source: Compiled by the author

To examine associations between context and outcomes, we used cross-tabulation with Pearson's chi-square tests and Cramér's V effect sizes. Specifically, we cross-classified community type (residential, commercial, mixed-use) and digital maturity level (high, medium, low) against (i) infrastructure additions by category, (ii) database growth by record class, and (iii) service evaluation score bands. Standardized residuals (Bonferroni-adjusted) were inspected to identify cells driving significant associations.

The outputs of these procedures are reported as frequency distributions and comparative graphics in Figure 5, Figure 6, Figure 7 and Figure 8, directly corresponding to the infrastructure, database, and service-evaluation indicators introduced above.

3.3.7. Validation Method

To ensure the accuracy and reliability of the model results, a multi-layered validation strategy is adopted. First, triangulation is conducted through cross-verification with the 2022 *Hangzhou Governance White Paper*, ensuring policy and structural alignment. Second, sensitivity analysis is performed by applying ±10% variation tests on key infrastructure investment parameters to assess model robustness under fluctuating conditions. Third, field validation is carried out via a 30-day pilot implementation in selected communities within Xihu District in December 2022.

To further enhance data accuracy and integrity, a comprehensive network data security mechanism is integrated into the modeling system. This includes functions for data confidentiality, recovery, and deletion. The model operates on Ali Government Cloud, a cloud computing service tailored for governmental use, compliant with national cybersecurity regulations and the enhanced-level security review standards of the Central Cyberspace Administration. A robust permission control system and multiple layers of confidentiality protocols ensure secure data handling. Access rights are role-based, providing users with authorized queries while preventing unauthorized access. Data exchange is safeguarded through a secure SSL-VPN private cloud, where client devices establish encrypted connections to the VPN gateway via dial-up authentication, ensuring secure and verified usage.

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4. Finding

4.1. Empirical Insights Based on the Grid-Based Governance Simulation

Based on the simulation model and empirical data collected through stratified sampling in Hangzhou communities, this section presents key findings structured along the four governance layers: infrastructure, database construction, application support, and public service outcomes. The results are directly derived from the methodological framework described in Finding section, ensuring consistency between the model logic and real-world implications.

4.2. Analysis of the model mechanism for the optimization of grassroots grid-based governance

In this model, the construction of each level breaks the "autonomy" of each region in the original grassroots governance, and uses the big data information system to collect the grassroots information, such as residents' household registration information, economic situation, service needs, etc., and then forms a stable, large capacity and good security database (Wu et al., 2024). It is easy to provide relevant services for quick inquiry, forming a unique "data and information integration" pattern of grid-based governance. At the same time, the model relies on huge information sources and transforms them into convenient application systems to realize the rapid transformation of virtual-reality in the work, for example, the model is designed with a multimedia system that can help interconnect the computer management terminal and cell phone app. This improves the timeliness, accuracy and validity of data and breaks through the geographical limitation. At the same time, this data model can take into account the whole grid, not limited to a specific grid, but from the global perspective, at the beginning of the design to consider the compatibility of various application systems, to determine the data docking that data collection and processing solutions. In the subsequent inter-institutional work, it can batch import or export the data required for work according to different work requirements, and can batch import data from other systems into this system. It solves the problem of data interfacing with various platforms and greatly reduces the work burden of grassroots cadres (Ying, 2023).

The last thing is that this grassroots grid-based governance model can make intelligent analysis and generate analysis charts based on the data in the system (Shen, 2022). At present, it can accurately query the geographic location, population structure, education, key personnel and collective economy of each village and community and other common information (Atha et al., 2020), which is convenient for the grassroots authorities to grasp the system to learn and query statistics, and provide data guarantee for accurate decision-making of the street and the government.

