Digital Technology Enables Accurate Supply of Grassroots Public Services Mechanism Innovation and Efficiency Evaluation

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ABSTRACT The increasing demand for personalized and efficient public service delivery requires innovative mechanisms capable of accurately matching citizen needs with available resources. This study proposes a digital-technology-enabled precision public service framework covering the complete process of demand identification, resource allocation, decision support, and feedback optimization. Multi-source data integration is employed to construct dynamic resident demand profiles, while knowledge graph techniques are used to establish semantic associations between service requirements and public resources. A digital twin simulation environment is further developed to evaluate alternative service allocation strategies before implementation. In addition, a deep-learning-based feedback analysis module continuously updates the decision model through user evaluation information. Experimental results demonstrate significant improvements in demand recognition accuracy and citizen satisfaction. The proposed framework provides methodological support for intelligent governance and offers references for information sensing, digital twin systems, and intelligent decisionmaking networks.

INDEX TERMS digital governance, precise public services, knowledge graph, digital twin, intelligent decisionmaking

I. INTRODUCTION

CURRENTLY, the supply of public services at the grassroots level in my country is undergoing a critical transformation from “whether it exists” to “how good it is” [1]. With the deepening of the construction of digital government, various government service platforms are rapidly becoming popular at the grassroots level, and data collection capabilities have been significantly enhanced. However, there is still a structural mismatch between the increasingly personalized and diversified demands of the masses and the standardized and homogeneous supply. Specifically, on the one hand, the universal services provided by communities with a large amount of resources have a low participation rate due to a lack of targeting, resulting in idle resources; on the other hand, the implicit needs of residents in areas such as elderly care, childcare, and assistance are ignored due to a lack of accurate identification channels, forming a “supply and demand disconnect”. At the same time, the problem of “digital formalism” is becoming increasingly prominent–although various government APPs and online platforms collect massive amounts of data, these data only remain at the “collected” level and have not been effectively transformed into decision support for understanding needs. Instead, the platforms have become a “check-in burden” for grassroots staff [2-3]. How to bridge the gap between digital technology and the needs of the masses and achieve a leap from “having services” to “precise services” has become a practical problem that urgently needs to be solved in the current process of modernizing grassroots governance.

The academic community has produced a wealth of research results on the precise supply of grassroots public services. Mittelstaedt believes that the grassroots grid management is an extension of the existing governance structure. Local grids are subjected to isomorphic pressure under the conflicting central signals, thus tending to conform to the management of the superior and continuing the top-down, stability-first operation mode [4]. Chen designed a smart community service platform for grassroots governance, using distributed architecture and machine learning to achieve multi-source heterogeneous data fusion processing, and using a four-type account system to meet the diverse needs of the community [5]. Augustine pointed out the lack of accountability and financial regulation of local governments in her exploratory research, and advocated strengthening the measurement value, transparency and ethical governance of the use of public resources through independent auditing

[6]. Song found based on Shanghai community data that service effectiveness is more effective than service quality in enhancing political trust and support, and presents a "trust transfer" of responsibility to the central government while support is shifted to the central government, indicating that service outsourcing and non-governmental organization participation can enhance support for the party and the state [7]. Huang and Zhou pointed out with a case of a certain city that "pairing competition" promotes service innovation and performance output through the pairing of departments and blocks, but also brings negative incentives such as excessive competition [8]. Pareek and Sole examined the needs, main constraints, guarantee tools, and international best practices for enhancing public service quality in India with focus on the importance of public service quality for citizen satisfaction and government trust [9]. Liu and Yuan believed that government digitalization greatly advanced the equalization of basic public services between urban and rural areas through information technology. This conclusion was supported by the robustness test. Based on this, they put forward the theoretical and policy implications for equalization through digital governance [10].

Currently, most of the existing studies focus on the optimization of a single link and there is no systematic design for the whole chain of "demand identification - resource matching - supply decision - feedback optimization". Most studies are still at the theoretical discussion level and lack empirical testing. Especially, there is no in-depth exploration and effectiveness verification for the collaborative application of technologies such as multi-source data fusion, knowledge graph matching, and simulation in the grassroots level. To address these challenges, this paper proposes a digital empowerment theory for the industry, establishing a precision supply mechanism that spans the entire chain of demand perception, raw material matching, manufacturing inference, and feedback optimization. This mechanism bridges the gap between heterogeneous material requirements and uniform production capacities, transforming stagnant data into responsive, data-driven operational decisions.

