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Research on Automation Technology for Last-Mile Delivery of Campus Express Services

Jingkai Lu *

Changzhou Institute of Technology, Changzhou, Jiangsu, 213032, China
*** Corresponding author Email:** 1819058849@qq.com

Abstract: With the booming development of e-commerce, numerous problems have emerged in the last-mile delivery of campus express services. Slow delivery speed, high labor costs and poor parcel collection experience for teachers and students have become increasingly prominent. This paper sorts out three types of automated equipment: unmanned delivery vehicles, smart parcel lockers and RFID identification devices. From the perspectives of technical implementation and system matching, it analyzes the practical collaborative application modes of the above technologies on campus. The research shows that the coordinated operation of various automated devices can greatly improve delivery efficiency, cut labor expenses, and effectively solve management problems such as misdelivered parcels, lost packages and missed pickups. This paper puts forward a set of operable intelligent upgrading schemes for campus express delivery, which can provide references for the logistics transformation of similar universities.

Keywords: Campus Express Delivery; Last-Mile Delivery; Automated Equipment; Unmanned Delivery Vehicles; Smart Parcel Lockers.

1. Introduction

The global e-commerce industry is thriving, which has brought tremendous changes to people's shopping habits. Teachers and students in universities have strong demand for online shopping, leading to a sharp surge in the volume of express parcels on campus.

However, the efficiency and service quality of campus last-mile delivery fail to keep up with the rapid growth of parcels. At present, campus express delivery still mainly relies on manual operation, and this traditional mode has many inherent drawbacks.

First, labor costs rise year by year while the overall operational efficiency remains low. Second, express stations are cluttered with piles of parcels, and misdelivery and parcel loss happen frequently.

These problems make it difficult for the traditional delivery model to meet the diversified and time-sensitive parcel collection needs of teachers and students, and cannot deliver accurate and efficient services. The whole industry is in urgent need of transformation. Against such a backdrop, introducing mature automated equipment and reorganizing delivery processes through technological means has become a core solution to address the above pain points, reduce costs and boost efficiency.

Based on the above background, this paper focuses on three major modules: the implementation methods of unmanned delivery equipment, the layout optimization of smart parcel lockers, and the comprehensive application of RFID identification devices. It elaborates on the deployment logic, operation mechanism and practical application effects of automated equipment in campus last-mile delivery one by one. This paper aims to develop a fully automatic campus express delivery scheme featuring high efficiency, low cost and wide promotion potential, and offset the defects of existing delivery modes through collaborative innovation of multiple devices.

2. Literature Review

2.1. Theoretical Basis

Relevant researches on the automation of campus last-mile delivery are built on two classic theories, which form the overall research framework and provide theoretical support.

The first is logistics distribution theory. Its core idea is to optimize the whole supply chain, allocate resources rationally, reduce intermediate links and raise transportation efficiency.

When applied to campus express scenarios, this theory guides the implementation of automated equipment. For example, intelligent route planning and dynamic vehicle scheduling can maximize the utilization of delivery resources.

The second is automatic control theory. It serves as the underlying logic for the automatic operation of unmanned delivery vehicles and smart parcel lockers. Its core relies on sensors, controllers and actuators to automatically handle various complex tasks.

The two theories not only offer scientific guidance for the automatic upgrading of campus express delivery, but also lay a solid foundation for the subsequent design of the complete technical scheme.

2.2. Domestic and Foreign Research Status

In recent years, scholars at home and abroad have achieved abundant research results concerning the automated last-mile delivery of campus express services.

In the field of unmanned delivery vehicles, autonomous equipment based on the ROS system has become a popular research hotspot. Researchers integrate autonomous driving technology with wireless communication, which effectively improves delivery efficiency and accuracy.[1][2]

Research on smart parcel lockers mainly focus on function upgrading and layout optimization. Some studies add temperature control and disinfection functions to lockers to meet the storage demands of special parcels; other scholars adopt mathematical models to work out reasonable

installation positions for lockers.[3]

RFID identification technology also brings new ideas to campus express management. Relevant studies prove that this equipment can track parcel locations in real time and improve overall management efficiency.[4][5]

Existing researches have made breakthroughs in single equipment, yet few studies explore the collaborative effects of multiple automated devices working together.[6]

2.3. Research Gaps in Current Studies

Although existing researches have laid a certain foundation for campus express automation, many contents remain to be further explored.