4.2. Analysis of finding

4.2.1. Infrastructure construction results of grassroots grid-based governance

After the calculation of the model, the number of infrastructures in the region is 192, which is a significant increase compared with 72 before the grid-based governance model was applied. And these infrastructures can be of the types of pension, education, medical care, party building, etc. No matter which one, the number of infrastructures

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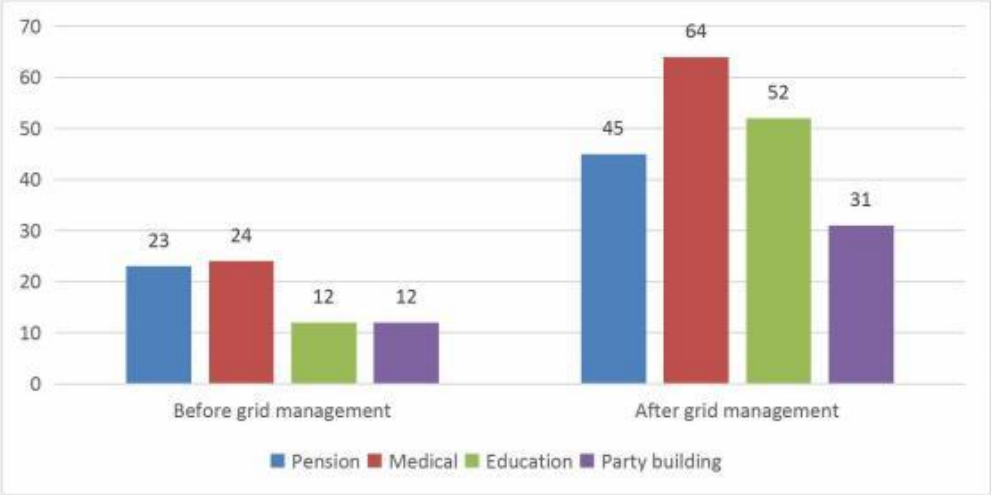
after grid-based governance is more or less improved, and the specific number of infrastructures can be seen in Figure 5.

Figure 5: The number of infrastructures before and after the grid-based governance at the grassroots level

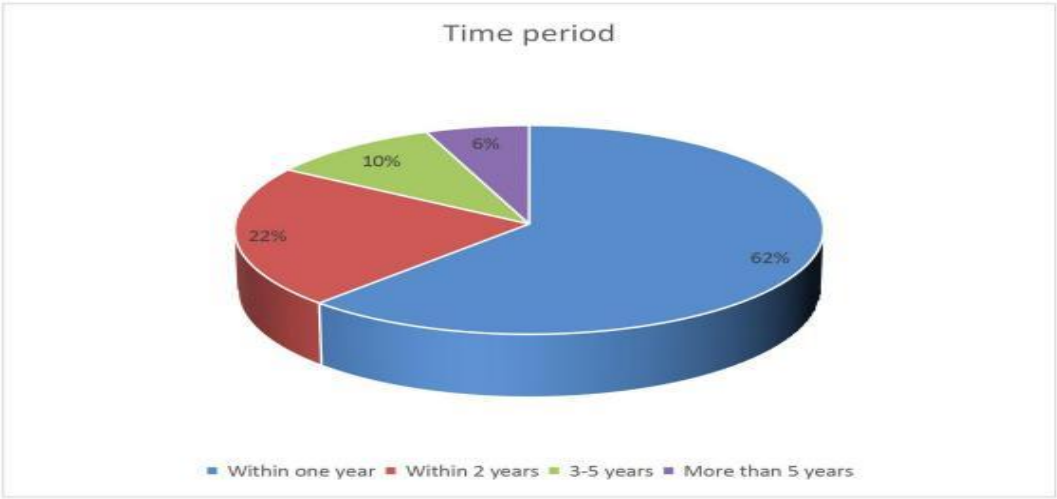


Source: Compiled by the author

4.2.2. Results of database construction for grassroots grid-based governance

In the data capturing and database building, there is also a big difference before and after the grid-based governance (Do & Frör, 2022). Before the application, it was difficult for the grassroots staff to include every household in the daily jurisdiction, and many data were still in a visit long ago, which had long lost its timeliness (Liu et al., 2022). After the application, the data collection ability of grassroots governance has been greatly strengthened, and the database has more stable, more realistic and richer information data by going to every household and visiting them in the field (Sultana et al., 2022). As shown in Figure 6, the implementation of the grid-based model has resulted in a marked improvement in the timeliness of the data used for grassroots governance.