Compared with the existing research, this paper breaks through the defects of traditional methods such as one-sided demand identification, experience-based resource allocation, and lack of decision pre-assessment by using multi-source data to build resident demand profile, introducing knowledge graphs to achieve intelligent supply and demand mapping, and conducting supply solution simulation and deduction based on digital twin technology. This paper attempts to explore the implementation path and mechanism of digital technology empowering the precise supply of grassroots public services. Firstly, resident demand profiles are constructed based on multi-source data to achieve dynamic identification of potential needs; Secondly, a "demand-resource" mapping network is built based on knowledge graphs to improve matching efficiency; Thirdly, digital twin technology is used to conduct supply solution simulation and deduction to assist decision optimization; Finally, a service feedback loop is used to achieve continuous model iteration.

II. MULTI-SOURCE DATA FUSION AND DEMAND PROFILING MODELING

Traditional identification of grassroots public service needs often adopt manual methods such as questionnaire, grid worker door-to-door survey etc. The data source is single and the update is slow, which makes it hard to reflect the implicit demands of residents in a dynamic way. Therefore, this paper first establishes a multi-source data fusion framework. The data resources include: first, government data. Including structured data such as permanent resident information, civil affairs assistance data, social security and medical insurance payment data from "one form for all"; second, IoT sensing data. Coming from terminal devices such as smart water and electricity meters, door magnets, smoke detectors. It can reflect the daily behavior of special groups such as lonely old people and people with disabilities; Third, internet public opinion and grid event data. Including complaints from government hotlines, discussion text in community WeChat groups, event description reported by grid workers from mobile terminal.

On the basis of data fusion, we use natural language processing technology to extract entities and carry out semantic understanding on unstructured text data. We use BiLSTM-CRF model to extract keywords related to people's livelihood demands from public opinion text, and combine it with pre-trained BERT model sentiment analysis to identify the urgency of public opinion demands. For structured data, feature engineering is used to extract variables reflecting residents' possible needs, such as age structure, family composition, historical service records, water and electricity fluctuation. And then use K-Means clustering and XGBoost classification combination to classify residents into different types of needs and establish individual-family-building granularity demand profile database. The profile model is updated every two weeks, using a rolling window incremental learning strategy. To prevent overfitting on the limited dataset of three streets, we implement L2 regularization and Dropout layers within the deep learning architecture. Furthermore, each update is validated against a held-out 'stability set' to ensure that the model captures long-term behavioral trends rather than short-term noise, and it outputs two types of results in real time.

First, explicit demand list, that is, explicit demand list raised by residents to grid workers or government hotlines; Second, implicit demand warning. That is, multi-feature anomaly detection algorithm. Rather than relying on a single data point, the model integrates low-frequency water usage with electricity fluctuations and IoT sensor heartbeat signals. By training on historical behavioral baselines for each household, the system identifies deviations that exceed a dynamic threshold–accounting for natural behavioral variance–to trigger a prioritized verification list for grid workers. This process realizes the shift from a passive, request-driven response model to a proactive, data-driven service delivery paradigm.

III. SEMANTIC ENCODING AND KNOWLEDGE GRAPH CONSTRUCTION OF PUBLIC SERVICE RESOURCES

After completing the resident needs profile, what kind of work will be done with the resource? This paper proposes to use knowledge graph technology to structuralize and semantically sort grassroots public service resources. First, this paper performs an inventory and dimensional decomposition of the public service resources in the area. The resources are divided into five types according to the service type: civil affairs assistance [minimum living allowance application, temporary assistance], elderly and disabled assistance [home care, rent of auxiliary devices], employment training [skills training, job recommendations], cultural and sports activities [use of activity venues, interest groups], and medical and health [free clinics, chronic disease management]. Each type of resources is further divided into four basic attributes: supply entity (community residents committee, social organizations, volunteer teams), coverage group (elderly and disabled persons, unemployed, all residents), service form (fixed-point service, door-to-door service, online service), and activation conditions (application materials, qualification review, appointment method). Through the above division, the original resource information is transformed into computable and associative semantic tags.