First, researches on multi-device linkage are insufficient. Most literature only analyzes one single device separately, and rarely discusses the coordination effect of different equipment. For instance, the data interaction mechanism between RFID identification devices and unmanned delivery vehicles has not been thoroughly analyzed in current studies, which limits the overall intelligence of the delivery system.

Second, there is a lack of research on adaptation to complex campus environments. Most existing models assume an ideal and simple campus environment, while real campuses face practical problems such as signal interference and uneven roads, which are rarely covered by relevant studies.

Therefore, this paper takes multi-device integration and adaptability to complex campus environments as the entry point, and designs a complete delivery scheme suitable for campus parcels to fill the deficiencies of existing researches.

3. Analysis of the Current Situation and Existing Problems of Campus Last-Mile Delivery

3.1. Main Modes of Current Campus Express Delivery

At present, there are three mainstream forms of campus last-mile parcel delivery: express stations, temporary pickup points and smart parcel lockers.[7][8]

Express Stations

Mostly operated by third-party logistics companies or school logistics departments, express stations are the most common delivery mode on campus. Their advantage lies in centralized processing of large quantities of parcels, with staff on hand to assist teachers and students with pickup.

Nevertheless, express stations are fixed at specific locations with limited coverage. Students living in remote dormitory areas have to take extra trips to collect parcels. During major shopping festivals, long queues and congestion at stations further reduce pickup efficiency.

Temporary Pickup Points

As a flexible supplementary mode, temporary pickup points are widely used during shopping carnivals such as Double 11 and 618 to ease the pressure on express stations. Schools set up temporary shelves and tents in open spaces to sort parcels for self-service pickup.

However, they lack unified management, which easily leads to messy scenes and potential safety hazards. Besides, they cannot function normally under extreme weather such as rain, snow or high temperature.

Smart Parcel Lockers

A popular intelligent pickup tool in recent years, smart parcel lockers support 24-hour self-service pickup and solve the time conflict between traditional delivery and students' class schedules. They are usually installed near dormitories and teaching buildings for easy access.

Survey data shows that the utilization rate of smart parcel lockers in some universities has exceeded 60%, reflecting rising acceptance among teachers and students.

Still, smart lockers have obvious drawbacks: limited total storage capacity, inability to hold oversized parcels, which calls for optimized layout and diversified cabinet specifications.

3.2. Prominent Problems in Campus Express Delivery

Campus last-mile delivery is plagued by multiple tough problems, which drag down delivery efficiency and greatly worsen the pickup experience of teachers and students.

Low Overall Delivery Efficiency

Campuses have a huge volume of parcels scattered across various dormitory buildings, and pure manual operation cannot process orders efficiently. During peak periods, express stations and temporary points suffer from staff shortages, resulting in massive parcel backlogs and long waiting times for students.

Rising Labor Operation Costs

Labor wages keep climbing, and express companies have to spend continuously on recruiting and training sorting and delivery staff. Meanwhile, high turnover of couriers adds extra difficulties to personnel management and further pushes up operating costs.

Frequent Mis delivery and Parcel Loss

Manual sorting and concentrated pickup during rush hours easily lead to human errors. Such incidents increase after-sales costs for enterprises and trigger numerous complaints from teachers and students.

Chaotic Management of Pickup Spaces

Parcels are stacked randomly at temporary pickup points, which not only creates safety risks but also ruins the neat campus environment.

Time Conflict Between Delivery and Students' Daily Schedules

Most express deliveries are scheduled in daytime class hours, making it inconvenient for students to collect parcels in a timely manner.

