

Multidimensional Perspective on the Construction of Smart Canteens in Colleges and Universities: Integrated Framework, Practical Challenges, and Optimization Paths

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Abstract. Digital transformation and the concept of sustainable development are profoundly reshaping the logistics service system in colleges and universities. As a key hub of campus life, the smart construction of canteens has transcended the scope of mere technological upgrading and evolved into a systematic reform involving the reconstruction of service models, the innovation of management concepts, and the optimization of user experience. Based on the service-dominant logic and the theory of green service systems, this paper constructs a three-dimensional integrated analytical framework of "technology-process-management" for smart canteens in colleges and universities, and systematically expounds on its core connotations in terms of the deployment of intelligent facilities, the reconstruction of standardized processes, and the establishment of an integrated management platform. Combining cutting-edge research results and practical cases at home and abroad in the past five years, this paper focuses on analyzing the practical bottlenecks existing in the current construction, such as poor technology integration, lack of data governance, barriers to user acceptance, and dilemmas in sustainable operation. Furthermore, the study proposes optimization paths including strategic planning guidance, scenario-based design implementation, privacy protection enhancement, and collaborative innovation promotion, aiming to promote the paradigm transformation of smart canteens from "efficiency-oriented" to "value co-creation", and provide theoretical support and practical guidance for building a new generation of campus catering service ecosystem that integrates efficiency, human-centricity, and green development.

Keywords: Data governance, Green service systems, Optimization paths, Service-dominant logic, Smart canteens in colleges and universities, Value co-creation.

1. INTRODUCTION

As a core carrier of public services on campus, the service quality of college canteens is directly related to the daily experience and sense of belonging of teachers and students, and can be regarded as a "livelihood hub" for campus operation. However, the traditional canteen operation model is gradually showing limitations in meeting the increasingly diversified needs of teachers and students: the long queues during peak dining hours (with an average waiting time of over 15 minutes), the instability of food taste, the low transparency of food safety information, and an annual food waste rate of over 15% (Wu Jianping et al., 2021) all highlight the necessity of reforming the traditional model. Against this background, the accelerated maturity of the Internet of Things (IoT), big data, and artificial intelligence (AI) technologies has provided a core path of technological empowerment to solve this dilemma (Wu Jianping et al., 2021), and "smart canteens" have gradually transformed from a theoretical concept into a core practical direction for the reform of the logistics service system in colleges and universities.

It should be clarified that smart canteens in colleges and universities are not a simple accumulation of intelligent equipment, but a socio-technical system where technology, processes, organizations, and user needs are deeply coupled. Their construction effectiveness depends on the coordinated adaptation of multiple elements (Wu Yu et al., 2023). In recent years, many colleges and universities in China have launched the construction of smart canteens, but in practice, there are widespread imbalances such as "emphasizing hardware procurement while neglecting software empowerment" and "focusing on data collection while ignoring value transformation" (Zhang Zhi, 2023; Yin Shuang, 2024). The research focus of the international academic community has also shifted from the early verification of technical feasibility to the exploration of user value creation through technology application and the sustainability of the service ecosystem. For example, the evolutionary theory of service-dominant logic proposed by Ostrom et al. (2021) in the *Journal of Service Research* clearly points out that the essence of service value lies in the "value co-creation" process with user participation. This view provides a key insight for the construction of smart canteens in colleges and universities: the success of a smart canteen should ultimately be evaluated based on the active participation and actual satisfaction of teachers and students, rather than the formal presentation of technological applications.

Based on this, this paper breaks away from the "technology listing" analytical perspective, adopts an integrated and humanistic dimension, deconstructs the core composition of smart canteens by constructing a "technology-process-management" three-dimensional framework, systematically sorts out the practical challenges in the current construction, and proposes optimization paths combined with the service-dominant logic and the theory of green service systems, in order to provide references for the high-quality construction of smart canteens in colleges and universities.

2. DECONSTRUCTING SMART CANTEENS: AN INTEGRATED FRAMEWORK OF TECHNOLOGY, PROCESS, AND MANAGEMENT

A mature smart canteen in a college or university should have the closed-loop capability of "perception-response-decision-making", and its core consists of a three-dimensional structure of "technology layer (perception and interaction), process layer (operation hub), and management layer (decision-making core)". The coordinated operation of these three layers determines the overall effectiveness of the service system.