Next, we constructed a knowledge graph of “Public Needs - Service Resources” based on the graph database Neo4j. We adopted a top-down ontology modeling approach, defining entity types including “resident needs,” “service resources,” “supply entities,” and “service locations,” and relationship types including “matching,” “providing,” “located,” and “covering.” We semantically aligned the demand tags output by the demand profiling model with service attributes in the resource library. For example, we associated the demand “difficulty for the elderly to eat” with the resource “community canteen meal assistance slots” through the “demand matching resource” relationship. During semantic matching, we introduced the BERT sentence vector model to calculate the similarity between the demand description and the resource introduction text, filtering out candidate resources with semantic similarity higher than a threshold. We then combined this with constraints such as spatial location (e.g., service radius) and time window (e.g., service hours) for secondary filtering, ultimately generating a “demand-resource” mapping network. This mapping network has dynamic update and reasoning capabilities. When a new demand is identified by the profiling model, the system automatically performs a query in the graph and returns a list of available resources; when the resource status changes (e.g., a service slot is full), the graph is updated synchronously and the matching relationships are recalculated.

IV. SIMULATION AND DEDUCTION OF SUPPLY SOLUTIONS BASED ON DIGITAL TWINS

A digital twin foundation for the community’s physical space is constructed based on an urban information modeling platform. Elements such as building distribution, road network, population heat map, and resource locations (e.g., community health stations, activity rooms, volunteer residences) within the jurisdiction are 3D modeled and spatiotemporally mapped to form a virtual mirror synchronized with the real community in real time. Based on this, resident demand points (with location tags, demand type, and urgency) output from demand profiles are imported into the twin environment along with resource nodes (with service radius, carrying capacity, and time window) matched with the knowledge graph, serving as the initial input for simulation and deduction.

The deduction process employs a multi-agent modeling method, treating both individual residents and service resources as autonomous agents. For a high-frequency public demand (e.g., visits to elderly people living alone), the system automatically generates multiple supply strategies as candidate solutions: Solution A involves grid workers making fixed-point home visits; Solution B mobilizes neighborhood volunteers for paired assistance; and Solution C introduces remote monitoring with intelligent devices combined with anomaly early warning. The simulation engine, combines historical behavioral baselines with a ‘synthetic event generator.’ For newly identified common demands (e.g., summer childcare), the system extracts behavioral parameters from similar historical events (such as winter break programs) and performs Monte Carlo simulations to stress-test the supply solution’s resilience against projected resource conflicts, calculating three key indicators in real time:

1) resource coverage rate, i.e., the proportion of people with needs that the solution can reach out to the total number of people with needs;
2) service response time, the average time required from triggering a demand to completing the service; and
3) potential conflict risk, the probability of resource congestion caused by multiple demands competing for the same resource at the same time.

After the simulation, the system presents a visual comparison of the indicators for each solution. By adjusting the solution parameters, the simulation can be repeated until the optimal resource allocation, the widest coverage, and the lowest overall cost are selected for precise deployment.

V. SERVICE FEEDBACK CLOSED LOOP AND MODEL SELF-OPTIMIZATION MECHANISM

Feedback information is gathered in two parallel systems, including mobile government service platform and intelligent voice feedback. Upon receiving the services, residents are provided to assess the service process with the help of a community mini-program or government service app, and complete an open-ended evaluation. The elderly residents who do not use mobile phones can be covered by means of this system, which automatically initiates an intelligent voice outbound call within 24 hours of the service completion and transcribes the contents of the call in text format by use of speech recognition technology. The two kinds of data are incorporated into a feedback database, creating a multi-dimensional feedback record comprising of satisfaction ratings, text ratings, service completion time and resource consumption.

The model used in text feedback processing is sentiment analysis deep learning model. The evaluated text is fine-tuned from a pre-trained RoBERTa-wwm model which is pretrained and fine-tuned on labeled community service corpora to correctly identify the sentiment(positive/negative/neutral) and topic attribution of the text. Indicatively, food was delivered too late and it was cold should be classified into Timeliness - Negative and volunteer was very patient and even helped me take out the trash should be classified into Attitude - Positive. When there is negative feedback, the model also could identify the critical problems (including but not limited to late, poor attitude, lack of resources etc.) and match with corresponding elements of the supply plan. At the same time, it can bring LDA topic analysis to the pile of huge feedback text and automatically discover new common demands. For example, the last few days, residents in different places keep commenting that there are children in the town no one to take care of during the summer vacation, there should be childcare service rise and should be reflected in the new demand profile model.