All the above problems continuously degrade the quality of campus express services and demonstrate the necessity of introducing automated equipment.

3.3. Feasibility Analysis of Deploying Automated Equipment on Campus

From three dimensions including technical maturity, long-term cost benefits and campus environmental adaptability, automated equipment is highly suitable for campus express scenarios.

Mature and Reliable Technology

Unmanned delivery vehicles, smart parcel lockers and RFID identification devices have all entered the commercial application stage with stable operation performance.

Unmanned vehicles equipped with autonomous driving, positioning and obstacle avoidance functions can deliver parcels accurately on campus; smart parcel lockers are matched with online management systems to track the whole circulation of parcels.

The stable and reliable performance of these devices lays a solid foundation for large-scale promotion on campus.

Higher Cost-Efficiency in Long Run

Although automated equipment requires high upfront procurement investment, its long-term operating costs are far lower than the all-manual mode.

Unmanned delivery vehicles can drastically cut delivery manpower; smart parcel lockers optimize space utilization and lower site rental fees for express stations; RFID devices shorten the time for parcel warehousing and inventory checks to improve overall operation speed.

Good Adaptability to Campus Environment and High User Acceptance

Campus roads are well-planned with simple road conditions, which fit the operation of unmanned delivery vehicles. College students are more willing to accept new intelligent devices, facilitating the rapid deployment of smart lockers and unmanned vehicles.

Many universities have launched intelligent delivery solutions integrating artificial intelligence and logistics, and practical operation results verify the adaptability of automated equipment to campus scenarios.[9]

From both technical and economic perspectives, automated equipment has great potential for large-scale campus promotion and can support the full implementation of the complete delivery scheme.[10]

4. Automatic Supporting Solutions for Campus Last-Mile Express Delivery

4.1. Application Technology of Unmanned Delivery Vehicles

As the core equipment of automatic campus last-mile delivery, unmanned delivery vehicles rely on the coordinated operation of three technologies: autonomous driving, high-precision positioning and intelligent obstacle avoidance.

Autonomous driving technology adopts multiple sensors such as LiDAR, cameras and millimeter-wave radars, together with high-performance computing equipment to identify and judge surrounding environments in real time.[11]

The positioning system integrates GPS and inertial navigation to achieve high positioning accuracy, enabling vehicles to reach dormitory and teaching building destinations precisely along preset routes.

The obstacle avoidance function leverages deep learning algorithms to identify and classify road obstacles. Combined with dynamic route planning programs, it adjusts driving paths in real time to cope with unexpected situations on campus roads.

In campus delivery scenarios, unmanned vehicles have prominent advantages: reduced labor input, improved delivery efficiency and lower risks of mis delivery and parcel loss.

However, their deployment also faces difficulties: mutual wireless signal interference on campus, poor adaptability to complex road conditions, and unstable operation under rainy, snowy and other harsh weather. Continuous technical optimization is required to solve these problems in the future.[12]

4.2. Optimization Scheme for Smart Parcel Lockers

Scientific layout planning of smart parcel lockers is a key step to improve the efficiency of campus last-mile delivery.

The core optimization idea is to determine locker installation positions through scientific calculation based on campus pedestrian flow and parcel demand of different areas.

Specific implementation: establish calculation models based on queuing theory and operations research to minimize comprehensive costs including delivery expenses, site rental fees and waiting costs of users, and calibrate model parameters with real campus parcel data.

Meanwhile, intelligent calculation methods such as genetic algorithms and simulated annealing can improve the accuracy of layout planning, realizing full coverage without wasting equipment resources.[13]

After confirming installation positions, lockers of different specifications should be allocated according to regional parcel characteristics. Large-capacity lockers are deployed near dormitories with high parcel volume, while small lockers are used around teaching buildings to save space.

Refined planning of locker positions and specifications can raise the utilization rate of smart lockers and optimize the parcel collection experience of teachers and students.