Figure 6: Distribution of data time periods used in grassroots governance work



Source: Compiled by the author

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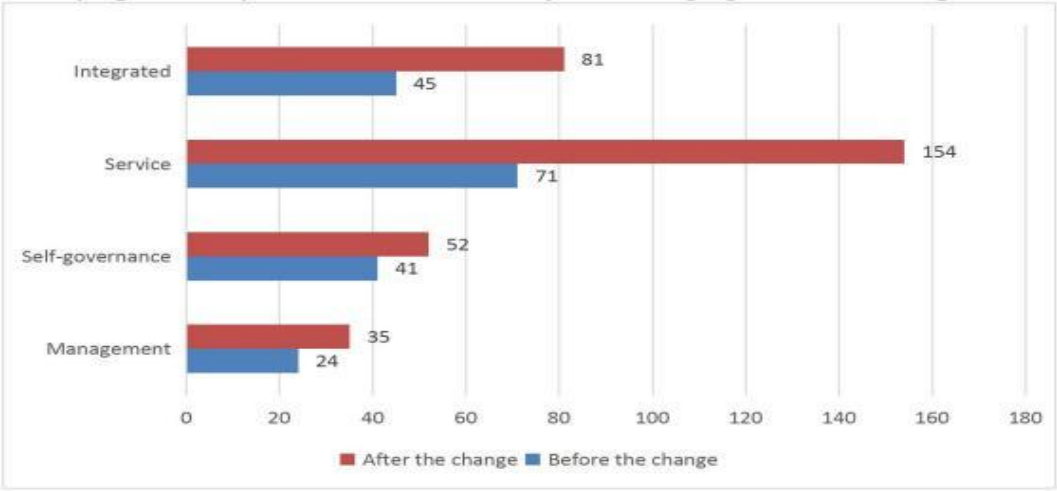
A substantial majority of the data (62%) is less than one year old, with an additional 22% being between one and two years old. Conversely, only a marginal 6% of the data is older than five years. This finding starkly contrasts with traditional governance models, where data often becomes outdated and loses its practical relevance. The freshness of the data confirms the effectiveness of the 'ecological cycle' described in the theoretical framework, where real-time field visits and digital inputs continuously replenish the database. This shift from a static to a dynamic data repository ensures that administrative decisions are based on accurate, up-to-date information, thereby significantly enhancing the precision and responsiveness of grassroots governance.

4.2.3. Application support results of grassroots grid-based governance

After absorbing sufficient data, according to the user data fitted by the model, the number of users in the region will climb sharply after the implementation of grid-based governance, which is closely related to the rapid development of big data and shows that the development direction of big data government is the trend of the times. On this basis, the model constructs a large comprehensive information database of community management, autonomy and service data, and further implements the simulation application by integrating public service information of the community and developing "one-stop" services for community residents (Varady, 2022).

As shown in Figure 7, a comparative analysis of the volume of data within the comprehensive community information database before and after the adoption of the grid-based system. The data reveals a substantial increase across all categories, with the most dramatic growth observed in the 'Service' data (from 71 to 154 units) and 'Integrated' data (from 45 to 81 units).

Figure 7: Changes in the data of the comprehensive community information database before and after gridding



Source: Compiled by the author

This quantitative expansion demonstrates the model's enhanced capacity to capture, process, and store a diverse range of community-relevant information. The particularly sharp rise in 'Service' data underscores the model's success in building the necessary information foundation for developing 'one-stop' services for residents, a key objective of the new governance paradigm. Furthermore, the significant increase in 'Integrated' data signifies a crucial shift away from fragmented, siloed information systems. By