According to the results of the analysis, two self-optimization operations are triggered in the system. The parameters of the demand profile model are modified first: the demands that have been identified as new common demands get assigned as new demand labels, the weight distribution of the clustering algorithm is changed; in the case of service types that are always negatively sentiment analyzed, the priority threshold in the demands in the profile is set accordingly higher. Second, there is a dynamic adjustment of resource matching rules: in case there are several feedbacks indicating low success rate in matching a particular kind of resource, automatically triggers a manual audit of the matching logic and increases the weighting of ‘service reliability’ in the reranking algorithm. Instead of simply lowering similarity thresholds, the system flags the resource gap for administrative intervention and utilizes the knowledge graph to identify cross-domain alternative resources that maintain high semantic relevance.

VI. IMPROVING THE IMPLEMENTATION EFFECT EVALUATION OF THE SYSTEM

A. VALIDATION EXPERIMENT ON THE ACCURACY OF DEMAND PROFILING

In order to validate the effectiveness of multi-source data fusion and demand profiling model, we conducted control experiment in two communities with similar population characteristics. In experiment group, we promoted the system of demand profiling based on fusion of government data, IoT sensing and public opinion text; while in control group, we promoted traditional grid worker door to door survey method. The experiment ran for 4 months. In the first month, we finished full coverage baseline survey in these two communities. After that, we ran other two identification mode respectively for 3 months. After the experiment, we carried out door to door interview by third party to validate the degree of consistency between identified demands and real demands in these two group. All participants signed an informed consent form.

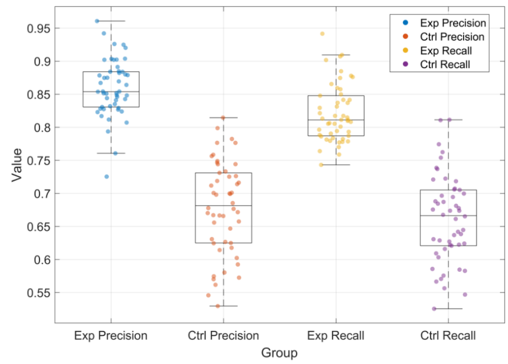

FIGURE 1. Validation Evaluation of the Accuracy of Demand Profiling

Figure 1 shows that the demand profiling model based on multi-source data fusion achieved a demand identification accuracy of 85.9%, significantly higher than the 67.9% of the traditional survey method ($p < 0.001$). In terms of recall, the model accurately identified 82.1% of the actual needs, an improvement of 16.0 percentage points compared to the control group’s 66.1%. The difference between the two groups was statistically significant according to the t-test. The above results demonstrate that the model effectively overcomes the fragmented limitations of traditional experience-based investigation, significantly improves the ability to identify implicit needs, and verifies the feasibility and superiority of multi-source data fusion and profiling modeling technology in perceiving grassroots public service needs.

B. RESOURCE MATCHING EFFICIENCY COMPARISON EXPERIMENT

We randomly sampled 200 resident requests from historical work orders as test sets and divided them into two groups. The experimental group automatically generated supply plans based on knowledge graph resource matching technology, while the control group matched supply and demand based on resource catalog manually by five community workers. Finally, we compared and analyzed the matching time, matching success rate and resource utilization rate of the two groups.