2.1. Technology Layer: Constructing an Intelligent Perception and Interaction Network

The technology layer is the core interface for smart canteens to connect with the physical environment and user needs. Based on Parasuraman et al.'s SERVQUAL service quality evaluation system, its core function is to enhance the "tangibility" and "responsiveness" of services through hardware empowerment, which is specifically reflected in the application of three types of technologies:

2.1.1. Intelligent Interactive Terminals: Reconstructing the Dining Experience

Devices such as self-service ordering machines (supporting touchscreen and voice interaction), embedded ordering modules in campus APPs, and AI visual checkout counters (with an recognition accuracy of 99.2%) realize the full-process optimization of "reserved ordering - intelligent meal pickup - second-level checkout" through Radio Frequency Identification (RFID) and machine vision technologies (Jiang Guiqing et al., 2024). This process reconstruction not only achieves a quantitative improvement in dining efficiency (reducing the waiting time during peak hours to less than 5 minutes) but also demonstrates respect for the user value of teachers and students by saving their time costs. It directly responds to the core requirement of the "responsiveness" dimension in the SERVQUAL system, i.e., the ability to quickly meet user needs.

2.1.2. Environmental and Safety Sensing Network: Building a Food Safety Defense Line

Temperature and humidity sensors (with a data collection frequency of once per minute), AI behavior recognition cameras (with an accuracy of over 95% in identifying non-compliant operations), and oil fume concentration monitoring devices deployed in the kitchen operation area, food storage warehouse, and dining area form a 24/7 "intelligent supervision network" (Bai Dangqiang et al., 2024). This network can real-time capture risk points such as abnormal temperature in food storage and chefs failing to wear work hats in accordance with regulations, transforming food safety management from "post-event traceability" to a proactive prevention and control model of "pre-event early warning - in-process intervention". It significantly improves the "assurance" dimension of service quality and enhances the trust of teachers and students in the canteen.

2.1.3. Green Energy-Saving Technology: Practicing the Concept of Sustainable Development

The application of technology in smart canteens needs to balance the dual goals of "efficiency" and "green development", which is specifically reflected in the deployment of intelligent lighting systems (automatically adjusting brightness based on passenger flow density), energy consumption monitoring platforms (real-time counting of water and electricity consumption and generating energy-saving suggestions), water-saving kitchen utensils (reducing water consumption by 30% compared with traditional equipment), and food waste reduction devices (Bai Dangqiang et al., 2024). Such technologies not only reduce the operating costs of the canteen (decreasing annual energy consumption costs by 12%-15%) but also integrate the concept of a green campus into daily services. As Chiu et al. (2023) pointed out in their research on green service systems, embedding sustainable practices into service processes can enhance the institutional brand image and user recognition through "concept visualization", which is highly consistent with the fundamental goal of colleges and universities to foster virtue through education.

2.2. Process Layer: Achieving Standardized and Agile Operational Collaboration

The realization of technological value relies on process reengineering; the deployment of technology divorced from standardized processes will fall into the dilemma of "hardware idling". The process layer of smart canteens focuses on improving operational efficiency and service reliability, with "standardization (SOP) + agility (dynamic adjustment)" as its core:

2.2.1. Construction of Full-Chain Operational Standardization (SOP)

A clear and quantitative standard operating process is established from food material inspection and acceptance, storage, and processing to food sales: in the food material inspection and acceptance link, a three-fold verification of "QR code traceability + sensory testing + rapid pesticide residue testing" is required; in the food processing link, a "standard recipe" system is implemented, which clearly specifies the food material ratio (e.g., the ratio of chicken to peanuts in Kung Pao Chicken is 3:1), cooking temperature ($\pm 5^{\circ}\text{C}$), and cooking time (± 1 minute) for each dish (Yin Shuang, 2024). This standardization not only ensures the stability of food taste (increasing the satisfaction of teachers and students with food taste by more than 20%) but also provides a basic support for cost control and food safety.

2.2.2. Human-Machine Collaborative Agile Operations

With the help of technical tools, a collaborative model of "machines performing standardized tasks + personnel focusing on value-added services" is realized: cooking robots can accurately reproduce standard recipes and prepare 300–500 servings of food per day; the intelligent inventory system generates procurement plans based on the past 30 days of consumption data and weekly demand fluctuation rules (e.g., a 15% increase in demand during exam weeks), controlling the food material loss rate within 5% (Jiang Guiqing et al., 2024). This collaborative model frees canteen staff from repetitive labor and shifts their focus to creative work such as food innovation (e.g., launching seasonal dishes according to the season) and user feedback response (handling complaints and suggestions within 24 hours), effectively ensuring the implementation of the "reliability" dimension in the SERVQUAL system, i.e., the ability to consistently provide the promised services.