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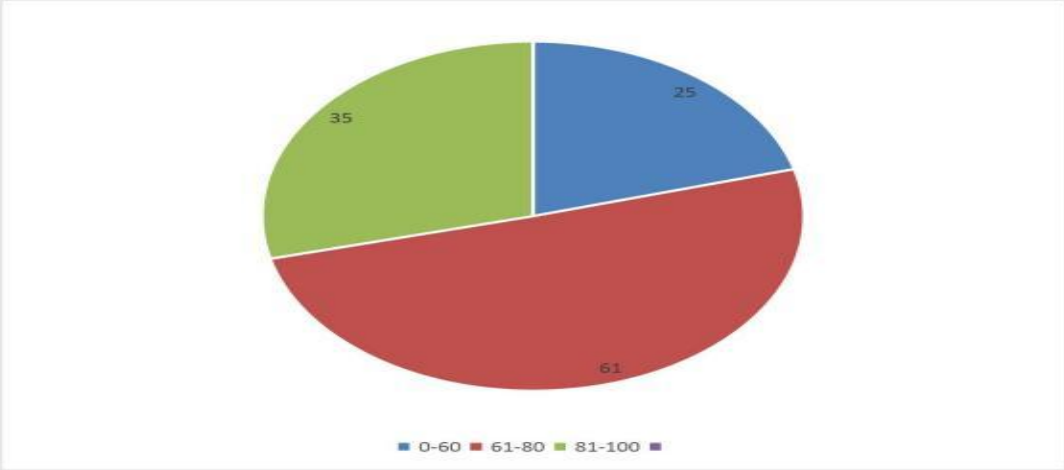
integrating data from various administrative functions, the grid-based model creates a holistic, interoperable database that supports more sophisticated analysis and coordinated decision-making, thereby enabling the development of more effective and comprehensive governance applications.

4.2.4. Application Service Results of Gridded Governance at the Grassroots Level

In the final application data service module, the most significant change brought about by grid-based governance is the move to the grassroots level, where the number of staff serving the needs of the masses is greatly increased and the interaction with the masses is greatly enhanced (Forbes-Mewett et al., 2022). The data reflected in the model is that the overall evaluation of these grassroots services by the masses is improving, and the evaluation scores received by the grid-based governance have also increased substantially, from the most proportion of scores near the previous pass to the most scores near the excellent now, and also the number of full scores is more, the number of scores of 0 is not one, the overall trend of substantial growth, and the specific evaluation score percentage can be seen in Figure 8.

Figure 8: Distribution of community service evaluation scores after gridding at the grassroots level



Source: Compiled by the author

4.3 Countermeasures to actively promote the gridding of grassroots governance

4.3.1. Promote "party building + communication" to build and promote each other

In the process of grassroots governance, it is necessary to clearly understand the importance of communication, actively close the relationship between the party and the cadres, and promote the harmonious development of the community. Especially in the grid model, grassroots people and party building staff have closer contact opportunities, communication is very necessary. Specific actions can be roughly divided into three situations: First, the Party's grassroots organization staff take the initiative to communicate with the masses in the gridded area, communicate with them in depth, understand their difficulties in work and life during the epidemic, and help them solve some of their problems in a timely manner. And it also combines the strengthening of the Party's construction of public resources with the maintenance of infrastructure. The grassroots governance department pairs up with high-level talents and carries out talks and exchanges twice a month to build a platform for the development of high-level

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talents and make suggestions. Secondly, we actively carry out various special activities to provide a platform for communication between the Party and the masses, bring the masses closer to the grassroots governance personnel in interesting activities, cultivate the awareness of responsibility and service on both sides, implement the original intention of keeping the righteousness and innovation and the mission of being responsible for the people into the practice of grassroots governance, and give full play to the Party's pioneering and exemplary role in the process of grassroots governance. This is consistent with recent research on party-led community engagement mechanisms in grassroots grid systems (Li & Ergenc, 2024).