4.3. Comprehensive Application of RFID Identification Devices

4.3.1. Role of RFID in Parcel Tracking and Management

RFID is an efficient automatic identification tool with outstanding advantages in the full-process tracking and management of campus parcels.

Its working principle relies on wireless signals to automatically collect and transmit parcel information without any manual entry.

A unique RFID tag is attached to each parcel. When a parcel enters the sensing range of identification equipment, all information stored in the tag will be automatically uploaded to the background system, allowing managers to check the real-time location and circulation status of parcels at any time.

The equipment supports batch reading, which can identify a large number of parcels at once during warehousing, outbound delivery and inventory checks, greatly improving the speed and accuracy of sorting and verification.

In campus scenarios, RFID readers installed on shelves can help the system locate parcel storage positions accurately and provide pickup navigation for students via display screens or mobile applications.

This automatic tracking mode can not only reduce labor costs, but also comprehensively upgrade the service level of express delivery.

4.3.2. Coordination Between RFID and Other Automated Equipment

The biggest strength of RFID equipment lies in fast parcel data collection. Its combined use with other automated devices can further boost the overall efficiency of the campus delivery system.

Matching unmanned delivery vehicles: RFID readers are installed inside vehicles to monitor parcel status during transportation in real time and prevent damage or loss in transit.

Matching with smart parcel lockers: When parcels are stored in lockers, RFID equipment automatically records storage time and locker numbers, synchronizes data to the cloud, and sends real-time parcel arrival reminders to students' mobile phones.

Matching with sorting robotic arms: Robotic arms read RFID tags on parcels to quickly obtain parcel size and recipient information, so as to complete accurate automatic sorting.

The multi-device linkage model gives full play to the strengths of each single device and builds a more complete campus intelligent delivery system.

5. Case Analysis of Automated Equipment Deployment

5.1. Case Background Introduction

With the rapid popularization of artificial intelligence and automation technologies, an increasing number of universities have started to renovate their campus express delivery modes. This paper selects Changchun Vocational Institute of Automotive Technology as a typical case for analysis.

Before the renovation, the university's express delivery only operated through manual stations and temporary pickup points. It suffered from slow delivery speed, frequent mis delivery and parcel loss, and messy pickup sites.

During shopping festivals such as Double 11 and 618, the surging parcel volume greatly extended students' waiting time for pickup and led to low satisfaction among teachers and students.

To tackle these problems, the university launched an AI-powered unmanned delivery system matched with smart parcel lockers to realize full-process automatic upgrading of last-mile delivery.

The complete workflow is as follows: cameras scan barcodes and measure parcel sizes, sorting robots conduct automatic classification, and unmanned delivery vehicles transport parcels to smart lockers in each dormitory building.

The new multi-device collaborative mode not only improves delivery efficiency, but also optimizes students' parcel collection experience.

5.2. Summary of Deployment Effect Data

Survey data of the case are sorted into the table below to intuitively reflect changes in delivery efficiency, operating costs and user satisfaction after automatic renovation:

Table 1. Changes in delivery efficiency, operating costs and user satisfaction after automatic renovation

Evaluation Dimension	Situation Before Renovation	Data After Automatic Renovation	Improvement Range
Delivery time from express station to dormitory	16 minutes per parcel on average	10 minutes per parcel on average	Reduced by about 40%
Annual labor operating cost	High basic labor expenditure	Labor expenditure cut by 30%	Saved 30% of labor costs
Parcel waiting experience for students	Long queues and crowded sites during peak hours	24-hour self-service pickup near dormitories	Greatly improved flexibility of pickup
Student satisfaction survey (500 questionnaires)	Satisfaction rate below 60%	Satisfaction rate reaches 85%; 90% of students feel pickup is much more convenient	Satisfaction increased by over 25%

5.3. Successful Experience and Existing Deficiencies of the Case

Successful Experience

1. The collaborative use of multiple automated devices is the core. The combination of unmanned delivery vehicles and smart lockers offsets various drawbacks of traditional delivery modes, complements device functions, and achieves a synergy effect of "1+1>2".