2.3. Management Layer: Building a Data-Driven Decision-Making Hub

The integrated management platform is the "brain" of the smart canteen, whose core function is to integrate data from various systems and realize the transformation from "experience-based decision-making" to "data-driven decision-making". This is specifically reflected in three capabilities:

2.3.1. Operational Status Visualization and Agile Scheduling

The platform integrates data from subsystems such as ordering, checkout, inventory, and energy consumption through data interfaces, and presents key indicators (e.g., current number of diners, remaining food inventory, and equipment operation status) in real-time in the form of an "operation dashboard" (Chen Qingli, 2023). For example, when the number of people queuing at a certain window exceeds 20, the system automatically sends a scheduling reminder to the manager, who then opens a temporary window in a timely manner to achieve rapid response to operational issues.

2.3.2. Big Data Analysis and Precision Service Optimization

Multi-dimensional analysis is conducted based on consumption data: user portraits are used to identify the preferences of different groups (e.g., male students prefer pasta, while female students prefer light meals), guiding the dynamic adjustment of the weekly menu (with an adjustment ratio of 15%–20%); underperforming dishes (with monthly sales of less than 50 servings) are eliminated through the food sales heat map to reduce food waste (Lu Jing, 2022). Mariani & Wirtz (2022) emphasized in their research on AI application in services that personalized services based on data analysis are the key to improving customer satisfaction and loyalty. This conclusion is reflected in the smart canteen scenario: the personalized recommendation function can increase the ordering efficiency of teachers and students by 25% and the repurchase rate by 18%.

2.3.3. Blockchain Traceability and Trust Relationship Construction

A food material traceability system is built using blockchain technology to record the entire process information from origin, supplier, and transportation to canteen acceptance (Zheng Haitao et al., 2023). Teachers and students can view the inspection report of the food material origin and transportation time by scanning the QR code on the food. This "transparent" operation not only strengthens the risk control of food safety but also builds a trust bridge between the canteen and teachers and students through information disclosure, which is in line with the core view of service-dominant logic that "trust is the foundation of value co-creation".

3. PRACTICAL CHALLENGES: BOTTLENECKS AND CONTRADICTIONS IN THE CONSTRUCTION OF SMART CANTEENS

Although initial results have been achieved in the construction of smart canteens, there are still multi-dimensional bottlenecks in the practical promotion. These problems are essentially contradictions between technological application and campus service needs, as well as management mechanisms.

3.1. Insufficient Technology Integration and the Dilemma of "Information Silos"

Most colleges and universities lack top-level design and unified technical standards in the construction of smart canteens, leading to insufficient compatibility between various subsystems. According to a survey of 28 domestic colleges and universities by Yin Shuang (2024), 67% of the institutions failed to clarify data interface standards in the early stage, resulting in the ordering system (mostly provided by Internet companies), payment system (campus all-in-one card platform), and inventory management system (developed by traditional software vendors) being owned by different suppliers, making data intercommunication impossible. For example, the food sales data of the ordering system cannot be automatically synchronized to the inventory system, requiring manual re-entry, which not only increases the workload but also causes delays in inventory early warning (with an average delay of 4–6 hours). Such "information silos" greatly reduce the "data-driven decision-making" capability of smart canteens, reducing them to a simple combination of multiple "automated

modules".

3.2. Barriers to User Acceptance and the Problem of "Digital Divide"

Technological design that ignores user heterogeneity will lead to service exclusion. Tarhini et al. (2023) found in their research on technology acceptance that perceived ease of use and social influence are key factors affecting the adoption of new technologies by different age groups. This conclusion is particularly prominent in the smart canteen scenario: the acceptance rate of intelligent checkout and APP ordering among young students exceeds 90%, while only 45% of faculty members over 55 years old can complete the operation independently (Wu Yu et al., 2023). A more prominent problem is that some colleges and universities have canceled all manual checkout channels in pursuit of "full intelligence" indicators, resulting in an increase of 12 minutes in the average dining time of elderly faculty members and even cases where payment cannot be completed due to operational errors. This "technology-first" one-size-fits-all model violates the inclusiveness principle of campus services and creates a new "digital divide".

3.3. Data Security Risks and Privacy Ethical Hidden Dangers

The operation of smart canteens relies on massive user data, including consumption records (high-frequency data), facial information (used for AI checkout), and location data (meal pickup window positioning). Without standardized management, this will trigger the risk of privacy leakage. A survey by Wu Yu et al. (2023) shows that 42% of the smart canteens in colleges and universities have not established a clear data classification and grading system, and there is a problem of "excessive data collection" (e.g., collecting users' mobile phone numbers, home addresses, and other information irrelevant to catering services); moreover, 28% of the institutions have not adopted data desensitization technology, and raw data is directly stored in ordinary servers, posing risks of hacker attacks or abuse by internal personnel. Once a data leakage incident occurs, it will not only violate the *Personal Information Protection Law* but also destroy the trust of teachers and students in the canteen, leading to a sharp decline in service recognition.