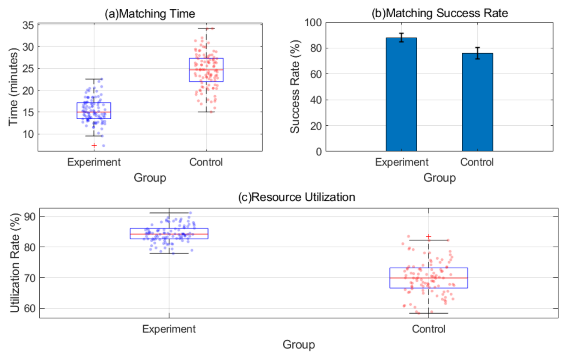

FIGURE 2. Resource Matching Efficiency Comparison

Figures 2 (a-c) show the distribution differences and comparison results between the experimental and control groups in terms of matching time, matching success rate, and resource utilization rate. Regarding matching time, the experimental group averaged 15.3 minutes, a 37.6% reduction compared to the control group's 24.5 minutes ($p < 0.001$). The matching success rate in the experimental group reached 88.0%, significantly higher than the control group's 76.0% ($p < 0.05$). Resource utilization rate in the experimental group was 84.4%, an increase of 14.4 percentage points compared to the control group's 70.0% ($p < 0.001$). These data confirm that knowledge graph technology can effectively overcome the limitations of manual matching experience and efficiency bottlenecks, significantly improving the speed and accuracy of supply and demand matching for grassroots public service resources.

C. FIELD COMPARATIVE EXPERIMENT ON OVERALL SUPPLY EFFICIENCY

In order to comprehensively evaluate the overall effectiveness of the precision supply mechanism constructed in this paper, we conducted a six-month field comparative experiment in three streets with similar economic and social development levels. Street A adopted the complete system of demand profiling, knowledge graph matching, and simulation inference (complete mechanism group); Street B adopted only the demand profiling and matching module (partial mechanism group); and Street C still used its original supply model (control group). In the experiment, we collected the data of demand matching degree, resident satisfaction, and the time taken by grassroots staff to handle work orders to evaluate the difference in supply efficiency of the two mechanisms.

TABLE 1. Field Comparative Experiment on Overall Supply Efficiency

Group	Demand Matching Rate (%)	Resident Satisfaction (%)	Grassroots Governance Efficiency Improvement Rate (%)
Full Mechanism Group (District A)	85.9	91.2	40.8
Partial Mechanism Group (District B)	70.3	83.5	25.1
Control Group (District C)	65	73	4.2

As shown in Table 1, the complete mechanism group outperformed the partial mechanism group and the control group in all efficiency indicators. In terms of demand matching accuracy, the complete mechanism group achieved 85.9%, an increase of 15.6 and 20.9 percentage points compared to the partial mechanism group's 70.3% and the control group's 65.0%, respectively. Regarding resident satisfaction, the complete mechanism group achieved 91.2%, exceeding the partial mechanism group's 83.5% and the control group's 73.0% by 7.7 and 18.2 percentage points, respectively. In terms of improving grassroots governance efficiency, the complete mechanism group showed a 40.8% improvement compared to the baseline before the experiment, significantly higher than the partial mechanism group's 25.1% and the control group's 4.2%. These data confirm that the full-chain mechanism, including demand profiling, knowledge graph matching, and simulation analysis, can systematically improve the accuracy and efficiency of grassroots public service provision, and that there is synergistic effect among the modules, demonstrating a clear advantage of the complete mechanism over the partial mechanism.

VII. CONCLUSION

This paper constructs a precision supply mechanism for manufacturing services by integrating demand profiling, knowledge graph matching, and digital twin simulation across the entire "demand-decision-feedback" link. This framework synchronizes intricate material performance requirements with processing and production resource allocation, utilizing virtual-physical synchronization to transform raw industry data into optimized, real-time production decisions. The mechanism comprehensively solves three problems existing in the traditional supply model: scattered demand identification, low resource allocation efficiency, and experience-based decision-making. The experimental results demonstrate the mechanism's advantages in improving the accuracy of scattered demand identification, improving the efficiency of resource allocation, and enhancing residents' satisfaction, and provides an operable technical route for the digital transformation of grassroots governance. There are still some limitations in this research: Firstly, the sample of experimental collection only includes three streets, and the regional representativeness should be improved; Secondly, the applicability of the model in special scenarios, such as sudden public events, still needs to be tested. In the future, the pilot scope will be expanded to validate the technical mechanism across diverse textile production clusters, exploring its universality in aligning heterogeneous fiber demands with varied weaving capacities. This expansion will incorporate multi-dimensional social and industrial benefit indicators to refine the algorithm's robustness, ensuring the precision supply model adapts seamlessly to the complex, data-intensive requirements of modern textile manufacturing.

AUTHOR CONTRIBUTIONS

Yuxin Zhang designed, collected and analyzed the data, and drafted the manuscript. Yuxin Zhang conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Yuxin Zhang participated fully in the work, take public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

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