2. Sufficient research and planning before deployment. Before launching the intelligent delivery scheme, the university collected data on campus pedestrian flow and parcel peak hours, so the scheme fits the actual campus demands and enjoys high implement ability.

Existing Deficiencies

3. Inadequate equipment debugging in the early stage caused positioning and navigation errors of some unmanned vehicles, leading to delivery delays.

4. The quantity and specifications of smart lockers failed to fully meet students' demands; lockers were fully occupied during peak hours, and students still needed to queue up for pickup.

The above problems indicate that in the subsequent deployment of automatic schemes, continuous optimization of equipment programs and extensive collection of feedback from teachers and students are required to improve the adaptability and stability of automated equipment.

6. Difficulties and Countermeasures in the Deployment of Automated Equipment

6.1. Technical Difficulties and Corresponding Solutions

The primary challenges of deploying automated equipment on campus are signal interference and poor adaptability to complex road conditions.

Dense wireless devices on campus cause mutual signal interference, which affects data transmission and instruction execution of unmanned vehicles and smart lockers.

Interlaced campus roads and heavy pedestrian flow impose higher requirements on the positioning and obstacle avoidance capacity of unmanned vehicles.

Corresponding solutions:

1. Solve signal interference: Adopt multi-channel data transmission combining 4G/5G and Wi-Fi to guarantee network stability; introduce edge computing to transfer partial data processing tasks to local equipment and avoid equipment failures caused by cloud delay.

2. Adapt to complex road conditions: Upgrade the fusion algorithm of LiDAR and visual recognition to strengthen vehicles' perception and judgment capacity in dynamic pedestrian environments; adopt route planning based on high-precision maps to automatically avoid congested road sections and ensure smooth delivery.

6.2. Cost Difficulties and Corresponding Solutions

Although automation can reduce costs in the long run, high upfront investment restricts its large-scale promotion.

Costs mainly fall into three categories: hardware

procurement fees for unmanned vehicles, smart lockers and sensors; maintenance fees for long-term equipment inspection and upgrading; daily operating expenses including electricity, network fees and staff training.

Cost control countermeasures:

1. Purchase equipment in bulk and establish long-term cooperation with manufacturers to lower unit procurement prices of hardware.

2. Adopt modular design for equipment to simplify maintenance procedures; build a fault early warning system to detect equipment problems in advance and avoid extra maintenance costs caused by equipment breakdowns.

3. Expand diversified revenue channels such as advertising on smart lockers and parcel data analysis services to share operating costs and improve overall economic feasibility.

6.3. Management Difficulties and Corresponding Solutions

The popularization of automated equipment has completely transformed the traditional express delivery management mode, bringing new challenges in personnel allocation and equipment safety.

Personnel Aspect

Automated equipment replaces a large number of manual sorting and delivery posts, so original couriers face post adjustment, which may trigger labor conflicts.

Equipment Safety Aspect

Unmanned vehicles have collision risks during operation; smart lockers store students' personal information, which faces risks of information leakage and intentional damage.

Supporting management measures:

1. Personnel resettlement: Carry out vocational skills training to transfer original couriers to equipment operators and maintenance staff for rational allocation of human resources.

2. Safety control: Formulate unified equipment operation standards and conduct regular daily inspection and maintenance; purchase insurance for equipment to reduce accident losses.

3. Multi-party collaborative management: Universities, express companies and local administrative departments jointly formulate management regulations for campus intelligent delivery and promote the coordinated upgrading of technical deployment and management systems.[1]

7. Conclusion

With the development of smart logistics and rising e-commerce penetration rate, the all-manual campus express delivery model has reached its efficiency ceiling. Problems such as rising labor costs, insufficient management precision and single parcel collection experience cannot be solved by traditional methods.

This paper constructs a complete automatic solution: unmanned delivery vehicles realize mobile unmanned transportation from express stations to dormitories; operations research algorithms are adopted to scientifically plan the layout of smart lockers and ease the conflict between limited campus land and surging parcel demands; RFID identification devices build a full-process digital tracking system for parcels.