3.4. High Initial Investment and the Contradiction of Sustainable Operation

The construction and maintenance costs of smart canteens impose pressure on the funds of colleges and universities: a complete set of AI visual checkout systems (including hardware and software) costs more than 200,000 yuan, and full campus coverage requires an investment of several million yuan; in addition, the annual software upgrade cost (about 15% of the initial purchase price) and equipment maintenance cost (5%-8% annually) require continuous investment (Gao Xiang, 2020). However, the logistics funds of colleges and universities are mostly fiscal appropriations, which tend to "emphasize construction while neglecting maintenance". For example, one year after the completion of a smart canteen in a college, 30% of the sensors were out of service due to lack of maintenance funds, and the intelligent inventory system was reduced to a "static ledger". How to balance short-term investment and long-term benefits and explore a sustainable operation model (such as school-enterprise cooperation and service outsourcing) has become a key challenge for the sustainable operation of smart canteens.

4. MOVING TOWARDS THE FUTURE: OPTIMIZATION PATHS AND VALUE ENHANCEMENT OF SMART CANTEENS

In response to the above challenges, optimization paths need to be proposed from four dimensions: strategy, design, system, and model to promote the transformation of smart canteens from "technology-driven" to "value-driven".

4.1. Strengthening Top-Level Design and Promoting Technology Collaborative Integration

The construction principle of "planning first, standard guidance" should be established: colleges and universities should set up a cross-departmental special working group (covering the Logistics Management Office, Information Center, Finance Office, and representatives of teachers and students) to formulate a 3-5-year development plan for smart canteens, clarify technical standards (such as data interface specifications and equipment compatibility requirements) and construction steps (pilot in sub-campuses - promotion across the campus). In terms of fund investment, it is recommended that more than 60% of the budget be allocated to the development of an integrated management platform (unified data center), the construction of a data governance system (including interface development and desensitization technology), and the training of operation and maintenance teams to avoid the imbalance of "emphasizing hardware while neglecting software". For example, a college realized the seamless connection of the ordering, payment, and inventory systems by unifying data standards, reducing the inventory early warning delay to less than 1 hour and the manual workload by 60% (Jiang Guiqing et al., 2024).

4.2. Adhering to User-Centricity and Implementing Inclusive Design

With "technology serving people" as the core, the needs of different groups should be considered in the

design: first, simplify the operation interface, such as setting an "elderly mode" (enlarged font and simplified steps) on the intelligent checkout counter, and arranging volunteer guidance during peak hours (11:00-13:00 daily); second, retain traditional service channels, with at least 2-3 manual checkout windows and cash payment options to ensure the right to choose for special groups; third, establish a user feedback mechanism (such as an built-in suggestion box in the canteen APP and monthly seminars with teachers and students) to dynamically adjust the technology application plan based on feedback. This design idea is in line with the concept of "smart service systems" proposed by Wunderlich et al. (2019) - that is, the system should have situational adaptability and provide flexible interaction methods according to user characteristics, rather than forcing users to adapt to technology.

4.3. Improving System Guarantee and Building a Solid Data Security Defense Line

A dual data security system of "technology + system" should be constructed: at the technical level, measures such as data desensitization (e.g., converting facial information into anonymous feature codes), encrypted storage (AES-256 encryption algorithm), and access control (role-based permission management) are adopted to prevent data leakage; at the system level, the *Smart Canteen Data Management Measures* are formulated to clarify the scope of data collection (only collecting data necessary for catering services), usage permissions (e.g., logistics staff can only view aggregated data and cannot access personal information), and destruction mechanism (deleting relevant data within 1 month after users graduate/leave their jobs). At the same time, the data usage policy should be proactively disclosed to teachers and students, and the purpose of data use should be informed through channels such as the campus official website and canteen bulletin boards to obtain explicit consent from users and gain trust through transparent operations.

4.4. Exploring Innovative Models and Promoting Green Collaborative Sharing

Break through the limitation of "single fiscal investment" in the operation model: first, implement a "school-enterprise cooperation" light-asset model, where enterprises are responsible for the procurement and operation of intelligent equipment, and colleges and universities cooperate through site leasing and service fee sharing to reduce initial investment (e.g., a college reduced the construction cost of the smart canteen by 70% through this model); second, establish a "regional college logistics alliance" to jointly carry out centralized procurement (of food materials and equipment) and share operation and maintenance teams (e.g., establishing a regional technical support center) with surrounding colleges and universities to reduce costs through economies of scale (Jiang Guiqing et al., 2024); third, deepen green service practices by combining intelligence with green development - for example, optimizing the meal preparation quantity based on consumption data to control the food waste rate below 8%; using the intelligent energy consumption system to reduce water and electricity consumption by 10% year-on-year, promoting the smart canteen to become a demonstration window for green campus development.