4.3.2. Reinforcing "party building + business" and promoting each other

In addition, it can also be promoted through the actual content of governance, to clarify the leading role of the party organization in the process, and then constantly improve its political leadership, so that it can play a positive effect, combining grassroots governance with the actual business. Specifically, one is to play the leading core role of grass-roots governance organizations to coordinate forces. Through the form of leading personnel leading the team, the work of grassroots governance is penetrated into the work of each grid, so that the work in the grid can be carried out around the Party's overall arrangement, effectively improving its degree of integration, and effectively improving the characteristics of mass service and selfless dedication. Second, strengthen the political leadership and political absorption of talents. The personnel management of grassroots governance is required to be carried out in line with the basic party line, and the system of contacting senior talents by the leadership team of grassroots governance is formulated, and monthly heart-to-heart talks are conducted. Combine the strengthening of the Party's construction of grassroots with the cultivation of grassroots governance talents, and actively cultivate "double leaders", grassroots leaders and governance leaders. After that, we promulgated a specific encouragement plan, and introduced the Three-Year Plan for Training Talents, implementing the construction mechanism of "introducing high-end talents from outside, promoting the development of basic talents, and developing and training specialized talents". Thirdly, in the process of implementing the grid, we actively promote the integration of grass-roots governance talent construction and local central work, and innovate the "double teacher" working model, that is, "to be a good grass-roots grid member and a good party member", so that the talent pioneers can shine on the post. In order to give full play to the political function of the party organization, the effect of the party members' demonstration to provide quality grassroots services is fully revealed, and the cause of "people-centered" is strongly promoted. Such integration of party leadership and functional business implementation is increasingly seen as key to modern grassroots governance (Han, 2024).

4.3.3. Strengthen "party building + education" to create and promote each other

While implementing grid-based governance, we also pay attention to ideological leadership, implement the responsibility of strict governance of the Party, transfer the spirit of the Party to the grassroots through ideology, and strengthen the organic combination of governance activities and education activities. During the epidemic, the local party branch combined governance activities with ideological education activities, using a variety of ways such as example to motivate, reward and encourage, ideological propaganda and other characteristics of governance + education to promote the smooth implementation of the work of the grassroots after the grid. Specifically, one is to insist

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on building a firm ideal and belief "backbone", give full play to the role of a fighting fortress, continue to solidly promote the theme of education, a level with a level of learning, learning a firm faith, learning absolute loyalty, learning to take charge of the mission, armed with Xi Jinping thought of socialism with Chinese characteristics in the new era, keep up with the development of big data situation, leading Party members and cadres to establish good professional ethics and build the ideal belief of serving the people wholeheartedly. The second is to adhere to the concept of innovation "main position". Political direction, technical level and service capability are the core elements of grass-roots governance. Grass-roots organizations will take the needs of the masses as the first signal to improve their work, rectify all the chaos that hinders development and bring humanistic care into the daily governance work, starting from the small, small and micro. This aligns with empirical findings on ideological education and civic training under grassroots grid governance systems (Mittelstaedt, 2022).

5. Conclusion

This study systematically examines the feasibility and optimization pathways of big data-empowered grid-based governance at China's grassroots level. Anchored in a four-tier model—infrastructure, data support, application support, and service provision—the research employs a mixed-methods approach integrating system simulation, policy analysis, and stratified community sampling in Hangzhou. Empirical results demonstrate that grid-based governance significantly enhances infrastructure development, improves the timeliness and accuracy of data collection, streamlines public service delivery, and increases citizen satisfaction (Bhowmick & Seetharaman, 2024).

Findings reveal that the modular, low-coupling architecture not only enables adaptive service deployment but also deepens integration between digital systems and grassroots administrative processes (Caragliu & Del Bo, 2019). By establishing a real-time, interoperable data network, the model overcomes traditional information silos in local governance, empowering both decision-makers and citizens. Furthermore, incorporating party-building initiatives, talent development, and public participation mechanisms strengthens the political legitimacy and social sustainability of the grid system. The study underscores critical policy enablers: institutional alignment, legal standardization, and strategic digital infrastructure investment. Results emphasize that governance innovations must be embedded within local socio-political contexts rather than applying uniform models (Sæbø et al., 2008). In conclusion, big data-supported grid governance—when contextually adapted—presents a viable and scalable approach to modernizing China's grassroots administration (Huang et al., 2020). Future research should explore cross-regional adaptability, long-term governance outcomes, and ethical implications of intensive datafication in community governance.

Ethics Approval and Consent to Participate

This study involved non-sensitive, publicly available data, and verbal informed consent was obtained from participants. No formal institutional approval was required.

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Conflict of Interest

The authors declare no conflict of interest.

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