The coordinated operation of the three types of equipment forms a closed-loop intelligent logistics system, which effectively solves long-standing pain points of traditional manual delivery such as low efficiency, high costs, frequent mis delivery and parcel loss, and isolated data systems.

Data from the case of Changchun Vocational Institute of Automotive Technology proves that the linkage of multiple devices is far more than simple equipment superposition and can generate synergistic benefits.

After renovation, delivery time is shortened by 40%, greatly cutting students' waiting time for pickup. The system reduces reliance on manual labor, lowers labor expenditure and improves the utilization rate of site resources. Meanwhile, 24-hour self-service pickup and precise location-based parcel services cater to college students' demand for convenient campus life.

In the future, with the continuous iteration of artificial intelligence algorithms, full popularization of IoT sensing devices and in-depth integration of 5G technology, campus last-mile delivery will no longer be limited to the automation of single transportation equipment.

The whole system will upgrade toward advanced intelligence featuring full-domain perception, autonomous decision-making and human-machine collaboration. Future campus logistics will build an interconnected intelligent equipment network to dynamically schedule delivery resources and adapt to changes in campus environments automatically, providing technical support for the construction of smart campuses and green logistics.

References

[1] Wang, F., & Wang, N. (2020). Autonomous delivery robots for campus scenarios. *Journal of North China University of Science and Technology (Natural Science Edition)*, 42(3), 104–112.

[2] Zhang, Y. Y., & Shi, X. Y. (2024). Research on delivery system based on autonomous vehicles. *Computer Application Digest*, 40(1), 33–37.

[3] Shi, S. B., Huang, Y. F., & Yan, W. (2015). Research on application of smart lockers in campus parcel delivery. *Computer Simulation*, 32(9), 421–424.

[4] Xiang, A., Mao, X. L., & Wang, S. J. (2022). Design of campus express management system based on RFID. *Shanxi Electronic Technology*, (5), 35–38.

[5] Zhu, Y. Z., Wu, Y. C., & Li, X. M. (2017). Campus express parcel management system based on RFID. *Computer Systems and Applications*, 26(6), 53–58.

[6] Bi, L., & Wang, L. B. (2023). Research on standardized management of campus express delivery in universities under the background of Internet Plus. *Logistics Engineering and Management*, 45(6), 124–126.

[7] Jiang, J. Y. (2021). Optimization analysis of campus express services in universities. *Modern Commerce*, (29), 80–82.

[8] Qin, X. T., Zhang, Z. Y., & Huang, Q. Q. (2024). Research on current situation and mode optimization of campus express services in universities. *Logistics Technology*, 47(9), 60–62.

[9] Liu, Y. Y., & Zhao, H. Y. (2021). Research on last-mile delivery mode of university logistics under new retail — A case study of Guangzhou Institute of Commerce and Technology. *Market Weekly (Theoretical Edition)*, (6), 52–53.

[10] Yang, B., & Chen, Y. L. (2021). Research on standardized management of campus express delivery under Internet Plus. *National Circulation Economy*, (13), 18–20.

[11] Chen, S. C., Yang, W. L., & Wang, C. B. (2022). Research on campus intelligent express service system based on artificial

intelligence technology. *Wireless Interconnection Technology*, 19(10), 40–42.

[12] Shen, Y. F., Zhu, Z. Y., & Wang, Y. F. (2021). Application of intelligent delivery and management under artificial intelligence + logistics. *Science and Technology Trends*, (8), 74–75.

[13] Wang, T. D. (2023). Research on optimization of last-mile delivery routes in universities based on hybrid genetic algorithm. *China Storage and Transportation*, (3), 54–55.

[14] Cong, X. A., Qiu, X. L., & Yu, Q. Y. (2022). Research on innovation of campus express logistics delivery modes in universities. *Logistics Technology*, 45(17), 37–39.