5. CONCLUSION

The construction of smart canteens in colleges and universities is not a one-time technological transformation project but a continuous iterative process of service ecosystem optimization. Its core value is not to pursue the "flashy" presentation of technological applications but to realize the in-depth integration of technology and services - allowing technology to serve as an implicit support and seamlessly integrate into the campus catering scenario, ultimately building a service space that is efficient, safe, green, and full of humanistic care. From the perspective of development trends, smart canteens will gradually transcend the single function of "catering supply" and evolve into a "campus living room" for teachers and students to communicate and interact, and for the dissemination of green concepts, becoming a concrete carrier of the "student-centered" concept in colleges and universities.

Future research can further deepen empirical exploration: on the one hand, adopt a longitudinal tracking design to conduct surveys on colleges and universities with smart canteens operating for more than 3 years, and quantitatively analyze their long-term impact on the satisfaction of teachers and students (e.g., SERVQUAL scores), campus food waste rate, and logistics operation costs; on the other hand, focus on the "value co-creation" mechanism, exploring how to enhance the user stickiness of smart canteens through the participation of teachers and students (e.g., food innovation voting, service design workshops), and truly realize the goal of "services co-built by teachers and students, and value shared by teachers and students".

REFERENCES

- Bai, D. Q., & Li, G. (2024). Exploration of smart green canteens in college logistics projects. *China Petroleum Enterprise*, (12), 106-107.
- Chen, Q. L. (2023). Research on the construction of smart canteens in colleges and universities in the new era. *Catering World*, (6), 17-19.
- Chiu, A. S., Chu, C. C., & Hsueh, S. L. (2023). Building green service systems: An integrative framework and research agenda. *Journal of Service Management*, 34(3), 345-365. <https://doi.org/10.1108/JOSM-07-2022-0227>
- Gao, X. (2020). Discussion on the "intelligent +" operation and service model of college catering. *China Informatization*, (6), 97-98.
- Jiang, G. Q., & Liu, Z. C. (2024). Research on the construction status and operation management of smart canteens in colleges and universities. *China Management Informatization*, 27(10), 152-155.

- Lu, J. (2022). Research on the management of smart canteens in colleges and universities based on IoT technology. *Logistics Engineering and Management*, 44(23), 166–168.
- Mariani, M., & Wirtz, J. (2022). AI in service: How to design AI-based services to enhance customer satisfaction and loyalty. *Journal of Service Management*, 33(4–5), 489–509. <https://doi.org/10.1108/JOSM-11-2021-0437>
- Ostrom, A. L., Parasuraman, A., Bowen, D. E., Patrício, L., & Voss, C. A. (2021). Service research priorities: Managing and delivering service in turbulent times. *Journal of Service Research*, 24(3), 329–353. <https://doi.org/10.1177/10946705211017707>
- Tarhini, A., Alalwan, A. A., Al-Qirim, N., & Algharabat, R. S. (2023). The role of age and digital literacy on the adoption of mobile health services: A cross-cultural study. *Information Technology & People*, 36(2), 870–894. <https://doi.org/10.1108/ITP-11-2020-0820>
- Wu, J. P., Guo, W., & Han, Y. G. (2021). Research on the informatization construction of logistics in colleges and universities under the background of smart campus. *Experimental Technology and Management*, 38(1), 252–256.
- Wu, Y., Du, L., & Zhang, W. (2023). Research on the optimization strategy of smart canteen services in colleges and universities from the perspective of digital divide. *Food Industry*, 44(5), 245–248.
- Wunderlich, N. V., Heinonen, K., Ostrom, A. L., Patricio, L., Sousa, R., & Vargo, S. L. (2019). Smart service systems: The interplay of people, technology, and value propositions. *Journal of Service Research*, 22(2), 115–128. <https://doi.org/10.1177/1094670518825191>
- Yin, S. (2024). Research and discussion on the intelligent construction of college canteens. *China Food Safety*, (22), 17–19.
- Zhang, Z. (2023). Current situation of smart canteen construction in colleges and universities and suggestions on operation management. *Cultural and Educational Materials*, (9), 128–130.
- Zheng, H. T., Liu, H. J., & Huang, G. Q. (2023). Construction and research of smart canteen management platform in colleges and universities based on food safety supervision. *Computer Knowledge and Technology*, 19(6), 58–60.